96th Congress }
2d Session }

COMMITTEE PRINT

NUCLEAR ACCIDENT AND RECOVERY AT THREE MILE ISLAND

A REPORT

PREPARED BY THE

SUBCOMMITTEE ON NUCLEAR REGULATION

FOR THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

U.S. SENATE

JUNE 1980

SERIAL NO. 96–14

Printed for the use of the Committee on Environment and Public Works

U.S. GOVERNMENT PRINTING OFFICE
54–058 O
WASHINGTON : 1980

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LETTER OF TRANSMITTAL

United States Senate,
Committee on Environment and Public Works,
Washington, D.C., June 23, 1980.

Honorable Walter F. Mondale,
President of the Senate,
Washington, D.C.

Dear Mr. President: We transmit herewith the report "Nuclear Accident and Recovery at Three Mile Island," the product of a special investigation carried out by the Subcommittee on Nuclear Regulation for the Committee on Environment and Public Works.

This report was developed by the Subcommittee under the Committee's standing jurisdiction over non-military environmental control and regulation of nuclear energy. We believe it will make a contribution to congressional and public understanding of the Three Mile Island accident.

Truly,

Jennings Randolph,
Chairman.
Robert T. Stafford,
Ranking Minority Member.

LETTER OF SUBMITTAL

UNITED STATES SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, D.C., June 6, 1980.

THE HONORABLE JENNINGS RANDOLPH,
Chairman,
THE HONORABLE ROBERT T. STAFFORD,
Ranking Minority Member,
Senate Committee on Environment and Public Works,
Washington, D.C.

DEAR JENNINGS AND BOB: We are pleased to transmit to you the report, "Nuclear Accident and Recovery at Three Mile Island," which is the result of the Special Investigation conducted for the Committee on Environment and Public Works by the Subcommittee on Nuclear Regulation.

On June 21, 1979, the Senate provided the Committee additional funds for the investigation and for a series of related policy studies on major issues arising out of the accident.

The one-year task of the Special Investigation will be completed by the end of June when the policy studies are transmitted to the Committee.

We believe the report makes a valuable contribution to Congressional and public understanding of the Three Mile Island accident. The investigation was conducted with a temporary staff that operated on a non-partisan, unified basis. All findings and conclusions are keyed to supporting facts in the text of the report, and these facts, in turn, are fully referenced to supporting documents.

The Special Investigation reviewed the work of other principal investigations of the accident, including those of the Presidential Commission on the Three Mile Island Accident and the Special Inquiry of the Nuclear Regulatory Commission. Our report also covers some areas not emphasized in the other investigations. We provide a detailed accounting of the first day of the accident, of certain pre-accident conditions that related directly to the accident, and of the cleanup and recovery operations at Three Mile Island.

By concentrating in greater depth on these areas, we believe that this report relates more directly to the oversight interests of the Committee and to possible legislative action to be taken by the Committee.

We extend our appreciation for your remarkable support and assistance throughout the term of the project. Your wise counsel and advice have been most important to the Committee Members and staff. We believe that the report is consistent with the high standards of the Environment and Public Works Committee of the U.S. Senate.

We also extend our appreciation to our superb staff which has worked unstintingly and professionally—out of the limelight—to produce a report that we all hope will contribute to serious and thoughtful public discussion of the future direction of nuclear power in our society.

Sincerely,

GARY HART,
Chairman,
Subcommittee on Nuclear Regulation.
ALAN K. SIMPSON,
Ranking Minority Member,
Subcommittee on Nuclear Regulation.

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PHOTO CREDITS

Allied Pix Service, Inc., pp. 60, 105, 174; Babcock & Wilcox, p. 75; Metropolitan Edison Co., pp. 42, 48, 95, 177, 180, 181; Nuclear Regulatory Commission, pp. 2, 8, 55, 88, 92, 133; Wide World Photos, p. 162.

Chapter 1

Introduction

The Three Mile Island nuclear power plant

Chapter 1

Introduction

The Committee on Environment and Public Works has jurisdiction over all matters relating to environmental regulation and control of civilian nuclear energy, including the activities of the Nuclear Regulatory Commission (NRC). This responsibility is carried out through the Subcommittee on Nuclear Regulation. The Committee was assigned this regulatory jurisdiction after the Joint Committee on Atomic Energy was abolished in 1977.

On June 21, 1979, the Senate approved S. Res. 171, providing funds for the Committee for a Special Investigation of the Three Mile Island nuclear accident and for a series of related policy studies on Federal regulation and control of the nuclear power program. The report accompanying the resolution stated that both the investigation and the policy studies were to be completed within one year for the Committee on Environment and Public Works by the Subcommittee on Nuclear Regulation.

This report on the investigation of the accident at Three Mile Island fulfills part of that assignment. The policy studies conducted by the Special Investigation staff will be completed by the end of the one year project. Together, the investigation report and the studies should assist the Congress in exercising its responsibility with respect to the Three Mile Island accident and in considering the need for legislative and administrative changes for more effective regulation and control of commercial nuclear power.

This independent Congressional investigation is consistent with the unique role of the Congress in the Nation's atomic energy program, a role that dates back to the establishment of the Atomic Energy Commission in 1946. Congress established the Nuclear Regulatory Commission in 1974, as it had the earlier Atomic Energy Commission, to be independent of the President and of the Executive Branch and to keep Congress "fully and currently informed" of its activities. This Congressional involvement carries with it a responsibility to develop independent findings and to come to independent conclusions about the facts and implications of Three Mile Island.

All findings and conclusions in the report are keyed to supporting facts in the text. These facts, in turn, are extensively referenced to supporting documentation. Reference numbers appear in parentheses in the text: the references themselves are the last section of the report.

This Senate Special Investigation is one of several inquiries into the accident. The inquiries of The President's Commission on the Accident at Three Mile Island and of the Nuclear Regulatory Commission Special Inquiry Group have been completed. The Senate investigation of the accident differed in several respects from those of the Presidential Commission and the NRC. This investigation was kept small in size and selective in scope, to avoid duplication of the comprehensive approach to the accident taken by the other inquiries.

The Special Investigation, consistent with an objective stated in the report accompanying the Senate resolution, examined the work of these other inquiries as part of its independent assessment of the accident. For example, the Special Investigation staff, in addition to examining original plant records, reviewed the files of other investigations to explore design and mechanical aspects of the accident. This permitted the Subcommittee to conduct the investigation and studies on a limited budget and with a small investigative staff. The General Accounting Office and the Congressional Research Service also provided assistance.

The Subcommittee on Nuclear Regulation received testimony on the accident from 61 witnesses at eight hearings. The Special Investigation staff conducted 97 transcribed interviews and conducted numerous others.

The Subcommittee and the investigation staff heard from a broad spectrum of those involved in and concerned with the accident, including members and staff of the Nuclear Regulatory Commission, both at NRC headquarters in the Washington, D.C. area and at the Commission's Pennsylvania regional office; executives of the parent and operating utilities, of the Three Mile Island plant designer and of the reactor-vendor; the Governor and Lieutenant Governor of Pennsylvania and senior State officials; local elected officials and interested citizens from communities near the plant; company and government workers involved in building and licensing the plant and in responding to the accident; members or staff of two State public utility commissions; members of The President's Commission and investigators from that inquiry and from the Special Inquiry Group of the NRC; and nuclear advocates, nuclear critics and concerned citizens.

The Special Investigation also examined thousands of pages of transcripts, depositions and other documents from the files of the NRC and of the involved companies.

Given the volume of this material, it was necessary and useful to be selective about what was investigated. The Subcommittee concentrated on specific areas that relate to the oversight interests of the Committee and to possible legislative action by the Congress.

The Subcommittee, for example, chose to focus on the first 24 hours of the accident. In doing so, the Special Investigation staff reviewed all of the transcripts of the telephone conversations between the TMI site and NRC headquarters during the first day—the period that is now known to have involved the greatest instability and uncertainty at the plant. This section of the report presents a detailed narrative of what was known and not known to plant operators and managers, and to NRC and State officials. and endeavors to account for why actions were and were not taken.

Beyond the uncertain hours of the first day of the accident, the Subcommittee focused on the cleanup operation at the site of the crippled reactor. More than a year after the accident, only a small portion of the cleanup work had been accomplished. Because cleanup and recovery at Three Mile Island are an extension of the accident itself, the Subcommittee explored this timely problem in all of its ramifications—technical, financial, social, legal and regulatory.

In addition to the events of the first day of—and the first year after—the accident, this report traces the evolution of the TMI Unit-2 plant from its originally proposed site on the Atlantic coast at Oyster Creek, New Jersey, to the island in the middle of the Susquehanna River where it was eventually built. The move to the new site affected subsequent decisions about the design of the plant's control room. Some elements of the control room design contributed to difficulties encountered by plant operators during the accident. The report also describes problems encountered during early testing and operation of the plant that were directly related to the accident.

The findings and conclusions of the investigation appear in Chapter 2 of this report. They are followed by three brief introductory chapters, intended for the general reader, describing in non-technical terms "How the Plant Works," "How the Accident Happened," and "Radiation Effects and Monitoring." The text of the investigation report itself follows these sections.

Glossaries of technical terms and of governmental and private organizations involved in the accident and recovery appear at the end of the report as appendices. Other appendices provide a chronology of the first-day responses to the accident; review previous nuclear accidents; and describe the organization of the NRC and the NRC licensing process.

The policy studies will focus on the adequacy of certain programs begun by the Nuclear Regulatory Commission and the nuclear industry as a result of lessons learned from Three Mile Island. In particular, the studies will examine programs to improve

—consideration of human factors in nuclear plant design and operation,
—the evaluation and dissemination of information on mechanical and operating problems experienced at nuclear power plants,
—emergency response to nuclear accidents, and
—the industry's new insurance program to cover replacement power costs following an accident.

Finally, a word about the non-partisan nature of this investigation. In keeping with a tradition of the Committee of a close working relationship between the majority and minority members, a temporary Special Investigation staff was set up on a unified, non-partisan basis. There were no separate majority and minority investigation staffs; there are no separate majority and minority views in this report. This was possible because of close cooperation between the Chairman and the Ranking Minority Member, and among all members, of the Nuclear Regulation Subcommittee.

The Subcommittee acknowledges the outstanding work of the Special Investigation staff.

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Chapter 2

Findings and Conclusions

Victor Stello of the NRC testifies before the Senate Subcommittee on Nuclear Regulation on the accident at Three Mile Island

Chapter 2

Findings and Conclusions [1]

I. THE ACCIDENT

A. CAUSES OF THE ACCIDENT

1. Malfunctions in plant equipment [2] initiated the accident at Three Mile Island, but they alone did not cause the uncovering of the core or the severity and duration of the accident. Feedwater transients such as the one that initiated the March 28 accident occur routinely at nuclear power plants. They result from a variety of minor equipment malfunctions or from human error such as experienced at TMI.[3]

Routine transients can evolve into serious accidents if complicated by human factor deficiencies and other deficiencies in training, in control room design, in instrumentation and equipment, in emergency procedures and in plant design. The psychological stress experienced by plant personnel during a crisis is a further complicating factor.

All of these factors can serve to confuse plant personnel and to render them unable to respond to a minor accident effectively. At TMI, these factors caused a minor event to evolve into a serious accident.

2. Plant operators and managers inappropriately overrode the automatic safety equipment—actions that were the immediate cause of the uncovering of, and severe damage to, the reactor core.[4] However, it is inappropriate and unfair simply to blame these personnel for the Three Mile Island accident. It should be emphasized that the utility, the reactor-vendor, the architect-engineer and the NRC were responsible for deficiencies in training,[5] in control room design,[6] in instrumentation and equipment,[7] in plant design,[8] and in emergency procedures.[9] These deficiencies were the underlying cause of the accident.

Many of these deficiencies resulted from insufficient attention by the utility, the reactor-vendor, the architect-engineer and the NRC to human factors in nuclear plant design and operation.[10] These human factor problems were beyond the control of the operators on duty during the accident and were so serious that they had consequences equivalent to those that could be caused solely by major mechanical failures and design defects.

3. Several major weaknesses in the design of TMI–2 contributed to the difficulties faced by plant operators and managers in understanding plant behavior, in stabilizing the plant, and particularly in preventing radiological releases to the environment.[11] In some cases they involved equipment designed for use in an accident that failed to fulfill its intended purpose on March 28.[12] In other cases, design had focused on normal operating conditions; instrumentation and equipment needed or useful under the emergency conditions at TMI had not been provided or were inadequate to the task.[13] These design weaknesses are of concern because of their possible generic safety implications.

Design weaknesses in the emergency-related equipment included:

- A system of some 1,200 alarms, of which several hundred went off in the first minutes. Operators said they had concluded prior to the accident that the alarms would provide little, if any, immediate assistance in diagnosing a major transient or in assigning priorities to accident conditions.[14] After the accident, operators said the alarms were "not very helpful" [15] and "got in the way." [16]

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[1] The reader may find it useful to read first the introductory chapters, "How the Plant Works," "How the Accident Happened" and "Radiation Effects and Monitoring" for descriptions of plant systems and explanations of technical terms.

[2] Most particularly problems with the condensate polishing system and the failure of the pilot-operated relief valve (PORV). See p. 94 of the text. All page references in this chapter are to the text.

[3] "Staff Report on the Generic Assessment of Feedwater Transients in Pressurized Water Reactors Designed by the Babcock & Wilcox Company," NRC, NUREG–0560, May 1979.

[4] Pp. 93–110. [5] Pp. 73–76. [6] Pp. 56–64. [7] Pp. 65–66, 69–71, 94, 96, 99–101, 103, 104, 155. [8] Pp. 96, 99–100.
[9] P. 58. [10] Pp. 56, 60–63. [11] Pp. 94–96, 99–101, 103–104, 155. [12] Pp. 96, 99, 103–104. [13] Pp. 94, 96, 100–101, 106, 113–114 116–117. [14] Pp. 68–70, 99. [15] P. 99. [16] P. 99.

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• A computer printer that was, as anticipated by the operators, of little help because it failed to keep pace with the sequence of alarms [17] and became severely backlogged.[18]

• A radiation monitor that was intended to be a key indicator of a loss-of-coolant accident (LOCA) but apparently did not sound on March 28. Prior to the accident it may have been miscalibrated, and on the first day it may have become disabled by the steam and water resulting from the LOCA.[19]

• The failure of the containment building to seal automatically on initiation of high pressure injection, resulting in the automatic pumping of radioactive water from the containment into the unsealed auxiliary building.[20]

Design weaknesses related to equipment that was needed in the emergency, but was unavailable or inadequate to the task, included:

• The lack of a direct indicator to show whether the pilot-operated relief valve (PORV) was open or closed.[21]

• Indicators of conditions in the reactor coolant drain tank (pointing to a LOCA) that were not directly visible to plant operators from the main console in the control room.[22]

• The lack of strip chart recorders for reactor coolant drain tank conditions, without which it was difficult for operators to reconstruct trends in the tank's temperature, pressure and water level.[23]

• The lack of instrumentation to measure water level in the reactor vessel directly. Instead, operators had to rely on water level in the pressurizer as an indirect indicator that proved unreliable during the accident.[24]

• The inability to maintain isolation of the containment building when use of the let-down system was required to cope with the accident.[25]

• The inability to seal off the pathways between the auxiliary building and the environment to prevent releases of radioactivity to the environment after operators overrode containment isolation in order to use the let-down system.

• Instrumention that was designed only for normal operating conditions and could not provide readings for the extreme conditions produced by the accident.[26] Thus control room personnel could not monitor those extreme conditions directly.[27] Since these misleading readings influenced actions taken to control the accident, the limited range of the instruments was a particularly significant weakness in plant design.

• In addition, as had happened before during early testing of the plant, the "candy-cane" curve in the hotlegs trapped steam formed from boiling of the coolant. This blockage inhibited natural circulation and contributed to difficulties in understanding plant behavior and in stabilizing the plant.

Had these weaknesses not been present in the design of the plant, the operators and managers would have been in a better position to understand and to respond to the accident.

4. The emergency procedures for Unit 2 were vague, confusing, incomplete and not fully understood by plant personnel.[28] They did not provide useful guidance to operators and managers in identifying and responding to the critical elements of the accident in the early hours.[29]

Better emergency procedures and better understanding of them by plant operators and managers would have facilitated diagnosis and understanding of the plant's behavior. It should be noted, however, that it is impossible to write emergency procedures to fit every possible accident sequence.

5. There were several weaknesses in the TMI operator training program that contributed to the difficulty control room personnel had in understanding and responding to the sequence of events of the March 28 accident.[30]

These weaknesses included:

• Limited training in multiple-failure accidents, particularly such prolonged ones as experienced on March 28 at TMI;[31]

• Limited training in the basics of nuclear power plant physics and behavior;[32]

• Failure to instruct operators on conditions in which water level in the pressurizer would not be a reliable indicator of water level in the reactor vessel. Operators had been directed never to let the pressurizer fill completely ("go solid") with water during plant operation.[33] This direction had been based on the concern that a pressurizer "solid" with water could limit their ability to control pressure in the primary system and could result in damage to the plant.[34]

Operators and managers would have been better prepared to respond to the accident if their training had been more extensive in these areas.

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[17] Pp. 69–70, 99. [18] Pp. 69–71, 99. [19] Pp. 103–104. [20] Pp. 99–101. [21] Pp. 65–66, 94–95, 155. [22] Pp. 100–101. [23] Pp. 100–101. [24] P. 96. [25] P. 96.

[26] Examples were the computer and control panel instrumentation used to monitor critical plant parameters, including temperatures in the hotlegs of the primary coolant system and temperatures inside the core. The scale for hotleg temperatures on the control panel went only to 620° F (they reached an estimated 720°–820° F during the accident) (see pp. 106, 113, 132, 142); the computer could print out incore temperatures only as high as 700° F (they reached an estimated 4,500° F), see p. 113.

[27] Pp. 113, 114. [28] Pp. 102–104, 154–156. [29] Pp. 102–104, 154–156. [30] Pp. 73–76, 96–97, 101, 106. [31] Pp. 73, 75. [32] Pp. 74, 104–108. [33] Pp. 74, 96–97. [34] P. 96.

6. Despite the inadequate training, confusing information and problems with instrumentation, one operator did diagnose the stuck-open PORV soon after he arrived at about 6 a.m.[35] He then directed that the block valve for the PORV be closed, thereby stopping the leakage.[36] In addition, within hours after the core was uncovered, at least three utility personnel correctly diagnosed that condition.[37] One of them was a member of the utility's emergency command team.[38] He stated that it had been generally recognized that the core may have been uncovered for an extended period after 7 a.m.[39] Yet statements by other senior managers on the utility's emergency command team suggest that they never recognized that the core was uncovered on the first day of the accident.[40]

B. SEVERITY

1. Three Mile Island was the most severe accident at a commercial nuclear power plant in the United States.

2. The severity of a nuclear accident is measurable in terms of duration, extent of damage, releases of radiation, near- and long-term adverse health effects on both the public and workers, and hazards of cleanup.

3. The accident at Three Mile Island was of prolonged duration, resulted in severe damage to the core, and left the Unit 2 facility highly contaminated by radioactivity. The cleanup task is still in its early stages and, as described below, is unprecedented in scope.

4. Three Mile Island is not the first serious accident at a nuclear reactor here or abroad. For example, in 1957 there was an accident at the Windscale plutonium-production reactor in Great Britain that involved offsite releases 1,000 times greater than those at TMI.[41] In 1961, three workers were killed in an accident at SL–1, a small research reactor in Idaho.[42] An accident at the Enrico Fermi power reactor in Michigan in 1966 resulted in a partial core melt.[43]

5. The Special Investigation reviewed some available data and the findings of other investigations regarding radiation releases. It found no persuasive evidence that releases during the accident resulted in adverse near-term physical health effects or will result in statistically significant adverse long-term physical health effects.[44]

The pending House-Senate conference report on the FY 1980 NRC Authorization Bill contains an amendment by this Committee directing the NRC and EPA to conduct a feasibility study on acquiring additional information for plant workers on the incidence of any adverse long-term physical health effects from the TMI accident. The State of Pennsylvania is also attempting to acquire additional information for the general population bearing on the incidence of any adverse long-term physical health effects from the accident.

The absence of evidence of major releases is supported by conclusions of the Food and Drug Administration based on its checking of photographic film in stores and facilities near the plant for fogging caused by radiation.[45]

Offsite radiation monitoring was both disorganized and insufficient during the early hours of the accident, making determination of actual releases difficult.[46] A high percentage of the portable radiation survey instruments were inoperable; the offsite dosimeters in place before the accident could register only total radiation exposure over time and not hourly dose rates; management of the utility's health physics program was inadequate.[47] Evidence of the limited extent of offsite releases was developed by extrapolating from releases measured at the boundary of the plant site and by backcalculating from measurements of later offsite releases.[48]

6. There have been accidental releases of radiation since the accident, but the Investigation found no persuasive evidence that releases since the accident resulted in adverse near-term physical health effects or will result in statistically significant adverse long-term physical health effects.[49] The pending House-Senate conference report on the FY 1980 NRC Authorization Bill contains an amendment by this Committee directing the NRC and EPA to conduct a feasibility study on acquiring additional information for plant and cleanup personnel bearing on the incidence of any adverse long-term physical health effects from these releases.

7. An important issue in determining the severity of the accident is whether the core was uncovered more than once on the first day of the accident. If it was, the risk to the public was greater than realized at the time, and there was even greater reason to consider protective action.[50]

The President's Commission concluded that there was a second uncovering of the core in the afternoon of the first day, when the utility was attempting to depressurize the reactor coolant system.[51] However, the NRC Special Inquiry Group and the industry's Nuclear Safety Analysis Cen-

[35] Pp. 108–109. [36] P. 100. [37] Pp. 113, 116. [38] P. 116. [39] P. 116. [40] Pp. 116–117, 124–127, 129–130. [41] P. 224. [42] P. 221. [43] P. 225.

[44] See, for example, "Population Dose and Health Impact of the Accident at the Three Mile Island Nuclear Station," Preliminary Estimates for the Period March 28, 1979 through April 7, 1979, NRC, NUREG–0558, May 1979, pp. 60–63.

[45] P. 45. [46] P. 44. [47] P. 44. [48] P. 44. [49] Post-accident radiation releases have been less than those during the accident itself. See fn. 44. [50] For details, see p. 17 of "Findings and Conclusions." [51] P. 141.

ter[52] have interpreted the evidence to show there was no second uncovering.[53]

The Subcommittee believes that the available evidence is insufficient to permit a final conclusion on whether the core was uncovered a second time. Further evidence to help resolve this issue may become available at such time as the core is removed.

C. EMERGENCY PLANNING

1. Effective emergency preparedness requires the assumption that serious accidents can happen and that adequate plans need to be made in advance to deal with them. Such plans should be based on a realistic consideration of the range of potential accidents and must ensure that the resources and procedures necessary for dealing with such realistic contingencies will be readily available.

2. Prior to the accident at Three Mile Island, emergency response planning was based on the assumption that certain types of accidents—those involving disruption of the core (designated as Class 9 accidents by the NRC)—were so unlikely that they did not need to be covered by emergency plans.[54] Emergency planning was based on accidents considered most likely—ones of short duration that did not involve disruption of the core.[55] Further, the focus was on accidents involving the failure of a single plant component, rather than on multiple failures (two or more components) such as occurred at TMI.[56]

3. Prior to 1975, the NRC did not anticipate playing an active emergency response role during an accident. The agency saw its role as simply monitoring the progress of an accident, using information provided by the utility. The NRC assumed that an accident would be over before the agency had a chance to get actively involved.[57]

However, as a result of the duration of the fire at the Browns Ferry nuclear power plant in 1975—and the agency's inadequate response—the NRC reevaluated its role.[58] A consultant's study concluded that the NRC might need to take an active role in managing an accident, and that a prerequisite for that role would be the capacity to obtain information, independent of the utility, about plant conditions. The consultant recommended that the NRC install an independent remote system for monitoring plant conditions, tied directly to NRC headquarters.[59]

At the time of the TMI accident, the NRC had identified an active managerial role as desirable in the long-term, but had not installed the communications system fundamental to fulfilling such a role.[60]

4. The accident at Three Mile Island was unlike anything anticipated by the utility, the NRC or the State.[61] None was prepared for an accident of this nature and duration.[62] Events showed that the utility, the NRC and the State did not readily have available the resources essential for a proper response.[63] According to the statements and testimony of the participants in the crisis, a fundamental reason for their lack of preparedness was conceptual: unduly narrow assumptions had been made as to the kinds of accidents to be anticipated.[64]

Thus:

—Neither the utility nor the State's emergency plans contained procedures providing for a continuous update of operational data or of changing conditions in the status of the reactor.[65]

—The NRC had conducted no drills of more than a few hours duration at its Incident Response Center.[66]

—The NRC's communications system provided for only one line to the Regional Office and did not cover direct contact between NRC headquarters and the Unit 2 control room; such contact was not established until about 4:30 p.m. on March 28, twelve and a half hours after the accident began.[67]

—The NRC's regional emergency response plan allowed up to six hours after notification for the NRC to get its inspectors onsite, a further indication that the agency was unprepared to take an active role onsite in a timely fashion.[68]

—The State did not have enough technically qualified staff assigned to its emergency response organization.[69]

5. There also were severe deficiencies in the organization and management of emergency response planning within and among the three organizations. These deficiencies went beyond problems caused by the unduly narrow assumptions as to the kinds of accidents to be anticipated.

Thus:

—The NRC headquarters and regional offices had produced several incomplete and in-

[52] Pp. 142–143. [53] Pp. 142–143. [54] Pp. 73, 75. [55] Pp. 83–84. [56] Pp. 73–75. [57] Pp. 83–84. [58] P. 82. [59] Pp. 82–83. [60] P. 83. [61] Pp. 83–84. [62] Pp. 73–74, 83–84. [63] Pp. 74, 120–121, 130–131, 160. [64] Pp. 73–74, 83–84. [65] Pp. 134–135, 160. [66] Pp. 83–84. [67] Pp. 120–121, 131, 137. [68] Pp. 130–131. [69] P. 135.

compatible plans defining emergency response.[70]

—The Commissioners never met as a body the first day.[71]

NRC emergency response plans were vague about the Commissioners' role in an accident. The Commissioners were to make policy as needed, but that role was not defined with any specificity. This was particularly true with respect to directing the utility's response and to considering the need for evacuation or other protective action.[72]

• There was no pre-planned coordination between the Commissioners in their offices in Washington, D.C. and the NRC emergency response center in Bethesda, Md. on the day of the accident. A system for briefing the Commissioners evolved on an ad hoc basis over the day.[73]

• The utility's response was inadequate, particularly with respect to management and communications. Statements by members of the utility's emergency command team indicate that many decisions during the first day were based upon incomplete information because they failed to share what they knew or believed about plant conditions.[74]

• The Met Ed Emergency Plan provided no guidance about how to assess the condition of the plant during an accident. Further, it provided no system for internal plant communications; it merely delegated the responsibility for developing internal communications procedures to the Emergency Director.[75]

• There was no procedure in the Emergency Plan for participation by the reactor-vendor, the NRC or the architect-engineer in assessing plant conditions.[76]

• The State had two organizations with three emergency response plans covering accidents at nuclear power plants, each of which differed in significant respects and none of which conformed to the utility's plan.[77]

• There was a lack of coordination among the utility, the NRC and the State in their emergency planning.[78]

• Although the NRC had provisions for Federal inter-agency review of plans submitted voluntarily by the States for NRC concurrence, the NRC had not concurred in any of Pennsylvania's plans.[79]

• The NRC, the utility and the State encountered severe communications difficulties involving both the means of transmission and the quality of information transmitted. This is further evidence of insufficient joint emergency response planning.[80]

6. Under the Atomic Energy Act, the NRC has overall responsibility for the health and safety of the public with respect to the operation of nuclear power plants. At the time of the accident, however, there was no NRC requirement mandating that a State have an adequate emergency plan prior to NRC licensing of a facility; nor a requirement that the utility's plan be consistent with the State's plan.[81]

D. RESPONSES TO THE ACCIDENT

1. GENERAL

a. The responses of the utility, the NRC and the State to the accident were inadequate.

b. Utility personnel, for the underlying reasons discussed in I.A.2 above, proved unable to diagnose the accident correctly in time to prevent a serious situation.[82] They took incorrect actions, aggravating what began as a minor problem.[83] The utility did not communicate effectively within its organization or with the State and the NRC, particularly with regard to the possible need for evacuation or other protective action.[84]

The utility's outside communications were poor, leading Congressman Morris K. Udall to raise questions as to "Why on March 28 . . . [government] officials and the public were denied important information" about plant conditions.[85] The NRC is still investigating this matter. The evidence reviewed by the Special Investigation does not confirm any intentional concealment of information by the utility on the first day of the accident.[86]

c. The NRC was unprepared for an accident of the duration and severity of that at TMI. It was unable, during the first day, to contribute effectively to either the diagnosis of the accident or to developing strategies for achieving stability at the plant.[87] It, too, was handicapped by highly deficient internal and external communications.[88] Finally, at no point during the first day did the NRC

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[70] For example, in the emergency response procedures drawn up by NRC headquarters, a role was not defined for the regional office in the integrated agency-wide response (see p. 80); the regional plan envisioned the regional office as the lead unit within the NRC and did not state how its response would relate to that of headquarters (see p. 80). The NRC's manual assigned the Office of Nuclear Reactor Regulation (NRR) specific responsibilities and called for the Office of Inspection and Enforcement (I&E) to define the implementing procedures for the entire agency's emergency response. (See p. 81.) Yet, the implementing procedures prepared by I&E did not include a role for NRR. During the accident, NRR and I&E had essentially separate emergency response teams (see pp. 157–158).

[71] Pp. 119, 131. [72] Pp. 81–82. [73] Pp. 79, 131. [74] Pp. 116–117, 124–127, 138, 141. [75] P. 160. [76] P. 160. [77] Pp. 84–85. [78] Pp. 84–86. [79] P. 84. [80] Pp. 110ff. [81] P. 84. [82] Pp. 94–109. [83] Pp. 94–109. [84] Pp. 113ff. [85] Pp. 113–117, 138–141. [86] Pp. 138–141. [87] Pp. 145, 147–149. [88] Pp. 119–120, 127–128, 130–132, 137–138, 143, 145.

give serious consideration to recommending protective action.[89]

d. The State did not actively solicit the information it needed to make independent judgments about plant conditions.[90] Rather, it simply relied on incomplete and often inaccurate information supplied by the utility. As a result, the State, which has primary responsibility for ordering protective action, did not appreciate the serious need to consider such action.[91]

e. A review of all the responses discloses three basic deficiencies:

- Pre-accident emergency response planning was inadequate.
- Transmittal of information was badly mishandled.
- Failure to perceive the need for serious consideration of protective action was a major oversight.

2. THE UTILITY'S RESPONSE

a. During most of the first day of the accident, plant operators and managers,[92] according to their statements, failed to diagnose the plant's condition—in particular, the loss of core coolant during the initial hours, and the subsequent uncovering of, and severe damage to, the core.[93] Control room personnel did not systematically bring together, review and track plant conditions. Such actions would have helped them in diagnosing the status of the reactor.[94] In some instances, they said they discounted plant behavior and indicators that suggested the core had been uncovered and damaged.[95] Their statements indicate that to the extent they discussed key symptoms or events, they did so without analyzing causes or possible consequences.[96]

These failures contributed to actions by control room personnel that led to a worsening of the accident and that contributed to its duration.

b. The actions of the plant operators and managers must be analyzed in the context of deficiencies in training,[97] control room design,[98] instrumentation and equipment,[99] plant design,[100] and emergency procedures,[101] as well as the stress and confusion produced by the crisis.[102]

c. One reason control room personnel failed to diagnose plant conditions correctly was that key readings of temperatures in the core were rejected. Instruments from which they had been taken—the incore thermocouples, which provide core coolant temperatures—were thought to be unreliable. Some thermocouples had failed, but others remained operational and were in fact giving the only direct and reliable readings of core temperatures.[103] The director of the utility's emergency command team said he was advised by the lead instrumentation engineer that an initial set of five thermocouple readings indicated all the thermocouples should be considered unreliable [104]—advice which proved to be incorrect.[105] The team did not receive a subsequent set of readings taken from all 52 thermocouples, although such information was available.[106]

Had plant operators and managers considered the thermocouples reliable, they would have had a clear signal that the core was or had been uncovered. The thermocouples also would have been useful in tracking the success of attempts to return the plant to a stable condition.

Another important instrument, the movable incore detector, also could have been used prior to severe core damage to help determine whether the core was covered and whether operating strategies were effective. Some utility personnel said they considered it to be a device for use by the reactor-vendor.[107] The instrument was not used the first day.

d. According to accounts by control room personnel, there were other instances in which they missed, misinterpreted or discounted critical information [108] and in which critical information was not communicated to and among key personnel, resulting in fragmentaion of information that impeded an effective response.[109] An example was the response to the hydrogen burn in the containment at 1:50 p.m. This burn was a symptom of uncovering of, and damage to, the core. There were several indicators of the burn, including [110]

—An unusually high reading of containment pressure—the "pressure spike"—which appeared on a strip chart in the control room;
—Automatic start-up of cooling sprays in the containment;
—Automatic isolation of the containment, in response to the high pressure;
—Automatic actuation of the high pressure injection system (a part of the Emergency Core Cooling System); and
—An unusual noise heard in the control room.

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[89] Pp. 119–120, 132–134, 146–147. [90] Pp. 121, 135–136. [91] Pp. 121, 135–136.

[92] Four control room personnel were on duty when the accident began and were responsible for the utility's immediate response. They were joined by a supervisor and two engineers within minutes, and later by other engineering and supervisory personnel. At 8 a.m. the utility established an emergency command team, which included a representative of the reactor-vendor. These control room personnel made decisions for the first 12 hours. (See p. 112.)

[93] Pp. 102–104, 120, 124–127, 129–130. [94] Pp. 99–109, 113–114, 141–143. [95] Pp. 113–114, 116–117, 124–127, 138–142. [96] Pp. 113–114, 124–127, 138–142. [97] Pp. 73–76. [98] Pp. 56–64. [99] Pp. 65–66. 69–71, 94, 96, 99–101, 103, 104, 155. [100] Pp. 96, 99–100, 125–126. [101] P. 58. [102] Pp. 97–101, 105, 109, 117, 124–127, 138–140. [103] Pp. 116–117. [104] Pp. 113–114, 116–117. [105] Pp. 116–117. [106] P. 114. [107] Pp. 74, 112. [108] Pp. 117–118, 124–127. [109] Pp. 102–104, 124–127, 143–144, 151. [110] Pp. 138–141.

Some control room personnel said they were unaware of any of the symptoms.[111] Those who said they were aware of most of the symptoms suggested that they had focused only on the pressure spike on the strip chart and that they had discounted it as an electrical malfunction.[112] Only one person said he concluded there had been a hydrogen burn.[113] Utility personnel maintained that they did not conclude the symptoms represented cumulative evidence of a core that had been uncovered and damaged.[114]

e. As noted, the failure of the utility to transmit accurate information on plant conditions during the first day, particularly regarding the hydrogen burn, has led to questions about whether the NRC, the State, and the public were denied important information by the utility.

The weight of the evidence does not support intentional concealment of information by the utility on the first day of the accident. There are conflicting statements as to whether the director of the utility's emergency command team was made aware of major evidence of uncovering of, and severe damage to, the core.[115] On balance, however, the evidence indicates that neither he nor other utility personnel deliberately withheld this information. In fact, the actions of these personnel during the first day of the accident indicate that, for all the underlying reasons discussed in I.A.2 and I.D.2.b above, they did not know or fully understand the information available to them. They were unprepared for, and unable to respond effectively to, the emergency.

3. THE NRC'S RESPONSE

a. The NRC's response during the critical hours of the first day was inadequate. The NRC did not contribute effectively to the utility's effort to diagnose conditions at the plant, nor did it provide guidance to the utility.[116] Though responsible for public health and safety, the NRC did not adequately consider evacuation or other protective action, nor did it advise the State in this area.[117] This was so even though on at least two occasions, key members of its emergency response organization expressed their belief that the core was or had been uncovered,[118] a situation clearly necessitating consideration of protective action.[119]

b. The NRC confined itself to monitoring events at the plant, relying on the utility for data on plant conditions.[120] For most of the first day, the NRC was unable to carry out even this limited role effectively because it lacked accurate data.[121] Information was frequently unavailable, incomplete or garbled in transmission to both regional and headquarters staff and between the regional staff and headquarters.[122]

c. No representative of the NRC was in the control room of the crippled reactor until 11:30 a.m., over seven hours after the accident began.[123] Even then, the NRC onsite team failed to obtain, assess and transmit in a timely fashion information on key aspects of plant conditions, including superheated steam in the hotlegs,[124] the utility's inability to depressurize to the point at which the decay heat removal system could be used,[125] and the symptoms of the hydrogen burn.[126] Both the onsite team and the regional office also failed to obtain in a timely fashion accurate information in response to specific requests from NRC headquarters, including those for incore temperatures and for strategies being pursued by the utility.[127]

d. The activities of the onsite and offsite teams were poorly managed.[128]

The NRC, both on- and offsite, did not have a systematic method for asking pertinent questions of the utility or for following up on issues raised, especially about whether the core was covered.[129]

At NRC headquarters, there was little, if any, coordination among the components of the agency's Incident Response Center.[130] NRC headquarters personnel who received important information did not systematically transmit it to decisionmakers at the Center or to the Commissioners.[131] As with the utility, there was no effective means for assuring that each of the responsible decisionmakers received and understood significant information, such as indications of superheated steam in the reactor and its implications.[132]

The NRC Commissioners exercised virtually no oversight of senior staff at the Response Center on the first day.[133] Their assumption had been that any possible accident would not be of sufficient duration to permit their active involvement, and they were not prepared for that role.[134]

e. The Acting Chairman, a member of the Commission since its inception, was unfamiliar with the NRC's emergency response organization and its responsibilities.[135] He served as Acting Chairman the first day because the Chairman, the most technically qualified member of the Commission,[136] was absent for personal reasons.[137] The remaining members of the Commission either were unaware

[111] P. 140. [112] P. 141. [113] P. 140. [114] Pp. 138–141. [115] Pp. 138–141. [116] P. 145. [117] Pp. 133–135. [118] Pp. 119–120, 145–148. [119] Pp. 85–86, 133–135. [120] Pp. 137–138, 145–146. [121] Pp. 119ff. [122] Pp. 119, 127–128, 131–132, 137–138, 143–144. [123] Pp. 130–131. [124] Pp. 145–148. [125] Pp. 141–144, 147. [126] Pp. 138–141. [127] Pp. 128, 137, 145, 159. [128] Pp. 137, 140, 145–147, 160. [129] Pp. 137, 140, 145–148, 160. [130] Pp. 146, 157–159. [131] Pp. 145–148. [132] Pp. 145–148. [133] Pp. 150–151. [134] P. 151. [135] Pp. 133–135, 146–147.

[136] Nuclear Regulatory Commission Special Inquiry Group, *Three Mile Island: A Report to the Commissioners and to the Public*, Volume II, part 3, p. 933.

[137] P. 119.

of available information on the plant's condition or did not understand its significance.[138] One Commissioner was told by an NRC staff member at 9 a.m. that the core probably had been uncovered and that the state of the reactor was uncertain. Yet neither the Commissioner nor the staff member raised the issue of protective action.[139]

f. Information communicated by the NRC to the White House and other Federal agencies during the first day was incorrect and misleading. During the afternoon, senior staff in the Center believed that plant conditions were unstable, and they were concerned that the core was uncovered.[140] Yet, during this same period, the Response Center informed the White House Situation Room and the Department of Health, Education, and Welfare that the utility was having no trouble keeping the core covered.[141]

This serious error, which has not been satisfactorily explained,[142] served to preclude the President and Federal officials from considering the need to mobilize Federal resources to assist the State and the NRC on the first day.

4. STATE AND LOCAL RESPONSE

a. The State's response was inadequate because of deficiencies in its plans, insufficient information, fragmentation and lack of resources, and poor management.[143] As a result, the State did not appreciate the serious need to consider evacuation or other protective action on the first day.[144]

b. The State's emergency plans led it to rely on the link between a State environmental agency—the Bureau of Radiological Protection (BRP)—and the utility for information about the plant.[145] This made the State dependent on the utility for such information.[146] Furthermore, the BRP had only one technically qualified person familiar with plant operations, a nuclear engineer. He was frequently called away to brief the State's emergency management group, and thus was not available to request and to analyze information from the plant.[147]

c. The State's response to the accident was managed by a group of State officials that had been organized that day and that had not been designated in any of its emergency response plans. This group failed to communicate information on the status of the reactor to either State or local agencies.[148]

d. The State is ultimately responsible for determining whether protective action is necessary and, if so, for ordering and implementing it.[149] The principal reason the State did not not perceive the serious need to consider protective action on the first day is that it did not receive accurate information on the severity of the situation at the plant. The utility did not provide the ongoing information on plant conditions necessary to determine the need for protective action, and the State did not solicit it.[150] State officials saw their role as acquiring data on actual radiation releases that they deemed to be the determining factor as to whether protective action was needed.[151]

5. INFORMATION TRANSFER

a. During the first 12 hours of the accident, a significant amount of information was mishandled, as a review of the responses of the utility, the NRC, and the State makes clear.[152] Accurate information on the following plant conditions was lost at one or more points in the chain of communications:

- —Lack of natural circulation;[153]
- —Superheated steam in the reactor;[154]
- —Concern that the core was uncovered;[155]
- —The correct setpoint for decay heat removal system;[156]
- —Hotleg temperatures;[157]
- —Incore temperatures;[158]
- —Symptoms of the hydrogen burn;[159] and
- —Strategies being pursued by the utility to stabilize the reactor.[160]

Information was lost within the utility,[161] between the utility and the State,[162] between the utility and the NRC's regional office,[163] between the utility and NRC headquarters,[164] between the utility and NRC onsite representatives,[165] between NRC onsite representatives and the regional office,[166] between the regional office and headquarters,[167] between members of the headquarters senior staff,[168] between senior staff and the Commissioners,[169] and between senior staff and other Federal agencies.[170]

b. As predicted in the consultant's study following the Browns Ferry fire, one reason the NRC lost information was that it had not established a com-

[138] Pp. 131ff. [139] Pp. 119–120. [140] Pp. 145–148. [141] P. 149. [142] P. 149. [143] Pp. 84–85, 121–123, 135–136. [144] Pp. 135–136. [145] Pp. 84, 122. [146] Pp. 84–86, 135–136. [147] Pp. 135–136. [148] Pp. 121–123. [149] Pp. 135–136, 159. [150] Pp. 135, 159. [151] Pp. 85–86, 135. [152] Pp. 113ff. [153] Pp. 120, 131, 143–144. [154] Pp. 114, 124–127, 142, 145–148. [155] Pp. 114, 116, 120, 126, 128–129, 132, 145. [156] P. 129. [157] Pp. 119, 132, 137–138. [158] Pp. 113–114, 116–117, 137, 145. [159] Pp. 138–141. [160] Pp. 127–128, 137. [161] Pp. 113–114, 116–118, 124–125, 127, 138–140, 142. [162] Pp. 121, 135, 159. [163] Pp. 118, 120, 127, 130–132, 145. [164] Pp. 143, 145. [165] Pp. 129, 138–140. [166] Pp. 137, 140. [167] Pp. 119, 131–132, 137, 145. [168] Pp. 132–133, 146. [169] Pp. 119, 133–134. [170] Pp. 120, 149.

munications system independent of the licensee.[171] The NRC did not heed prior recommendations for direct "hotlines" to operating reactors and for direct transmission of plant data offsite.[172]

c. The accident demonstrated, however, that adequate communications technology will not of itself ensure proper transmission of information. In the afternoon, senior NRC officials were questioning whether the core was uncovered.[173] When they finally obtained a direct link to the control room at Unit 2, a senior NRC staff member communicated his concern only to an NRC inspector in the control room. He did not pursue the question directly with the utility personnel. Nor did he ask the inspector to pursue the matter with the utility,[174] despite a suggestion from the Acting NRC Chairman that he do so.[175]

d. Implicit in the consultant's recommendation that the NRC improve its communications system was a recognition of the limits on human performance imposed by stressful conditions. Statements by utility operators and managers suggest that their confusion and anxiety under stressful conditions was an important factor contributing to the loss of information and failure in communications.[176]

e. Control room personnel were uncertain of the status of the reactor for a prolonged period on the first day of the accident. This uncertainty was itself a "plant condition" that should have been clearly communicated to the State and the NRC and used as a factor in determining the need for protective action.

6. PROTECTIVE ACTION

a. On the day of the accident, the emergency plans of the utility,[177] the NRC [178] and the State,[179] as well as the Environmental Protection Agency's (EPA) Manual of Protective Action Guides,[180] were inadequate or incomplete regarding either:

1) factors to be weighed in projecting dose rates so that adequate consideration could be given to the need for evacuation or other protective action;

2) information that a utility was required to communicate to the NRC, the State and the public during the accident.

b. The actions of the utility, the NRC and the State on the first day indicate that, in determining the need for protective action, they relied too heavily on the radiation dose levels specified in the EPA Protective Action Guides.[181] None adequately focused on plant conditions—including uncertainty—as key factors in projecting doses for determining whether action was needed to protect the surrounding community.[182]

c. The EPA has legal responsibility for providing guidelines to the States and utilities on protective action. Therefore, it must shoulder some responsibility for inadequacies in protective action decisionmaking during the accident.

The 1975 version of the EPA Manual makes one ambiguous reference to plant conditions as a factor to be used in projecting doses, without specifying their importance.[183] A January 1979 revision of the Manual (and a further revision made following the accident) make plant conditions a crucial element in formulating projected doses, but still do not define the term "plant conditions." [184] The various versions of the Manual also fail to specify any role for the NRC and do not provide guidance to the States and utilities as to how decisions on protective action are to be reached in the event there is uncertainty as to what is occurring at the plant.[185]

d. Although the EPA guidelines were ambiguous and incomplete, it should be stressed that even in the absence of any guidelines, the utility, the NRC and the State nevertheless should have given great weight to plant conditions, particularly the uncertainty about uncovering of the core, as being a determining factor in considering the need for evacuation or other protective action.

The utility was remiss in not clearly communicating its uncertainty on the morning of the first day to the NRC and the State. At the same time, the NRC and the State were remiss in failing to pursue effectively with the utility the issue of plant conditions, including most particularly its uncertainty about whether the core was uncovered.

Statements by members of the utility's emergency command team indicate that some of them were uncertain about whether the core was uncovered at 8:30 a.m. on the first day of the accident. It is unclear from statements by the team leader responsible for recommending protective action as to whether he was among those who were uncertain during this period. Two weeks after the accident, he said: "Based on the instruments we had, we didn't know if the core was covered." [186] Subsequently, he said: ". . . I didn't believe the core was uncovered, but I listened to people in my group looking for double assurance." [187]

e. If the utility official responsible for recommending protective action had properly understood his role, as defined by the EPA Manual and the utility's emergency plan, and if he had been substantially uncertain, based upon plant conditions at 8:30 a.m., about whether the core was

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[171] Pp. 82–83. [172] Pp. 82–83. [173] Pp. 145–148. [174] P. 147. [175] P. 146. [176] Pp. 126–130, 132, 137–139. [177] Pp. 79, 136, 160. [178] Pp. 79–82. [179] Pp. 84–85. [180] Pp. 134–135. [181] Pp. 133–136. [182] Pp. 85–86, 134–135. [183] Pp. 85–86. [184] Pp. 85–86. [185] Pp. 85–86. [186] P. 114. [187] P. 129.

uncovered, he then should have advised State officials that the condition of the plant at that time warranted consideration of a possible precautionary evacuation of the population within a close proximity of the plant.

E. PRIOR OPERATING EXPERIENCE

1. AT OTHER NUCLEAR PLANTS

a. Three Mile Island was not the first nuclear facility to experience the conditions that occurred in the early stages of the March 28, 1979 accident. Important information had been available to the reactor-designer of TMI and to the NRC on minor accidents at two other plants—Oconee in South Carolina and Davis-Besse in Ohio [188]—that were similar to the beginning of the TMI accident.

b. Both the reactor-vendor, Babcock & Wilcox (B&W), and the NRC had programs for evaluating and acting upon individual problems occurring at nuclear power plants. However, the responses of the reactor-vendor and the NRC to these similar accidents suggest that neither had procedures to assure an effective systematic review and analysis of potentially recurring problems.[189] For these reasons, TMI control room personnel did not have the benefit of analysis and guidance, based on similar accidents, that would have helped them in diagnosing and responding correctly to the early events of the accident on March 28.[190]

The deficiencies in industry and NRC programs for evaluating and acting on operating experience at nuclear power plants were among the most important inadequacies in the nuclear safety program brought to light by the accident.

2. AT TMI–2

a. Plant behavior during two incidents in the early testing and operating history of TMI Unit 2 was similar to plant behavior that TMI control room personnel failed to understand during the early hours of March 28.[191]

The first occurred in 1977 during "hot functional testing" of the plant.[192] Steam collected in the hotlegs of the reactor's primary coolant system, causing the water level in the pressurizer to increase as pressure in the system decreased. Details of this earlier event apparently had not been communicated to the operators on duty during the early hours of the March 28, 1979 accident. They neither recognized nor understood similar conditions on the day of the March 28, 1979 accident.[193]

The second incident occurred on March 29, 1978. A temporary loss of power to an electrical control system caused the pilot-operated relief valve (PORV) to open, allowing water to escape from the primary coolant system. The operators on duty did not know the valve was open because there was no indicator of its position in the control room.[194]

Subsequently, the utility installed a command-type indicator that would show whether an electrical signal was being sent to open the valve, but it did not show the valve's actual position. The operators stated that this type of indicator was less desirable than the one they had requested to show actual position directly.[195]

During the March 28, 1979 accident, plant personnel did not realize for more than two hours that the PORV was stuck open. One reason was that the operators took the absence of the light indicating a command to open the valve as evidence that the PORV was closed.[196]

b. Two other aspects of the operating experience of Unit 2 of the Three Mile Island plant contributed to the failure of plant operators and managers to diagnose the early symptoms of the accident correctly.

First, it was known by plant personnel that one or more of the valves on top of the pressurizer had been leaking coolant water for more than six months. Because of the leakage, the temperature readings for the discharge line leading from the valve were abnormally high during normal operations.[197] Statements of control room personnel indicated they had become accustomed to these elevated temperature readings.[198]

During the early hours of the accident on March 28, temperature readings in the line rose even higher after the PORV opened. When the valve stuck open, they remained at a higher temperature than the operators were accustomed to. Nevertheless, control room personnel were misled by the anticipated "normal" high readings and by their knowledge that the PORV had lifted briefly. They, therefore, failed to recognize that the readings during the accident were indicating

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[188] Pp. 76–77.

[189] In assessing a fine of $100,000 against the reactor-vendor, the NRC ". . . concluded that B&W did not have an effective system for collection, review and evaluation, and reporting of important safety information." (Letter from Victor Stello, Jr., Nuclear Regulatory Commission, to J. H. MacMillan, Babcock & Wilcox, re: "Notice of Noncompliance," April 10, 1980.) In response, B&W denied the charges, but paid the fine. (Letter from D. E. Gilbert, Babcock & Wilcox, to Victor Stello, Jr., Nuclear Regulatory Commission, re: "Notice of Noncompliance," May 20, 1980.)

[190] Pp. 77–78, 97, 101. [191] Pp. 65–66. [192] P. 65. [193] P. 97. [194] P. 66. [195] P. 66. [196] Pp. 94, 155.

[197] Usually, high temperatures indicate the valve has opened. Sustained high temperatures indicate that it is stuck open or that there is a slow leak.

[198] Pp. 108, 156–157.

a continuing and significant loss of coolant through the stuck-open PORV.[199]

Had the utility closed the block valve, as required by the plant's Technical Specifications, the loss-of-coolant accident through the stuck-open PORV would not have occurred. Had the utility corrected the PORV leakage, the operators would have been in a better position to determine that the elevated temperature readings indicated a Loss of Coolant Accident.

Second, although high pressure injection (HPI) is designed to actuate under loss-of-coolant conditions, there was a history at TMI-2 of actuation in response to relatively routine problems in the secondary system.[200] Plant personnel had become accustomed to initiation of HPI in response to these less significant incidents. On March 28 they throttled HPI before determining whether there was a loss-of-coolant accident.[201]

II. RECOVERY

A. GENERAL

1. The recovery process at Three Mile Island will take place in two stages: (a) cleanup of the radioactive debris from the accident and (b) final disposition of the plant—either refurbishing it as a nuclear or coal facility or permanently decommissioning it.[202] The Special Investigation addressed principally the cleanup, since discussion of the future of the facility can be only speculative at this time.

2. Cleanup is a large, potentially hazardous and technically difficult task. Large quantities of radioactive gases and water within the containment must be removed, as must damaged fuel and other contaminated material in the reactor vessel. All the radioactive waste must be disposed of.

3. Cleanup is not, however, simply a technical task. It involves many other factors. Financial, social and legal issues were addressed by the Special Investigation. All have a bearing on cleanup decisions.

4. The damaged plant at Three Mile Island must be decontaminated. *How* and *when*, however, are still unresolved.

The timing of the various steps of cleanup poses a dilemma. It is desirable to follow deliberate procedures providing for review of alternatives, for orderly decisionmaking and for public participation.[203] Yet as time passes, there is an increasing chance of accidental releases of radioactivity to the environment [204] and perhaps even of renewed fissioning (recriticality) of the damaged reactor core.[205] At present, the plant's condition is not fully known. Further deterioration can be assumed. Damaged and unmaintained equipment may fail, and there is the potential for human error.[206]

Both the surrounding community and, most immediately, the workers involved in cleanup are at risk.[207] These workers will continue to be exposed to radiation as long as the plant remains contaminated.[208] The hazard to them of accidental overexposure will be present as long as areas of high radiation are widespread.[209] As noted, the pending House-Senate conference report on the FY 1980 NRC Authorization Bill contains an amendment by this Committee directing the NRC and EPA to conduct a feasibility study on acquiring additional information for plant and cleanup personnel bearing on the incidence of any adverse long-term physical health effects from these exposures.

B. TECHNICAL ISSUES

1. The technical aspects of the cleanup at Three Mile Island present unprecedented challenges. For example, certain problems require the development of new equipment and techniques.[210] The most difficult of these is removing and disposing of the damaged core.[211]

However, measurements of samples from inside the containment building indicate that some anticipated technical difficulties in the cleanup, such as the amount of radioactive cesium on the inner walls of the containment building, will not be as extensive as feared, thus simplifying some aspects of the overall task.[212] Recently, on the other hand, the unsuccessful first attempt to enter the containment (the access door was stuck) raises the question of whether unforeseen problems, including corrosion, will make decontamination more difficult.

Similar problems have been solved in cleanups of other nuclear accidents in this country and abroad.[213] But there are differences. First, the cleanup problems at TMI are of a larger scale than ever experienced in the commercial nuclear power program.[214] Moreover, at TMI, unlike with those

[199] Pp. 71, 108. [200] P. 72. [201] Pp. 72, 96. [202] Pp. 188, 190. [203] Pp. 163, 205, 206. [204] Pp. 164, 166.

[205] An NRC report assessed the ways in which recriticality might occur and what the consequences would be. The report found that the most likely radiological consequence of recriticality would be increased dose rates inside the containment and that offsite consequences probably would be non-existent. Hence, the NRC found that the risk is to the workers. See also pp. 165, 166.

[206] If many years pass before appreciable cleanup progress is made, the chance of accidents, including recriticality, accumulates, since there will be roughly 1,800 workers onsite, all capable of human error that could trigger such accidents. See also pp. 164, 185.

[207] Pp. 166–167, 175–177. [208] P. 176. [209] P. 163. [210] Pp. 168, 187–188. [211] Pp. 168, 175, 187. [212] P. 186.
[213] Pp. 219–226. [214] Pp. 169, 221.

prior accidents, private rather than governmental entities bear primary responsibility for accomplishing the cleanup task.[215] Finally, the TMI cleanup is taking place within the context of recent environmental review requirements, including those for public hearings.[216]

More than one year after the accident, many uncertainties remain over the future course of cleanup. As late as early June 1980, the utility had not yet entered the containment in order to conduct a more detailed evaluation.[217]

C. FINANCIAL ISSUES

1. General Public Utilities Corporation (GPU) and its three subsidiary utility companies face financial problems as a result of the accident, as evidenced by the sharply decreased value of GPU common stock and by the downgraded bond ratings given the utilities.[218]

A major expense has been the purchase of replacement power. The three GPU subsidiary companies—Metropolitan Edison Company (Met Ed), Jersey Central Power & Light Company (Jersey Central) and Pennsylvania Electric Company (PENELEC)—have had to purchase electric power to replace the output previously provided by the damaged Unit 2 and by Unit 1, which has not been operating since the accident.[219] Replacement power costs ranged from $20 to over $35 million per month during 1979.[220] The utilities lack insurance to cover this expense and have requested and received considerable rate increases from the public utility regulatory agencies in Pennsylvania and New Jersey to help cover these costs.[221]

GPU has estimated that costs of cleanup alone will total at least $200 million. One management consultant has said that the final figure could be $500 million or more.[222] The utilities have $300 million in property damage insurance to offset part or all of the cleanup cost.[223]

The Pennsylvania and New Jersey public utility regulatory agencies have removed the capital and operating costs associated with Unit 2 from the utilities' rate basis.[224] Thus, the utilities' customers are not paying for cleanup costs.[225]

2. To cover immediate expenses, the utilities have borrowed substantial sums from a consortium of banks.[226] GPU and bank officials as well as officials from the Securities and Exchange Commission all have stated that Met Ed's continued solvency may depend on favorable rulings by the State public utility regulators.[227]

Utility regulators in Pennsylvania and New Jersey have acknowledged the importance of their actions.[228] Thus far, they have indicated their intention to provide the rate relief needed to help preserve the financial viability of the three utilities.[229] In its May 23, 1980 decision, the Pennsylvania Public Utility Commission stated that it was providing Met Ed an "adequate framework" for financial recovery and that it was up to Met Ed to convince bank creditors that it had "the will and the ability to rehabilitate itself." [230]

3. Given the financial situation, New Jersey utility regulators are considering alternatives to Jersey Central's existing operations.[231] For the same reason, Pennsylvania utility regulators considered withdrawing Met Ed's certificate of public convenience (its franchise to serve the public),[232] but in May 1980 decided that the public welfare would not be well-served by modifying or revoking it.[233] At the same time, they affirmed their authority to reconsider the issue.[234]

4. The financial future of the GPU companies also will be affected by an ongoing NRC regulatory proceeding to determine whether TMI Unit 1 will be returned to service.[235] Its resolution will affect the extent to which the utilities must continue to purchase—and require rate relief to cover—replacement power and whether the capital and operating costs of Unit 1 may be returned to the utilities' rate bases.[236] Hearings are not likely to begin before the fall of 1980, and no firm date for a final decision has been set.[237]

5. There have been few instances of bankruptcy proceedings involving major electric utilities. The GPU companies' financial condition, however, has raised this possibility.[238]

An SEC official stated that, as a practical matter, a utility providing electric power to the public would not be closed down.[239] GPU stated that Met Ed's bankruptcy would not be in the parent company's best interest.[240] Banks similarly testified that bankruptcy was not in the lenders' interest.[241]

6. The three operating utilities and their corporate parent, GPU, acknowledged their obligation to clean up the TMI site.[242] However, they declined to make a firm, blanket commitment to do so without regard to future circumstances, particularly bankruptcy of Met Ed.[243]

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[215] Pp. 168, 221. [216] Pp. 163, 202–207. [217] P. 184. [218] P. 190. [219] Pp. 190–191, 194, 212. [220] P. 190.
[221] Pp. 191, 193, 212–216. [222] P. 190. [223] P. 191.
[224] In April and May 1980, the two state public utility commissions also removed the Unit 1 capital and operating costs from the utilities' rate bases; see p. 191, fn. 93, and pp. 212–216.
[225] Pp. 191, 212–213, 215. [226] Pp. 191–192. [227] Pp. 192–193. [228] Pp. 193, 214–216. [229] Pp. 193, 214–216. [230] Pp. 193, 214. [231] Pp. 215–216. [232] Pp. 214–215. [233] Pp. 214–215. [234] P. 215. [235] Pp. 194, 212. [236] Pp. 194, 212.
[237] Pp. 194, 212.
[238] Pp. 193, 194, 214, 216; see letter from Grant G. Guthrie, Division of Corporate Legislation, SEC, to Jonathan Cottin, TMI Special Investigation Staff, November 2, 1979.
[239] P. 194. [240] P. 194. [241] P. 194. [242] P. 195, fn. 105. [243] Pp. 194–195.

Bankruptcy of Met Ed could further complicate cleanup.[244] Yet, the NRC only recently acknowledged the need to prepare plans for this contingency.[245] According to the testimony of NRC officials, the agency has the necessary legal authority to assume that responsibility.[246] However, they also stated that the agency had manpower resources only to manage cleanup activities, not to man all of the equipment.[247]

D. SOCIAL ISSUES

1. Concerns of the communities surrounding TMI have complicated cleanup. Many residents and local officials have expressed strong distrust of the utility and the NRC and have questioned the ability of those two organizations to manage the cleanup and to be candid in discussing problems and risks.[248]

Some of this distrust and anxiety is attributable to events during the March 28 accident and to the cleanup, including several reported accidental radiological releases.[249] Another factor is the failure of the NRC and the utility to agree on a definitive cleanup plan and the continuing attention TMI has received from the media and survey-takers.[250] In addition, there have been complaints that the NRC and the utilities failed to notify local officials of planned cleanup activities.[251]

2. The NRC and the utility have been unsuccessful in their efforts to increase public confidence. In late 1979, NRC and utility officials began holding biweekly public meetings so that cleanup plans could be discussed and residents could ask questions.[252] In addition, once the NRC decided to prepare an environmental impact statement, the agency held public meetings to discuss the scope of this document.[253] By early February 1980, the NRC also set up a permanent office in Middletown to keep in closer touch with events at the site and local concerns.[254]

Yet in late February, an NRC task force on cleanup concluded that segments of the community continued to have strong feelings of fear and anxiety.[255] The task force suggested that the agency consider funding a citizen's advisory group.[256]

Early in April, some citizens became upset with an NRC staff recommendation to vent the krypton in the containment building.[257] Governor Richard Thornburgh asked the Union of Concerned Scientists, a group opposed to nuclear power, to review the NRC staff recommendations,[258] reflecting an attempt to find a technically competent third party whose recommendations concerning cleanup would be accepted by those who remained distrustful of the NRC and the utility.[259] Following review of a number of independent studies, including the Union of Concerned Scientists' study, the Governor decided to support the NRC if it should decide to vent the krypton.[260]

Opposition to cleanup is by no means unanimous, however. Some local citizens are critical of the vocal opponents of cleanup and are anxious to proceed promptly with the cleanup steps proposed thus far so that the process can be expeditiously completed.[261]

E. LEGAL AND REGULATORY ISSUES

1. The legal and regulatory procedures applicable to the cleanup effort at TMI are intended to assure reasonable decisions through consideration of all relevant factors and viewpoints. However, the process results in cleanup proceeding at a deliberate pace. This creates a dilemma. The longer it takes to remove the radioactivity from inside the plant, the more likely it is that further accidental releases of radioactivity will occur before workers can repair or remove deteriorating equipment. Although the NRC has limited authority to act before the completion of the deliberate process, that authority does not completely resolve the dilemma.

2. Cleanup is taking place within the framework of legal and regulatory procedures. The NRC, aided by public comments, is preparing a comprehensive environmental impact statement, which will set forth a range of alternatives for accomplishing cleanup and will consider their environmental effects.[262] In addition, separate environmental assessments have been prepared by the NRC, and circulated for public comment, to assess whether certain specific cleanup steps thus far proposed would have significant adverse environmental consequences.[263]

The NRC is also reviewing proposed modifications to the Unit 2 license. Its procedures provide for formal hearings involving the licensee and parties who may be affected by the modifications.[264] At issue will be: (a) whether the proposed modifications are necessary and sufficient for the maintenance of the facility and for the protection of public health and safety; and (b) whether they would significantly affect the quality of the environment.[265]

The various procedures are intended to afford orderly decisionmaking that provides an opportunity for some form of input from interested parties, including members of the public, particu-

[244] Pp. 194–195. [245] P. 196. [246] P. 196. [247] P. 196. [248] Pp. 196–200. [249] Pp. 197–198, and fn. 114, p. 198. [250] Pp. 197–198. [251] Pp. 197–199. [252] P. 198. [253] P. 198. [254] P. 198. [255] P. 199. [256] P. 198. [257] Pp. 199–200. [258] P. 201. [259] P. 201. [260] P. 201. [261] P. 200. [262] Pp. 201, 204–205. [263] Pp. 201–204, 205–207. [264] P. 208. [265] P. 208.

larly on environmental matters.[266] They also are intended to help resolve differences among the parties involved in or affected by cleanup. These decisionmaking processes are by nature deliberative and extend the time required for reaching final decisions.

3. Legal and regulatory procedures do not necessarily prevent the NRC from taking immediate action that otherwise would await an environmental review. Both the NRC and the Council on Environmental Quality (CEQ) have agreed that if there is an "emergency circumstance," the NRC is authorized to take prompt, specific action even before completion of the comprehensive environmental impact statement.

In non-emergency situations, the NRC, but not necessarily CEQ, maintains that the NRC may take prompt, specific action before completion of the impact statement when necessary to protect public health and safety and so long as an assessment has been made, with public comment, that the particular action will not have a significant adverse environmental impact.[267]

Any differences between the two agencies should be resolved promptly on what may be done in nonemergencies.

4. In October 1979 the NRC authorized prompt use of EPICOR–II to clean radioactive water in the auxiliary building based on the NRC's finding that such action was necessary to protect public health and safety and would have no significant adverse environmental impact. The CEQ concurred but only after concluding that there was an "emergency circumstance." [268]

In June 1980, the NRC authorized prompt venting of the containment, finding that it was in the best interest of public health and safety, would not have a significant adverse environmental impact, and would not limit the choice of reasonable alternatives for future cleanup steps. In those circumstances, CEQ concluded the action would not violate applicable Federal Regulations.

5. The investigation found problems relating to the NRC's planning and management of cleanup that cannot be attributed to the deliberate pace of legal and regulatory procedures.

In early November 1979, some seven months after the accident, the NRC had not formulated new and specific regulatory guidelines to govern radiological releases during cleanup activities; nor had it permitted the licensee to follow the existing regulations, which applied to normal plant operations.[269] Certain cleanup steps thus were reviewed on a case-by-case basis without any clear indication of what radiological releases, if any, would be acceptable.[270]

In addition, even though the issue had been raised within two months of the accident, the NRC took until November 21 to decide whether to prepare a programmatic environmental impact statement, losing many months of valuable time. Finally, at Subcommittee hearings in early November, NRC officials offered no specific schedules for how long cleanup would—or should—take to complete.[271]

More than three months later, problems in these areas persisted. In late February 1980, the NRC Special Task Force concluded that interim criteria were needed to permit radiation releases associated with plant maintenance and data-gathering activities because, lacking any criteria whatsover, NRC staff had tended to submit for prior approval by the Commissioners every cleanup proposal that did not meet a "zero release" requirement.[272] The task force also found that although completion of the environmental impact statement was an important milestone in the cleanup, the staff still was not clear as to how the Commissioners intended to use the statement.[273] Finally, the task force found that cleanup schedules were needed, noting that over the months both the NRC and the licensee had begun giving less priority to developing and implementing cleanup plans.[274]

Based on the task force's recommendations, interim criteria for releases finally were prepared. As of May 1980, however, the NRC still had to determine how and by whom major cleanup decisions would be made after the environmental impact statement is completed. The Commission also still had to determine the role this statement would play in making these important decisions.[275] The Commission had to decide, for example, whether the agency will insist on those cleanup proposals that are believed to have the smallest adverse environmental impact, whether it will set explicit regulatory guidelines to govern radiological release during cleanup and who will have authority to give final approval to proposed steps as cleanup proceeds. These are decisions that must be made.

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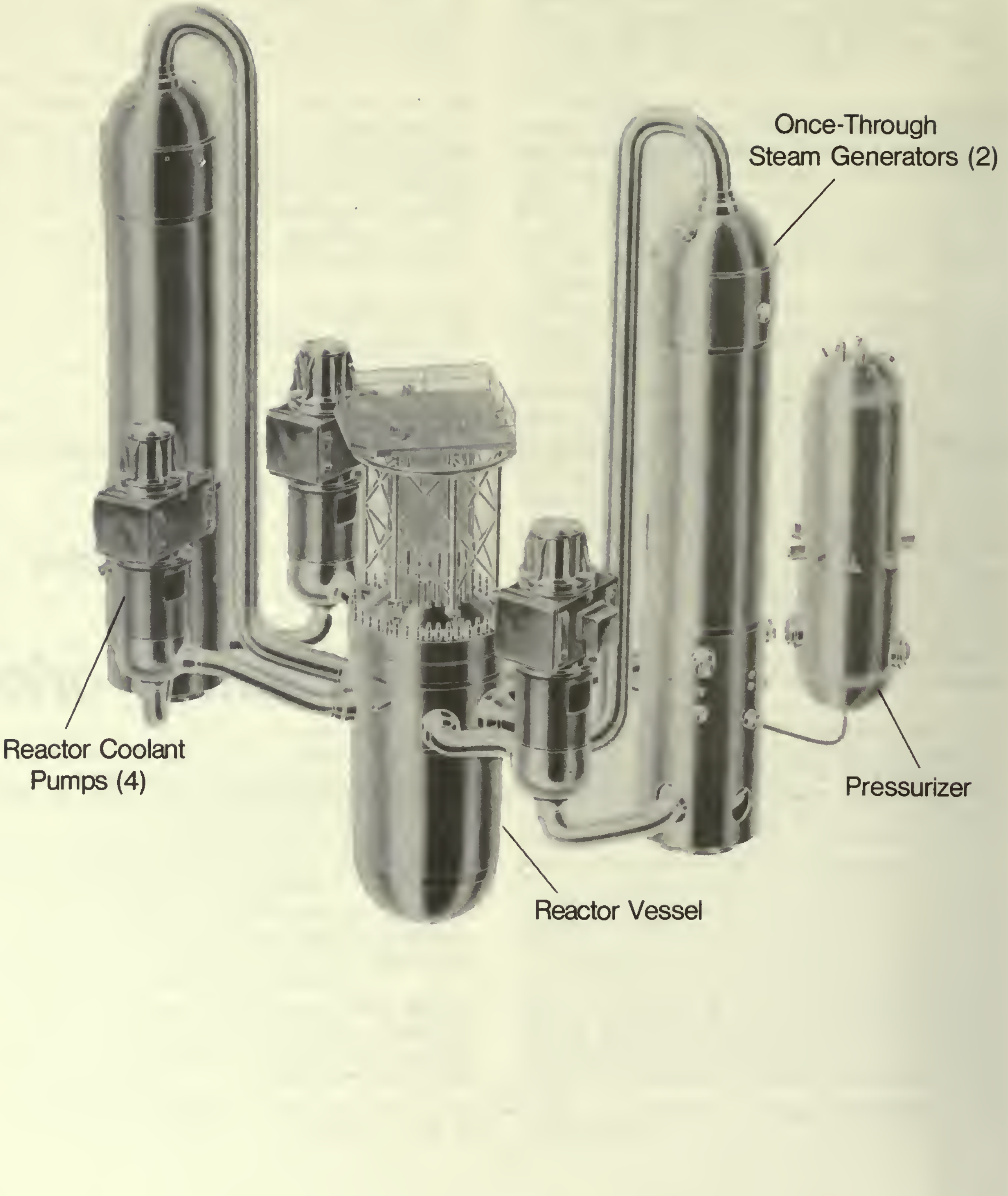
[266] Pp. 198, 202, 205–208. [267] Pp. 203, 206. [268] Pp. 203, 207. [269] Pp. 169–170. [270] Pp. 169–170, 206. [271] Pp. 169–170. [272] Pp. 169–171. [273] Pp. 171, 204. [274] P. 171. [275] Pp. 171, 204.

Chapter 3

How The Plant Works



Adaptation from, Babcock & Wilcox diagram

The nuclear steam supply system at Unit 2, Three Mile Island

Chapter 3

How The Plant Works

NUCLEAR VS. NON-NUCLEAR PLANTS

To understand how a nuclear powerplant works, two important points should be kept in mind.

First, a nuclear plant is very similar to a conventional coal- or oil-fired powerplant. In both, water is heated to produce steam. The steam turns a *turbine* that drives a *generator* to produce electricity. Each type of plant has a large, elaborate plumbing system to heat the water, carry steam to the turbine, condense the steam back into water, and then return the water to the source of heat—similar to the way plumbing in a house carries heated water from a furnace to the radiators and back to the furnace for reheating and recirculation to the radiators.

Second, a nuclear powerplant is very different from a non-nuclear plant in certain essential features. The plumbing in a nuclear plant serves as a *safety system* that is not needed in a fossil-fueled plant. Nuclear fuel is a ceramic made from uranium, a metal, that produces much more intense heat than does fossil fuel. It must be kept covered by rapidly moving water, or *coolant*, that removes the heat and keeps the temperature of the fuel below its melting point. Molten nuclear fuel has the potential to penetrate a plant's structure and foundation and to cause hazardous offsite releases of radioactivity. Even after a nuclear plant is shut down, the fuel produces considerable heat—enough to melt the fuel—and must be cooled for a substantial period by circulating water.

The plumbing in a nuclear plant, therefore, provides a series of redundant safety systems to ensure that the fuel is constantly covered with water. Fossil fuel does not continue to produce large amounts of heat after the fire is stopped and, therefore, does not require this kind of cooling.

THREE MILE ISLAND, UNIT 2

The Three Mile Island Nuclear Power Station has two nuclear *reactors*, Unit 1 and Unit 2, each capable of delivering about 880 million watts (880 megawatts) of electricity, enough to serve a city of nearly 2 million people.

Each reactor is a *pressurized-water* type, meaning that pressure within the reactor and the pipes leading to and from it is kept high—at about 2,200 pounds per square inch. By maintaining this high pressure, water running through the reactor is prevented from boiling at the usual boiling point of 212° Fahrenheit. This permits the water to be heated to much higher temperatures and still be kept in a liquid state without steam bubbles. This, in turn, permits the plant to produce steam far more efficiently than if the water were to boil at normal, atmospheric pressure. (Another type of reactor, the *boiling water reactor*, is less pressurized—1,000 psi—and produces steam directly from the boiling water in the reactor.)

THE BUILDINGS

The *reactor* is the heart of any nuclear powerplant. At Three Mile Island Unit 2, the reactor is housed inside a massive, domed structure known as a *containment building*, also referred to as the *reactor building*. This structure, rising 193 feet above the Susquehanna, has steel-lined, reinforced concrete walls almost two feet thick. The containment provides the final line of defense against escape of high levels of radioactivity from inside the reactor. The containment building also holds some of the major elements of the plant's *nuclear*

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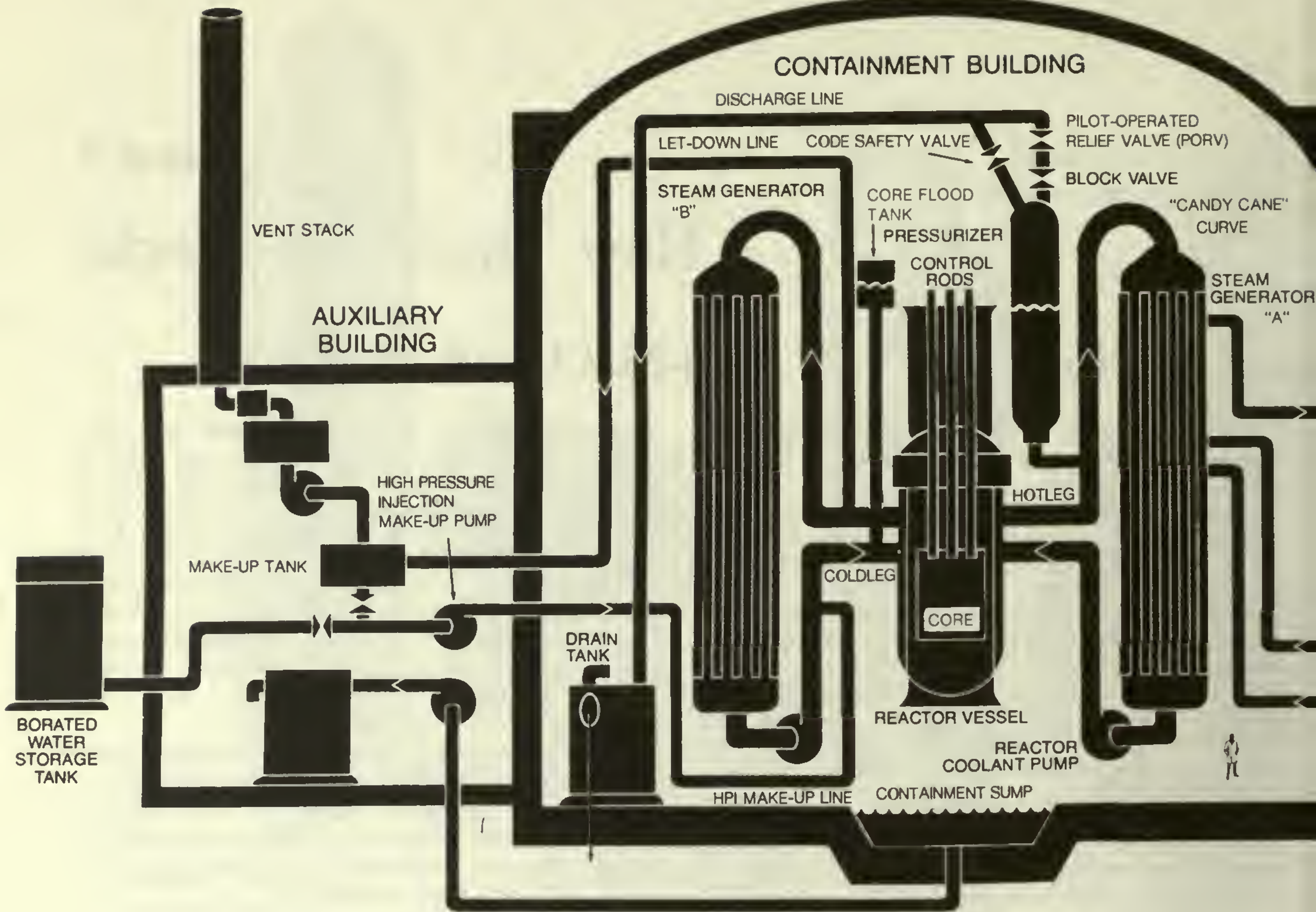


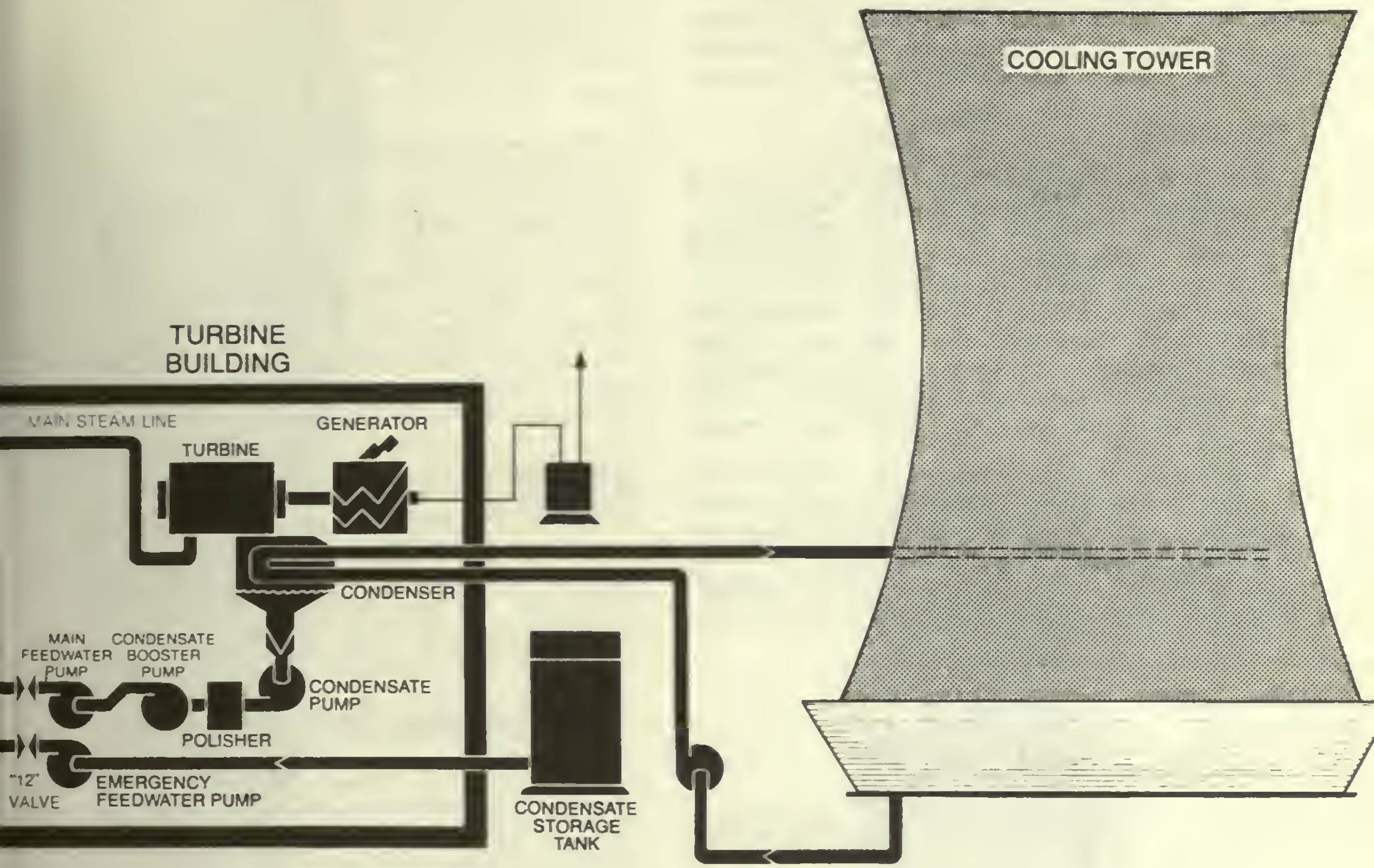
steam supply system—a massive array of pipes, pumps, tanks and valves for circulating coolant through the reactor, and a pair of *steam generators*, each one a 73-foot tall cigar-shaped structure in which steam to drive the turbine is produced. In addition, the containment building houses portions of the *Emergency Core Cooling System* (ECCS), which ensures an adequate supply of water to the nuclear fuel in the event of an accident.

The containment is but one of several buildings and structures that comprise Unit 2. Only one building is shared by the two TMI units—the *fuel handling building*, where relatively non-radioactive fresh fuel is stored without shielding before being loaded into the two reactors. It is also where, after being removed from the reactors, the highly radioactive *spent fuel* is stored in steel-lined "*swimming pools*" beneath 40 feet of water.

Unit 2 has an *auxiliary building* where large pipes, pumps, tanks and filters help to maintain the level and purity of the water flowing through the nuclear steam supply system in the adjacent containment building. This building also contains portions of the Emergency Core Cooling System.

There also is a *turbine building* where the *main steam line* from the steam generators in the containment connects with the *turbine* to drive the electricity-producing *generator*. Here the steam is also cooled and condensed into water and the water purified of minerals before being returned to the steam generators in the containment building.

Outside the Unit 2 turbine building stands a



Adapted from: The Report of the President's Commission on the Accident at Three Mile Islan

Schematic of principal systems and components, Unit 2

pair of 350-foot tall *cooling towers*—the now-familiar hyperboloid structures from which plumes of vapor rise, a product of the process of condensing the steam that has passed through the turbines.

Finally, there is the *control building* in which the *control room*, the nerve center of each plant, is located. It is from here that operators monitor and control the operations of vital plant equipment to ensure that heat is being removed effectively from the reactor.

THE REACTOR

The reactor is a nuclear furnace in which uranium fuel gives off intense heat, leading to fuel temperatures of as much as 3,250° F under normal operating conditions. The heat is produced by *nuclear fission*, the same splitting of uranium atoms in a *chain reaction* that takes place in nuclear weapons and that has been known to exist in nature. But it happens at a slower, controlled rate in nuclear powerplants, so that it is impossible for them to experience nuclear explosions. This is partly because the reactor's fuel is in a dilute form known as *low-enriched uranium*. Even in the worst conceivable accident, there cannot be an atomic explosion.

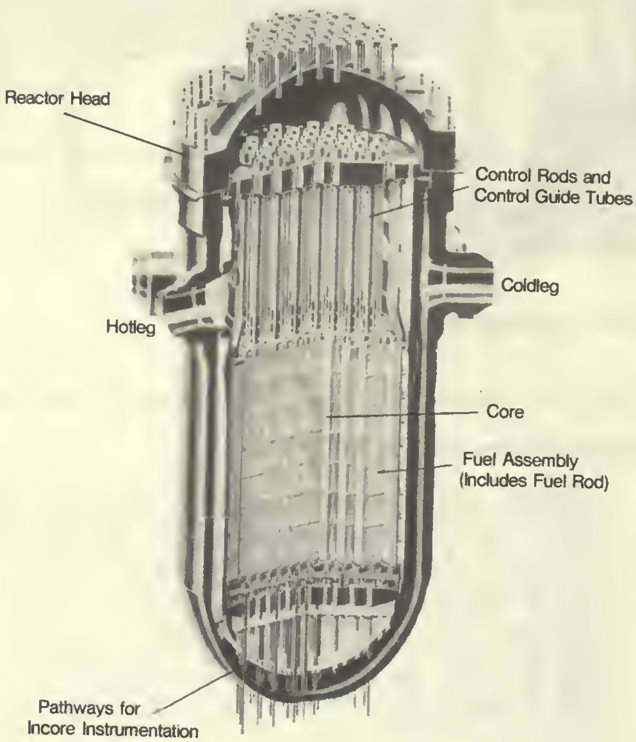
The reactor in the TMI–2 plant has several component parts. It is encased in a 36-foot high tank with steel walls nearly nine inches thick. This tank, known as the *reactor vessel*, is in turn encased by 9½ feet of steel and concrete in the form of two separate shields. The top of the vessel, the *reactor* *head*, is removable to allow for refueling. The reactor vessel and its shielding provide the intermediate line of defense against radioactive releases from the fuel inside the reactor core.

THE CORE

The *core* at TMI–2 holds almost 100 tons of uranium within 177 *fuel assemblies*. Each fuel assembly holds 208 *fuels rods*—thin, 12-foot-long metal tubes containing the uranium fuel. The fuel inside the rods is a compressed powder known as *uranium oxide* that is molded into ceramic *fuel pellets*. Each pellet is about an inch long and less than half an inch wide; they are stacked inside the fuel rods, which, in turn, are grouped into the fuel assemblies. In all, there are 36,816 fuels rods in the reactor core.

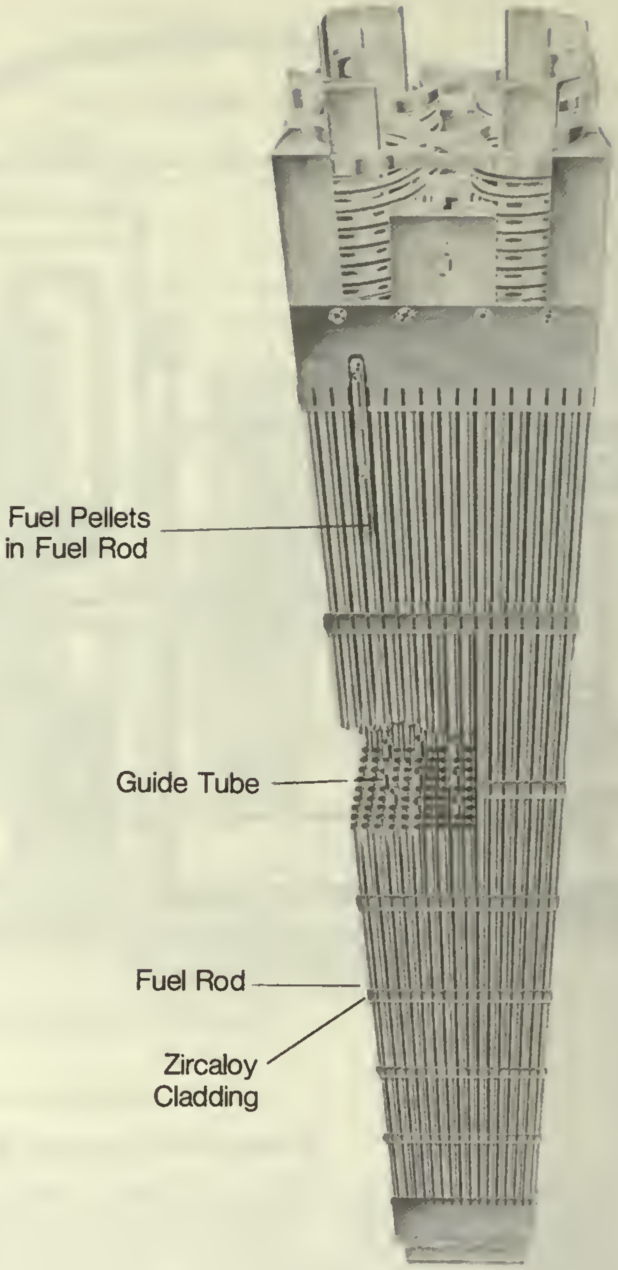
The fuel rods, which are made of an alloy of the metal *zirconium*, known as *Zircaloy*, serve three purposes. First, they provide the initial line of defense against the potential release of hazardous radioactive materials, known as *fission products*, that form in the uranium fuel when the reactor is operating. The products are contained within the Zircaloy walls, or *cladding*.

Second, the Zircaloy cladding permits the almost unobstructed passage of atomic particles called



Reactor Vessel and Core
(vessel filled with coolant)

Adapted from: Babcock & Wilcox



Fuel Assembly

Adapted from: Babcock & Wilcox

neutrons, which, when jettisoned in the splitting of uranium atoms, strike other atoms, causing them to split apart—the so-called chain reaction.

Finally, the fuel rods promote the transfer of heat from the fuel to the coolant water being pumped through the core.

The nuclear fission process inside the reactor is controlled by the insertion of *control rods* into the fuel assemblies and by the addition of *boron* into the coolant. The control rods are long tubes shaped like the fuel rods. They contain materials that absorb neutrons. These materials, known as "*poisons*," include *indium* and *cadmium*.

During normal, full-power operations, the control rods are withdrawn from the core. The rate of the chain reaction is then controlled by *boron* in the coolant, the amount of which can be adjusted. Boron, too, absorbs neutrons.

During an accident, or any sequence of events that seriously interferes with the normal removal of heat from the core, the control rods will automatically drop all the way into the core, thereby "*tripping*" the reactor and instantaneously terminating the chain reaction. This, in turn, stops most of the heat generation by the core, although considerable heat, called *decay heat*, remains.

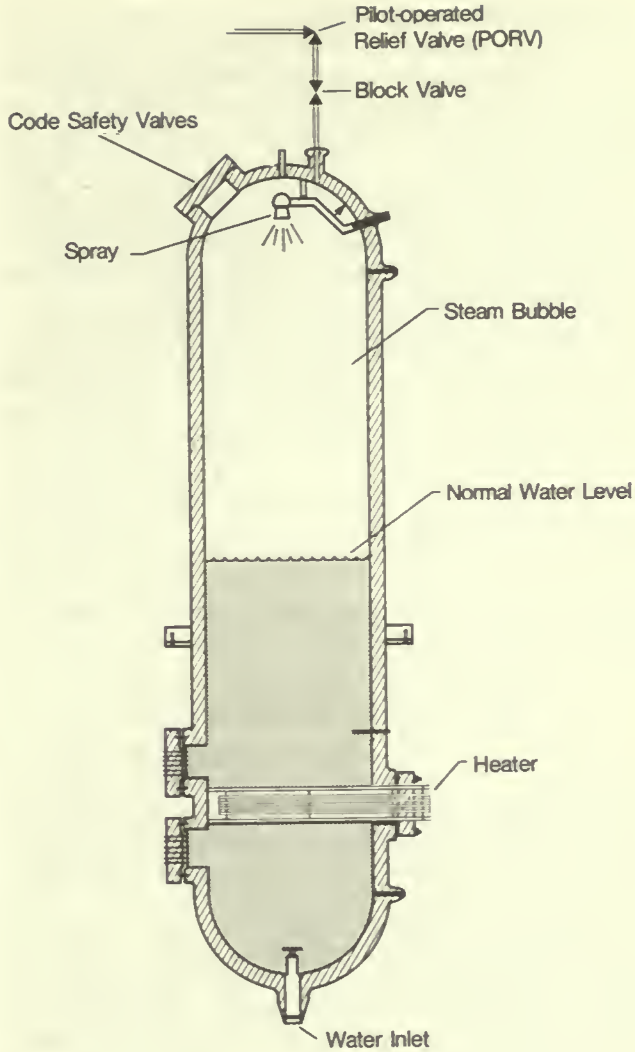
THE PRIMARY SYSTEM

Normally, a nuclear powerplant operates with marvelous precision on a massive scale. Water flows through the core at a rate of 92,400 gallons a minute, pushed by four *reactor coolant pumps*—each five stories high and 9,000 horsepower. Under normal operating conditions the water is heated to nearly 600°F and is subjected to some 150 atmospheres of pressure (2,200 pounds per square inch, equivalent to pressures nearly a mile deep in the ocean). The water leaves the reactor through two pipes, each three feet in diameter, known as the "*hotlegs*." One hotleg leads to steam generator A—the so-called "*A loop*," the other to steam generator B, the "*B loop*." This system for circulating water through the core is known as the *primary system*.

THE PRESSURIZER

Pressure in the primary system is maintained and fine-tuned by a 42-foot-high tank known as the *pressurizer*. In some ways, the pressurizer is like an expansion tank in a home hot water heating system: it provides a place for water in a closed plumbing system to collect when it expands after being heated. An expansion tank, however, is a passive device that simply collects excess water, whereas the pressurizer actively controls pressure in the primary system.

The pressurizer at TMI–2 normally holds 800 cubic feet of water, on top of which is a cushion,



The Pressurizer

Adapted from: Nuclear Safety Analysis Center

or "*bubble*," of 700 cubic feet of steam. Pressure is controlled in the rest of the system by expanding and contracting the steam bubble, which pushes against the primary system water at the bottom of the tank. The bubble is expanded by means of *heaters* in the tank that produce more steam, increasing pressure; or it is diminished by means of *sprays* that condense some of the steam into water, thereby lowering pressure.

If the bubble is lost while the reactor is operating, it is extremely difficult to control pressure in the primary system. Sudden increases in pressure could damage the primary system or break primary piping, since there would be no bubble serving as a buffer. The bubble can be lost if too much water gets into the pressurizer. Operators are trained to avoid having the pressurizer "go solid," as a pressurizer full of water is called.

If pressure in the reactor rises so rapidly that the pressurizer sprays cannot counteract it, a *relief valve* at the top of the pressurizer, known as the *pilot-operated relief valve*, or *PORV*, opens automatically. Steam is released through a *discharge line* that leads to a *reactor coolant drain tank* on the floor of the containment. The PORV is designed to close automatically as pressure in the primary system returns to normal.

There is a back-up safety system that comes into play if additional pressure must be relieved, or if the PORV fails to open or has been "isolated" by a *block valve* because it is leaking. This system involves what are known as *code safety valves.* They open automatically on high pressure and close automatically as normal pressure is restored. Unlike the PORV, the code safety valves cannot be isolated, that is, blocked on command from the control room. They are intended to serve as the final line of defense against excessive pressure in the primary system.

THE STEAM GENERATORS

Under normal operating conditions at TMI–2, the heated, pressurized water in the A and B primary loops passes through the hotlegs, which have "*candy cane*"-shaped curves at their high point, and then enters the corresponding A and B steam generators.

This water transfers some of its heat to cooler water that enters the steam generators from a separate closed system—the *feedwater system* on the *secondary side* of the plant. The water on the primary side, which is radioactive, passes through the steam generators in a series of long, narrow tubes, around which the non-radioactive secondary system water flows. The radioactive primary system water leaves the bottom of the steam generators via pipes known as "coldlegs" and is pumped back into the reactor for reheating and recirculation to the steam generators.

THE SECONDARY SYSTEM

The non-radioactive water in the steam generator boils and turns to steam after being heated by radioactive coolant water from the reactor. The non-radioactive steam leaves the steam generators through the main steam lines and travels out of the containment and into the turbine building, where it enters the turbine. The turbine drives the generator, which produces electricity. Steam from the turbine enters a *condenser*, where it is condensed into water. A *condensate pump* then pushes this water through a *condensate polisher* unit that purifies it in a manner similar to the way a home water-softener works.

A *condensate booster pump* then moves the purified water to the *main feedwater pump* that, in turn, pushes the water back into the secondary side of the steam generator, where it is boiled into steam again for recycling to the turbine.

CONDENSER COOLING SYSTEM

The condenser is cooled by water from yet another closed system. This water, which absorbs heat from the steam in the condenser, is pumped from the condenser to the cooling towers. There it cascades down a series of steps, giving up heat which appears as vapor clouds rising into the sky. This vapor is not radioactive.

Water from the cooling towers is pumped back to the condenser, where the cycle is repeated.

THE SAFETY SYSTEMS

TMI–2, like other pressurized water reactors, has elaborate and redundant safety systems on both the secondary and primary sides of plant to assure adequate cooling of the core.

A LOSS OF FEEDWATER

On the secondary side, a loss of feedwater to the steam generators is a potentially serious problem because the steam generators soon would run dry, thus eliminating the principal means of removing heat from the primary system. This, in turn, would cause temperature and pressure in the core and elsewhere in the primary system to rise rapidly.

In the event of a loss of feedwater caused by a broken pipe, failed pump or other malfunction on the secondary side of the plant, there is a set of *emergency feedwater pumps* that can provide an alternative supply of water from a *condensate storage tank.*

However, the emergency feedwater pumps can be overriden by shutting a set of valves known as the "*No. 12 valves*" that block the flow from these pumps to the steam generators. Inexplicably, these valves were closed at TMI at the start of the accident on March 28, 1979.

In the event the flow of feedwater to the steam generators cannot be maintained, then the supply of steam to the turbine cannot be maintained either. The turbine will automatically react to this problem when the feedwater pumps trip. The turbine will then *trip*—that is, shut down to avoid damage.

On the primary side, if conditions depart sufficiently from the norm, the reactor will automatically trip by dropping its control rods all the way into the core, thus terminating the chain reaction. This is also known as a "*scram.*"

A LOSS OF COOLANT

The sudden increase in temperature and pressure prior to the scram may cause the PORV to open briefly, but, as noted, it is designed to close as pressure drops back to normal. If the PORV should remain open without being detected by control room personnel, as it did at the start of the TMI accident, then the primary system will lose coolant through the pressurizer—a potentially serious "*small-break*" in the system, resulting in a *loss-of-coolant accident* (*LOCA*). If sufficient coolant were lost without being replenished, the core could become uncovered, and severe damage could result, including melting of the fuel.

Again, there is a safety system—the plant's Emergency Core Cooling System. It consists of several back-up safety subsystems designed to compensate for *small-break LOCAs*, such as leakage through the pressurizer, or even for a *large-break* loss-of-coolant accident, such as a rupture of the three-foot-wide coldleg or hotleg pipes.

SMALL-BREAK LOCAS

In the event of a small break in the primary system, additional coolant is provided by the automatic start-up of the *high pressure injection* (*HPI*) *system*. It uses the *make-up pumps*, located in the auxiliary building, that are normally used to replenish the primary system through the high pressure injection of *borated water* into the coldlegs. The source of this additional water is the *Borated Water Storage Tank*. This emergency system operates when pressure in the primary system is high, the case with small-break loss-of-coolant accidents, in which little pressure is lost because, as the name implies, the break is small.

LARGE-BREAK LOCAS

In the event of a large break in a coolant pipe, pressure would drop so low that the high pressure injection system would be supplemented by other parts of the Emergency Core Cooling System. *Core flood tanks* directly above the reactor would dump thousands of gallons of coolant directly into the reactor vessel. They drop their water onto the core as soon as reactor pressure drops below 600 psi.

As pressure drops further, a *low pressure injection* (*LPI*) *system* (not shown in the figure), also drawing from the Borated Water Storage Tank, provides coolant at a much higher rate.

If the supply of water in the tank is depleted, water may be drawn from the *containment sump*, where water flowing out the break will collect.

DECAY HEAT REMOVAL SYSTEM

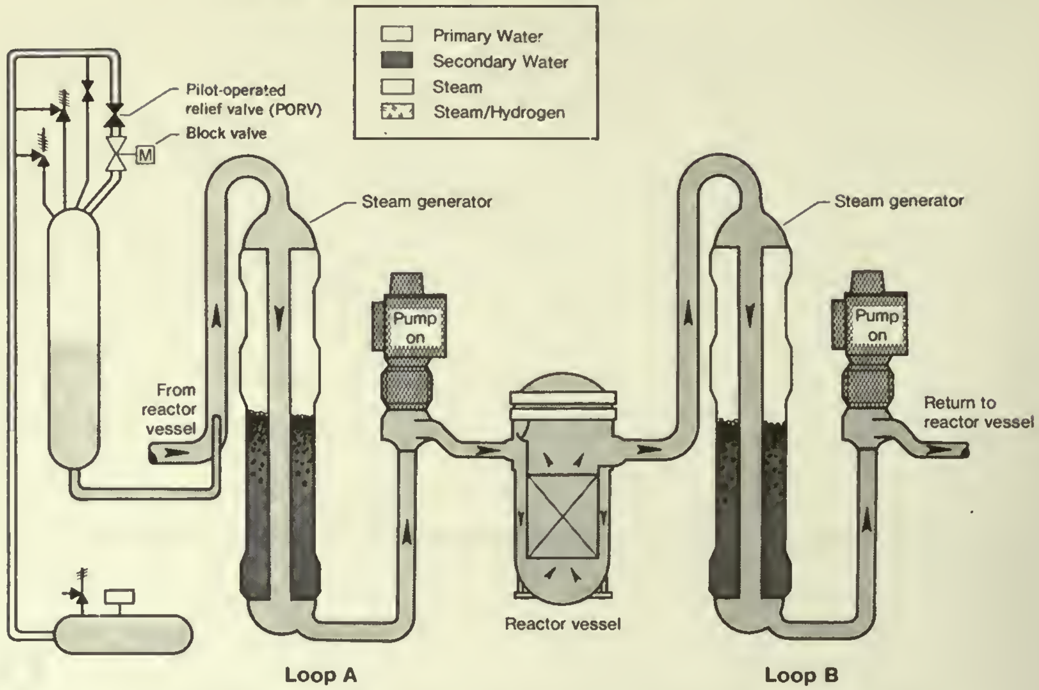
After a reactor scram, residual or decay heat must continue to be removed from the core. This is the heat generated by the radioactive decay of fission products in the nuclear fuel even after the chain reaction has been halted. This decay heat is substantial—substantial enough to melt the fuel if the core is not kept covered with coolant water. But it diminishes rapidly at a steady rate over a period of several hours to a relatively low level, but still substantial amount, of heat.

With the Emergency Core Cooling System keeping the core covered, plant operators work to bring primary system temperature and pressure down by removing heat through the steam generators. When temperature is reduced to about 300°F and pressure to about 400 psi, low pressure injection pumps would be used to circulate coolant. In this case, the coolant goes not to the steam generators, but to a separate heat exchanger located outside the containment. The LPI pumps (when used in this manner), the heat exchangers, and the piping are known as the *decay heat removal system*. This system permits temperature to be lowered below the boiling point of 212°F—to about 120°F—and depressurization to atmospheric pressure. At that point the plant is in a stable state known as *cold shutdown*.

Chapter 4

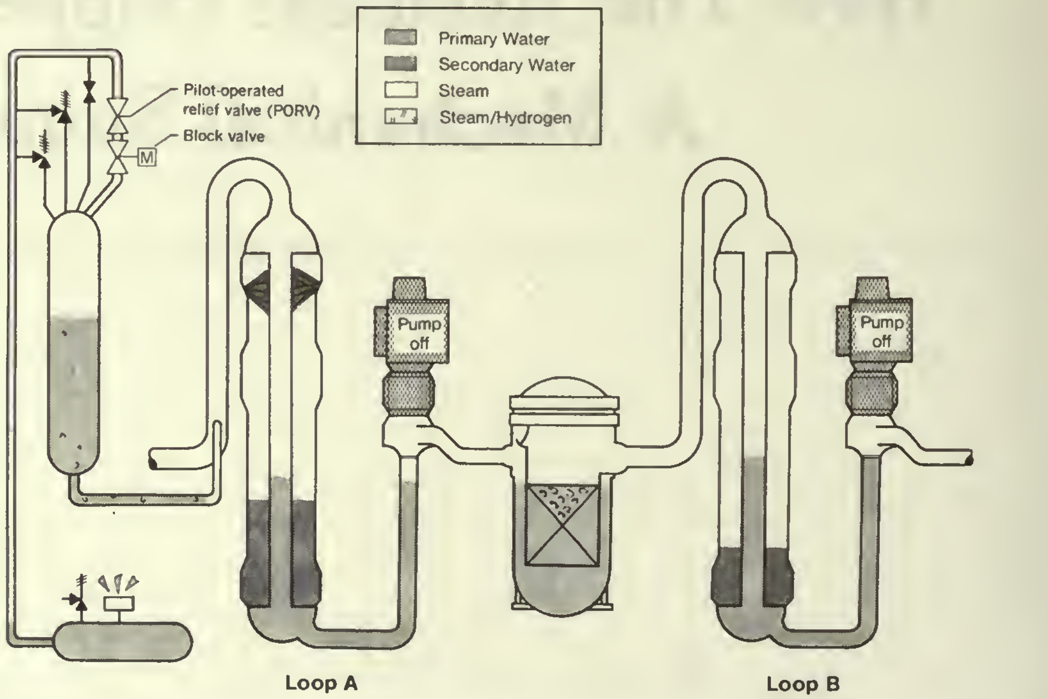
How The Accident Happened: A Mechanical Summary

FROM NORMAL CONDITIONS . . .



1. Coolant throughout the primary system; core completely covered.

TO SATURATED STEAM . . .



2. Coolant lost through the stuck-open PORV; decreased pressure caused coolant to boil; reactor coolant pumps had to be turned off; saturated steam rose out of coolant; core barely covered with coolant.

(Continued on page 36)

Chapter 4

How The Accident Happened: A Mechanical Summary

THE FIRST SECONDS

The nuclear accident at Unit 2 of Three Mile Island began 36 seconds after 4 a.m. on March 28, 1979, when all the outlet valves on the condensate water polishing system closed, tripping the feedwater pumps. This, in turn, stopped the flow of water to the steam generators on the secondary side of the plant. At that point, the turbine tripped. The emergency feedwater pumps activated automatically to maintain flow to the steam generators, but, inexplicably, the valves were closed between the pumps and the steam generators, blocking the flow. As a result, no water on the secondary side could reach the steam generators.[1]

All this occurred in the first seconds. Heat in the reactor vessel and the rest of the primary system began to increase, causing a rapid rise in pressure in the primary system. This, in turn, caused the pilot-operated relief valve (PORV) on the pressurizer to lift. Pressure continued to rise. Very soon the reactor tripped, and the control rods fell into position between the fuel rods. Pressure in the primary system began to fall as less heat was generated in the reactor. The accident was still only seconds old.

A LOSS OF COOLANT ACCIDENT

The PORV failed to close, as designed, when the pressure dropped. Steam and water continued to flow, undetected, out of the pressurizer.

Pressure in the primary system continued to fall as the volume of coolant contracted from the loss of heat and as coolant escaped through the stuck-open PORV.

A loss-of-coolant accident (LOCA) was underway. It went undetected because control room personnel did not realize the PORV was stuck open.

Two minutes into the accident, the high pressure injection system (HPI), an emergency system designed to compensate for a loss of coolant, automatically started pumping water into the reactor vessel at 1,000 gallons per minute. Meanwhile, the pressurizer was filling with water. In response, operators severely throttled this flow to avoid overfilling the pressurizer.

The limited amount of water flowing into the primary system was inadequate to replace the amount being lost through the PORV—a potentially dangerous loss of coolant if not corrected.

STEAM IN THE SYSTEM

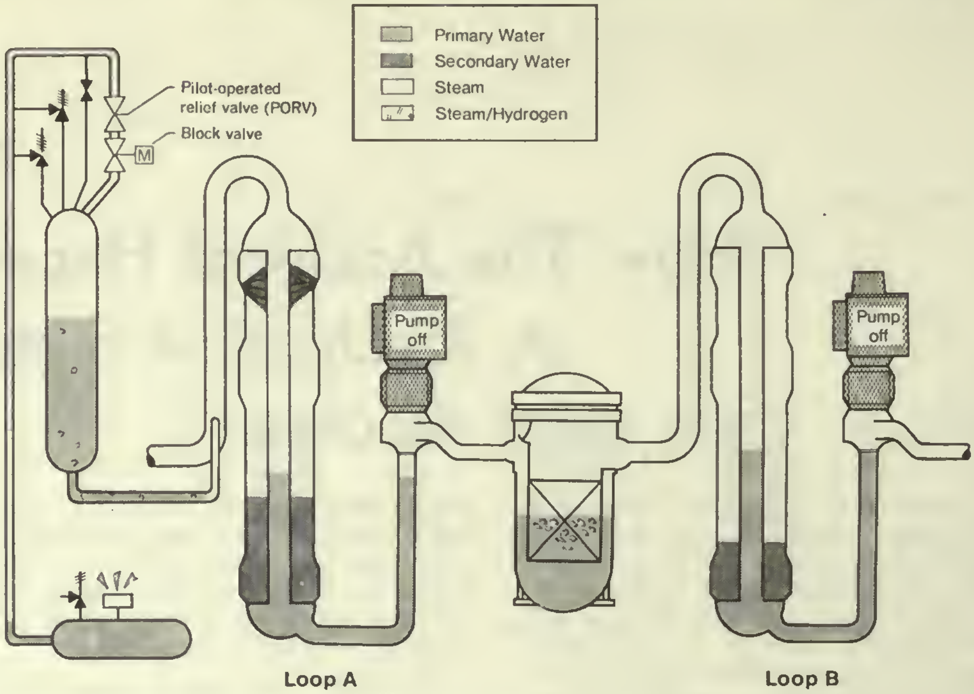
Within minutes, as a result of the loss of pressure in the primary system, the coolant began to boil, causing saturated steam to form in the coolant. At about one hour into the accident, the reactor coolant pumps that circulate the water through the primary system began vibrating because they were beginning to pump the steam-water mixture produced by the boiling. At about 1¼ hours, two were turned off to prevent damage; the last two were turned off at 1¾ hours into the accident.

CONDITIONS WERE NOT UNDERSTOOD

For the first 1¾ hours, control room personnel struggled to understand what was happening in the plant. Hundreds of alarms went off, signaling such things as unusual conditions in the reactor coolant drain tank, high temperature and pressure in the containment building, and low pressure in the primary system. The conditions that developed were beyond those that control room personnel had experienced in their training or in their operation of the plant. The symptoms described in the emergency procedures did not exactly fit the situation and proved of little help.

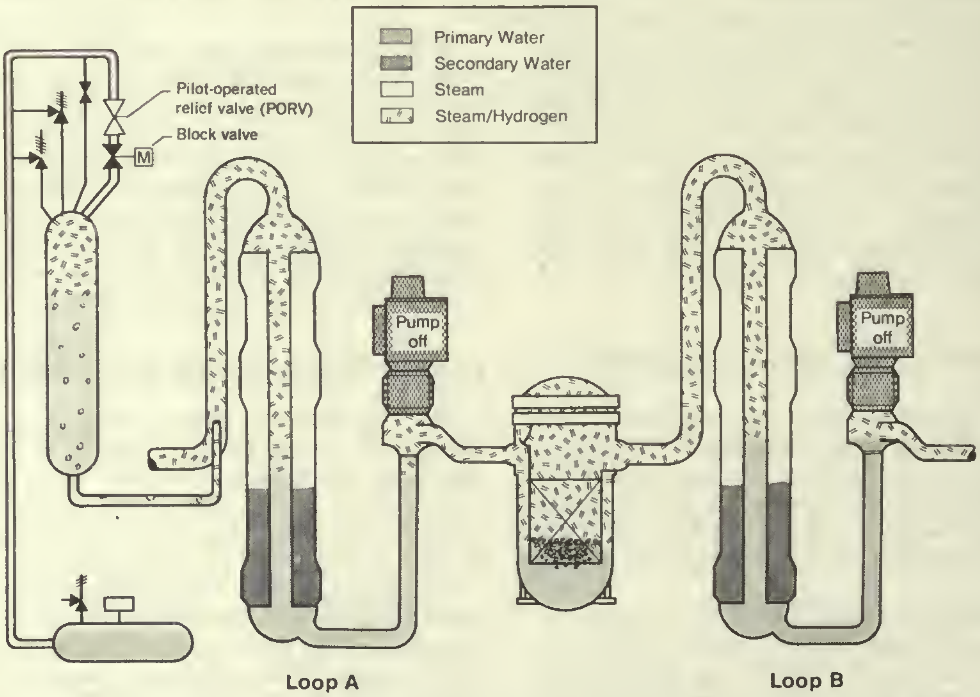
[1] Eight minutes later an operator opened the valves after discovering they were shut.

THEN CORE UNCOVERING AND SUPERHEATED STEAM . . .



3. Core becoming uncovered, exposed fuel heating up; steam in system became superheated.

AND HYDROGEN



4. Core uncovering continuing; temperatures in core hot enough that hydrogen was generated as a result of a chemical reaction between superheated steam and the Zircaloy fuel cladding; hydrogen and superheated steam collecting in hotlegs.

CORE UNCOVERING

Around 5:45 a.m., very soon after the shutdown of the last two reactor coolant pumps, the core became uncovered. The uncovering of the core occurred because, with the pumps off, steam generated by the boiling in the core rose to the higher portions of the reactor vessel and the rest of the primary system, while water continued to escape from the stuck-open PORV and while the HPI remained throttled. Water level fell below the top of the core.

Over the next half hour, the water level fell further until the top two-thirds of the core was exposed. Fuel rods crumbled. Hydrogen was produced as steam reacted chemically with the Zircaloy fuel cladding. Fission products escaped from the failed fuel into the coolant of the primary system.

Plant operators and managers still did not realize the core was uncovered. They were unaware of the stuck-open PORV, and they had no direct means of measuring the level of water in the core.

Finally, at about 6:20 a.m., a shift supervisor who had arrived in the control room about a half hour earlier realized the PORV was stuck open. He ordered that a backup valve, the block valve, be closed. It was, and the loss of coolant was stopped.

A SITE, THEN GENERAL EMERGENCY

At 6:45 a.m., a site emergency was declared, based on radiation levels inside the plant. At 7:24 a.m., a general emergency was declared, based on the potential for offsite radioactive releases. The utility notified State and Federal officials when it declared the site and general emergencies.

Shortly before 7:30, flow from the high pressure injection system was increased. The core was eventually covered again. But steam and hydrogen gas had become trapped in the hotlegs of the primary system, blocking circulation of water through the system.

By this time, three and a half hours into the accident, most of the damage to the core had been done, and radiation levels in the plant were high.

STRATEGIES TO REACH STABILITY

For the rest of the day, control room personnel struggled to regain stability in the plant. The principal problem was to ensure a reliable flow of water through the core. In the morning hours, they first tried to repressurize the system in order to collapse what they believed to be saturated steam bubbles in the system. The blockage was actually caused by a mixture of superheated steam and hydrogen, neither of which could have been condensed into the coolant.

With the failure of repressurization, concern arose over whether the core was covered and whether the limited supply of HPI water available would become exhausted. These uncertainties led to the next strategy—depressurization of the primary system. Utility personnel reasoned that lower pressure would activate the core flood tanks, which would dump more water onto the core, assuring that it would be covered.

WAS THE CORE COVERED?

At about 11:30 a.m. the block valve was opened, allowing steam and gas once again to escape from the pressurizer. Pressure dropped. The core flood tanks eventually dumped water onto the core, but only a limited amount. Some control room personnel interpreted this to mean the core was covered; others concluded that the core had never been uncovered.

Confident the core was covered, at 1:10 p.m. plant operators and managers halted depressurization.

THE HYDROGEN BURN

About 40 minutes later, two members of the emergency command team decided to depressurize again in the hope of reaching a low enough level of pressure to permit use of the low pressure decay heat removal system. As the block valve was opened, there was an extremely sharp increase in pressure and temperature in the containment, accompanied by activation of the containment sprays. This happened when hydrogen in the containment ignited. The hydrogen which had been generated by a chemical reaction between the cladding of the fuel and the steam, burned only a few seconds.

Depressurization again was unsuccessful. For reasons still not definitey understood, pressure in the primary system could not be lowered to the point at which the decay heat removal system could be initiated. During this time, the core may have been uncovered again.

STABILITY ACHIEVED

Finally, about 5:30 p.m., utility executives off-site ordered the emergency command team to re-pressurize the system again. The objective was to collapse enough steam in the primary system to permit the restart of a reactor coolant pump. This time the strategy worked. At 7:50 p.m., relatively stable conditions were achieved as the pump started circulating water through most of the core and the rest of the primary system.

All the damage to the core occurred on the first day. More crises followed, with discovery of the damage to the core on the third day and the ensuing uncertainty caused by the now-famous hydrogen bubble.

Finally, several days later, natural circulation in the primary system was finally achieved.

CHRONOLOGY OF EVENTS, MARCH 28, 1979

Following is a brief chronology of the major events of the accident during the first day:

Brief chronology of events,[1] *March 28, 1979*

Clock time	Elapsed time since the accident began	Event
4:00 a.m.	00:00:00	*Loss of feedwater.* Initiated the accident; emergency feedwater system starts but fails to supply the steam generators because of closed valves.
Do	00:00:01	*Turbine shuts off.* Automatic upon loss of feedwater.
Do	00:00:03	*PORV opens.* Relieved high primary system pressure; provides path for loss of coolant.
Do	00:00:08	*Control rods drop.* Stops fission process, but decay heat still must be removed.
Do	00:00:13	*PORV fails to reclose.* Mechanical failure of the valve resulting in continued loss of primary coolant; plant personnel do not realize valve is still open.
4:02 a.m.	00:02:02	*High pressure injection initiated.* Automatic upon low primary system pressure.
4:05 a.m.	00:04:38	*High pressure injection throttled.* Throttled back to maintain constant pressurizer level.
4:06 a.m.	00:05:30	*Saturation conditions in primary system.* First steam bubbles form in the primary system.
4:08 a.m.	00:07:29	*Pumps start sending water to auxiliary building.* Automatic with high water level in the containment sump; water only slightly contaminated.
Do	00:08:18	*Emergency feedwater valves opened.* Plant personnel notice closed valves; opened to initiate flow to steam generators.
4:11 a.m.	00:11:00	*High containment sump level alarm.* Abnormal amounts of water present in containment.
4:15 a.m.	00:15:00	*Reactor coolant drain tank ruptures.* Flow from PORV ruptures tank; water spills onto containment floor.
4:20 a.m.	00:20:00	*Abnormal neutron flux behavior.* Instruments measuring neutron flux begins reading abnormally high.
4:38 a.m.	00:38:00	*Pumps that send water to auxiliary building shut off.* Water retained in containment sump after about 8,000 gallons of slightly radioactive water pumped to the auxiliary building.
5:14 a.m. 5:41 a.m.	01:14:00 01:41:00	*Reactor coolant pumps turned off.* Essentially, flow through the core stops.
5:45 a.m.	01:45:00	*Initial core uncovering begins.* Water level drops and heat removal is diminished; fuel damage results.
6:22 a.m.	02:22:00	*Block valve for PORV closed.* Loss of coolant halted.
6:56 a.m.	02:56:00	*Site emergency declared.* Because of high radiation; NRC and State officials notified.
7:20 a.m.	03:20:00	*High pressure injection increased.* Operators initiate increased high pressure injection flow.
7:24 a.m.	03:24:00	*General emergency declared.* Because of high radiation; NRC and State officials notified; offsite radiation monitoring teams dispatched.
7:56 a.m.	03:56:00	*Containment automatically isolated.* High containment pressure initiates automatic isolation to prevent radiation release.
8:26 a.m.	04:26:00	*Sustained high pressure injection.* From this time on, high pressure injection is continuously maintained, at varying flow rates, after having been turned off altogether for about 5 minutes.
9:15 a.m.	05:15:00	*Initial repressurization.* Attempt to collapse vapor bubbles in the system and establish natural circulation.
11:38 a.m.	07:38:00	*Depressurization.* Operators open PORV block valve to reduce pressure and inject water from core flood tanks to assure themselves that core is covered.
12:41 p.m.	08:41:00	*Core flood tanks initiated.* Little water injected; plant personnel believe that this indicates core is covered.

[1] Footnote at the end of table.

[1] Footnote at the end of table.

Brief chronology of events,[1] March 28, 1979

Clock time	Elapsed time since the accident began	Event
1:10 p.m.	09:10:00	*Depressurization halted.* Convinced core covered, plant personnel close the PORV block valve, halting further depressurization.
1:50 p.m.	09:50:00	*Second depressurization and containment pressure "spike."* Operators open the PORV block valve to depressurize to allow use of the decay heat removal system. Simultaneously, a containment pressure spike occurs because of the combustion of hydrogen in the containment.
3:08 p.m.	11:08:00	*Depressurization ends.* Operators close PORV valve, ending attempts to depressurize further. They failed to reach pressure for decay heat removal system.
5:20 p.m.	13:20:00	*Repressurization.* Attempt to collapse vapor bubbles and establish forced circulation using reactor coolant pump.
7:50 p.m.	15:50:00	*Reactor coolant pump started.* Forced circulation through core and relatively stable plant conditions established.

[1] All times are approximate.

Chapter 5

Radiation Effects And Monitoring

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Helicopter monitoring radiation releases during March 28, 1979 accident

Chapter 5

Radiation Effects And Monitoring

The foremost concern in the event of an accident at a nuclear power plant is the amount of radioactive material that may escape and its adverse health effects on plant workers and the surrounding population.

MEASURING RADIATION

TYPES OF RADIATION

All life is constantly exposed to natural and manmade radiation that is transmitted in such common forms as *visible* and *invisible* (*infrared*) *light*, *radiowaves* and *microwaves*, *X-rays* and *cosmic rays*. There are two types of radiation—the "*non-ionizing*" type, as produced by microwave ovens, and the "*ionizing*" type, as produced by radioactive materials such as those used and produced by nuclear power plants.

Radiation, in its passage through matter, can activate atoms to generate heat but still leave the basic structure of the atoms unaltered in the process. This is characteristic of non-ionizing radiation. Ionizing radiation, on the other hand, can alter the atomic structure by knocking a negatively charged *electron* from an atom, leaving behind a positively charged atom known as an "*ion*"—hence the name "ionizing radiation." These ions can be produced in molecules found in the cells of living tissue. Since normally functioning cells depend on a delicate electro-chemical balance, the presence of ions within cells can cause harm to the body. As described below, the extent of cellular damage and bodily harm depends on the type of ionizing radiation and the amount absorbed by the body.

Radioactive materials such as *uranium* produce two basic types of ionizing radiation: one in the form of *atomic particles* (*alpha* and *beta particles*), known as *particulate radiation;* the other in the form of *electromagnetic energy* (*gamma rays* and *X-rays*), known as *electromagnetic radiation.*

CHARACTERISTICS OF RADIATION

The comparatively heavier alpha particles travel only a few inches in the air and cannot penetrate the skin. However, they are hazardous if the radioactive material producing alpha particles is breathed or eaten. Then these particles can cause intense damage to nearby cells.

The smaller, lighter beta particles are more penetrating, travel greater distances and can penetrate the upper layers of the skin.

Gamma and X-rays take the form of energy moving at the speed of light. Gamma rays are more energetic than X-rays and can penetrate deeper; they can be used to take "photographs" through such relatively impenetrable material as steel. Gamma rays and X-rays, unlike alpha and beta particles, can penetrate the body from outside and damage tissue deep within the body.

PRODUCTION OF RADIATION

Radioactive materials emit one or more types of radioactive particles or energy over various periods of time, eventually losing their radioactivity. The overall rate of decay of these materials into non-radioactive forms is measured in terms of the *half-life* of the material—that is, the amount of time it takes one-half of the atoms in the material to decay and become non-radioactive.

At a nuclear power plant, a large number of radioactive materials are produced by the fissioning of the uranium in the nuclear fuel. The half-lives of these "*fission products*" range from seconds to hundreds of millions of years. These products in turn produce alpha and beta particles, gamma rays and X-rays.

UNITS OF MEASURE

Ionizing radiation can be quantified using several different units of measure.

The *curie* describes the amount of radioactivity in a given amount of material such as a nuclear core. A release of some of that material would be measured as a certain number of curies. Subunits are the *microcurie*—one-millionth of a curie, and a *picocurie*—a trillionth of a curie.

The *roentgen* indicates the amount of X-rays or gamma rays that will ionize a certain amount of air.

A more general, but similar unit, the *rad*, is the dose of any type of radiation (X-rays, alpha particles, etc.) that delivers a fixed amount of energy [1] to some material (such as tissue, air, etc.).

The *rem* is a more useful measure of dose for those concerned with health effects. It takes into account the different biological damage done by different kinds of radiation. One rad of alpha radiation may result in a dose equivalent to 10 rem, whereas one rad of X-rays to the same tissue could result in a dose equivalent to only one rem. The rem allows the health effects of radiation releases to be estimated more easily and the health effects of different releases to be compared.

Because the rem is a larger dose than normally occurs in routine exposure to radiation, dose equivalents are generally expressed in *millirems* (*mrem*), or thousandths of a rem.

The rate at which exposure to radiation occurs is expressed as the *dose rate per hour.* A person receiving a dose of 100 mrem over a period of one hour is receiving a dose rate of 100 mrem/hr. Another unit of dose rate is *rads/hr.* If a release involves different types of radiation producing doses of varying amounts of millirems per hour, the total dose rate would be the sum of various dose rates.

The sum of the individual doses received by each member of a certain group or population within a specific area is called the *collective dose.* It is expressed in *person-rems.* A thousand people, each exposed to one rem, would have a collective dose of 1,000 person-rems.

Another measure is the *cumulative dose.* This is the total dose an individual or group receives over a certain period. An individual who is exposed to a dose rate of one rem/hr for five hours will amass a cumulative dose of 5 rems.

RADIATION MONITORING AT TMI

INADEQUACIES IN MONITORING

Because the monitoring of offsite releases in the early stages of the accident was inadequate, it has been difficult to determine the total amount of radioactive material released, especially on the first day, and to determine the exposure of the surrounding population. About 50 percent of the portable radiation survey instruments were inoperable.[2] Only a limited number of fixed instruments (3) were in place before the accident occurred, and they measured only total radiation exposure, rather than dose rates. (4) Both factors made it difficult for health physics personnel to ascertain the rate of offsite radiation doses. (These are important for projecting future doses of radiation and for determining the need for evacuation or other protective action.) Finally, offsite measurements were not taken until about 8:30 a.m.[3]

Some of these problems can be traced to inadequacies in the management of the health physics program at TMI. The NRC Special Inquiry Group noted gaps in the radiation protection organization and stated that plant management and operations staff regarded radiation protection as a "necessary evil." (5) The Special Investigation found, as did the NRC Special Inquiry Group, that on several occasions the utility transmitted incorrect or misleading information on the radiation levels measured by monitoring teams.[4]

ESTIMATED RADIATION DOSES

For the above reasons, the exact exposure of the population to radiation during the entire accident is uncertain. Nevertheless, several groups have developed estimates that are consistent.

The Ad Hoc Interagency Dose Assessment Group, comprised of scientists from the Nuclear Regulatory Commission, Environmental Protection Agency, Food and Drug Administration and the Center for Disease Control, estimated that the dose to the entire population within 50 miles of the plant was between 1,600 and 5,300 person-rem,

[1] Radiation imparts some of its energy to the medium with which it interacts. One rad equals 100 *ergs* of energy delivered to one gram of material. The amount of radioactivity that produces one rad varies according to the type of radiation.

[2] The NRC found that only about half the portable radiation dose rate monitors (58 out of 107) were available. (1) According to the report of the Task Group on Health Physics and Dosimetry of the President's Commission on Three Mile Island, the high percentage of inoperable instruments could have contributed to difficulties in getting data during the first several hours of the accident before the Radiological Assistance Program (RAP) teams began to arrive, and to difficulties in achieving good health physics techniques. (2)

[3] See "The Accident at Three Mile Island: The First Day," p. 112.

[4] See fn. 2 above and "The Accident at Three Mile Island: The First Day," pp. 132–133. Since the accident, the utility has still had problems with its health physics program. See "Recovery at Three Mile Island," pp. 175–177.

depending on what assumptions were used in the calculation. (6) The Dose Assessment Group stated that its calculations were based on conservative assumptions which "introduced significant overestimates of actual doses to the population."[5] (8) The Group also estimated the average dose to an individual to have been 1.5 mrem. (9)

The Dose Assessment Group concluded the effects of offsite releases were minimal throughout the accident.[6] (10)

The President's Commission generally agreed with the figures derived by the Dose Assessment Group and, like the Group, concluded that it was possible to derive reliable estimates: ". . . these deficiencies [related to measuring releases of radiation] did not affect the Commission staff's ability to estimate the radiation doses or health effects resulting from the accident." (11)

The NRC Special Inquiry Group also concurred in the dose estimates, concluding that the average dose to an individual was about 1.4 mrem. (12) It likewise said that ". . . although the monitoring efforts could have been better . . . , the monitoring of releases during the accident was adequate to ensure that the estimates of dose to the population are adequate." (13)

A test by the Food and Drug Administration of the U.S. Department of Health, Education and Welfare provided additional support for the estimates. Scientists from the Bureau of Radiological Health of that agency collected photographic film from stores near the site to ascertain if it had been fogged by radiation and, if so, what the levels of radiation had been. It did not find abnormal or excessive fogging.[7] It concluded that if the fogging had been produced solely by radiation, the exposure levels would have been less than 5 mrem.[8] This finding is in line with other estimates. (15)

Based on these estimates, the average total dose to an individual from the accident was about 1.4 to 1.5 mrem. Total dose rates were less than 6 mrem per hour.

COMPARATIVE DOSES

The following examples of doses are provided for purposes of comparison: (16)

—No observable adverse health effects result from a short-term dose to the entire body of less than 25,000 millirem (mrem) (25 rems). Severe adverse health effects (radiation sickness) are observable within two hours for doses of 200,000–600,000 mrem (200–600 rems). Immediate lethal effects result from doses in excess of 1,000,000 mrem (1,000 rems).

—The U.S. population receives an average of about 100 mrem per year from natural background radiation (e.g., from the sun, radiation from buildings, soil, etc.). Because Denver, Colorado, is at a high altitude, and consequently less radiation is filtered by the atmosphere, the rate is 193 mrem per year. In Harrisburg, Pa., near TMI, background radiation is 116 mrem.

—The U.S. population receives an average of 100 mrems per year from medical diagnoses. A chest X-ray using good equipment produces 15 mrem.

—The NRC standard for nuclear power plant workers is a whole body dose of 3,000 millirem, or 3 rem, every 3 months. The EPA standard for individual exposure to radiation from the uranium fuel cycle associated with the operation of a nuclear plant for one year is 25 mrem.

—The average federally recommended limit for exposure of the general population is 170 mrem; for an individual it is 500 mrem (1–5 rems).

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[5] The Group calculated total population dose using data collected from the utility's dosimeters in place before and deployed during the accident, from NRC measurements and from DOE aerial surveys made during the accident. (7)

[6] It calculated the amount of the releases both by extrapolating from releases measured at the boundary of the plant site and by back-calculating on the basis of offsite measurements.

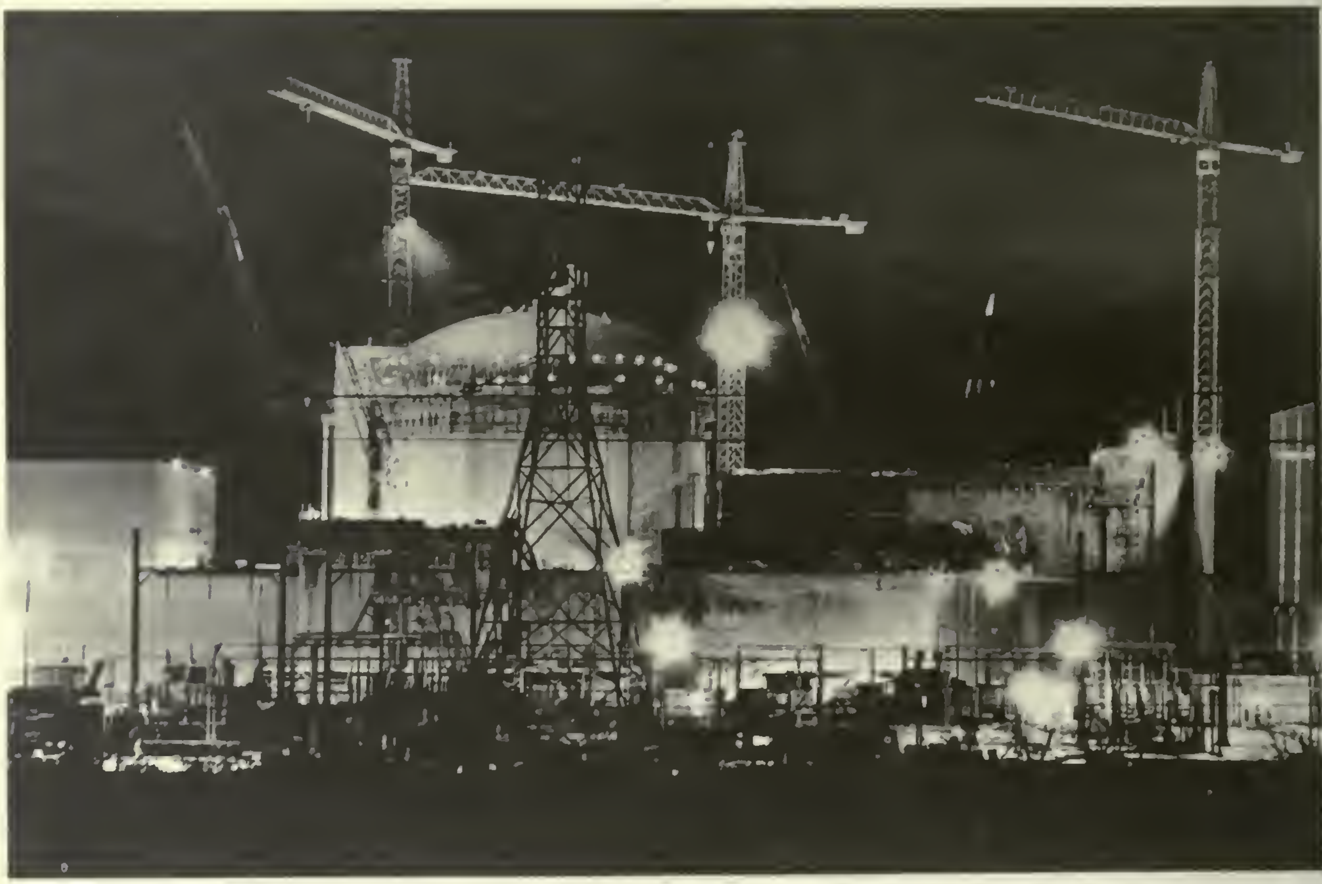
[7] Fogging also can be produced in other ways, such as by heat.

[8] Six rolls of Kodacolor 400 film, recommended by Kodak for this purpose, were collected from each of five sites within a few miles of Three Mile Island. The film was analyzed for fog levels by the Bureau after processing by Kodak. A batch of film purchased in Rockville, Maryland, was used as a control.

When both sets were developed, that from Rockville showed similar levels of fogging to that from the TMI area. When compared with film of similar age stored in freezers at Kodak, these fog levels were found to be smaller than those of the Rockville film. (14).

Chapter 6

Prior To The Accident



Three Mile Island under construction

Chapter 6

Prior To The Accident

INTRODUCTION

The Special Investigation explored the period prior to the accident as part of its examination of why a minor transient was able to escalate into a major accident and why the responses of the utility, the NRC and the State were inadequate. To this end, the development of Unit 2,[1] the nature of accidents at other facilities and the emergency response planning of the three organizations were reviewed.

THE EVOLUTION OF UNIT 2

The Special Investigation's review of the design, construction and early operating experience of TMI–2 was instructive as to how decisions about the plant were made and what types of operational and other difficulties had occurred.

Some of the problems that emerged from this review bore directly on the March 28, 1979 accident. Among the more important were a number of deficiencies in control room design and instrumentation that control room personnel had identified and had asked to have changed. For example, they requested that a direct indicator of the position of the pilot-operated relief valve (PORV) be installed in the control room. The utility installed an indirect indicator which, on March 28, misled the operators into thinking the valve had closed. In fact, it had stuck open, allowing coolant to escape the reactor vessel.[2] A further example was the alarm system. In the event of a major accident, hundreds of alarms would activate in the first few minutes, far more than the control room personnel could assimilate. In addition, because of the design of the system, in the process of clearing an alarm it was possible to acknowledge others that had sounded but were not yet noticed. Although modifications were made to the alarm acknowledgement system, they were insufficient according to the control room personnel, who decided, before March 28, 1979, not to acknowledge any alarms in the first minutes of an accident.[3]

Control room personnel had also come to discount key indicators of abnormal conditions because of recurrent equipment malfunctions. The safety-related emergency high pressure injection system, designed to activate for losses of coolant, was coming on for less severe problems.[4] One or more of the valves on the pressurizer was leaking, causing elevated temperatures in the lines leading from it.[5] On the day of the accident, control room personnel did not interpret actuation of high pressure injection to mean a loss of coolant, nor did they interpret the even higher valve temperatures to mean the pilot-operated relief valve was stuck open, allowing coolant to escape.[6]

Various incidents that occurred during testing and startup of the reactor during the years prior to the accident would reoccur March 28. For example, in 1977 steam became trapped in the hotlegs and blocked the flow of coolant. The level of coolant in the pressurizer went up, while pressure in the primary system dropped—an unusual occurrence. On March 28, similar conditions oc-

[1] It was beyond the resources of the Special Investigation to examine all facets of Unit 2's development. The AEC's and NRC's involvement in licensing and inspection, and management's position on many of the issues raised since the accident, could not be fully addressed. Information on early design and operating problems was derived principally from control room personnel.

[2] See "The Accident at Three Mile Island: The First Day," p. 94.

[3] See p. 69. [4] See p. 72. [5] See pp. 71–72.

[6] See "The Accident at Three Mile Island: The First Day," pp. 96, 108.

curred, but control room personnel on duty apparently were unaware of the early problems, did not understand the conditions, and responded in ways that contributed to a worsening of the loss of coolant.[7]

Training was an area of importance, given the inability of plant personnel to diagnose the accident and their ineffective attempts to return the plant to stable conditions for much of the first day. The Special Investigation found major deficiencies in the utility's training program and the NRC's oversight of training, as did other investigations.[8]

Other aspects of the plant's pre-accident history are less directly related to the events of March 28. Management of the design and construction of the facility was fragmented. For example, Met Ed, the utility that ultimately operated the plant, had limited involvement in decisionmaking until after the plant was fully constructed.[9] Several future operators of TMI–2 said that control room personnel had little to do with evaluation of the final design, particularly of the control room, prior to startup operations, although they were responsible for plant operations.[10]

Economic considerations quite naturally influenced decisionmaking. When the plant was transferred from the New Jersey site to Pennsylvania, General Public Utilities, the parent company, established a policy of minimum change. Although Unit 2 met all NRC safety requirements, some desirable changes in the final design of Unit 2 identified by plant personnel during the final construction and early operation of the plant were not made, in part for economic reasons, and the weaknesses those changes would have corrected contributed to the difficulties utility personnel had in responding to the accident on March 28.[11]

ACCIDENTS AT OTHER PLANTS

The problems at TMI were not entirely unique. Prior to 1979, two other plants had experienced accidents that were quite similar to the early stages of TMI–2. Both were diagnosed in time to help prevent the later, serious conditions experienced at TMI. Information regarding these accidents was not effectively disseminated industry-wide by the NRC or by the vendors of affected systems.[12]

EMERGENCY RESPONSE PLANNING

The responses of the utility, the NRC and the State to the accident revealed that their emergency response planning was seriously deficient. Prior to the accident, there was no coordination among the three providing for an integrated response. This was especially apparent with respect to consideration of protective action.[13] Responsibilities were not carefully delineated, and inadequate means were developed for communicating and assessing information on the status of the reactor.[14] Federal guidelines promulgated by the Environmental Protection Agency were vague and gave insufficient guidance to the State and the utility with regard to what information was germane in assessing the status of the reactor, how that information was to be collected and by whom, who was to receive it, and how that information was to be used as a basis for taking action to protect the public.[15]

In addition, none of the three had adequate technical or manpower resources available at the outset of the accident. All experienced serious difficulties with both internal and external communications.[16] These problems were, in part, a result of limited assumptions that were made as to the kinds of accidents to be anticipated.[17]

THE EVOLUTION OF UNIT 2

PLANNING

Three Mile Island Unit 2, constructed between 1969 and 1977, is located on an island in the Susquehanna River, 10 miles southeast of Harrisburg, Pennsylvania. The surrounding area is still predominately rural and agricultural, but recently there has been substantial industrial development. Within a five-mile radius of the plant, the population numbers about 30,000–35,000; within 10 miles, 125,000–135,000; and within 20 miles, 750,000–900,000. (1) The nearest town—Goldsboro, population around 550—is 1½ miles west of the facility.

TMI–2 is owned jointly by three operating companies: Metropolitan Edison Company (Met Ed)—50 percent; Pennsylvania Electric Company (PENELEC)—25 percent; and Jersey Central

[7] See p. 65. [8] See pp. 73–76. [9] See pp. 51–58. [10] See p. 58. [11] See pp. 59–60, 66–72. [12] See pp. 76–78. [13] See pp. 84–86. [14] See pp. 84–86 [15] See pp. 85–86. [16] See pp. 82–83 [17] See p. 83.

Power and Light Company (Jersey Central)—25 percent. (2) All are wholly owned subsidiaries of General Public Utilities Corporation (GPU), an electric utility holding company headquartered in Parsippany, New Jersey. (3) Under the license issued by the NRC, operation of TMI–2 and its sister plant, Three Mile Island Unit 1 (TMI–1), is the responsibility of Met Ed.

Two aspects of TMI–2's early development are significant. First, it was initially planned for another site, and the decision to move it to Three Mile Island only came after the preliminary design had been completed. Second, management of the plant in the early years was scattered among GPU and its subsidiaries.

These factors affected the plant's ultimate design and decisions about modifications requested by TMI operations staff.

FRAGMENTED MANAGEMENT

In the early 1960's, GPU decided to build a second nuclear plant at its Oyster Creek site in New Jersey. Ownership was to be shared by the three GPU subsidiaries; however, Jersey Central, responsible for Oyster Creek Unit–1, was to operate it. (4)

While planning for the Oyster Creek 2 project was getting underway, GPU decided to aggregate the company's nuclear resources, thus eliminating redundancy among the managerial and technical staff of its three subsidiary operating companies. (5) Thus, in 1967, GPU established the Nuclear Power Activities Group to serve as central coordinator for the design and construction of all its nuclear projects. (6) The parent company's plan was that the three subsidiaries would eventually be responsible only for operating completed plants. (In 1967, no GPU nuclear plant was operational.)

In 1968, a year after the Activities Group was established, the operating companies still exercised many of the functions the Activities Group had been set up to take over. (7) Jersey Central, for example, had solicited bids for the design and construction of the new Oyster Creek plant and had managed the preparation of the application for a Construction Permit, submitted to the Atomic Energy Commission on April 22, 1968.[18] (8) Met Ed was still managing the TMI–1 project.

Management after the Site Transfer

In December 1968, GPU decided to move the Oyster Creek 2 plant to Three Mile Island.[19] (9) Even though the plant was officially transferred to Met Ed, Jersey Central continued to provide technical support and had a major role in managing the project. (10) According to Tom Hendrickson of Burns and Roe,[20] part of GPU's rationale for continuing involvement by Jersey Central was to avoid delay in getting the plant on line. (11)

The change in location presented an opportunity for either the Activities Group or Met Ed to begin assuming principal responsibility, and some organizational conflicts resulted. GPU's objective was to consolidate the engineering construction management for all nuclear projects of its subsidiaries under the Activities Group. (12) On the other hand, Met Ed wanted to take primary responsibility for TMI–2, and, in 1969, it took administrative control of the TMI–2 project for 18 months. (13)

As a result of the various maneuvers, there was no continuity in the management oversight for the project. (14)

In 1971, GPU initiated a second attempt to consolidate its nuclear programs. It abolished the Activities Group and formed the General Public Utilities Service Corporation (GPU Service Corporation) as a subsidiary, (15) with basically the same responsibilities. The new entity was to draw on the resources of the three operating companies, thus creating actual links among them. (16)

As GPU Service Corporation grew, it gradually absorbed the design and development capabilities of the operating companies. However, the process was slow, and for seven years after it was established, it shared oversight responsibility with the GPU operating utilities. (17)

Management Problems Identified

By 1977, GPU commissioned a management consulting firm, Booz, Allen and Hamilton, to conduct a managerial audit. Among the firm's conclusions were:

—An evaluation should be made of the authority and responsibility of Met Ed functional officers with respect to GPUSC [GPU Service Corporation].

—Policies that define the respective roles and responsibilities of GPUSC and Met Ed in the design and construction of new facilities need to be reevaluated and clarified.

—Communications between GPUSC and Met Ed need to be strengthened in project-related areas.

—The effectiveness of present systems (maintenance) is reduced by their somewhat limited application and use.

—An approach and formal program should be developed to improve the overall effectiveness of . . . maintenance . . . at Met Ed.

—There is a wide disparity in the quantity and quality of plant operator procedure documentation and training programs.

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[18] See box on "The Nuclear Regulatory Commission Reactor Licensing Process," pp. 52–53.
[19] The reasons for the move are discussed on p. 54.
[20] Burns and Roe, an architect-engineering firm, designed the Oyster Creek, later TMI–2, plant. See pp. 54–55.

NUCLEAR REGULATORY COMMISSION

In order to build and run a nuclear power plant at a particular site, a utility must obtain a Construction Permit and then an Operating License from the NRC.[1] The NRC, like the Atomic Energy Commission before it,[2] licenses, regulates and inspects the construction and operation of commercial and other nonmilitary nuclear facilities.

Prior to construction, the utility submits to the NRC a Preliminary Safety Analysis Report and an Environmental Report, which include information on safety design (in terms of construction, equipment and systems); site characteristics; public health issues; personnel; management and administration; emergency response plans; response to hypothetical accidents; environmental aspects; quality assurance; control of radiation effluents and wastes; and financial capability.

NRC staff reviews this material according to set procedures and criteria (these apply to subsequent reviews as well). They may require additional material. The utility has to demonstrate that it meets the requirements for licensing set forth in the NRC's regulations and has to justify any departure from standards set by the NRC.

After examining the material, the NRC staff prepares a Safety Evaluation Report summarizing its findings. The Advisory Committee on Reactor Safeguards, an independent body of experts established by law, reviews the report and all background material. The full committee submits its findings to the NRC Commissioners.

The NRC also provides a Draft Environmental Statement for analysis by Federal, State and local agencies and the public. Comments are incorporated into a Final Environmental Statement.

Public hearings are required on all applications for a Construction Permit; they are held before an Atomic Safety and Licensing Board. If the Board issues favorable findings, the NRC will issue a Construction Permit. Any decision by the Board may be appealed to and is reviewed by an Atomic Safety and Licensing Appeal Board, and there is an opportunity for final review by the Commission.

The entire licensing procedure takes approximately 2½ to 3 years, on the average, depending on the design, the extent of the public hearings and the number of issues requiring further clarification and justification.

At all stages, the utility is required to file amendments for any changes that would affect safety; these are subject to NRC approval.

When a utility has reached the point in plant construction where it is able to present final design information and operating plans, it submits a Final Safety Analysis Report, a requirement for issuance of an Operating License. The NRC review procedure is similar to that for the Construction Permit, except that a public hearing is not held unless requested (in accordance with the Commission's rules). In its final report, the utility must present additional material on the final design of the facility, including data on the containment, the nuclear core and the waste handling system.

When the Final Safety Analysis Report is approved and any hearings are completed, the NRC issues an Operating License with Technical Specifications for safety and environmental protection measures and other operating criteria the utility must meet to ensure public health and safety.

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[1] See "The Nuclear Regulatory Commission Reactor Licensing Process," Appendix C, pp. 233ff, for more detail.
[2] The NRC inherited the AEC's regulatory authority when the AEC was abolished in 1975.

—Formal guidelines and minimum standards should be developed to help ensure continued safe, reliable power plant operations. (18)

In 1977, Robert Arnold, Vice President for Generation at Met Ed, was made Vice President for Generation at GPU Service Corporation. He was given responsibility for implementing some of the Booz, Allen recommendations and for consolidating GPU's nuclear projects. (19) In addition, he was to develop within GPU Service Corporation a complete capability for basic design of nuclear plants. Such a capability would permit GPU to avoid contracting with architect-engineers. (20)

Arnold said of his mission:

> [T]he issue was a very real one to us. It was one that was emphasized by Herman Dieckamp [President of Met Ed] when I went into the job. of the need to couple together the operating plant experience with the plant design and to provide the kind of technical review of what was happening at the plant that was necessary to have the reliability of operation and safety operation that was necessary. (21)

Arnold further commented:

> We . . . established a procedure which we had a great deal of difficulty getting

REACTOR LICENSING PROCESS

An Operating License can be issued even while some safety-related questions are unresolved. For example, if it is determined that a question involves a generic issue, that is, it applies to a class or type of plant, the issue may be left unresolved until a final generic solution is developed.[3] A license cannot be issued, however, if the NRC staff determines that the question involves a safety factor that should bar continued operation or should require licensing actions prior to completion of the longer term review. (26) These same stipulations apply to non-generic safety issues.

Once a plant is in service, the utility must file with the NRC a Licensee Event Report (LER) if it experiences an unusual incident (e.g. a transient). The NRC responds to these reports in several ways. They are placed on a computer, and a listing is published each month. Each event is also briefly summarized in a monthly publication, NUREG-0020, "Operating Unit Status Report."

NRC staff in the Commission's regional offices and, to a lesser extent, at headquarters also review Licensee Event Reports for incidents of special safety, safeguards or environmental significance and to ascertain whether they have generic implications. Licensees are informed of generic concerns through Bulletins, to which they must respond in writing; through Circulars, to which they need not respond; or through Generic Letters or Orders.

The NRC licensing functions associated with construction and operation of nuclear reactors are performed by the Office of Nuclear Reactor Regulation. There were four main divisions in the Office which carried out this responsibility at the time of the accident at TMI.

The Division of Project Management was assigned management functions in connection with reviews of reactor safety up to the time an Operating License was issued.

The Division of Systems Safety carried out the actual safety reviews connected with applications for Construction Permits and Operating Licenses.

The Division of Site Safety and Environmental Analysis reviewed all safety and environmental aspects of reactor sites.

The Division of Operating Reactors took over from Project Management and Systems Safety responsibility for reviewing proposed design and operational changes at operating reactors. Thus, when an Operating License was issued, primary responsibility within NRR for a plant was transferred from the Division of Project Management to the Division of Operating Reactors.

There sometimes was a delay in this transfer of responsibility if a safety issue was unresolved. The Division of Operating Reactors did not accept responsibility for TMI-2 until August 1979, five months after the accident, because there had been such unresolved questions. (27)

Plant construction and operations are monitored by the Office of Inspection and Enforcement (I&E). It consists of a headquarters group and five regional offices, charged with the development of policies and the implementation of programs for inspection of licensees, applicants and their contractors and suppliers to ascertain whether they are complying with NRC regulations, rules, orders and license conditions. Inspectors from this Office were monitoring TMI-2 during the period immediately prior to the accident.

[3] An example of a generic problem found at operating plants was an error discovered in calculations relating to the performance of piping systems during earthquakes, a problem that involved several plants.

executed reliably, so I would not want to take too much credit for what it was, but a policy was set out and it is indicative of what we were putting into place as one of the ways to address this problem. (22)

* * *

. . . I don't think we felt at any point that the structure we had was inadequate or inappropriate. We rather felt that there were ways in which we wanted to improve it as we kept building toward the future. (23)

When the Operating License for TMI-2 was issued by the NRC, on February 8, 1978, complete responsibility for the operation and safety of the nuclear plant devolved to Met Ed, although for a time GPU was to retain responsibility for completing the project and for the schedule. (24)

TRANSFER TO THREE MILE ISLAND

By the end of 1968, a large portion of the facility and equipment for Oyster Creek 2 had been procured. However, the AEC had not yet issued a Construction Permit, and no major construction work had been undertaken. (25)

In December 1968, there was a meeting involving: GPU and its subsidiaries; Burns and Roe, the architect-engineer; and the major contractors and vendors for the facility. (28) Among the latter was Babcock & Wilcox, which was to supply the nuclear reactor.[21]

At the meeting, GPU announced a decision to transfer the plant to Three Mile Island. (30) According to Louis Roddis, then Director of the Nuclear Power Activities Group,

> The problem was related to construction labor difficulties in the central New Jersey area at that time frame which were basically resolved after the Colonial Pipeline cases came to trial and were settled. It was just a very unfavorable labor climate to operate in. (31)

Burns and Roe's Hendrickson elaborated on Roddis' explanation in an interview with Special Investigation staff:

> Late during the construction phase of Oyster Creek Unit No. 1, the Oyster Creek Plant, there were difficulties experienced by the utility, basically labor-related difficulties in the Jersey company's area down there where it was being built. They were not anything that we were involved in except that a decision was made by General Public Utilities to relocate the unit from the Oyster Creek site to the TMI island site. (32)

Prior to the meeting, GPU had commissioned a comprehensive study of the factors involved in the transfer. (33) A summary of the findings was spelled out in November 1968 in a memorandum Roddis sent to GPU President William G. Kuhns. (34) The following are the key points made in the memorandum: (35)

Subject:	Study conclusions:
Cost	Operating cost at TMI would be less, with a possible annual savings of $100,000 in operating labor expenses.
Site problems at TMI	Manageable.
Ocean discharge	No problem at TMI.
Plant reliability	No change.
Construction schedule	A delay was anticipated with the transfer.
Construction contractor	The Architect Engineer should be the same for both plants at TMI.

DESIGN QUESTIONS

Transferring the plant involved some difficulties. For example, dovetailing the construction of the two TMI units was possible to only a limited extent.[22] Although the basic reactor designs were the same (Babcock & Wilcox pressurized water reactors), overall plant designs differed. Much of the equipment Burns and Roe had chosen for the Oyster Creek plant was of different origin than that for the TMI–1 plant, then under construction by the architect-engineering firm of Gilbert Associates, Inc. (37)

There were differences of opinion within both GPU and Met Ed as to whether the two plants should have different designs. (38) Both companies had discussed with the other operating companies the possibility of completely redesigning TMI–2 to match TMI–1, (39) but economic and scheduling considerations ran counter to this plan. (40)

Another issue was whether Burns and Roe should remain the architect-engineer for TMI–2. (41) Met Ed had a longstanding contractual relationship with Gilbert Associates, Inc., because of TMI–1 and previous power plant projects. (42) Further, Roddis believed that Gilbert was "a better design engineer." (43) He added,

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[21] The report of the Special Inquiry Group provides a concise description of the relationship among the various organizations that play a part in the construction of nuclear plants:

> Some of the first commercial nuclear plants were "turnkey" projects designed and built entirely by vendors—General Electric or Westinghouse—for a fixed price and then turned over to utilities for operation. In this country that pattern has changed. A utility now hires an architect-engineer firm like Bechtel, Stone & Webster, or, in the case of TMI–2, Burns and Roe, to serve as "general contractor," design the overall layout of the plant, and serves as the utility's technical advisor in buying a vendor's reactor system. . . . It is typical to have different companies involved in the construction and operations of the plant. (29)

[22] There is a growing practice of preplanning multi-plant power stations. The theory is to design the plants identically, then construct them in tandem. The typical scheme is to stagger the schedules of twin plants by two or three years, allowing the development stages of design, engineering and construction to be shifted sequentially from the lead plant to the following plant, with substantial economic savings. Maintaining the same plant design also affords operational conveniences. As James Neely, GPU project manager for Oyster Creek in 1968, stated:

> It is generally accepted practice that if you have two plants . . . duplicate on the site, you are in a much better position from the standpoint of overall operability and maintainability than if you have two different plants on the same site. (36)

Such a construction scheme was even less feasible at Oyster Creek because of differences in plant designs and schedules. For example, Oyster Creek 1 was a boiling water reactor, while Unit 2 was to be a pressurized water reactor.

> If we were building TMI–1 and TMI–2 as a paired plant at that location, I certainly would have one AE [architect-engineer] for the whole job, and in the time frame of 1966, whenever that decision was made by Metropolitan Edison to choose Gilbert, it [Gilbert] would have been the one for both of them. (44)

Roddis later explained his comments by saying, "We didn't have that option. That was the point I am trying to make." (45) He also noted:

> [The TMI–2 design] was adequate. It was in the licensing process [Construction Permit] at an advanced stage. It was being done by an architect-engineer that was competent . . . it was different than Unit 1, but there was nothing that said necessarily that any feature of it was better or worse. (46)

A MINIMUM CHANGE POLICY

At the same meeting where the transfer was announced, GPU stated that final design and construction of TMI–2 were to involve "minimum-change." (47) This objective was reflected in Burns and Roe's minutes of the meeting:

> It is a requirement that the minimum possible disturbance be made to the existing design, so as not to detract from the schedule. A design will be used, even though not optimum, provided it is adequate and can save time. (48)

According to Neely, "The overall decision to move the plant with the minimum changes was based on economic considerations." (49)

In accordance with the GPU directive, Burns and Roe remained the architect-engineer for TMI–2, and construction proceeded with significant differences in the design of the two TMI plants.[23] (50)

Changes Still Required

The transfer necessitated some major changes in the original Oyster Creek design. For example:

1. The heat rejection system, which releases unusable waste heat from the plant to the environment, was converted from an open circulation[24]

Major buildings of Unit 2, Three Mile Island Nulear Station, including the Epicor-II

[23] For example, the turbine generator and condensate polishers for the two plants were supplied by different manufacturers; operationally, Unit 2 was designed for a higher level of power generation than Unit 1. The control room designs were also different. (The TMI–2 control room is discussed in detail on p. 61.)

[24] In open circulation, cooling water is continuously drawn from a body of water (e.g., the Atlantic Ocean near the Oyster Creek site) and then discharged back to it at a slightly higher temperature because of the waste heat from the plant. In closed circulation, cooling water heated by waste heat is pumped through a recirculation loop and into the cooling towers. The heat is transferred to air drawn through the structure of the towers. Thus both methods discharge heat to the environment, but open circulation systems heat the water, whereas closed systems heat the air.

to the closed circulation design of TMI–1, which was using the multi-story cooling towers (51) that have become a familiar feature of nuclear and other power plants.

2. Major structures in both TMI units, including the containments that house the reactors, were reinforced to withstand the collision of a jet airliner landing or taking off at the nearby Harrisburg airport. Since such a crash might involve instantaneous explosion and burning of jet fuel, safety-related design changes also had to be made in the TMI corridors and ventilation system. (52)

3. The foundations of the plant were modified to accommodate the difference in terrain between Oyster Creek and TMI. The TMI site was composed of bedrock, whereas Oyster Creek had a more penetrable composition of sand and gravel. (53)

The AEC required that the utility provide a safety assessment of the proposed modifications. It was submitted, and on November 4, 1969, the AEC granted Met Ed a Construction Permit for TMI–2.

THE TMI-2 CONTROL ROOM

The control room is the operational center of a nuclear power plant. From it, the operator, using his training and experience and assisted by written procedures, assesses the status of the plant and controls its operation. In the event of an accident, it is primarily in the control room that operators diagnose the problem and take corrective actions to bring the plant to a stable condition.

The Special Investigation's review of the evolution of the control room revealed that several deficiencies had surfaced during the construction and testing phases, as well as during two minor accidents that occurred after the plant went critical in 1978. Operators and supervisors had requested that management modify many of the troublesome features, but at the time of the March 28 accident, a number remained unchanged or had been changed unsatisfactorily in the operators' opinion. (54)

PLANNING OF THE CONTROL ROOM

Human Factors Engineering

To achieve a workable design for a control room, design engineers, working within the broad framework of NRC requirements, apply their expertise and experience with instrumentation and controls. (55) An important consideration in developing a control room is "human factors," and a control room should be designed in accordance with human factors engineering practices.[25]

NRC Requirements

Design of the TMI control room had begun in 1968. At the time, the NRC regulations had only a few general requirements:

> A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions, including loss-of-coolant accidents. Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident. (56)

The NRC's guidelines did not explicitly cover human factors aspects of a control room. (57)

Salvatore Gottilla, the lead instrument engineer at Burns and Roe in 1969, commented on the NRC's regulatory requirements:

> Let me say briefly that there were no regulatory guides or standards that dictated the design of control rooms. There were a number of regulatory guides which had requirements which impacted on the control room design . . . for example, there is a commonly used standard in the industry: it's an IEEE standard 279, which [was] enforced as a requirement . . . for the design of safety shutdown systems. This had some requirements for the kind of equipment we use, the way we specify it, requirements for redundancy, requirements for pegging, et cetera, et cetera, all of which, to some extent, impacted on the design of the control room. (58)

CONTROL ROOM DECISIONMAKING

The TMI–2 control room was designed primarily by Burns and Roe, with input from the GPU Service Corporation. Met Ed engineering personnel participated at times, corresponding indirectly with Burns and Roe through the Service Corporation and occasionally directly with Burns and Roe through letters and memos. (59) On many occa-

[25] The term "human factors" in the context of nuclear power plant design refers to the physical and psychological needs and capabilities of plant personnel. Accounting for these needs and capabilities in the design and operation of machines is called human factors engineering. Examples of human factors that became important at TMI on the day of the accident were the ability of individuals to recognize, assess and respond to a barrage of information and signals, and their ability to work in protective garments, such as respirators.

sions, representatives from GPU Service Corporation, Met Ed and Burns and Roe all participated in conferences related to the project. (60) Moreover, Burns and Roe had contracted with many other vendors, among them Babcock & Wilcox, to supply instruments, controls and, in some cases, entire prefabricated control panels. (61)

Thus, there was a considerable number of contributors to the design and development of the control room, (62) and differences of opinion occurred. For example, in 1968, when the plant was still planned for Oyster Creek, Babcock & Wilcox had sent Burns and Roe some drawings of the model control room at the B&W nuclear reactor simulator facility (63) in Lynchburg, Virginia. About a month later, B&W proposed that Burns and Roe use the design of the simulator control room for the Oyster Creek 2 plant. (64) B&W stated that to do so would be particularly advantageous if plant operators were to train on the simulator at the B&W facility.[26] (65)

Ed Gahan of Burns and Roe, the supervising instrument engineer responsible for the design criteria and review of the Oyster Creek, later TMI–2, control room, advised against the proposal. (66) In his opinion, B&W had built the simulator to support their engineering design work, and it lacked many of the proper warning systems, indicators and displays necessary in commercial operations to account for the human element. (67)

In a memo to Gottilla dated December 27, 1968, Gahan expressed his thoughts on the B&W proposal:

—B&W had not explained how the simulator would be available for training.

—Items found on actual control room panels, such as annunciators, were not present on the simulator panels.

—Instruments and controls on the B&W design were not of the "heavy duty type consistent with power plant design practice." (68)

Eventually, Gahan designed the Oyster Creek Unit 2 control room. (69) Babcock & Wilcox was commissioned to supply three of its modular panels.

By the time the decision was made to relocate the Oyster Creek plant in 1968, the preliminary work on control room design had been completed. (70) In fact, Burns and Roe had already begun to tailor specific details around requests by the Oyster Creek personnel who were to operate the plant. (71) The design and engineering work slowed while the utility management deliberated the policy and strategy of the transfer, and detailed design efforts were deferred while major changes in plant systems were considered. (72)

One or Two Designs at TMI

As a result of the transfer, utility management had had to choose between two opposing concepts regarding design of the control room: (73)

1. To retain as much of the original Oyster Creek design as the required plant system changes would allow, or
2. To redesign the control room for Unit 2 to match the design of the TMI–1 control room.

Those who supported redesigning the control room argued that cross-licensing[27] of operators would be simplified if the two control rooms were identical. (74) Those opposed to redesign argued that to have similar control rooms for plants with different physical characteristics could confuse cross-licensed operators. (75) Implicit in the latter argument was that some aspects of the design of the two plants at TMI would be different, in accordance with GPU's minimum-change objective.

In January 1969, Burns and Roe received a letter from J. Bartman of Met Ed Operations, requesting that the TMI–2 control room be redesigned to match TMI–1. (76) Gottilla consulted with representatives of Jersey Central, who advised that Bartman's request be ignored. (77)

Bartman persisted, and he had the support of others at Met Ed. At a Burns and Roe conference in March 1969, he again made his request. (78)

Redesigning the control room still conflicted with GPU's minimum-change objective. (79) A debate ensued over the cross-licensing issue, and a call was made to the AEC. The agency confirmed that similarity in control rooms was not a mandatory criterion for cross-licensing. (80) Those at the conference accepted GPU's objective.

At the conclusion of the meeting, GPU stated that

> . . . [it] would have the final word on control room design changes, and that Burns and Roe should accept no proposed changes from Met Ed without prior approval of either GPU or JCPL [Jersey Central]. (81)

PROBLEMS WITH THE DESIGN

Burns and Roe did encounter some problems with the control room's design. For example, in 1971, its engineers discovered that the controls for the feedwater system had accidentally been divided between two of the main console panels and were located 22 feet apart. (82) One of the two

[26] Prior to 1979 there was only one simulator in operation for a B&W-type reactor. Therefore, the B&W facility would likely have been used by Met Ed no matter what control room design was used.

[27] The NRC may license an operator to run more than one plant, a procedure known as cross-licensing. At TMI only senior reactor operators in supervisory positions became cross-licensed for both plants.

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panels had been supplied by Burns and Roe, the other by B&W. After Burns and Roe informed GPU of the problem, a series of design change proposals was made and jointly studied by Burns and Roe and GPU. (83)

Some of the proposals did not consider changing the position of individual instruments and controls on the panels. Instead, the common suggestion was to reposition several of the 17 major panels in the control room. These preliminary attempts proved impractical, for when the panels were rearranged to regroup controls for one system, those of another would become separated.

The designers finally became convinced there was no simple solution. They resolved the problem of the separated feedwater controls both by rearranging the positions of the control panels and by redesigning several control panel layouts. (84)

REVIEW OF THE CONTROL ROOM

According to Bill Zewe, the Station Shift Supervisor on duty at the beginning of the March 28, 1979 accident, in late 1973 and early 1974, the shift foremen and shift supervisors who were to work at TMI-2 were able to review and comment on the design plans for the control room. Zewe said his review was limited by the advanced state of planning:

> Certain little features that had not yet been finalized, I had the time to comment on those, but most of the engineering effort has already been completed by that time, and had been pretty well set. (85)

Edward Frederick and Craig Faust, two operators also present in the control room at the start of the accident, were comparatively junior operating personnel at this time. They said they were not asked to review or comment on the design of the control room at all during this phase. (86)

Design of the control room was substantially complete in 1975.

Special Investigation staff asked Hendrickson of Burns and Roe whether his company had ever reviewed the control room in terms of operator response to the accidents postulated in the Final Safety Analysis Report submitted to the AEC. He noted that since they did not have operating procedures for Unit 2,[28] the designers had had no opportunity to perform a "task analysis"[29] of the control room and to modify the design based on the findings. In his words:

> Well, I think it's really very simple. We did not do that [conduct the review], and we could not have done it because we did not have—the operating procedures. Those were a matter that Metropolitan Edison developed. And the only way it [perform a task analysis] can be done is to review the procedures against the control room. (87)

DEVELOPING PLANT PROCEDURES

James Floyd, Operations Supervisor for TMI-2, was one of the people responsible for developing operating and emergency procedures for TMI-2.[30] Special Investigation staff asked him whether subsequent testing of the procedures helped operations staff identify problems with the design of the control room.

Floyd responded:

> Yes. The classic example, of course, is the high-pressure injection flow meters. From where you're controlling the valves, you can't read the meters that you're trying to control. It was identified as soon as the procedure [was] delivered to the control room. (89)

Floyd commented on the response of operations staff to this particular problem:

> [A solution] of course, would have been to try to move the meters down to where you could see them. But that involves the ES system, engineering safety features system . . . which have to have mechanical as well as electrical separation. It would have involved fire barriers and the whole gamut of things involved, and it was probably just easier to let the meters [stay] where they were and take the three steps if you needed to. (90)

OPERATORS IDENTIFY PROBLEMS

In 1976, while the control room was still under construction but after the various panels had been

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[28] Operating procedures provide directions to plant operators controlling, monitoring and responding to the mechanical systems of the plant in a normal state. There are also procedures for emergency and abnormal conditions.

[29] A task analysis is a review to determine the specific actions required of people performing a given function, for example, monitoring or controlling machinery.

[30] In general, procedures for TMI-2 were prepared in several stages. In the first, the procedures already in existence for TMI-1 or original drafts by Met Ed, B&W, Burns and Roe or NUS, a Met Ed consultant, were modified. Then they were reviewed by the Met Ed procedure writing group, after which they went to the PORC (Plant Operations Review Committee) for review and a first approval. (The Review Committee is a group of Met Ed operators and engineers who advise plant management on reactor and radioactive waste safety.) The procedures were then "red-lined" and sent back to the Review Committee for review and approval. ("Red-lining" refers to a process by which procedures are tested and corrected.) The procedures then were sent to the Generation Review Committee for final review and approval. (88) The NRC did not systematically review all procedures, and its approval was not required.

assembled, TMI–2 operators were able to familiarize themselves with the room. (91) In 1977, testing began (a phase that continued into 1978).

Throughout this period, operations staff expressed concern about certain features. (92) They used several formal means for commenting on and requesting changes in the control room design, including the *Field Change Request Form*, the *GPU Startup Problem Report* and the *GPU Field Questionnaire.* (93) Requests for design changes were forwarded to GPU management for review and possible implementation. (94)

GPU did not make all the requested modifications. Some it made only in response to actual difficulties. For example, Frederick said that with respect to one problem, operators had asked repeatedly for a position indicator for the valves in the feedwater system. (95) An indicator was not installed until after a minor accident on April 23, 1978, which involved excess feedwater going through a feedwater valve that had closed more slowly than expected.[31] (96)

The Alarm System

Frederick pointed out another problem—the tremendous number of alarms in the control room:

> When the operators first went over there and started examining the control panels as they were being built, we were impressed right away with the number of alarms.... (97)

He added, "that was a comment that we had from the beginning, that the alarm system seemed rather extensive." (98)

Alarm Acknowledgement

In addition to the number of alarms, operators from the beginning expressed concern about the system used to acknowledge and clear the alarms in the control room. (99)

When an alarm activates in the TMI–2 control room, one of about 1,200 2″ x 3″ annunciator windows begin flashing brightly and a loud horn sounds. (100) The operator acknowledges the alarm from a control button on the main console, causing the horn to stop and the alarm window light to cease flashing and remain lit.

As soon as the cause of the alarm is taken care of, the horn sounds and the alarm window light begins flashing again, but more dimly than originally. This is known as the "ring-back" feature of the alarm system. (101) The operator, by depressing the same button on the console, can then clear the alarm, silencing the horn and turning the alarm window light completely off.

Conceptually, the ring-back feature of the alarm system is a useful analytical tool for the operators. However, with only a single button both to acknowledge and to clear lighted alarms, (102) operators cannot acknowledge and clear them independently. Without realizing it, they could inadvertently acknowledge new alarms coming into the control room while clearing previously acknowledged alarms in the ring-back mode.

The TMI–1 plant, in contrast, had separate buttons for acknowledging and clearing the alarms. (103)

By the spring of 1978, after the hardware for the TMI–2 control room was already purchased, the operations staff requested that GPU redesign the acknowledgement system for the alarms to match that of Unit 1. (104) Floyd recalled GPU management's response:

> . . . the hardware that was [already] purchased would not allow that kind of acknowledging system . . . And it was my understanding that the alarms in Unit 2 could not be made to respond that way without a tremendous additional expense. . . . (105)

Additional Instrumentation

Operations staff also asked for additional instruments. Given the advanced stage of the control room, the placement of additional instrumentation was makeshift. Floyd recalled two specific cases. One related to the Liquid Waste Disposal Panel (known as 8A):

> We added the panel 8A, which has come under criticism; the one that has the reactor coolant drain tank instrumentation [temperature and pressure] on it. To get the indication into the control room, that was the only spot that was available. So, it was added at a back panel; and hence, out of the line of sight of the operator. Some people may consider that a major change. It was an addition and not added in the proper location. (106)

This particular panel was a factor in the accident on March 28, 1979. Abnormal conditions in the reactor coolant drain tank can be a sign of a loss of coolant through a leaking or stuck-open relief valve on the pressurizer, a situation that occurred at TMI–2 that day. Since the indicators of conditions in the tank were out of sight of the main control room console and since there were no strip chart recorders for these conditions, control room personnel found it difficult to see changes and to track them over time.[32]

The second case cited by Floyd related to the location of some of the alarms on the panels. When the sections of the panels containing the alarm windows were designed, the need for additional alarms was anticipated, and excess win-

[31] This incident is described on pp. 66–70.
[32] See "The Accident at Three Mile Island: The First Day," pp. 100–101.

dows were provided. Twenty percent of the windows at TMI–2 originally had not been designated for particular alarms. As time went on, these windows were used for new alarms. Eventually it became hard to find a free window near the appropriate control. Floyd commented:

> . . . you tried to locate them in the area where they were most useful to you for the components controlled or alarming. Sometimes this was not possible; therefore, you had to go clear to the other side of the control room to find a planning window to light. (107)

In trying to retrofit and redesign the control room in the final stages of its development (see box on the TMI–2 control room for details on the final design), Floyd stated that he

> . . . wasn't free to move all the controls around to get them the way I wanted them, necessarily. So, it was a limited choice that I exercised. (108)

According to Roddis, the TMI–2 control room features generally did not compare favorably to those of TMI–1:

> Well, it [TMI–1] has the feel in the plant of having been laid out with somewhat more consideration for the operator. For instance, I was looking, when I was out there a few weeks ago, at the purification system, the water cleanup system, the control panel is much more thoughtfully laid out, and the valve locations are near the things you are trying to control. The same unit in [TMI–2] is put together with much less thought to the operator being able to perform his functions easily. . . . (109)

HUMAN FACTORS ENGINEERING

Many of the deficiencies in control room design that TMI personnel had identified related to human factors engineering. During the 1970's, both industry and the Government began studying this area of design. Up to that time, their principal focus had been on designing safe mechanical equipment and systems. The NRC and other groups then became increasingly interested in the potential for human error and saw a need to assess its relation to the reliability and safety of nuclear reactors.

The various studies revealed that insufficient attention had been paid to human factors in designing nuclear power plants and that there was potential for human error attributable to poor design.

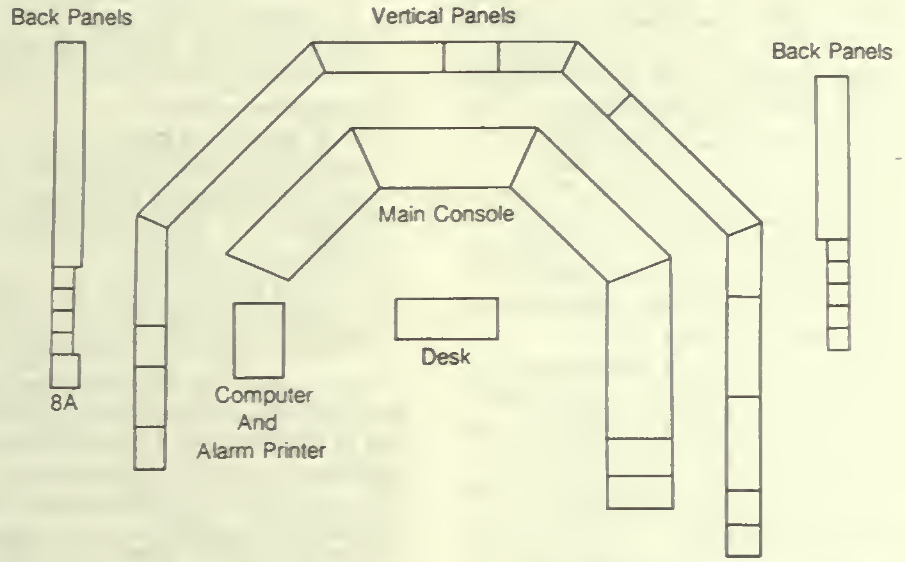
One of the earliest studies was performed in 1972 by Dr. Alan Swain of Sandia Laboratories. At the request of the AEC, he visited the Dresden Nuclear Power Facility in Illinois. After his review, he prepared a memo in which he discussed some of the major departures from standard human factors engineering practices that he had observed. (117) They included: (118)

1. The control rooms for Unit 2 and Unit 3 were mirror images of each other;
2. A large number of displays and controls were not grouped functionally; and
3. There was a constant barrage of alarms, even under normal conditions.

The control room at Three Mile Island, Unit 2

THE TMI-2 CONTROL ROOM

As it was finally constructed, the control room looked as follows:



Adapted from Metropolitan Edison Diagram

The innermost U consists of console-type panels, the tops of which are about chest high. Information displays and control equipment used frequently during operations, the start-up controls and the computer panel and protective equipment needed quickly in emergencies are all mounted on these consoles. Included are the indicators and controls for the reactor power output, steam generators and turbine generator, reactor coolant make-up and purification system, safety features actuation system and condensate and feedwater systems. (110)

Behind the consoles, and separated from them by a walkway, are the vertical panels. They stand approximately seven feet high and contain the radiation monitoring equipment indicators, the indicators and controls for the containment isolation valves, the individual control rod position indicators, the status of engineered safety features, recorders for the temperatures of all major equipment and of the primary system, and fire indicators. These panels also contain the annunciator lights that are part of the alarm system. (111)

Behind the vertical panels are two back panels, out of the line of sight of the main console. They contain the indicators for the heating and ventilating system, the sump pumps and the liquid waste disposal system which include indicators for the temperature, pressure and level of the reactor coolant drain tank. (112)

The alarm system in the control room consists of both visual and audible warning devices that alert the operator if any system is approaching unsafe conditions. (113) The annunciator boards located near the top of the vertical panels constitute the visual portion of the alarm system. They are divided into approximately 50 individual boxes or windows, each a few inches on a side. Each window bears the name of a system or component. A computer with printout capabilities monitors plant performance and alarms. It is also used for logging data. (114)

In a typical control room, the most common controls are selector switches, pushbuttons, rotary knobs, thumbwheels, levers, toggle switches, and switch lights. (115) The most common indicators are lights and meters. Strip chart recorders are also used extensively in control rooms to record trends in given parameters over time. There are two basic types of chart recorders—those that provide numerical printouts and multi-pen recorders that draw trend lines. The recorders help the operator monitor the systems. (116)

A large number of controls, instruments, and alarms does not necessarily imply a better or worse design. More important to ease of operation is the arrangement and display of control room devices.

Dr. Swain concluded that there had been no formal or systematic consideration of human factors technology in the design of the plant. (119)

In an interview with Special Investigation staff, Dr. Swain said that, presumably as a result of this work, the AEC decided to look more closely at human reliability in the operation of nuclear power plants. (120) The agency asked him to participate in the preparation of WASH-1400, the Reactor Safety Study, and he was one of the primary contributors to the Human Reliability section of that report, issued in 1975. (121)

The February 1974 edition of *IEEE Transactions on Nuclear Science* contained an article entitled "Control Room Standardization: A Safety Goal." In it, Dr. Stephen H. Hanauer, then Director, Office of Technical Advisor, Regulation, AEC, raised two major concerns: (122)

> 1. In an emergency, a reactor operator is relied on to perform important safety functions for which he has been trained only on a simulator. Therefore, the designs of simulators and actual control rooms should be similar. He recommended that since the number of simulators is small, the number of different control room designs should be small. Hanauer called for the industry to standardize its control room designs.
>
> 2. Control room designs were not optimal in terms of safe reactor operations. Hanauer suggested that some of the human factors engineering used in the space program be applied to nuclear plants.

On March 13, 1975, Dr. Hanauer sent a memo to NRC Commissioner Gilinsky, with copies to Chairman Anders, Commissioners Kennedy, Mason and Rowden, and other senior NRC staff. The subject was "Important Technical Reactor Safety Issues Facing the Commission Now or in the Near Future." One focus was human performance. (123)

According to Dr. Hanauer, the Commission did not follow up on either document. (124)

Earlier in 1974, the AEC contracted with Sandia Laboratories to do a human factors analysis of a typical nuclear power plant to identify human factors problems and their effects on operator reliability. Dr. Swain conducted the study and in October 1975 issued a report entitled "Preliminary Human Factors Analysis of Zion Nuclear Power Plant." (125) His major findings were:

> 1. Standard human factors techniques could be used to identify inadequacies in the design of equipment, in the provisions for training and practice, and in operating procedures.
>
> 2. Control room design deviates in many ways from accepted human factors engineering standards and increases the probability of human error. Swain cited, as examples, the poor layout of controls and displays, the excessive number of annunciators (alarms), misleading and inadequate labels on controls and displays, and a confusing use of color to indicate the status of equipment.

He concluded that:

> 1. Some relatively minor and inexpensive redesigning of equipment, more emergency response drills and changes in the format and content of written procedures could improve human reliability.
>
> 2. Valuable data on human performance could be collected for detailed quantitative human reliability analysis studies. (126)

One of the report's principal recommendations was that industry-wide standards be developed on the application of human factors engineering to equipment, written procedures, operating methods, and onsite training and practice for nuclear power plants. (127)

Based on this report, the NRC's Human Engineering Research Review Group [33] recommended that a Regulatory Guide be prepared on control room design. According to William Farmer, Chairman of the Group, there was some agreement within the NRC that such a guide was needed, (128) but it was never developed.

The NRC sponsored another study to provide data for a standard being developed by the American National Standards Institute on Criteria for Safety-Related Operator Actions (ANSI 660). The objective was to determine the amount of time an operator needs to respond to a situation and to adjust controls or take corrective actions. The study also was to assist the Office of Nuclear Reactor Regulation, NRC, in deciding when to require automatic responses by plant equipment and when an operator could be responsible for taking corrective action.

The preliminary data supported NRR's general standard that if response were required in less than 10 minutes, it should be automatic. (129)

In 1975, under contract to the NRC, The Aerospace Corporation began to assess the effect of control room design on operator performance during stressful conditions. (130) The study also briefly addressed the impact of operator training and emergency procedures on operator performance. Seven nuclear facilities were visited in the course of the study.

In February 1977, The Aerospace Corporation issued its report, "Human Engineering of Nuclear Power Plant Control Rooms and Its Ef-

[33] An interoffice group of staff interested in human factors. See "Nuclear Regulatory Commission Organization," Appendix B, pp. 227ff.

fects on Operator Performance." (131) It identified several weaknesses in control room design, such as: (132)

1. The layout of the controls and instruments combined with the number of actions required of an operator could lead to serious errors under accident conditions.
2. The color systems used to indicate the status of equipment were confusing under both normal and accident conditions.
3. Control panels that contain row upon row of identically shaped push buttons and/or switch handles may lead to operator error.

The report questioned the usefulness of emergency procedures during stressful situations and emphasized the value of simulator training to prepare for emergencies. It, too, mentioned the limited number of control room simulators available for training and the fact that simulators were dissimilar from actual control rooms. (133)

Major recommendations were: (134)

1. The NRC should develop a Regulatory Guide to provide direction for utilities in human factors engineering as applicable to control rooms and to encourage the use of advanced concepts for controls and displays.
2. Useful data should be collected on the nature and frequency of operator errors as part of an assessment of the effectiveness of different control room designs.
3. A study should be conducted to determine whether available simulators are capable of providing operators with the training needed to minimize errors under conditions of severe stress. The study also should evaluate the effectiveness of training on a simulator that does not realistically correspond to the actual layout of the control room.

The report endorsed the use of mimic-type flow diagrams [34] on control panels to help operators understand the relationship of key system components, as well as the trend toward the use of cathode ray tube displays [35] and computers in the control room. (135)

The report was widely distributed within the NRC in 1977. (136) However, according to Thomas Ippolito, Branch Chief in the Office of Nuclear Reactor Regulation, because of other priorities and limited resources, a Regulatory Guide was not developed, nor were follow-up studies conducted. (137) However, Sandia Laboratories, in an NRC-sponsored study, did start collecting data on operator error rates.[36] (138)

In March 1977, the Electric Power Research Institute (EPRI) [37] published a report on human factors. It was entitled "Human Factors Review of Nuclear Power Plant Control Room Design," (139) and was the result of a study carried out by the Lockheed Missiles and Space Company, Inc. under contract with EPRI. Lockheed had conducted a survey at five representative control rooms at operating nuclear plants. The report cited significant problems relating to human factors, such as: (140)

—Certain instruments and controls could not be read easily because they were too high or too low, the lighting was poor and the labels were too small.
—The absence of standards for color codes, control dimensions, label descriptions and abbreviations promoted confusion.
—The control panel layouts lacked functional grouping of related controls and alarms.
—The layout of some control rooms hampered the operator's ability to respond to an incident.
—The large number of alarms distracted the operator from identifying and resolving a problem.
—Written emergency procedures were in some cases incompatible with control room design.

The report stated that the most convincing evidence of deficiencies in control room design were the design modifications that the operators had introduced to improve their response in emergencies. (141)

The report had wide distribution within the NRC, and the NRC's Human Engineering Research Review Group held meetings to discuss it. (142) However, the NRC took no specific action. (143)

The various reports stressed common themes. They warned that inadequate attention was being paid to human factors engineering at nuclear power plants. They cautioned that the risk of human error was increased by design features which were incompatible with the needs and capabilities of plant personnel. They repeatedly urged that design standards and a Regulatory Guide be developed in this area.

In spite of these findings, the NRC did not issue the Guide. It gave as the primary reasons a heavy workload and limited budget for technical assistance. (144) Human factors engineering was assigned a low priority, and other regulatory matters took precedence. (145)

The accident at Three Mile Island was to bear out many of the predictions made in the reports.

[34] A sketch of the system is superimposed on the control panel. Controls and indicators are placed on the panel at the positions on the sketch which correspond to their system function.

[35] A cathode ray tube display uses a tube similar to the picture tube in a television set.

[36] This addresses the probability that an operator's action or task will not be completed successfully within the required time.

[37] EPRI is a research institute supported by electrical utility companies.

TMI-2'S DESIGN IN RETROSPECT

Two senior officials of GPU and Met Ed acknowledged that Met Ed operations personnel had had limited participation in the design of the plant at the time construction was nearly complete. GPU President Herman Dieckamp stated:

> I think Met Ed people did, to some degree, participate in the design reviews, even though I am sure that was not as extensive as . . . the operating people say they should have had. (146)

Met Ed President Walter Creitz stated that:

> There were opportunities for general input available during the period of construction, and yet I must admit that sometimes a person might observe a proposed change, and it could be too late; maybe it wasn't identified on the drawing. (147)
>
> * * *
>
> . . . I remember walking through the plant with Gary Miller and/or Jack Herbein, and various things might have been pointed out, like the valve example; this shouldn't be here, it should be here, or we should have done this, or we should have done that. I guess you learn from experience. Perhaps, it is just that man is not capable of putting down on paper the ultimate in what he would like to build. (148)

EARLY OPERATING EXPERIENCE

TMI-2 PLANT TESTING

The TMI–2 reactor went critical on March 28, 1978, one year to the day prior to the accident. Before it went critical, the utility spent about a year conducting a number of tests to ensure that all systems were functioning properly. Two problems occurred during this testing that would play a part in the March 28, 1979, accident.

Problem with the Condensate Polishers

On October 19, 1977, a problem arose that was almost identical to the one that triggered the 1979 accident. The outlet valves on the condensate polishers closed, and operators could not open the bypass valve from the control room because the control was inoperable. Instead, they had to open it manually. (149) The manual control station for the polisher bypass valve was, however, nearly inaccessible, and it took great effort, in a physically awkward position, to operate. (150) Later, it was found that water had entered the air lines; this was assumed to be the cause of the malfunctioning of the outlet valves. (151)

Analysis of the Incident

John Brummer, a TMI–2 electrical engineer, and Michael Ross, Unit 1 Supervisor of Operations at the time of the March 1979 accident, analyzed the event and prepared a memorandum. (152) They discussed the problem of water getting into the instrument air lines and suggested solutions to preclude a recurrence. The memorandum also stated a concern that if this malfunction were to occur while the plant was at power, the emergency feedwater system might be actuated, the turbine would trip and the reactor might trip as well. (153)

Brummer filed a problem report with R. J. Toole, Manager for Startup Testing for GPU, (154) to which he attached the memorandum. The problem report focused on possible solutions to the problem of water in the air lines and recommended installation of an automatic bypass valve in the system.

Response by Management

GPU did not implement this recommendation. Ronald P. Warren, a member of the Plant Operations Review Committee, provided some insight into that decision:

> WARREN: I think it was because they said it was a plant improvement that really didn't have to be made.
>
> Question: Didn't they say it costs too much?
>
> WARREN: They might have. That might have been a better way of putting it. (155)

At the same time, GPU said that it would reevaluate the problem of water in the lines after the plant had begun to produce power, in the belief that the problem might have originated with earlier flooding at the plant. (156)

Problems with the condensate polishers persisted,[38] and at one point a full-time crew was assembled with one responsibility—to work on the polishers. (157) Nevertheless, difficulties recurred. In fact, a crew was working on the system when it malfunctioned on March 28, 1979, initiating the accident.

The utility did not inform the NRC of the problems with the condensate polishing system, and the Office of Inspection and Enforcement did not learn of the October 19, 1977 event until its investigation following the March 28, 1979 accident. (158) However, the agency's reporting requirement applied only to defects believed to affect safety. (159) According to the NRC, "problems related to the condensate-feedwater system were not considered by the licensee to be reportable be-

[38] By design, the polishers have to be changed periodically (every couple of days). One is taken out and recharged, while another is rotated into its place. The procedure is difficult and has caused continuing problems, particularly in terms of maintaining proper flow through the system.

cause the plant is designed to safely sustain a loss of normal feedwater." (160) Burns and Roe informed the Special Investigation by letter that it had been responsible for the development of the performance specifications and technical review of the bids for the condensate polishing system. The initial design provided that the outlet valves in the system would fail "as is" if the air system controlling them were to malfunction (e.g., if water were to enter the air lines): ". . . [the] specification [required] that the condensate polishing system valves fail 'as-is' upon loss of either instrument air or control [electrical] power."[39] (161)

Burns and Roe stated that the utility had not told the company of the problems with the condensate polishing system on or after October 19, 1977. Burns and Roe did locate in its files a copy of a GPU Problem Report concerning the October 19, 1977 occurrence, believed to have been submitted in late 1978 in connection with another project. GPU had not asked Burns and Roe to take any action, and Burns and Roe did not provide any recommendations. (162)

Burns and Roe implied in its letter to the Special Investigation that the valves may have failed closed because of a design change of which it was not informed. It wrote:

> . . . all outlet valves of the condensate polishing system had all closed causing a complete loss of feedwater flow. In one case [this one], the problem was associated with water in the instrument air lines . . . [This incident] indicate[s] a discrepancy between the actual performance of the condensate polishing system and our specification requirement. . . ." (163)

September 1977: Steam in the Hotlegs

At one point during hot functional testing[40] in September 1977, steam became trapped in the hotlegs. The primary system seemed to be filled with water, but operators had difficulty establishing natural circulation. Two operators on different shifts noted that the pressurizer level would increase when the pressurizer was vented in order to decrease primary system pressure. (164) This behavior was unexpected. (165) At least one operator suspected steam in the lines that measured the pressurizer level. (166) An operator on yet another shift deduced that the system not only had steam in the measuring lines, but in the hotlegs as well. (167)

The operators eventually corrected the situation by pumping nitrogen into the pressurizer, raising the pressure sufficiently to force water from the pressurizer into the hotlegs, thereby collapsing the steam bubble. (168)

Babcock & Wilcox's site representative,[41] Leland Rogers, explained the problem to Special Investigation staff:

> . . . a phenomenon had occurred [in this plant] where we had trapped a lot of hot water [steam] in the hotlegs, and subsequently had the rest of the system colder. And without the ability to run the reactor coolant pumps, which we did not have at that time [during hot functional testing], we could not get the heat out of those hotlegs; even with the system filled with water, we could not move any heat from that. It's in a natural trapped condition. (169)

Rogers attributed the problem of stagnation in the hotlegs to the "candy-cane" shape of the lines:

> It was accepted as a condition because of the layout of the plant . . . It has happened at other B&W plants, so it was not a brand new problem. (170)

The behavior of the pressurizer and primary system during this incident—water level in the pressurizer increasing as pressure decreased—was found to have occurred when steam formed in the system. (171) When these same conditions appeared on March 28, 1979, they were neither recognized nor understood because details of this earlier incident apparently had not been communicated to operators on duty during the accident.[42]

GOING CRITICAL

As noted, the TMI–2 reactor went critical on March 28, 1978. It was the first day of the normal operational testing phase that would continue for several months. Over this time the plant gradually would be brought up to full power and put in service.

The unit experienced two minor accidents during this period, both of which in retrospect were significant in terms of the major accident that was to come in March 1979.

MARCH 29, 1978: A FUSE BLOWS

The day after going critical, with the unit at less than 1 percent power, a fuse blew in the plant's electrical system, and power was lost to an elec-

[39] The post-accident investigations concluded that the valves did not fail "as is" on March 28, 1979.

[40] Hot functional testing, performed prior to initial loading of nuclear fuel, is designed to verify the ability of the reactor coolant system to operate properly at pressures and temperatures comparable to those of normal operation.

[41] A vendor frequently will assign a full-time representative to a plant to assist in operations.

[42] See "The Accident at Three Mile Island: The First Day," pp. 97–98, 105–108.

trical control system associated with the pilot-operated relief valve (PORV) on the pressurizer.[43] The system had been wired so that the PORV would open automatically if power were lost. (172) It did so, and water drained out of the primary coolant system. Pressure dropped from 2,188 psi to 1,173 psi. (173) The high pressure injection system actuated automatically. (174)

Power was returned to the electrical system about four minutes after the transient began, and the PORV automatically closed. (175) Prior to that point, however, the operators had not known it was open because the TMI-2 control room did not have an indicator showing the valve's position. (176)

A PORV Indicator Installed

In response to this minor incident, the electrical circuits were rewired so that the PORV would remain closed in the event of a loss of power in the electrical system. In addition, a position indicator for the PORV was installed in the control room. This indicator did not, however, provide a direct indication of the position of the valve. Instead, it was a command-type indicator that sensed whether an electric command was being sent to the valve, ordering it to open. If a signal to open were being sent, then an indicator light in the control room would be lit, suggesting to the operator that the valve had opened. Conversely, the absence of a light suggested it was closed. (177)

James Floyd discussed the request made after the March 29 accident that a position indicator for the PORV be installed. He stated:

> Met Ed put in the problem report. We asked for valve position indication, the decision comes back from bosses that all we're going to get is command valve command signal light. And he comes into the control room and he has to sell me on that, and if he can't sell me, then I'm going to raise a stink and push for what I wanted in the first place, or some compromise in between his position and mine. (178)

Floyd later commented on his attitude toward management's oversight and response to the PORV issue. He said he "wasn't too happy" with the decision to install an indirect indicator, but added:

> . . . my reaction was not to raise a big stink and say, "Hey, I asked for valve position indication. That's what I want.". . . I was the type that is much more inclined to do things on a low-key basis and get them accomplished, rather than making a big fuss and not getting anywhere. (179)

Other TMI-2 operators interviewed indicated that at the time they likewise accepted the decision to install a command-type position indicator rather than a direct indicator. According to Floyd and Faust, an indirect indicator was better than no indicator at all. (180) Zewe said that in a "generic sense" a direct indicator would have been preferable, but that he never specifically raised the issue of having one installed. (181)

Operators Requested a Change

Nine months after the March 29, 1978 accident, in January 1979, the TMI-2 maintenance and engineering staffs requested a design change in the TMI-2 PORV position indicator. Joe Logan, the Unit Superintendent, Richard Bensel, a lead engineer, and Daniel Shovlin, Supervisor of Maintenance, signed the request. They proposed that the indicator be modified so that a limit switch [44] on the solenoid of the PORV would activate it. Although this modification still would not have provided a guaranteed indication of the PORV's position, it would have provided a more reliable indication than did the command-type indicator then in use. (182)

The request for this change was forwarded for review to the Met Ed Generation Engineering Department in Reading, Pennsylvania. That department disapproved the proposed modification. In a March 16, 1979 memo to Shovlin, R. C. Noll of the Generation Engineering staff said that "After discussing this modification with the TMI-2 staff, it has been agreed that this modification is not necessary or required." (183) Bensel has stated that he and George Kunder, the Unit 2 Superintendent for Technical Support, had concluded that "the added indication . . . wouldn't have been that much better." (184)

Since it is still not known what part of the PORV failed during the March 28, 1979 accident, it cannot be determined whether the proposed modification would have shown that the PORV was stuck open.

APRIL 1978: A MORE SEVERE PROBLEM

On April 23, 1978, the TMI-2 reactor experienced a more severe problem while at 30 percent power. (185) According to a Met Ed analysis, (186) a minor equipment malfunction caused the TMI-2 reactor and turbine to trip almost simultaneously. When the turbine tripped, pressure on the secondary side of the steam generators

[43] See "How the Plant Works," p. 30, for a description of how the PORV operates.

[44] The limit switch provides mechanical contact between the solenoid plunger and the solenoid housing when the solenoid plunger moves into the valve-open position. The command-type indicator just shows that a signal has been sent to move the solenoid plunger.

increased, and some of the main steam safety relief valves opened. (187) Several failed to close, and pressure in the secondary system dropped rapidly. (188)

Two other factors complicated the problem. First, the computer-controlled valves that regulate flow in the feedwater lines closed much more slowly than expected. (189) Second, the operators failed to throttle the feedwater pumps until 1 minute 20 seconds into this minor incident. (190) Thus an excessive amount of water flowed to the steam generators. (191) The result was rapid depressurization and cooldown of the primary system. (192) The coolant in that system contracted to such an extent that the pressurizer was emptied of water. A steam bubble then formed in the hotlegs of the primary system. (193)

The operators started a second make-up pump, and shortly thereafter the high pressure injection system automatically activated. (194) These responses restored the water level in the pressurizer, and the operators eventually brought the plant to a stable condition. (195)

Too Many Alarms

Effective operator response had been hampered by a number of factors. Several hundred alarms had activated so quickly that the operators had to ignore them temporarily and concentrate on the gauges that measured key plant conditions. (196) Further, the computer that printed out the activation of alarms in sequence became backlogged. (197) In Frederick's words, the alarms "were not being typed out fast enough to be of use in evaluating the transient." (198) Only after the operators had ascertained that the plant was stable did they turn to the alarms.

Faust said that as a result of this minor accident, he concluded that the alarm system would be "useful" only if no more than three or four alarms were activated. (199) If more came on, ". . . then you had to pick through them to find the ones that were significant. It took too much time." (200) That had been his experience on April 23—"it was just useless to try to really sort out all the alarms that were coming in." (201)

Frederick agreed: "I was forced to ignore most of the alarms," and commented that he had to rely on the information presented by the gauges on the control panels. (202) He noted:

> . . . with that much alarm information, the information begins to lose its value . . . the flood of information has no priority and no time sequence. (203)

Analysis of the Accident

Shortly after the April 23, 1978 accident, James Seelinger, the Technical Support Superintendent for TMI–2, prepared a detailed analysis of it. (204) He identified a number of equipment failures that had contributed to the incident, including failures or deficiencies in the main steam safety relief valves, the main feedwater block valves and the emergency feedwater control valves. (205)

In addition, although he praised the operators for their response to the reactor trip and actuation of high pressure injection, he was critical of two other aspects of their performance: their failure to slow the feedwater pumps sooner and to diagnose the accident correctly. (206) As a result of the latter failure, he concluded that some of their responses had been inappropriate:

> While the operators responded correctly to the reactor trip, they did not realize the casualty they were really dealing with was a major steam leak (through the relief valves).
>
> The operators during the transient never fully grasped the damaging effect of feedwater on this situation. . . . (207)

In his report, Seelinger noted that indicators of several "critical operator items" were needed in the control room and recommended they be installed. (208) They included position indicators for the main steam safety relief valves, feedwater block valves and emergency feedwater control valves. (209) However, in his report Seelinger never associated the lack of indicators on the positions of the valves with the operators' inappropriate responses. (210)

Seelinger recommended that an effort be made to reduce the number of "nuisance" alarms that would activate while the plant was operating normally.[45] (217) He also recommended that additional alarm acknowledgment stations be added in the control room. (218) His report did not discuss whether these features had contributed to the incident.

Response by the Operators

Seelinger's analysis was distributed to control room operators at TMI–2. Three of those present in the control room during the accident—Ed Frederick, Hugh McGovern and Craig Faust—discussed the report and the accident. (219)

Frederick responded to Seelinger's criticisms. (220) Although Frederick said his letter to

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[45] Nuisance alarms are alarms that remain activated in the control room during periods of normal operations. (211) They can be activated as a result of faulty wiring or if the sensors that trigger the alarms are overly sensitive. (212) In addition, some alarms are wired to activate in response to routine actions of operators, such as turning off a pump. (213) Many can remain lit for extended periods. (214)

Zewe stated that in 1978 at times over 100 "nuisance alarms" would be lit in the TMI–2 control room. Electrical engineer John Brummer estimated the average was about 70. (215) For comparative purposes, the TMI–1 control room typically had about five nuisance alarms lit. (216)

Seelinger represented only his views, Faust said that Frederick had showed it to him and that he agreed with it. (221) In Faust's opinion, Seelinger's analysis

> . . . seemed to be pointing a heavy finger at the operators as the cause of some of the problems we had at the time in that transient and we were just saying that not all the indications that we could have used were available to us at the time. . . . (222)

Frederick said he wrote Seelinger on May 3, 1978 in order to identify "the problems that I saw in the accident. that I didn't think were touched by his evaluation." (223) In his letter he commented on the alarm system:

> The alarm system in the control room is so poorly designed that it contributed little in analysis of a casualty. The other operators and myself have several suggestions on how to improve our alarm system—perhaps we can discuss them sometime—preferably before the system as it is causes severe problems. (224)

Frederick said he intended that Seelinger would assign an engineer to work with the operators "on a long-term basis" to correct the problems. (225)

Elsewhere in his letter Frederick challenged Seelinger's analysis of the causes of the accident:

> I feel that the mechanical failure, poor system designs, and improperly prepared control systems were very much more the major cause of this incident than was operator action.
>
> You might do well to remember that this is only the tip of the iceberg. Incidents like this are easy to get into—and the best operators in the world can't compensate for multiple casualties which are complicated by mechanical and control failures. (226)

Frederick said that by "improperly prepared control systems," he meant the absence of several important valve position indicators in the control room. (227) In Frederick's words, "We couldn't see all the valves that were necessary to control the system." (228)

Frederick closed his letter with the following comments:

> Some of our suggestions are good. We made suggestions on FW [feedwater] valve indication 2 years ago (submitted many FCR's). We have complained about the alarm system since day one. Let's get together and try to prevent this from happening again.[46] (229)

Seelinger replied to Frederick's letter the same day. (230) He reemphasized that the operators' response had been "good and proper." (231) As to the alarm system, he stated that Frederick's concerns were addressed by the recommendations in Seelinger's report on the accident. (232) In response to Frederick's "tip of the iceberg" comment and his concerns about the difficulties operators had in responding to accidents such as that of April 23, 1978, Seelinger commented, "the ability to do this comes with experience, and I think the operators who had this transient performed well considering their experience." (233)

Frederick told Special Investigation staff that he believed he was "fairly pacified" by Seelinger's response. (234) However. Faust said that he and Frederick "didn't exactly like the response we got back." (235) Faust added that at the time, Frederick thought that "what we were asking about or mentioning just wasn't going to have too much followup. . . ." (236)

According to Frederick, after receiving Seelinger's response, he had one brief, informal discussion with him about their letters and Seelinger's analysis. (237) However, they "never had the meeting that I requested about the alarm system." (238)

Design Modifications

TMI–2 was shut down for approximately four months after the April 23 accident. (239) During that period, the utility tested and ultimately replaced the main steam safety relief valves. (240) TMI–2 control room operators said that their emergency procedures were also revised in an attempt to ensure they would not overfeed the steam generators in the event of a similar accident. (241) The revised procedures and the April 23 incident were discussed in operator training programs at TMI. (242)

With respect to control room instrumentation, the utility installed position indicators in the control room for the valves in the feedwater system. (243) In addition, it set up a microphone in the vicinity of the main steam safety relief valves and wired it to a speaker in the control room so that operators could hear when the valves were open. (244)

Changes in the Alarm System

As to the alarm system, Floyd said that after the accident, the operations staff requested the installation of several additional alarm acknowledgement buttons in the control room. (245) They wanted each to acknowledge only the alarms in a certain section of the control room. (246) This would lessen the chance of an operator inadvertently acknowledging new alarms coming into the control room during a transient while clearing

[46] FCR's—Field Change Requests—are one of the formal means by which operators can request design changes.

previously acknowledged alarms, since he would be working only with one section of the control room at a time.

The utility installed several additional buttons, but they still acknowledged all the alarms in the control room. (247) Management's rationale was that this system would be easier for operators moving around the control room. (248)

Evidence reviewed by the Special Investigation indicates that the addition of the acknowledgement buttons was the only design change in the TMI-2 alarm system made specifically in response to the April 23 accident. (249) Beyond that, in late 1978 and early 1979, Met Ed and B&W engineers did reduce the number of "nuisance alarms," as Seelinger had recommended. Nevertheless, just before the March 28, 1979 accident began, about 50 of those alarms were activated. (250)

Operators Dissatisfied

Even with these modifications, operators were still dissatisfied with the alarm system. Floyd said that no effort had been made to restructure the alarm system so that the operators could identify and react quickly to the most important alarms. (251) He concluded that such an approach "wasn't recognized as being necessary" and added, "I don't know that it was really a recognized need until this transient on March 28, [1979]." (252)

Alarms To Be Ignored

One result of their dissatisfaction with the alarm system was that Faust, Frederick and Zewe said they would not acknowledge alarms activated during the initial stages of a complicated transient. (253) They knew that they would not be able to read all the alarms and respond to the situation at the same time. If they were to acknowledge the alarms without first reading them, they might inadvertently clear some without noticing they had been activated. (254)

In an interview with Special Investigation staff, Floyd confirmed that the TMI-2 operators had decided not to acknowledge any alarms during the early stages of a transient. He said he considered this approach to be acceptable, since all the occurrences prior to March 28, 1979 had been of very short duration:

> . . . the reactor trips and it's all over. Thirty seconds, and it takes the operator two minutes to realize that it's over. And then he can scan his board and put the plant back together again. (255)

Floyd did not specifically recall telling operators after the April 23 accident to "ignore" the alarms during a major transient, although he said, "I certainly wouldn't be surprised if I did." (256) He commented:

> If the man came up to me and said, "Hey, the alarms are absolutely worthless during this transient," I would say, "Yes, they always are, but you got these meters and recorders over here. They are what are going to keep you out of trouble. Go ahead and ignore those overhead alarms, but pay attention down here. This is where it's at." (257)

In Zewe's opinion, the alarms would not, in any event, play a "major role" in operator efforts to diagnose a major accident:

> . . . I've been involved in several transients and we handled them pretty much the same, whereas we didn't use the alarms and accepted what we had and we just used it to the best of our ability. (258)

Zewe did, however, note one problem with failing to acknowledge the alarms as they were activated. (259) The operators would not know the sequence of their activation. (260) Given that the computer alarm printer would become backlogged during a major transient,[47] there would be no way to obtain the complete alarm sequence, probably until the transient was over.

The ability to reconstruct a sequence of alarms is an important analytical tool for an operator faced with a complex transient. As Frederick noted,

> . . . if [an operator] makes a misjudgment early on in the accident, he has the ability to review the effect of that misjudgment on the trend as a whole and retrace the steps: start a more logical strain, have more logical information [on which] to base his decisions. (261)

On March 29, 1979 the operators would have the same problems with the alarms as they had during the March 1978 accident. Frederick noted that most operators simply did not use the visual and computer alarm systems in the early stages of a transient:

> The general consensus and the training that we received, that led most of the operators to not use the computer as a source of information during a transient, you could use it after things settled down, but during the first phase of any transient, you would just have to go by the information available on the panel, since neither the [annunciator] nor the computer will be able to give you good time sequence and prioritized alarm information. (262)

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[47] Computer alarm deficiencies are discussed in greater detail on p. 71.

According to Frederick, he was also concerned about the alarms on the back control panels that were completely out of sight of the main control console. He noted that if the alarms on the front and the back control panels were to come on simultaneously, the operators could acknowledge the front panel alarms without necessarily noticing those on the back panel. (263)

Frederick stated that he believed the TMI–2 control room alarm system could have been designed to be useful during a major accident:

> We need an alarm system that is designed to be useful during analyzing one of these problems. We need alarms that are meaningful. In other words, you need an alarm that tells you when you have lost a feed pump, but you don't need one that tells you that there is trouble in the turbine building elevator. Out of the 1200 or 1600 alarms that are displayed up there, I am sure we could narrow that down to 100 or 200 without losing any vital indications. The need to acknowledge wouldn't be necessary. (264)

Thus, prior to the accident on March 28, it is clear that the operators had decided that the alarm system would not be of any immediate assistance in a major transient or an accident. On March 28 the operators acknowledged the alarms in the early moments to silence them, but did not read them.[48]

The Usefulness of an Alarm System

In their statements, several operators suggested that an alarm system was not really important in an accident. Floyd made a number of comments on this issue. He said that the March 28, 1979 accident made him realize that operators cannot themselves handle the "information overload" created by the activation of several hundred alarms during the first minutes of a transient. The operator:

> . . . needs the prioritization to take place automatically for him . . . you have to give the operator some assistance to sort out those several hundred alarms which are coming in so very rapidly, all of them calling for his attention, when, in fact, he should only be paying attention to a half dozen of them. (265)

At the same time, Floyd recognized that the operator would have to work with his other instrumentation and equipment:

> There's an information overload during a transient that the control room operator has to live through. And neither the annunciators nor . . . the high-speed printer is going to get him out of that difficulty. The information overload is going to be there and he has to go back and rely on his console indication on the meters, on temperature, pressure, flow and power . . . Whether it's a short-term transient or a long-term transient, he's got to pay attention to those big four. That's fundamental. (266)

Floyd elaborated on this point. Even if the alarm system were structured so that operators could react quickly to important alarms,

> . . . the operator is still not going to run his control room based on the alarms in the transient; he's going to run the control room based on the panel indication. He has to. That's the only thing that's in the real time. (267)

He added that

> . . . you don't want to try to cure all the operator's problems with a sophisticated alarm system . . . [although] you can do some additional sophistication that we don't have, to get him pointed in the right direction, to maybe help explain what those four big meters are supposed to be telling him already in the console. (268)

When Zewe was asked if the instrumentation had caused the failure of control room personnel to diagnose the stuck open PORV on March 28, 1979, he replied:

> It is pretty hard to say, but I think it is a matter of a combination [of things]. I think you could pick any certain area and say, "Yes, we should improve that area and instrumentation, improve the procedures we use, improve this or look at something else." All of that certainly had a factor and to what degree depends on whose evaluation it is. So I could rationalize and say, "Yes, I think there were many things we could have done better," certainly without a doubt. And through every instrument we had [,] I think we had all the mechanisms we needed to cope with the situation at this point, but there were certainly things that could be improved upon that would cause more awareness or recognition of the problem: yes. (269)

He concluded:

> I feel the plant is of a good design, that it is adequate. I feel the training was good and adequate. There again, I felt the instrumentation was adequate, too. Like I

[48] See "The Accident at Three Mile Island: The First Day," p. 99.

mentioned before, everything needs further improvement. We can always use that. (270)

OTHER PROBLEMS AT TMI-2

Control Room Computers

Some alarms are not represented by flashing lights in the control room, but instead appear only on the computer printout. (271) One such alarm that played a role in the March 28, 1979 accident was the alarm indicating a high water level in the containment sump. (272)

The computer in the TMI–2 control room is a Bailey 855. (273) It has two printers similar in appearance to electric typewriters. (274) One prints out system conditions on request; the other prints out alarm information, at a rate of approximately 14 alarm messages per minute. (275) If the alarms are activated faster than that, they are stored in sequence in a memory bank that can hold a total of 1,365 alarm messages. (276) The computer will automatically print out the alarm messages in the memory bank until the backlog is reduced to zero. (277)

Scheimann, Faust and Frederick noted prior to the March 28 accident that the computer alarm printer would become backlogged during routine reactor and turbine trips. (278) Frederick stated that it "can be as much as an hour behind on just the turbine trip." (279) Zewe likewise said he knew it would become backlogged during "major" transients. (280) Faust and Frederick both stated that the printer became backlogged during the April 23, 1978 transient. (281)

As noted, determining the sequence of alarms can be important to diagnosing an accident and responding properly. The computer could be of assistance in that determination. Because of the backlog problem, however, operators recognized that the TMI–2 computer would be of little help. In Zewe's words,

> During any major transient, I would totally ignore the alarm typewriter, knowing from past experience that it would backlog and I wasn't interested or concerned in past history, more so in current parameters. So I would only use the computer for current parameters or until it caught up to the real time frame of the alarm, then I would start to use it in a normal one-on-one fashion. (282)

Leakage of the Pilot-Operated Relief Valve

Since October 1978, the pilot-operated relief valve (PORV) had been leaking, (283) as indicated by high temperatures in the discharge line leading from the valve to the reactor coolant drain tank. Temperatures, usually a little below 130° F, were averaging around 170° F or 180° F during normal operation, a little below the 200° F point at which an alarm indicating a high temperature sounds in the control room. Prior to the 1979 accident, plant personnel were aware of some leakage, but were not certain whether it was the PORV or one of the two code safety valves on the pressurizer. (284)

Emergency Procedure 2202–1.5, "Pressurizer System Failure," requires that plant personnel respond to suspected PORV leakage by closing a "block" valve located in front of the PORV and to suspected code safety valve leakage by recording their discharge line temperatures on an analog trend recorder, if temperatures exceed 130° F. (285)

The utility had neither closed the block valve, nor used the recorder, nor repaired the leaking valve prior to the March 29, 1979 accident. (286) Frederick said there had been some consideration of closing the block valve; (287) but this was not done because of the possibility of its sticking in the closed position.[49] (288)

The actions of the control room personnel on March 28, 1979 indicate that they had become accustomed to the elevated temperatures produced by the leakage. That, combined with their knowledge that the PORV had lifted briefly, releasing more hot steam and water and raising the temperature still further, and the fact that the indirect indicator light in the control room went out, according to the control room personnel, misled them into thinking the valve was closed. (289) For more than two hours, they did not recognize that the PORV was stuck open.[50] (290)

Inspectors from the NRC's regional office had conducted 25 inspections of varying types at TMI–2 between October 1978 and the March 1979 accident. The inspectors never noted the leakage from the PORV. (291) The NRC explained that the alarm setpoint of 200° F was never reached, and that an inspector doing an audit type of inspection would not have been expected to note the elevated temperature, unless the alarm had gone off. (292)

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[49] See "Recovery at Three Mile Island," pp. 210–211. Most of the civil penalty of $155,000 the NRC assessed Met Ed for violations can be attributed to the utility's failure to respond to the leakage as required.

In connection with this same leakage, in 1980 the NRC asked the Department of Justice to investigate allegations by Harold Hartman, a former TMI control room operator, that the utility had manipulated the calculations of the rate of leakage in order to get figures within the limit set by the Technical Specification governing plant operations. According to Hartman, plant personnel added water to the coolant in the primary system and altered the hydrogen overpressure in the make-up tank but did not include those changes in conditions in the calculations.

[50] See "The Accident at Three Mile Island: The First Day," pp. 93–109.

If the leakage had been severe enough to necessitate repairing the PORV, the utility would have to have shut the plant down. In that event, the utility would have been required to notify the NRC of the leakage. (293)

Frequent Actuation of High Pressure Injection

Actuation of the high pressure injection (HPI) system indicates a potentially severe problem, since it is designed to replace coolant lost during a small loss-of-coolant accident. The system automatically comes on when primary system pressure falls to 1,640 psi, ordinarily reached only during a loss-of-coolant accident. (294)

At TMI–2, however, the HPI system had actuated four times in the 12 months prior to March 1979 in response to relatively routine problems in the secondary system, rather than to loss-of-coolant conditions.[51] (295) TMI–2 operators had become accustomed to initiation of HPI under less severe conditions. In the words of TMI shift supervisor Ken Bryan, "It is not a big deal" for the HPI system to activate at TMI–2 during a turbine/reactor trip. (296)

The NRC Office of Inspection and Enforcement noted in its investigative report of the accident that "the operators were not surprised by HPI actuation." (297) Further, "the operators were conditioned to promptly bypass ES [engineered safety] without first determining the condition of the RCS [reactor coolant system]."[52] (299)

It can be inferred from the NRC's findings that, on the day of the accident, the control room personnel throttled the HPI severely without determining if there were a loss of coolant because of their past experience with its initiation.

The utility had reported the previous HPI activations to the NRC. (300) Each was, in turn, reported in NUREG–0020, "Operating Unit Status Report," better known as the Grey Book, and was analyzed by personnel in the regional offices. (301) The analysis of the HPI activations focused, however, on the effect of the addition of sodium hydroxide, a chemical added to the injected water, on the system, rather than on the fact that HPI came on for other than loss-of-coolant conditions. (302)

In response to the HPI problem, the low pressure reactor trip setpoint was raised 100 psi to 1,900 psi and the point at which HPI could be bypassed was raised by 100 psi to help reduce unnecessary actuations. (303) The NRC issued no special notification to other utilities of the problem. (304)

Babcock & Wilcox also looked into the actuation of HPI at TMI, but took no action to limit its activation under non-loss-of-coolant conditions, (305) nor did it notify other utilities with B&W systems of the problem. (306)

The Special Investigation staff discussed with the NRC the possibility that operators might secure HPI in a loss-of-coolant accident if they were accustomed to the system starting in response to feedwater problems. (307) An NRC official expressed concern, although for a different reason. (308) In a loss-of-coolant accident, the reactor coolant pumps should be shut off to slow the rate at which coolant is lost from the system. NRC staff is seeking unambiguous signs that will alert the operator to a loss of coolant so that the operator will know to shut the pumps off. One sign could be HPI, but only if the system were to come on just for losses of coolant. (309) NRC staff has stated that the Special Investigation staff's concern about operator conditioning is valid and complementary to its concern. (310)

IN RETROSPECT

During the three years from 1976 until the March 1979 accident, TMI operators and supervisors became aware of several weaknesses in the design of the control room and its instrumentation. Most of those problems became apparent during several minor accidents that occurred at the plant during operational testing in 1978. Many played a role in the March 1979 accident. However, according to Zewe, although instrumentation and procedures could have been improved, the personnel "had all the mechanisms we needed to cope with the situation" on March 28, 1979. (311)

The history of TMI–2 provides a good example of the consequences of the lack of attention given to human factors engineering in control room design. In various events that occurred during early operations, the TMI–2 control room alarm system overwhelmed operators with information and failed to assist them in diagnosing the situation. Although the deficiencies of the alarm system were of obvious concern to several control room operators, the TMI–2 Supervisor of Operations was less concerned, since he believed that during a transient the operators would have to concentrate on indicators of plant conditions, and not on the alarms. Others shared his opinion.

Control room personnel had identified other problems as well. These problems also influenced events on the day of the accident. They involved:

1. The condensate polishing system;
2. The configuration of the hotleg piping, which could trap steam, blocking the flow of coolant and causing unusual plant behavior;

[51] The March 29, 1978 incident evolved into a loss of coolant accident after the PORV stuck open.

[52] The report also said that "the normal course of most ES initiations, those which did not involve a loss of coolant, required bypassing of ES and securing of HPI. . . ." (298)

3. The leakage through the pilot-operated relief valve; and

4. The actuation of the high pressure injection system under non-loss-of-coolant conditions.

Neither the utility, its suppliers nor the NRC responded to these problems in a way that effectively prevented their recurrence.

OPERATOR TRAINING AND LICENSING

A critical element in the safe operation of nuclear powerplants is the preparedness of plant personnel, particularly the operators and supervisors. As became evident on March 28, 1979, the TMI–2 operators and supervisors were not adequately prepared to diagnose and respond to the accident. In light of this, the Special Investigation reviewed briefly the training provided to utility personnel.[53]

In general, operator training at TMI emphasized plant operations under normal conditions and response only to selected "standard" accidents. Operators had limited instruction or practice in diagnosing and responding to multiple failure accidents, particularly prolonged ones, such as occurred on March 28.

Further, their emergency procedures, which they had been trained to use in unusual situations, did not provide needed guidance in the first hours of the accident. In addition, the operators had insufficient instruction on the basics of nuclear powerplant physics and behavior. This contributed to the difficulty they had in diagnosing and responding to the accident.

Although the utility is largely responsible for the inadequacy of operator training, the reactor vendor, which helped develop the training program, and the NRC, whose involvement in training was too limited, are also responsible for the inadequacy.

OPERATOR TRAINING

Operators are required to have specialized education and training and to be licensed by the NRC. Training is conducted by the utility, frequently in conjunction with the suppliers of plant systems. In the case of Unit 2 operators, Met Ed had contracted with Babcock & Wilcox to provide certain portions of the operator training program. (312) The contract called for classroom and simulator instruction for trainees. The courses were both developed and taught by the B&W training department. (313)

Weaknesses in the Training Program

There were several significant weaknesses in the TMI operator training program that made it difficult on March 28, 1979, for the control room personnel to understand and respond to the sequence of events.

Orientation of Training

For the most part, training was geared to normal plant operations and to the hypothetical accidents postulated in the Final Safety Analysis Report submitted to the AEC. (314) Of significance in the context of the TMI accident, the program included only limited training in multiple-failure events and events of prolonged duration. (315)

Emergency Procedures

In addition, although the operators had been trained extensively with the emergency procedures, none of those procedures precisely anticipated the actual chain of events at TMI–2.[54] Faust stated:

> That is what we were having a big problem with that day, trying to follow limits set forth in our tech specs [Technical Specifications], as well as our Emergency Procedures, where we were having a difficult time doing that because we saw something diverse, something different from what our training had taught us in the past. (316)

Further, the sequence of events at the start of the accident was much different than what the operators had studied and from what they expected. Zewe commented on his training for loss of coolant accidents:

> . . . If you look at any LOCA [loss-of-coolant accident] we've ever had, if you have . . . pressure in the building, and also reactor coolant system pressure, they're within seconds of each other. (317)

During the accident these events seemed disjointed to the operators.[55]

Duration of Accidents

The TMI–2 accident also lasted longer than anticipated. The operators found it difficult to reconstruct events over that extended period and to assess their evolution. Instead, operators focused on the state of the reactor at a given moment. As Scheimann stated:

> In the event that we had an emergency that didn't fall within the scope of an emergency procedure, the thing we would

[53] The President's Commission and the NRC Special Inquiry examined operator training extensively. The Special Investigation independently reviewed their materials and findings, as well as materials and interviews it compiled.

[54] It should be noted that written procedures are based on certain foreseeable circumstances and are not meant to cover all possible situations or to substitute for operator training in responding to unforeseen situations.

[55] See "The Accident at Three Mile Island: The First Day," pp. 102–103.

do would be to treat the symptoms, in other words, respond to what we were seeing in front of us. If pressure were decreasing, we would try to increase pressure, and vice versa. . . . (318)

Basics of Plant Operations

Training was deficient in the basics of nuclear powerplant physics and behavior. As is detailed in the next chapter, the unusual behavior of the plant was neither understood nor quickly diagnosed. For example, control room personnel failed to appreciate the significance of the data on pressure and temperature indicating saturated steam conditions in the core. Marshall Beers, Met Ed Group Supervisor of Nuclear Training, explained that saturation conditions in the core were not anticipated as long as pressurizer level was maintained. He added that, prior to the March 28 accident, operators were not trained for saturation conditions in the core, although in hindsight these conditions might possibly have existed during previous reactor trips at TMI. (319) He further noted:

> . . . the significance of temperature-pressure and the possibility of uncovering the core under these types of conditions . . . was never specifically taught [to the operators]. (320)

In addition, while several of the control room personnel recognized as early as 10 a.m. on the first day of the accident that superheated conditions were present, the Special Investigation staff found no evidence that they linked that condition to core uncovering.

Pressurizer Level

Operators had not been instructed that under certain conditions the pressurizer level would be an unreliable indicator of water level in the reactor vessel. In addition, their training led them to believe that as long as there was adequate water in the pressurizer, there had to be adequate cooling water around the core. (321) This belief, along with the standing instruction never to permit the pressurizer to "go solid" (fill completely with water) during plant operations, led the operators to throttle high pressure injection early in the accident. (322)

Zewe, a TMI–2 operator who was on duty the day of the accident, said he was confused over why the pressurizer level stayed high in the early hours of the accident, even though coolant level should have been decreasing as a result of the throttling of high pressure injection and increased drainage of coolant through the let-down system. (323) Similarly, James Floyd, TMI–2 Operation Supervisor, said, ". . . to see the pressurizer level high and the plant pressure low was just a situation that . . . was never prepared for." (324)

Use of Instrumentation

The operators had not been familiarized with the use of the movable incore detector, a component of the plant's nuclear instrumentation that could have been used as an alternative means of detecting core uncovery. (325) Special Investigation staff interviews revealed that some utility employees who might have been expected to be knowledgeable about the use of the detector—Met Ed's instrumentation foremen and technicians—did not even consider the device to be the property of the utility:

> . . . As far as I was concerned, it was not part of our equipment. The only time I have seen it in operation was when B&W people were moving it up and down. The Metropolitan Edison instrument men never had anything to do with it. It was in a separate cabinet all to itself over by the side. (326)

Other utility personnel had never seen the detector used, and no one the Special Investigation staff interviewed recalled its being discussed or considered on March 28, 1979.[56] (327)

Further, the control room personnel were not trained to use the fixed neutron detectors to determine water level in the core.[57] (328)

The remaining nuclear instrumentation available on March 28, 1979 were the source and intermediate range monitors, which measure neutron activity in the core. The operators were not trained to use them to determine if the core is uncovered. (329) Rather, they were instructed to use the monitors when bringing the reactor back to full power following a shutdown (for this reason they are referred to as "start-up" monitors).[58] (330)

The Simulator

An important part of the training program involved practice on a reactor simulator. This was done at the B&W facility in Lynchburg, Va.

The simulator is a computerized mock control room that can reproduce events that occur in a nuclear powerplant. However, the B&W simulator differed in significant ways from the control room at TMI–2. (331) For example, it was smaller

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[56] See "The Accident at Three Mile Island: The First Day," p. 112.

[57] Part of the reason for not relying on the fixed incore neutron detectors is that under normal operating conditions, accurate readings are produced by the control room computer only if the reactor is above 15 percent power. When a reactor is shut down following a reactor "trip," normally there would not be enough current for the computer to produce readings of neutron activity in the core. As a result, the operators tended not to rely on the neutron detectors when the reactor was at a low power.

[58] See "The Accident at Three Mile Island: The First Day," pp. 111–112, 117–118, for further details.

The Babcock & Wilcox simulator, used in training operators of Three Mile Island

and more compact. It did not have nearly as many alarms (150 vs. 1,200), and all the electrical distribution instrumentation was on one panel, instead of taking up one-third of all the panel space, as in the control room at TMI–2. (332) Further, the simulator was not programmed to reproduce all the emergency conditions an operator might possibly have to address, (333) including the sequence of events experienced during the March 28, 1979 accident.

As was noted, the program did not include extensive training in multiple failure events. Craig Faust and William Zewe, two TMI–2 operators who were on duty March 28, 1979, commented on their simulator training in this area. Faust said, ". . . we didn't train for multiple casualties." (334) Zewe said that prior to the accident, he had been trained "only to a limited extent" in multiple failures at the B&W simulator. (335) He added, "Maybe we would have two failures or one failure and we caused another one by how we reacted to it, but not to the extent which they train now, to where they will give you . . . several failures in a row, not like that, no." (336)

The lack of attention to multiple failure events was the result in part of the NRC's single failure criterion. According to this criterion, the licensee only had to assume a limited number of concurrent failures in the analysis of certain accidents.[59] Its operators would be trained accordingly. (337)

OPERATOR LICENSING

On completion of their training, operators must be licensed by the NRC before they can operate the plant. They must pass oral and written examinations administered by the Operator Licensing Branch (OLB) of the NRC's Office of Nuclear Reactor Regulation, the unit responsible for the operator licensing program. (338) The TMI–2 operators on duty on March 28 had all scored above average on the exams.

The NRC's licensing requirements for operator training are contained in Part 55 of Title 10 of the Code of Federal Regulations.[60] These provisions

[59] These events are spelled out in Chapter 15 of the Safety Analysis Report.

[60] In addition to the regulations, NRC has two Regulatory Guides that address operator training. Regulatory Guide 1.8, "Personnel Selection and Training," endorses ANSI Standard 18.1, "Selection and Training of Nuclear Power Plant Personnel." This standard outlines criteria for the selection, training, qualifications and responsibilities of operating personnel. The standard was redrafted and circulated for comment by the American Nuclear Society as ANS 3.1 just before the accident at TMI. Following the accident, the draft standard was recalled and revised. The newly drafted version is to be issued for comment in July 1980.

Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," provides guidance regarding information that is to be submitted to the NRC on training programs for plant staff. The plans are reviewed by the Operator Licensing Branch, using the criteria contained in NUREG–75/087, Standard Review Plan, Section 13.2, "Training."

establish two types of licenses: an operator's license for personnel who handle the reactor controls; and a senior operator's license for those who supervise or direct the activities of the control room.

As outlined in the American National Standards Institute Standard 18.1, an operator must have a high school diploma or its equivalent and have two years of experience at a powerplant or its equivalent, with a minimum of one year at a nuclear powerplant. A senior reactor operator must have a high school diploma or its equivalent and four years of powerplant experience in a position of responsibility. A maximum of two years of experience can be fulfilled by academic or related technical training.

There are no NRC requirements for psychological evaluation of license applicants, (339) nor is there any investigation to determine the applicant's employment history or whether he has a criminal record. (340)

The NRC's role in operator training has been quite limited and has principally involved auditing the training programs. (341) It has set no qualifications for the instructors who carry out operator training, (342) and has no requirements that training include proper response to significant transients that have occurred at nuclear reactors. (343)

Requalification

In addition to the initial operator training, the NRC requires that a utility conduct annual requalification programs for its licensed operators. Requalification is actually continued training, intended to ensure that licensed operators maintain their technical skills and are aware of new procedures. Biannually the NRC audits the program by checking the contents of examinations. (344)

The NRC's Role

Paul F. Collins, Chief of the Operator Licensing Branch of the NRC, described some of the shortcomings of the NRC program:

—In the written requalifying examination, only two of the seven or eight parts contain questions on procedures relating to safety and emergency equipment. An operator could do poorly in these areas and still achieve an 80 percent score overall, thereby qualifying for license renewal. (345)

—The NRC does not audit the requalification training program administered by vendors and utilities for operators placed in accelerated training after scoring less than 70 percent on the written examinations, if they perform well on the oral examinations. (346)

—Since 1973, the NRC has not required an applicant for a new license to start up the reactor in the presence of an NRC examiner. Perhaps once a year. NRC examiners observe students perform this task on a simulator. However, the NRC does not audit the requalification training on simulators. (347)

—If two units are sufficiently similar, an operator licensed on one unit may be cross-licensed for the other upon completion of a "differences" course and an examination administered by the utility. A utility that wants to cross-license its operators is entirely responsible for that program. An NRC examination is not required, and the NRC does not audit those given by the utility. (348)

—The Operator Licensing Branch does not coordinate its work with that of the NRC staff who review design aspects of a plant. Thus, there is no direct communication within the NRC on issues involving "where man and machine come together." (349)

—While the oral examination covers normal and emergency operating procedures, the NRC does not directly observe operators using these procedures. (350)

RELATED ACCIDENTS AT OTHER PLANTS

Three Mile Island was not the only nuclear facility to experience the kind of events that occurred in the early stages of the March 28, 1979 accident.[61] The Special Investigation confirmed that the problems experienced at TMI had a parallel elsewhere in the industry. Two accidents proved of particular interest.

THE OCONEE ACCIDENT

On June 13, 1975, a minor accident occurred at Unit 3 of Duke Power Company's Oconee Nuclear Generating Station in Oconee County, South Carolina. This accident was quite similar to the early stages of that at TMI–2.

[61] See "Three Mile Island in Perspective: Other Nuclear Accidents," Appendix A, pp. 219ff.

The plant, which is equipped with a Babcock & Wilcox reactor, was at 15 percent power and in the process of shutting down for maintenance when a loss of feedwater initiated a reactor trip. (351) Pressure in the primary system increased to the point where the pressurizer relief valve opened. As was to happen at TMI–2, the valve failed to close when pressure in the primary system decreased. Further, the valve position indicator light in the control room malfunctioned and indicated that the valve was closed. (352)

With pressure down, the HPI system activated. Water continued to flow out of the stuck-open valve into the reactor coolant drain tank. Eventually the tank ruptured, spilling approximately 1,500 gallons of reactor coolant into the containment. (353)

The operators diagnosed the leak and closed the block valve before the water in the primary system boiled. The situation never became serious enough to damage the nuclear fuel. (354)

The valve failure was caused primarily by a build-up of boron in the valve, a problem that was later corrected. Once repaired, the valve was tested to ensure that the position indicator functioned properly. Duke Power management informed the operators, following its analysis of the incident, that closing the block valve was the proper action in such an occurrence. (355)

NRC's Region II Office reviewed Duke Power's analysis, raised some additional questions and ultimately found the analysis to be satisfactory. (356) The event was routinely reported in NUREG–0020, the NRC's "Grey Book." However, the NRC did not perceive any generic safety significance and did not further notify other licensees. (357)

B&W likewise reviewed the event, since its equipment was involved, and determined that the problem with the PORV could have generic implications. As a result, all B&W plant owners were advised to inspect the PORV's periodically.[62] (358)

THE DAVIS-BESSE ACCIDENT

On September 24, 1977, there was a minor accident at the Davis-Besse Unit 1 plant operated by Toledo Edison in Ohio. It was also very similar to the early minutes of the Three Mile Island accident.

While the plant was at nine percent power, feedwater problems caused primary system pressure to rise to the point at which the pressurizer relief valve opened. Again, the valve failed to close, this time because of a missing relay in the valve's control circuit. It opened and closed nine times within 40 seconds before sticking open. (359)

Pressure in the primary system dropped, actuating the HPI system. Water flowing out through the PORV eventually caused the reactor coolant drain tank to rupture, and approximately 11,000 gallons of water were released into the containment. (360)

Although at first the symptoms were commonplace—water in the pressurizer initially dropped as primary system pressure dropped—an unusual condition soon became apparent. Water in the pressurizer began to rise and reached a maximum level as the coolant approached the boiling point. The operators responded to the filling pressurizer by turning HPI off after about four minutes. (361) Thus, water being lost through the undiagnosed open relief valve was not being adequately replenished. Coolant in the primary system began to boil.

The operators noticed a combination of indicators, particularly high pressure in the containment and a ruptured drain tank (362) that ultimately led them to diagnose the situation. They isolated the leak after 21 minutes, before sufficient coolant had been lost to threaten the nuclear fuel. (363)

ANALYSIS OF THE ACCIDENT

Toledo Edison, Babcock & Wilcox, who had supplied the reactor, and the NRC all analyzed the accident. The reviews focused primarily on the mechanical problems associated with the PORV; less attention was paid to operator actions. (364)

One issue related to operator actions was identified as having potential safety significance—premature termination of the HPI. The Office of Nuclear Reactor Regulation, NRC, suggested to the Office of Inspection and Enforcement at headquarters that it should ask that Toledo Edison address the matter of operators turning off HPI in its formal report. (365) However, according to the NRC, "no significant action resulted from this effort." (366)

The NRC reported the incident in the Grey Book, but did not further notify the utilities. (367) Nor did the inspectors' analyses reveal any generic safety concerns, (368) in part because they believed the problems were unique to the incident. (369)

Some months later James Creswell, a Region III inspector, did raise several issues. One was that the operators might have incorrectly turned off HPI. As a result, emergency procedures at

[62] It is not known at this time what caused the TMI–2 PORV to stick open, as it cannot be removed and inspected until the containment can be entered.

Davis-Besse were modified to caution operators against turning off HPI in the event of a leak in the pressurizer. (370) This possibility was not recognized as a generic safety concern, and the NRC failed to take further action or to notify other utilities. (371)

When B&W reviewed the incident, it too concluded that the circumstances at Davis-Besse had been unique to that plant. (372) As a result, other utilities owning B&W plants were not informed. (373) Although several B&W engineers independently questioned the premature termination of HPI, internal discussions regarding a change in operator instructions were still ongoing at the time of the TMI-2 accident. (374)

THE MICHELSON REPORT

At about the time of the Davis-Besse accident, TVA engineer Carlyle Michelson,[63] who was also a consultant to the NRC's Advisory Committee on Reactor Safeguards (ACRS), was undertaking an analysis of hypothetical small break loss-of-coolant accidents at B&W plants. His conclusions were contained in a draft report dated September 1977 (375) and in a revision of the report dated January 1978. (376) In both he described and explained how he believed the primary coolant system would behave in the case of very small breaks.

The Michelson Report did not address actual accidents, but rather its conclusions about certain hypothetical accidents relate to events at TMI in March 1979.

Of particular relevance to TMI-2 was Michelson's analysis of the behavior of the pressurizer. He concluded that:

> A full pressurizer is not considered a reliable indication for prescribing certain operator actions such as HPI pump trip. (377)

He stated that pressurizer level would not necessarily reflect the water level in the reactor vessel. He also noted that the reactor coolant pumps should be turned off in such situations. (378) Michelson strongly urged that emergency procedures and operator training cover proper actions in the event of very small break losses of coolant. (379)

NRC RESPONSE

In early fall 1977, Michelson gave a handwritten draft of his report to Jesse Ebersole, a member of ACRS. (380) In or around October 1977, Ebersole sent a copy to Sanford Israel, a member of the Reactor Systems Branch within the Division of Systems Safety, Nuclear Reactor Regulation, NRC. (381) Israel in turn provided a copy to Gerald Mazetis, also in that branch. (382) They were the only people in the Office of Nuclear Reactor Regulation who knew of and had copies of Michelson's draft report, (383) and neither saw anything of concern in it. (384) Israel reviewed the report from the perspective of the small break issue and did not find anything "new or different." (385) He knew Ebersole was interested in loss of natural circulation and noncondensibles,[64] but he himself was not. (386)

In January 1978, Israel did prepare a note that addressed the chief concern raised in Michelson's report—that in certain circumstances pressurizer level would not be an accurate indication of coolant level in the reactor vessel and operators could be misled by their instruments to turn off the Emergency Core Cooling System. (387) Israel could not recall whether he wrote this as a result of his review of the report, his knowledge of the Davis-Besse incident, questions posed by Ebersole to the Pebble Springs applicant, or some combination of these factors. (388)

Israel's note, dated January 10, 1978, was signed by his supervisor, Thomas Novak, and was distributed to about 15 people within NRR. Again, there is no evidence to show that it produced any technical interest, and no generic safety problem for operating plants was identified. (389) Although a related question based on Israel's note was prepared in connection with an application for a new nuclear plant which had a Westinghouse reactor, the NRC never sent it, as plans for the reactor were cancelled. (390)

In January 1978, Michelson provided Ebersole with a revised typed version of his report, but Ebersole did not distribute it elsewhere in the NRC until after the accident at Three Mile Island. (391)

BABCOCK & WILCOX RESPONSE

On April 27, 1978. TVA sent Babcock & Wilcox (B&W) a copy of the Michelson report, which it referred to as a preliminary draft study, (392) along with a letter asking B&W to respond to the concerns addressed in the report.

The B&W reviewer did not see the report as raising a substantive safety issue and assigned it a low priority. (393) His reply, which TVA received nine months later (it was dated January 23, 1979) did not satisfy all of Michelson's concerns. Michelson therefore sent a second letter, dated February 8, 1979, requesting further clarification and additional explanation.

B&W did not inform its customers of Michelson's concern and had not replied to his second letter as of March 28, 1979. (394)

[63] Michelson is now Director of NRC's Office of Analysis and Evaluation of Operating Data.

[64] A noncondensible gas, such as hydrogen in the reactor vessel, cannot be converted into a liquid at its existing temperature and pressure. If a sufficient quantity becomes lodged in the piping, it will block the flow of coolant.

EMERGENCY RESPONSE PLANNING

Yet another factor contributing to the difficulties encountered during the March 28, 1979 accident was inadequate emergency response planning by the utility, the NRC and the State of Pennsylvania. Planning by each failed to meet the demands of an accident of the duration and severity of TMI.

EMERGENCY PLANNING: THE UTILITY

As a prerequisite for a license, the NRC requires that the licensee prepare an emergency plan that describes such things as the licensee's emergency organization, employees with special qualifications for handling emergencies, means of monitoring radioactive releases and procedures for notification of offsite organizations. (395) The plan must contain detailed procedures for implementing emergency responses.

The TMI–2 Emergency Plan in effect on March 28, 1979 (396) classified accidents according to degree of severity:

1. *Local or personnel emergencies*, which involve: contamination or exposure of individuals to excessive levels of radiation and spills in working areas; flooding, fire or other conditions that might require first aid or evacuation of buildings or a controlled area.

2. *Site emergencies*, which are triggered by high radiation readings at vent gas monitors,[65] high radiation levels at the perimeter of the site, or a loss of primary coolant pressure coincident with high pressure and/or high sump level in the reactor building. This class required evacuation of all affected buildings, monitoring of the perimeter for radiation, and notification of, among others, the NRC regional office and the State.

3. *General emergencies*, which have the potential for serious radiological consequences to the health and safety of the public. The plan listed several conditions that required declaration of a general emergency, all based on radiation levels either inside the containment building or in atmospheric or liquid effluents. Again, the licensee was to notify the State and the NRC regional office as well as other agencies. In addition, it was to initiate offsite monitoring[66] and establish an Emergency Control Station as soon as possible.

The NRC required that the utility meet certain obligations related to State emergency response as a condition of issuing a license. Foremost was that the utility provide the State with information throughout the accident as it was progressing. However, the NRC did not specify what information was to be transmitted. (397)

EMERGENCY PLANNING: THE NRC

In 1979, the NRC had a number of plans, program documents, studies and procedures covering emergency response. (398) The basic document describing the agency's overall goal for emergency response was a chapter in the NRC Manual. (399) As stated there, the goal was:

> . . . to assure that proper actions are taken to protect health and safety, the environment, and property from the consequences of incidents which occur as a result of NRC-licensed activities; to provide, as appropriate, for common defense and security; and to assure that the public is kept informed of actual or potential hazards to health and safety arising from such incidents. (400)

To meet this goal, five basic program objectives were set forth:

> . . . gathering or providing information, evaluating response, coordinating with other agencies, assisting where appropriate, or directing where necessary. (401)

The chapter outlined a program according to which, during a nuclear incident, the agency was to set up an incident response organization consisting of three basic groups: an Incident Response Action Coordination Team (IRACT), an Executive Management Team (EMT) and the Commissioners. IRACT and the EMT were given specific duties. (402) The Commissioners, on the other hand, were vaguely charged with responsibility for providing "general policy which determines the overall course of action NRC takes in response to incidents." (403) Unlike IRACT and the EMT, the Commissioners were neither assigned specific duties nor charged with developing specific procedures governing their emergency response.

Neither the NRC Manual nor any of the other NRC documents relating to the agency's incident response program contained any provision specifically relating to recommendations on evacuation or other protective action. They did not set forth any role in this respect for the Commissioners or any other entity in the agency's incident response organization, despite the program's stated

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[65] These are radiation detectors located in the plant's vent gas stacks.

[66] Offsite monitoring refers to the dispatching of survey teams equipped with radiation monitors to determine the amount of radiation at various locations outside the plant's boundaries.

goal of protecting the health and safety of the public. (404)

As noted, the NRC Manual outlined specific duties for IRACT and the EMT. It delegated to the Director of the Office of Inspection and Enforcement (I&E) responsibility for developing and maintaining procedures for implementing those duties according to the type of incident; other NRC offices were to review and approve those procedures. (405) The Director of I&E in turn assigned that responsibility to the Divisions within I&E.

The NRC Headquarters Incident Response Plan contained both the general provisions of the Manual on implementing IRACT's and EMT's duties, as well as the separate implementing procedures prepared by the I&E divisions.[67]

The I&E Office also had a Manual. One chapter established "policy and procedures," whereas two others provided "instructions" concerning the agency's incident response program. All the chapters in the I&E Manual predated the NRC Manual by several years; none had been revised since December 11, 1975. (409) As a result, in March 1979 the I&E and NRC Manuals provided for different incident response organizations and responsibilities. The failure to revise the I&E Manual suggests that the NRC considered emergency response planning a low priority. Further, it contributed to lack of coordination among the offices that would respond to an emergency. That lack of coordination would become very evident during the March 28 accident.

Finally, the regional office had a plan. Although it had been updated in February 1979, it did not reflect the most current planning by headquarters. For example, the plan called for the Regional Office to be the lead unit in the NRC's emergency response, but did not define how the Region was to interact with headquarters. The NRC Manual, on the other hand, called for an integrated, agency-wide response.

THE INCIDENT RESPONSE CENTER

According to the NRC Manual, the Headquarters Incident Response Plan and the I&E Manual, (410) one of the first actions to be taken in the event of a nuclear accident was to set up an Incident Response Center. It was to be comprised of two principal units—IRACT and the EMT—which were to be located in adjoining offices in one of the buildings at NRC headquarters in Bethesda, Maryland. Personnel from I&E and other offices at headquarters would be called on as support staff and would work out of the Incident Response Center. There was some contradiction within the various documents over the composition of the support staff, as described later.

The Center was to be the heart of the NRC's response to a nuclear accident. IRACT was to receive and evaluate incoming information, identify real or potential problems and develop alternative solutions. (411) Once IRACT had received and evaluated the information, it was to pass it on to the EMT. IRACT was to filter and process the incoming information for transmission to the EMT according to guidelines spelled out in the NRC Headquarters Incident Response Plan. (412)

Although the plan assigned IRACT responsibility for providing the EMT with "adequate" information for EMT's decisionmaking and other functions, it did not define "adequate" precisely. It said only that "EMT should be provided with evaluation of information acquired, not with details external to the evaluation, e.g., unevaluated raw data." (413)

Both the NRC Headquarters Incident Response Plan and IRACT implementing procedures were specific as to how information was to flow between IRACT and the EMT. As spelled out in the Plan, all information was to pass through an IRACT/EMT Liaison Officer: (414)

> 1. The Liaison Officer personally comes from the Operations Room (IRACT) to the Executive room (EMT) for each briefing.
>
> 2. The initial portion of each briefing consists of a brief, concise statement of the situation or update of the situation.
>
> 3. After the update of the situation, the Liaison Officer states:
>
> The principal questions now being pursued by IRACT are . . . (a concise listing of those questions being pursued by IRACT including previously submitted EMT questions, if any.)

IRACT

IRACT was to support the decisionmaking and policy-setting functions of the EMT and the Commissioners. (415) This structure was established

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[67] IRACT implementing procedures were developed and approved by three of the four I&E divisions whose division directors were assigned to IRACT. (406) Depending on the type of incident, one of the directors would become the IRACT Director and the implementing procedures for that division would pertain. The procedures for incidents at operating reactors such as TMI–2 were developed by I&E's Division of Reactor Operations Inspection (ROI); they were dated November 29, 1978. (407)

The ROI procedures called for IRACT and its support staff to be organized into seven functional groups, each with specified responsibilities and authority: (1) IRACT Director, (2) Technical Coordinator, (3) EMT/IRACT Communicator, (4) Field Communicator, (5) Plant Systems Effects group, (6) Radiological and Environmental Effects group, and (7) Incident Response Center Operations Staff. (408)

in 1978.[68] The specific actions to be undertaken by IRACT and its support staff were spelled out in the IRACT implementing procedures, (419) within the framework of the general guidelines contained in the NRC Manual. The Manual stated that the procedures were to be "designed to implement the Incident Response Program . . . with a minimum of confusion." (420) It called, among other things, for procedures for "identifying and assembling IRACT support staff" and for "issuing oral or written directives to licensees," and, in general, for whatever "other procedures [were] deemed necessary to meet incident response objectives." (421)

The Manual also specified that IRACT was to be composed of four I&E Division Directors, two Division Directors from the Office of Nuclear Material Safety and Safeguards (NMSS) [69] and one Division Director from the Office of Nuclear Reactor Regulation (NRR). (423) The IRACT Director was to be selected from among the four I&E Division Directors, and the Director of I&E was to be a member of the EMT. (424) The team was to be assisted by a support staff drawn from appropriate NRC offices, to be determined on the basis of the type of accident.

The NRC Manual stated that NRR was to provide IRACT a team member and support staff and that these people were to have important roles.[70] Neither the NRC Headquarters Incident Response Plan nor the ROI implementing procedures, however, specified any procedures by which the NRR representatives were to carry out their functions, although the Manual directed that those documents contain that information. This was another example of the incompleteness and lack of coordination in the NRC's emergency planning.

The Executive Management Team

The NRC Manual provided for an Executive Management Team (EMT), to be composed of the NRC's Executive Director for Operations and the Directors of I&E, NRR and NMSS or their designated alternates. (426) The EMT's role was to "transform Commission policy into specific guidance for the response organization and make major decisions affecting NRC's response actions." (427)

EMT's responsibilities and duties were further delineated by the Headquarters Incident Response Plan. It stated that the EMT would have to decide such issues as "should NRC provide assistance or on-site direction?" (428) The EMT was expected to approve "specific NRC directives to the licensee during incident response." (429) In addition, the EMT was charged with notifying "senior governmental officials," including the White House and the Chairman of the NRC, of the incident. Another EMT duty was to coordinate "NRC offices' joint activities related to the incident" and "policy with other agencies." (430)

The Commissioners

The NRC Manual defined the Commissioners' responsibility as one of providing general policy on the NRC's overall emergency response. (431) That policy would provide the EMT with the framework for managing the incident response organization. The EMT would transform that policy into "specific guidance" to IRACT and the rest of the NRC's response organization.

According to the Headquarters Incident Response Plan, the IRACT Communications Officer was to notify the Commissioners, except for the Chairman, of an emergency. EMT was to notify the Chairman. (432) The Communications Officer also was to update any Commissioners outside the response center on an accident's evolution. (433) The plan did not require that the Commissioners be stationed in any specific location or even that they deliberate as a body.

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[68] Prior to the formulation and approval of NRC Manual Chapter 0502 in February 1978, neither the Commissioners nor the senior technical staff outside I&E had a defined management role within the agency's incident response program. Commission policy, as reflected in I&E's Manual Chapter 1300, was simply that the "actions taken in response to incidents will be planned and coordinated" by IRACT. No mention was made of an EMT, and executive-level officials and the Commissioners were referred to only in the context of being kept informed of actions that IRACT might undertake. (416) IRACT had consisted solely of high-level I&E officials, with the Director of I&E designated as the Director of IRACT. (417) Officials from other NRC offices were responsible only for contributing to the IRACT support staff "when necessary." (418)

Adoption of NRC Manual Chapter 0502 and continuing revision of the NRC Headquarters Incident Response Plan led to significant changes in the structure of the agency's response program. The composition and scope of IRACT's responsibilities and authority were changed. More detailed guidance was given on how IRACT was to implement its part of the agency's response and on the relationship of IRACT with the Commissioners and the newly established Executive Management Team.

[69] The NRC Manual and Headquarters Incident Response Plan conflicted over NMSS participation in the incident response program. The Manual called for NMSS participation on both IRACT and the EMT, while the Plan made NMSS participation on IRACT dependent on the type of accident, calling for the "appropriate NRR or NMSS Division Director" to become the fifth IRACT member. Under the provisions of both the plan and the Manual, NMSS was to participate on the EMT. (422)

[70] The NRR participant on the IRACT support staff "evaluates information with respect to the likely future course of the incident"; "evaluates corrective action taken and proposed by reactor licensees in response to [the] incident": "determines alternate courses of future action available"; "evaluates the feasibility of assistance to the licensee or others, recommends to the IRACT the initiation of such assistance, and participates in the provisions of assistance as appropriate"; and "evaluates the need for formal intervention by NRC and recommends the initiation of such intervention to the IRACT." (425)

The various plans did not call for the Commissioners to take an active role in the NRC's emergency response. Commissioner Ahearne described the Commissioners' view of their role:

> As far as the issue of what is the role of a Commissioner . . . during emergency response, my understanding of it prior to and certainly during [the accident] was that the way the NRC system was designed was for the senior technical people in the agency to be responsible for monitoring and taking whatever action might be necessary as far as the technical issues. (434)

Commissioner Gilinsky noted:

> . . . generally speaking, the technical, minute-by-minute decisions and recommendations have to be handled by our staff. And the Commissioners have got to deal with things that are more general in nature . . . but the technical questions have got to be examined by the staff, and it is they who have to be in direct touch with the licensee as well as counterparts in the State. (435)

Chairman Hendrie and Commissioner Ahearne explained that the NRC Manual assigned the Commissioners only a policy-making role based on the premise that accidents would be over very quickly. For this reason, "the Commissioners themselves were not assumed to have a role in participating" in the agency's response, and the response organization would make "whatever decisions had to be made." (436) The Commissioners were envisioned "as sort of an ultimate policy decisionmaking body for the agency for those things that might follow in the aftermath" of an accident. (437)

Commissioner Gilinsky pointed out, however, that the Commissioners should be prepared to be flexible:

> It is hard to put down in a manual a set of rules that will cover every possibility. It is the nature of accidents that unusual things turn up and often require unusual solutions. The Commissioners are in charge of this agency, and ultimately have to be responsible for what it does. And it may be that decisions will be required of them that they didn't expect to have to make . . . and they have to be ready to do that. . . . (438)

Commissioner Gilinsky's observations reflect lessons learned from the Commissioner's response on March 28. On that day there were several points at which a well-informed, actively involved Commission might have made important contributions.

The foremost example involved the need for protective action. During the Subcommittee's hearings following the accident, three Commissioners indicated that they would have considered protective action on March 28 had they had the information available to the utility.[71]

NRC REGION I

The various plans also called for the activation of a Regional Incident Response Center. The Region I Incident Response Plan designated the rear half of the main conference room at the Region I offices in King of Prussia, Pennsylvania, as the location for the center. (439) Two teams were to be set up: (1) a Regional Incident Response Action Coordination Team and (2) an Onsite Inspection Team. (440)

When notified of an incident at a nuclear facility under its jurisdiction, the Region was to classify it according to severity and decide whether to activate the response center and dispatch an inspection team to the facility. It also was to notify NRC Headquarters and other incident response support organizations. (441)

Further defining Region I's response were the implementing procedures in the Region I Incident Response Plan.[72]

While a Regional Office might have the lead responsibility in the early stages of an accident, as an arm of I&E it was ultimately subordinate to IRACT at headquarters. (443)

NRC EMERGENCY COMMUNICATIONS

On March 22, 1975, a major fire broke out at the Browns Ferry nuclear powerplant in Decatur, Alabama. It took hours to bring the reactor under control. The NRC had substantial difficulty in responding effectively, particularly because of weaknesses in its communications system.

After the accident, the NRC appointed a Special Review Group to "distill from the available information those lessons that should be learned for the future." (444)

By February 1976, the NRC's Special Review Group had analyzed the agency's response. In its report, it described the flow of information during the accident from plant operators to onsite NRC inspectors to the regional office to NRC headquarters and on to other government officials. (445) The Group commented: "The well-known game of 'password' shows how poorly information is transmitted through such chains." (446)

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[71] See "The Accident at Three Mile Island: The First Day," pp. 150–151.
[72] This document was revised in February 1979. (442)

The Group recommended that communications facilities (which is left unspecified) be provided and that "the problem deserves a deeper study and more expertise than [we] are able to bring to bear on it, and that a systems study (who should communicate with whom, when and how?)" be commissioned. (447).

In June 1976, the NRC hired the MITRE Corporation, a consulting firm, to conduct a study on "Communications and Control to Support Incident Management." MITRE was "to define new communication concepts, requirements and procedures which will allow the Nuclear Regulatory Commission to respond more effectively to nuclear incidents involving its licensees." (448) The original contract was for $94,000.

MITRE issued a two-volume report in November 1977. (449) It outlined three possible communications systems, based on different roles the NRC might assume in responding to accidents. For each alternative, the study provided startup procedures, requirements for making the system operational on an interim basis, and the actions necessary to reach full operational capability. (450)

The concept behind the first system was that the NRC would simply monitor the course of a nuclear incident:

> In this concept the NRC's involvement would be limited to monitoring the activities of the various response units and coordinating Federal information exchange. (451)

In this case, the NRC would depend on other organizations for information.

The second alternative conceptualized the NRC as an advisor to the licensee, but dependent on it for information:

> This concept would allow the [Incident Response Center] to provide detailed advice, if needed, based on information supplied by the calling party or on file in the [Center]. (452)

The third option was particularly noteworthy in that, in many respects, it foreshadowed how the NRC would come to see itself and how it would restructure its incident response program following the TMI accident. (453)

The third system envisioned an NRC that would serve as an advisor to its licensees on the basis of data on the status of the reactor that the NRC would collect independently:

> In this concept, the [Incident Response Center] would receive sensor information transmitted directly from reactor instrumentation. Transmission would probably be triggered by [automatic] alarm. During normal operations the [IRC] could dial up any reactor on a standard telephone line to scan the reactor instrumentation data. In an incident, the alarm would trigger automatic dial-up from the reactor site to the [IRC] where data would be recorded. The [IRC] would also be able to select any number of the sensor inputs for concentrated attention.
>
> By adding a source of reactor performance data independent of licensee personnel, the [IRC] may be able to help anticipate new complications in an incident and to offer the [offsite response center] alternative remedies. The licensee would still decide, ultimately, what instructions to pass on to his site personnel. The capability to assess the situation independently, however, provides the [IRC] the information base required to intervene in the licensee response if it should ever be necessary. (454)

At the time of the accident, the NRC had expressed its intention to implement the third alternative but had not yet established the necessary communications system. In the interim, it adopted the second alternative—advisor, dependent upon the licensee for data.[73] (455) It did so despite a prophetic warning from the consultant:

> The dependence on information furnished by the calling party [licensee] or on file in the [Incident Response Center] is the most obvious limitation [of this option], since the [Center] is unlikely to have enough information to anticipate a problem not already noted by the caller. (456)

Lee Gossick, a member of the EMT, explained to the Special Investigation staff the assumption underlying incident response at the time. It provided a possible rationale for selection of the second option. The assumption was that an event would last only a short time. The emergency response drills of the Incident Response Center prior to the accident were based on that assumption and did not provide experience with accidents of long duration. (457) "The Three Mile Island thing was an event unlike that which any of us . . . anticipated," Gossick told the Special Investigation staff. (458).

Edson Case, like Gossick a member of the EMT on March 28, confirmed that the drills were based

[73] On March 28 the NRC was dependent on the utility for data on key plant conditions, such as hotleg temperatures, incore thermocouple readings, and the status of natural circulation. For most of the first day, it received incomplete or erroneous information or was unable to get answers to requests. See "The Accident at Three Mile Island: The First Day," pp. 110–111, 119–121, 126–128, 131–132, 137–138, 143–145.

on events of short duration. (459) He said that planning for accident scenarios was based on a range of accidents, including some that would involve large releases of radiation, but that generally the accident would be over before the NRC could play an active role. (460) According to Case, the NRC conceived its role to be one of directing offsite actions to minimize public exposure to radiation, rather than giving advice or direction to the licensee on how to operate his plant. (461)

It should be noted that Case's perception of the NRC's role conflicts with that spelled out in both the NRC Manual and the alternative the NRC chose from among the three provided by the consultant.

The week of March 28 at Three Mile Island underscored dramatically the inaccuracy of the presumption that accidents would be of short duration.[74]

EMERGENCY PLANNING: THE STATE

The NRC had, and has, no regulatory authority over a State's emergency response or plans. (462) Therefore, there was no requirement that the State in which a nuclear plant was located have an adequate emergency response plan. (463) Nor was there any requirement that an adequate State plan be in existence before a nuclear power plant located in that State would be licensed.

The Commission had general authority to impose such a requirement, if it determined that such a requirement was necessary to protect the public health and safety. The Commission never made such a determination.

The States could, however, voluntarily submit their emergency plans to the NRC for "concurrence." As of March 28, 1979, eleven States had secured NRC concurrence; Pennsylvania was not among them.

The NRC's regulations recognized certain State responsibilities, the most important of which is to decide on protective action such as evacuation. In turn, local governments, with State support, would implement that decision. (464)

EMERGENCY MANAGEMENT

In Pennsylvania, the designated lead agency for the State's response in the event of an emergency at a nuclear plant was the Pennsylvania Emergency Management Agency (PEMA). Its role was "to assure prompt, proper and effective discharge of basic Commonwealth responsibilities related to civil defense and disaster preparedness, operations, and recovery." (465) A Council headed by a Chairman was to set the Agency's overall policy. A State director hired by the Council supervised PEMA's activities. (466)

PEMA headquarters were to be located in the basement of the Transportation and Safety Building. During an accident, the Emergency Operations Center (EOC) was to be located there. PEMA was to enlist and coordinate the assistance of other State and Federal agencies as the situation required. Upon activation of the EOC, affected State agencies were to dispatch representatives to cubicles within the Center. In the event that protective action became necessary, PEMA was to be responsible for its implementation.

The Bureau of Radiation Protection (BRP), a division of the Pennsylvania Department of Environmental Resources (DER), is an important component of Pennsylvania's emergency response organization. Its Division of Environmental Radiation is routinely involved with environmental surveillance, laboratory activities and emergency planning. (467) During an accident involving releases of radiation to the environment that could require protective action, BRP was to serve as PEMA's technical advisor. In fact, once PEMA had been notified of an emergency at a fixed nuclear site, it would no longer talk directly to the site, but would rely on BRP personnel. BRP would receive information from the site, coordinate radiation monitoring and advise the Commonwealth on protective action such as evacuation.

Although PEMA had divided the Commonwealth into several areas, each with its own small office, the political subdivisions were to carry out protective action and other tasks as required. (468) During an emergency, county and local emergency preparedness directors were to marshal personnel and equipment from county and municipal agencies. They were to receive information from and be coordinated by PEMA operations personnel.

STATE EMERGENCY PLANS

The State had three emergency plans that outlined its response; these plans were distinct from the Met Ed plan, described above. PEMA had a Departmental Operations Plan that served as the general emergency guide for the Commonwealth of Pennsylvania. The August 1978 edition of Annex E of the PEMA plan dealt with radiological incidents at fixed nuclear sites in Pennsylvania. BRP had two response plans which applied to TMI. The first was a general plan which applied to all nuclear plants in the Commonwealth. (469) The second was limited to TMI. (470) While notification channels were similar to those in Met Ed's

[74] There is evidence that this presumption contributed to the communications difficulties the NRC had on the first day. See, in particular, "The Accident at Three Mile Island: The First Day," pp. 120–121.

site emergency plan, the classifications of nuclear incidents were different.[75]

As discussed above, none of the plans had been submitted to the NRC for voluntary review and concurrence. (477)

In addition to these plans, county directors were to have written umbrella plans, along with annexes that they were to submit to PEMA for approval. (478) However, local Civil Defense personnel were usually volunteers, and many had no written emergency plans at the time of the accident.

EVACUATION

A crucial question that utilities, the NRC and the States have to address in the event of a nuclear accident is whether to take protective action, and most particularly, whether evacuation is necessary.

Since January 1973, the Environmenal Protection Agency (EPA) has had responsibility for issuing Federal and State guidelines governing protective action in relation to actual or projected releases of radioactivity beyond the boundaries of NRC-regulated facilities. (479) The guidelines cover levels of radiation at which protective action is mandatory, and methods for projecting dose rates so that a determination of the need for protective action can be made in advance of actual releases.

As described below, the version of the EPA guidelines in effect in March 1979 was incomplete with respect to projecting dose rates; it did not spell out clearly the criteria to be used in making the appropriate calculations. Most important was the failure to define "plant conditions" and how they were to be used, particularly in terms of worsening conditions, to project releases and dose rates.

EPA GUIDELINES

In September 1975, the EPA established criteria for determining the need for protective action, such as evacuation, in response to nuclear accidents that could expose the public to radiation. These criteria were set forth in the EPA's "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents."[76] (481)

A key chapter of the EPA Manual—Chapter 5, "Application of Protective Action Guides for Exposure to Airborne Radioactive Materials from an Accident at a Nuclear Power Facility"—was being revised at the time of the accident. A draft of this chapter was ready in January 1979, but it was not issued until June 1979, (482) several months after the accident.

Other chapters in the 1975 Manual detailed a number of steps in protective action decision-making. Beyond pre-accident planning, they were: (1) evaluation by the facility operator of the projected effect of a nuclear accident on public health and safety, (2) notification by the utility of State and local officials that an accident had occurred, and (3) collection of additional information and/or warnings to the public. (483) Even if an initial determination was made that protective action was not warranted, the State still would need to collect and evaluate information in order to assess whether that determination should be modified. (484)

The facility operator was to provide "detailed information," such as projected doses, to the public and to the State. These doses were to be estimated from data obtained at the point of release or from "releases anticipated for particular types of nuclear incidents." (485) If the operator did not provide that information,

> . . . the emergency plans of the State should provide for action in the immediate downwind area of the facility based on notification that a substantial release has occurred or that plant conditions are such that a substantial release potential exists. (486)

As was evident on March 28, neither the utility, the NRC nor the State were clear what data

[75] The General Procedures and Guidelines Manual of the Bureau of Radiation Protection (471) has a classification system for accidents based on NRC regulations. These classes can be briefly described as:

Class I—Incidents with no radiological consequences, but of potential public interest.
Class II—Abnormal occurrence, i.e., major reduction in protection for health and safety.
Class III—Threat of radioactivity offsite, e.g., LOCA. (472)

These classes are the same as those in PEMA's Annex E. (473)

However, the BRP site specific plan for TMI (474) has four types of accidents:

Type 1—Unplanned release to Susquehanna River.
Type 2—Potential release to the atmosphere.
Type 3—Release to the atmosphere as a result of system failure.
Type 4—Major failure with failed safeguards. (475)

The Three Mile Island nuclear station site emergency plan has yet another system of classification, each with its own descriptions and notification procedures. These classes are:

(1) local emergencies,
(2) site emergencies, and
(3) general emergencies. (476)

The inconsistent and overlapping classifications of nuclear accidents contained in the various plans reveal little attempt at uniformity.

[76] Protective Action Guides (PAGs) describe "projected radiological doses . . . to individuals in the general population that warranted protective action following a release of radioactive material." (480)

the utility was to transmit, and the utility did not provide the State with information on plant conditions.[77] In effect neither the utility nor the NRC considered uncertainty as to uncovering of the core a condition that warranted serious consideration of evacuation.[78]

REVISED EPA GUIDELINES

The revisions of Chapter 5 referred to above elaborate to a limited extent on the "detailed information" needed by the State. The State is to have (1) Protective Action Guides (PAGs) adjusted for local conditions and (2) projected doses for comparison with the adjusted PAGs. (487) The projected doses were to be derived from one or more of three sources:

(1) plant conditions.

(2) release rates and meteorological conditions, or

(3) offsite radiological measurements, or combinations thereof. (488)

An appendix to the Manual, dated January 1979, defines the first of these three data bases as "reactor system status." However, it provides no further guidance as to how this information is to be used in connection with protective action. Rather, it notes: "Dose projection based on reactor system status will be primarily the responsibility of nuclear facility officials and will not be discussed here." (489)

The updated version also assumed that the facility operator is the most likely to have accurate information on plant conditions. As Floyd Galpin, EPA's Director of the Division of Environmental Analysis, wrote the NRC following the accident:

> . . . [A]ll of our guidance to States have implied a first order dependence on the facility operator for information on the releases. . . . (490)

PROJECTING DOSE RATES

Of the three sources of data, field measurements were considered the most accurate for making projections, as they reflected dose rates at the time of measurement. Continuous monitoring would provide data that the State could use to evaluate initial and subsequent protective action decisions. (491)

This source, however, has one major weakness. It assumes there will be no change at the site that could abruptly alter the release rate. This assumption might not be correct in the case of an ongoing incident. For that, the first source of data specified in the January 1979 Appendix—accurate and up-to-date information on plant conditions (reactor system status)—would be needed. That would include actual or anticipated changes in the condition of key components or systems. Only with this information can future releases be projected effectively. (492)

Thus "plant conditions" or "reactor system status" are key elements in projecting dose rates, on the basis of which the need for protective action can be determined. The revised version of the Guidelines, which neither the State nor the utility had seen in 1979, does not go far beyond the older version of the EPA Manual, which provided insufficient guidance. It states only that plant conditions are defined as "reactor system status" and should be used in determining projected doses in consideration of protective action.

The EPA, in response to a request by the Subcommittee, stated that by "plant conditions" it means "observable parameters onsite that could be used to predict the course of the accident, including its seriousness with regard to releases." (493) The EPA also told Special Investigation staff that the operator is (and was) to report to the State whether specific safeguards might fail and what the consequences would be, what offsite releases in what ranges would follow, what checks were in place and the time before an event might take place. Public health officials could then take advantage of maximum lead times. (494) The State, of course, must have people who can understand the dose projections.

This definition of plant conditions as plant parameters was not specified in the Manual, nor does the Manual define which of the hundreds of parameters should be considered. Further, it does not provide guidance as to what should be done if the reliability of a key indicator is in doubt, for example, water level in the core.

Beyond this, neither the revised nor the old Manual spells out adequately who is responsible for protective action, and neither version specifies any role for the NRC, despite the NRC's mandate to protect the health and safety of the public.

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[77] See "The Accident at Three Mile Island: The First Day," pp. 135–136.
[78] See "The Accident at Three Mile Island: The First Day," pp. 134–135.

Chapter 7

Accident At Three Mile Island: The First Day

Control room personnel discussing plant conditions and strategy during the accident

PRINCIPAL PARTICIPANTS IN THE ACCIDENT AT THE THREE MILE ISLAND PLANT[1]

AHEARNE, John F. NRC Commissioner. One of three who spent part of first day of accident at the Incident Response Center in Bethesda. Named Acting Chairman of the NRC in November 1979. Told by Edson Case at 9 a.m. core probably had been uncovered.

ARNOLD, Robert. Vice President for Generation of the GPU Service Corporation. Said he questioned control room personnel on core uncovering. Contributed to the strategy that finally succeeded in returning the plant to stable conditions in late afternoon.

BENNETT, Skip. Instrumentation Foreman at TMI. Deduced, based on incore thermocouple readings, that core had been uncovered.

BENSON, Michael L. Lead Nuclear Engineer at TMI–2. Arrived at the Unit 2 control room about 7 a.m. Deduced that neutron detectors showed excess neutron leakage from core.

BRADFORD, Peter. NRC Commissioner. One of three who spent part of first day at the Incident Response Center.

BRUNNER, Eldon. NRC Branch Chief at Region I. First official at Region I to receive word of the incident. Activated Regional Incident Response Center.

BRYAN, Ken. Shift Supervisor at TMI–1. Arrived in Unit 2 control room eight minutes into the accident.

CASE, Edson. Deputy Director of NRC's Office of Nuclear Reactor Regulation. Was member of the NRC Executive Management Team. Advised Commissioner Ahearne at 9 a.m. that core might be uncovered.

CHWASTYK, Joseph. Shift Supervisor at TMI. Only person whose statements indicate he correctly attributed pressure spike in the reactor building to a hydrogen burn.

CRAWFORD, Howard C. Nuclear Engineer at TMI. Performed initial projected dose-rate calculations about 7:15 a.m. based on containment dome-monitor readings.

CRITCHLOW, Paul. Governor Thornburgh's Press Secretary and Director of Communications. Was involved with press statements, news conferences and briefings conducted by Pennslyvania State officials.

DAVIS, John. Acting Director of NRC's Office of Inspection and Enforcement. Member of NRC Executive Management Team. Activated the Incident Response Center in Bethesda on March 28.

DENTON, Harold R. NRC's Director of Nuclear Reactor Regulation. Became member of the Executive Management Team in the afternoon.

DORNSIFE, William P. Nuclear Engineer with the Pennsylvania Department of Environmental Resources, Bureau of Radiation Protection. Only nuclear engineer with the State emergency response organization. Was on-call duty officer on March 28.

DUBIEL, Richard W. TMI–2 Supervisor of Radiation Protection and Chemistry at TMI–2. In charge of radiation-protection activities, including assessment of onsite and offsite monitoring during accident.

EISENHUT, Darrell. Deputy Director of NRC's Division of Operating Reactors. Assembled reactor-systems and radiological-assessment teams for NRR. Periodically briefed Harold Denton and relayed information between Babcock & Wilcox and Victor Stello.

FAUST, Craig. Control Room Operator at TMI–2. Present in control room when accident began. One of four responsible for initial response to accident.

[1] Unless otherwise indicated, descriptions refer to positions held or roles played on Wednesday, March 28, 1979.

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PRINCIPAL PARTICIPANTS IN THE ACCIDENT

FLINT, John. Babcock & Wilcox, Engineer and Start-up Representative at TMI–2. Arrived Unit 2 control room about 9 a.m. Was among first to recognize core had been uncovered and superheated conditions in the reactor vessel.

FOUCHARD, Joseph. Director, NRC's Office of Public Affairs. Responsible for generating press releases issued by NRC from the EMT office during the accident.

FREDERICK, Edward. TMI–2 Control Room Operator. Present in the control room when accident began. One of four responsible for initial response to accident.

GILBERT, Bob. Instrumentation Technician at TMI–2. Arrived in cable room while incore thermocouple readings being taken. Did not interpret readings to indicate core had been uncovered.

GILINSKY, Victor. NRC Commissioner. Acting Chairman of NRC first day while Chairman Hendrie away. At NRC headquarters in Washington, D.C., most of day. Told by Stello at 4:30 p.m. that core was uncovered.

GOSSICK, Lee V. Executive Director for Operations at NRC. Director of NRC Executive Management Team. Participated in conference call at 4:30 p.m. to Commissioner Gilinsky concerning uncovering of the core.

GRIER, Boyce. Director of NRC's Region I. Notified John Davis at NRC headquarters of accident. Coordinated early Region I response with Smith and Brunner.

GRIMES, Brian. Assistant Director of Engineering and Projects in NRC's Office of Nuclear Reactor Regulation. Office representative on support staff of Incident Response Center in Bethesda.

HAVERKAMP, Donald R. Project Inspector in NRC's Region I. Served as liaison on the first day of the accident between Region I and the site.

HENDRIE, Joseph. Chairman of the NRC. Was absent first day of the accident.

HERBEIN, John G. Met Ed's Vice President for Nuclear Generation. Became utility spokesman to the press, the Lt. Governor, and the NRC. Contributed to strategy that finally brought plant to stable conditions in late afternoon.

HIGGINS, James C. Inspector at NRC's Region I. Member NRC onsite inspection team. One of the two NRC inspectors in Unit 2 control room. Said he was unaware of pressure spike in the reactor building and did not report it to NRC.

HITZ, Gregory. Shift Supervisor at TMI. Served as intermediary between Victor Stello and the TMI–2 operators. First at site to learn of Stello's concerns regarding superheated steam and uncovering of the core.

KENNEDY, Richard T. NRC Commissioner. Notified of accident by John Davis at 8:52 a.m. Spent day at NRC headquarters in Washington, D.C.

KISTER, Harold. Inspector at NRC's Region I. Manned the phones to TMI and to IRACT. Received Victor Stello's request around noon for incore thermocouple readings.

KUNDER, George. Superintendent of Technical Support and the on-call Duty Officer at TMI–2 during morning of first day. Placed in charge of technical support and communications.

LOGAN, Joseph B. Superintendent at TMI–2. Charged with ensuring that all required procedures and plans were reviewed and followed.

MEHLER, Brain. Shift Supervisor at TMI. Arrived in TMI–2 control room about 6 a.m. Recognized PORV was stuck open and ordered block valve closed at 6:22 a.m. Deduced steam in the hotlegs around same time.

MILLER, Gary. Station Superintendent at TMI. Arrived TMI–2 control room shortly after 7 a.m. Became Director of Met Ed's Emergency Command Team. Said he was unaware core had been uncovered and said he did not know about the pressure spike in reactor building.

AT THE THREE MILE ISLAND PLANT

MOSELEY, Norman. Director of NRC's Division of Reactor Operations Inspection. Was Director of the Incident Response Action Coordination Team. At Victor Stello's direction, raised issue of superheated steam with James Higgins in Unit 2 control room at 4:30 p.m.

PORTER, Ivan. Met Ed's Lead Instrumentation Engineer. Collected incore thermocouple readings around 8 a.m. and told Gary Miller they were unreliable. Oversaw installation of resistance bridge for reading hotleg temperatures.

ROGERS, Leland. Babcock & Wilcox's Site Operations Manager at TMI. Was in TMI–2 control room much of day and served as liaison with B&W's Division of Nuclear Generation in Lynchburg, Va.

ROSS, Mike. Supervisor of Operations at TMI–1. Placed in charge of operator activities in the Unit 2 control room.

SCHEIMANN, Fred. Shift Foreman at TMI–2. Present in control room during early stages of accident. Was in the auxiliary building when the accident began. One of four responsible for initial response to accident.

SCRANTON, William. Pennsylvania Lt. Governor and Chairman of the Pennsylvania Emergency Management Council, which directs Pennsylvania Emergency Management Agency. Took lead in State's emergency response on first day.

SEELINGER, James. Superintendent at TMI–1. Given responsibility for Met Ed's Emergency Control Station in Unit 1 control room.

SMITH, George. NRC's Chief Health Physicist in Region I. Coordinated Region I response with Eldon Brunner.

SNIEZEK, James. Director of NRC's Fuel Facility and Materials Safety Inspection, Office of Inspection and Enforcement. Responsible for assembling and assessing radiological information received by Incident Response Action Coordination Team on the first day.

STELLO, Victor, Jr. Director of NRC's Division of Operating Reactors. Member of Incident Response Action Coordination Team. First among NRC's top officials to diagnose uncovering of core and existence of superheated steam. Now Director of Office of Inspection and Enforcement.

THORNBURGH, Richard. Governor of Pennsylvania. Responsible for determining whether an evacuation was necessary.

WARREN, Ron. Met Ed Engineer. Notified NRC Region I of accident and manned phone linking Region I and the site during morning hours.

WEAVER, Douglas. Instrumentation Foreman at TMI. Involved in taking incore thermocouple readings and installing a device to widen range of hotleg readings during morning.

WEISS, Bernard. NRC's IRACT Communications Officer. Incorrectly told White House Situation Room and Department of Health, Education and Welfare that there was never a problem keeping core covered.

WILBER, Howard "Mike". NRC, Field Communicator at Incident Response Action Coordination Team.

WILKERSON, Scott. Nuclear Engineer at TMI. One of three engineers onsite during first three hours of accident. Asked by George Kunder to analyze whether the reactor was going critical again.

WRIGHT, Thomas. Instrumentation Technician at TMI–2. One of four technicians who took incore thermocouple readings.

YEAGER, Bill. Instrumentation Technician at TMI–2. One of four technicians who took incore thermocouple readings. Based on readings, concluded core uncovered at time readings taken.

ZEWE, William. Shift Supervisor in charge of both TMI–1 and TMI–2. On duty when accident began. One of four responsible for initial response.

The NRC Commissioners testify before the Subcommittee on Nuclear Regulation

Chapter 7

Accident At Three Mile Island: The First Day

INTRODUCTION

At 36 seconds past 4:00 a.m., on March 28, 1979, several valves in the secondary system of Unit 2 at Three Mile Island malfunctioned, causing first the turbine and then the reactor to trip.[1] These minor problems were compounded by yet another valve that malfunctioned, this one in the primary coolant loop of the plant. But it, too, was a minor event. Safety systems came into play, as programmed, to control the situation.

Despite the correct functioning of the safety systems, a variety of other factors complicated the situation in such ways that the operators were unable to respond effectively, and a serious accident resulted.

It was a week before the plant could be declared "stable." That week was characterized by further problems, among them offsite releases of radiation, a recommendation for protective evacuation, the possibility of a hydrogen explosion and tremendous anxiety among local residents. By the end of the week, the Unit 2 facility was known to have been severely damaged. How severely damaged could not be determined because high levels of radioactivity inside the containment precluded entry.

The events of that week were largely determined by the damage done to the reactor in the first two or three hours. During that initial period, utility personnel had been unable to diagnose what was happening and, therefore, took incorrect actions. What began as a routine incident very rapidly escalated into a major and serious accident, although just how serious was not discovered until two days later. The inappropriate decisions and actions taken in the early hours were compounded by the failure to diagnose plant conditions further into the accident and by improper actions throughout the day on the part of the utility, the NRC and the State.

Because of the importance of what happened during the first day and the need to insure proper response during the critical, early hours of an accident, the Special Investigation focused on that period. This chapter recounts and analyzes the events of those hours and the responses of the utility, the NRC and the State.

4:00:36—THE BEGINNING

Four men were on duty in Unit 2 at Three Mile Island in the predawn hours of March 28, 1979: William Zewe, Station Supervisor; Fred Scheimann, Shift Foreman for TMI–2; and Edward Frederick and Craig Faust, control room operators. Each was a graduate of the Navy's nuclear training program and had had at least five years of Navy experience. All four had been through Met Ed's training program, which included five to nine weeks of practice on the Babcock & Wilcox simulator, and all had been licensed as plant operators by the NRC. (1)

At 4:00 a.m., Frederick and Faust were in the control room performing routine duties. Zewe was in the shift supervisor's office at the rear of the control room. (2) Scheimann was in the turbine building overseeing maintenance on the plant's troublesome condensate polishing system.

[1] For a description of plant equipment and plant systems, see "How the Plant Works," pp. 23–31.

As had happened in the past, a polisher had become blocked by resin. Scheimann and his crew were trying to break up the blockage with a mixture of air and water. (3)

At 4:00:36 a.m., a year to the day and the hour since TMI–2 had first gone critical, (4) valves in the condensate polishing system malfunctioned and shut off the flow of water to the feedwater pumps.[2] The feedwater pumps, responding to the lack of flow, automatically closed down, stopping the flow of feedwater to the steam generators.

The pumps for the emergency feedwater system, a back-up safety system designed for this kind of equipment failure, started automatically to pump water toward the steam generators. However, closed valves in the feedwater lines stopped the flow from reaching the steam generators.

THE TURBINE TRIPS

With no water going to the steam generators, insufficient steam was produced to run the turbine. At two seconds into the accident, 4:00:38, the plant's safety system automatically shut down (tripped) the turbine in response to the feedwater pump trip.

In the control room, Faust heard the alarms signal the shutdown of the main feedwater pumps and said to Frederick, "Something's going wrong in the plant." (5) Zewe came out of the shift supervisor's office and noticed the turbine had tripped.

With no water going into the secondary side of the steam generators, not enough heat was being removed from the primary system. The temperature of the coolant went up, and pressure in the primary system began to rise as the rapidly heated water expanded. Pressure in the pressurizer rose to 2,255 pounds per square inch (psi),[3] 100 psi more than normal.

About three seconds after the start of the accident—at 4:00:39—the pilot-operated relief valve (PORV) atop the pressurizer opened automatically to relieve the mounting pressure. Steam shot out the valve and flowed into the reactor coolant drain tank in the containment, where it condensed into water.

THE REACTOR SCRAMS

Pressure inside the reactor vessel continued to rise, triggering another automatic safety response: at eight seconds into the accident—4:00:44—the control rods automatically dropped down into the core, and the reactor "scrammed," terminating the fission reaction instantaneously.[4]

As a result of the reactor scram, the heat being generated by the core decreased sharply.[5] This decrease in the rate of heating, in combination with the continued dissipation of some heat through the secondary system, caused temperature in the primary system to drop. As it did so, the coolant contracted, thereby reducing pressure; it would reach 1,100 psi within 20 minutes after the accident began and then fluctuate between 1,000 and 1,100 psi for the next hour or so. (7)

All this occurred by 4:00:49—13 seconds into the accident.

About 16 seconds into the accident, an operator in the control room noticed instrumentation indicating that the emergency feedwater pumps had been automatically activated. (8) No one saw the two lights indicating that the feedwater valves were closed, blocking the flow from the pumps to the steam generators.[6] (10)

THE PORV FAILS TO CLOSE

By about this time—16 seconds into the accident and about 12 seconds after the PORV had opened—pressure in the pressurizer had decreased to 2,205 psi, the point at which the valve was supposed to close. The indicator light in the control room went out, a signal that power to the valve had gone off. The operators assumed the valve had closed.[7] In fact, it had stuck in the open position. (11)

A LOCA IN PROGRESS

The situation had become a multiple-failure accident.[8] More important, the plant was now ex-

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[2] It was later determined that water had entered the air lines, a problem similar to that which triggered an incident in 1977. See "Prior to the Accident," pp. 64–65, for further details.

[3] References to psi throughout this section are to pounds per square inch *gauge*. It is equivalent to absolute pressure less the atmospheric pressure of 14.7 psi.

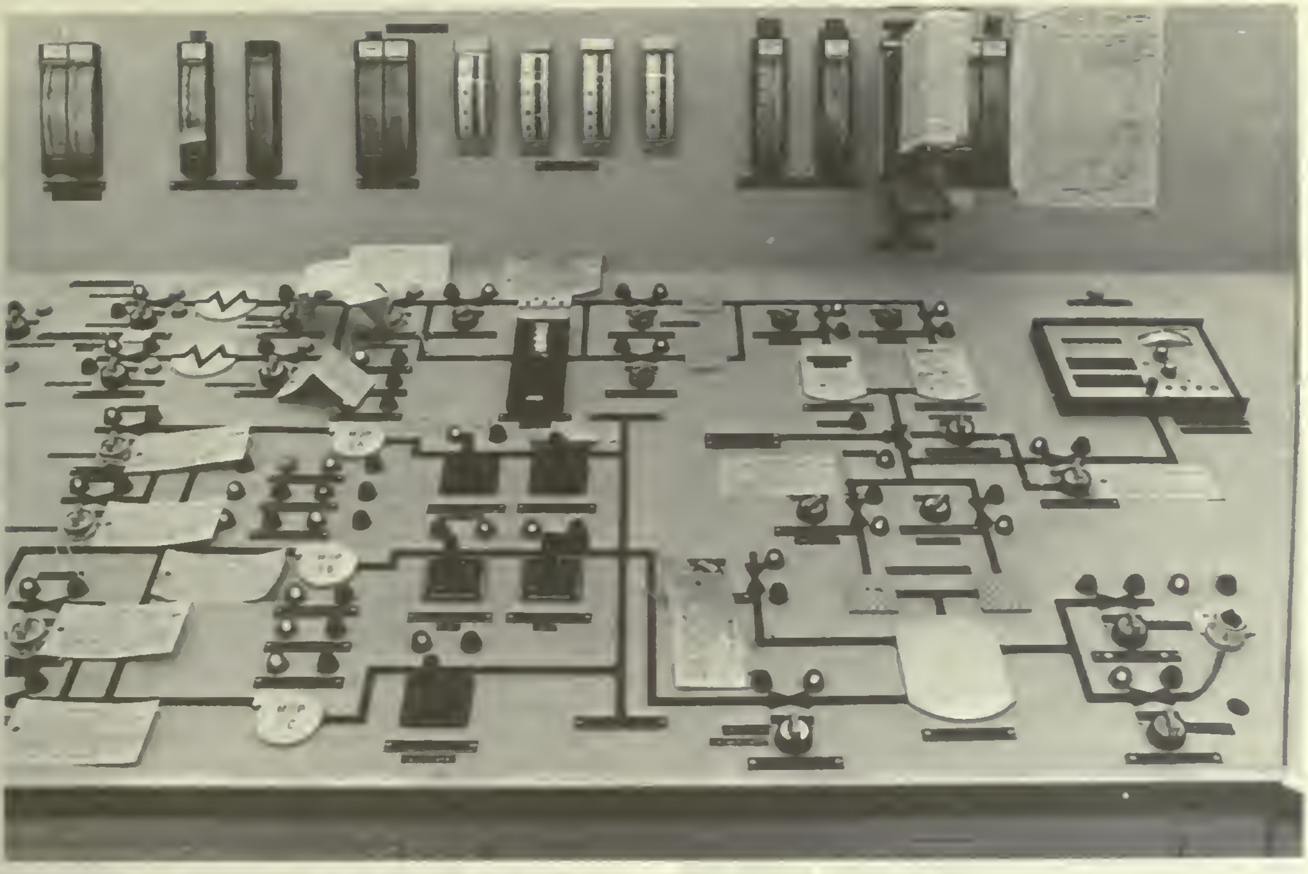
[4] See "How the Plant Works," p. 30.

[5] When fission stops, the heat produced by the core drops dramatically, initially to about six percent of the heat produced when the reactor is operating at full power. (6) The residual heat, known as decay heat, decreases with time.

[6] An operator told Special Investigation staff that a maintenance tag obscured one light. (9) There has been no explanation for the failure to notice the other.

[7] See "Prior to the Accident," p. 86, for a discussion of the PORV position indicator.

[8] When the condensate polishing system malfunctioned, it started what is called a loss of feedwater transient. This was the initiating event. The closed valves in the feedwater line which blocked the flow of emergency feedwater to the steam generators was the first failure in the unfolding event. The PORV sticking open was the second failure. The event thus bcame a multiple-failure loss of feedwater accident.



Control room console showing maintenance tags

periencing a loss-of-coolant accident, since the failed PORV had become an undetected pathway for coolant to escape the primary system.

Normally, equipment in the plant will automatically detect the drop in a pressure that accompanies a loss of coolant and activate the Emergency Core Cooling System, which will control the problem until it is resolved, if the system is left to respond as designed. For a variety of reasons, control room personnel did not diagnose the stuck-open PORV and the resulting loss-of-coolant for over two hours. In fact, they overrode the Emergency Core Cooling System shortly after it came on. A minor incident would soon become a major accident.

At 41 seconds into the accident, 4:01:17, the operators, as they had been trained to do when the reactor scrams, manually started one of the three make-up pumps that inject borated water into the primary system in order to counteract the decrease in pressure that typically follows a scram.[9] Boron absorbs neutrons, further insuring shutdown of the nuclear chain reaction. Zewe later explained that this was a normal operator response to a feedwater transient. (12)

In less than a minute after the reactor tripped, the water level in the pressurizer had fallen from its normal level of between 200 and 250 inches to a low of 158 inches. (13) Pressure in the primary system also continued to fall. This pattern was typical of what happens after a reactor scrams, and the transient seemed to be routine.

CONFLICTING SIGNALS APPEAR

At about this time, an unusual condition arose. The level of the coolant in the pressurizer suddenly began to rise; by six minutes into the accident, it would reach at least 400 inches.[10] (14) At the same time, pressure in the primary system continued to decrease.[11] The operators, not realizing the PORV was still open, would be confused by these conflicting symptoms.

[9] One make-up pump was running when the accident began. See p. 115 for a description of the relation between make-up and high pressure injection systems.

[10] Actual levels could not be read since the scale only went to 400 inches.

[11] Normally pressurizer level and primary system pressure move together.

Without the flow of feedwater, the secondary side of the steam generators soon boiled dry, and even less heat was being removed from the primary system. The reactor coolant heated up still further, expanding and pushing the water level in the pressurizer farther up. Pressure in the primary system continued to drop.

HIGH PRESSURE INJECTION COMES ON

By two minutes into the accident, pressure in the primary system had fallen to 1,640 psi, the point at which the Emergency Core Cooling System is actuated. (15) The high pressure injection system (HPI), part of the Emergency Core Cooling System, started automatically.[12] Two pumps injected water from the borated water storage tanks into the primary system at a combined rate of 1,000 gallons a minute. This rate of flow was fully adequate to compensate for the still-undetected loss of coolant through the PORV.

Normally, automatic actuation of the HPI system indicates a loss-of-coolant accident. However, as described in the previous chapter, on several other occasions, the HPI system at TMI–2 had come on in response to less significant incidents, and the operators had come to discount it as a clear indication of a LOCA.[13]

Further, the pressurizer level was continuing to rise, a condition the operators found significant. They had no direct way of measuring the water level in the reactor vessel and therefore had to rely on the water level in the pressurizer for an indirect indication. Their training led them to interpret the high pressurizer level to mean there was adequate water in the primary system to cover the core. (16)

A "SOLID" PRESSURIZER?

In fact, as the water level continued to rise rapidly, the operators said they became worried that the pressurizer was "going solid"—that is, filling completely with water. (17) This could cause the steam bubble normally at the top of the pressurizer to collapse, which would in turn seriously impede the operators' ability to control pressure in the primary system.[14] Such a condition could result in damage, possibly as severe as a rupture in the primary system, (18) if there should be sudden increases in pressure. Consequently, operators were taught to prevent the pressurizer from going solid. (19)

THE OPERATORS OVERRIDE HPI

At 3 minutes and 13 seconds into the accident—4:03:49—the operators overrode the safety equipment and took manual control of the HPI pumps. At 4 minutes and 38 seconds into the accident, 4:05:14, they greatly throttled the flow of HPI by turning off one pump and cutting the other back from 500 to about 25 gallons per minute. The operators also began to drain coolant out of the primary system through the let-down line[15] at a rate in excess of 160 gallons per minute. (20) By this action, the operators also overrode the automatic isolation of the let-down system. Water drained through the let-down system is pumped into the adjacent auxiliary building, which cannot be sealed; this system later became a pathway for radioactive releases.

Both actions—throttling the HPI and draining off the coolant—were intended to lower the water level in the pressurizer. By 4:06, the pressurizer appeared to be solid. No matter what actions the operators took, they could not reduce the water level in the pressurizer significantly or reestablish the steam bubble.

In fact, their actions were worsening the loss-of-coolant. Water escaping through the stuck-open PORV and the let-down system was not being adequately replaced.

WHY HPI WAS THROTTLED

All the operators have stated that they throttled HPI in response to the rapidly increasing pressurizer level, (21) that they had been worried the system would "go solid." The level was reading at least 400 inches (the top of the scale) and fluctuated between there and 370 inches for most of the next two hours. (22)

Scheimann, who by this time had returned to the control room, recalled that when he gave the order to throttle HPI, pressure in the primary system was "low and stable." (23) Although troubled by the low pressure, he said, "It would have concerned me a heck of a lot more if it [the pressure] was still going down." (24)

Michael Ross, the TMI–1 Supervisor of Operations who had come over to Unit 2 shortly after the accident began, explained the operators' preoccupation with the pressurizer level to Station Manager Gary Miller. At a review meeting held by GPU two weeks after the accident, he said:

> One thing on the pressurizer level that I want to make sure you [Gary Miller]

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[12] When HPI came on, it tripped one of the make-up pumps that was already operating, increased the flow of the pump started earlier by the operators, and activated a third pump.

[13] See "Prior to the Accident," p. 72.

[14] The steam bubble acts as a cushion to dampen fluctuations in primary system pressure.

[15] See "Technical Glossary," Appendix E, p. 371.

fully understand. We've taught our operators, and we have a B&W written caution to never take the plant solid. Unconsciously we have told them all the time, "never take the plant solid."[16] (25)

A CONFUSING SITUATION

Even with HPI throttled and the let-down flow increased, the control room personnel still could not reestablish the steam bubble in the pressurizer. Frederick later noted that the personnel realized their attempt to lower the pressurizer level by throttling the HPI flow "was not working." (26)

> We increased letdown, and we verified the path from the bleed tank. We thought maybe our letdown passage was blocked; that's why we filled up so fast. We tried several things to try to establish pressurizer level. (27)

The problem with the pressurizer preoccupied the control room personnel for much of the first hour of the accident. In Scheimann's words:

> . . . we sat there for quite a while with pressurizer level up at the high end and pressure holding constant at around 1100 to 1200 pounds. And it sort of, like stabilized out right where it was at. Periodically, I could, by use of the letdown system, get pressurizer level back down into a visible range; however, it just wouldn't seem to stay there. It would drift down a little bit, then would go back up again. (28)

Zewe could not understand why the pressurizer level remained high despite the operators' efforts:

> I didn't know where the water could be coming from. except that if [maybe] we had some high-pressure injection valves leaking that were still feeding water. even though we were throttling back—I did not know where the water was from. (29)

He added that:

> It was a real problem, in that I really couldn't determine why it was acting that way. I really couldn't think of any logical explanation. . . .[17] (30)

The control room personnel said that the response of the primary system to the solid pressurizer also confused them. In Frederick's words,

> . . . The pressurizer went full and we believed it [the reactor coolant system] was full. It must have been full of water, but the next confusing thing was the system wasn't reacting as if it was solid. We weren't seeing pressure spikes, so I don't know if anyone concluded that there was steam building someplace else. It was happening so fast, but we knew that we weren't solid.[18] (31)

Frederick said further that at one point the control room personnel began to doubt the accuracy of the pressurizer level gauge. (32) According to Zewe, they checked several redundant level indicators, requested a reading on the level from the computer in the control room and had an auxiliary operator check the level from a station in the auxiliary building. Zewe said they became convinced the gauge was accurate. (33)

The control room personnel did not realize that under certain conditions, pressurizer level cannot be relied on to reflect the water level in the reactor vessel.

Those conditions were present that morning at the plant. They had also been present during a previous incident in 1977, when steam became trapped in the hotlegs, causing water level in the pressurizer to rise, while pressure in the primary system fell. The operators on duty at this time were apparently unaware of this earlier incident.[19]

Faced with two anomalous symptoms, one indicating too much water in the primary system (high pressurizer level), the other a condition in which water was being lost or the primary system was being cooled too rapidly (low primary system pressure), the operators chose to respond to the first. By throttling HPI, they had in effect concluded that the problem was not the result of an ongoing loss of coolant.[20]

SATURATION IS REACHED

By about the time the pressurizer appeared to be solid—about six minutes into the accident—saturation had been reached in the primary system: with pressure down, the water had begun to boil.[21] The resulting steam bubbles in the coolant

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[16] The text of the caution appears in the addenda to this chapter. See Addendum 1, p. 153.

[17] For further statements by control room personnel regarding the high pressurizer level, see Addendum 2, p. 153.

[18] When the system is solid, pressure responds very rapidly to perturbations in the flow of coolant. As more water is being pumped in, the instrumentation should show sharp increases in pressure, or spikes. These did not appear, confusing the operators.

[19] See "Prior to the Accident," p. 65, for a description of this earlier incident which occurred during pre-operational testing. Steam would become trapped in the hotlegs later on in the day.

[20] See Addendum 3, p. 153.

[21] When pressure is lowered, the boiling point of the coolant is lowered. As that point is reached, bubbles begin to form in the water, also known as voids. This condition is called saturation.

displaced the water, pushing it into the pressurizer and keeping the level up. The water being lost through the stuck-open PORV was not being adequately replenished, as the operators had throttled the HPI pumps in an unsuccessful attempt to keep the pressurizer from going solid. The core was on its way to being uncovered.[22]

FEEDWATER IS RESTORED

During this period, and for about the next two hours, Faust was responsible for the feedwater system on the secondary side, while Frederick and Scheimann handled the primary system. (35) Zewe supervised their efforts. (36)

Eight minutes into the accident, Faust realized that no emergency feedwater was flowing into the secondary side of the steam generators. He had been checking the valves and discovered that a pair of emergency feedwater valves—"No. 12 valves" that were always supposed to be open—were closed. Faust opened them, thus reestablishing the flow. (37)

It is generally accepted that the loss of emergency feedwater for these eight minutes had no significant effect on the outcome of the accident. (38) However, it did add to the confusion and distracted the operators as they sought to understand what was happening. (39)

It is still not known when or why the valves were closed. No TMI plant worker, operator or supervisor has acknowledged closing them. Two days prior to the accident, the system had been tested, which required shutting and reopening the valves.[23] The utility admits the possibility that the valves were not reopened following this test.[24] (40)

Once Faust had established the flow of emergency feedwater, he attempted to reestablish flow in the main feedwater system to facilitate cooldown of the plant.[25] However, the control room personnel found other problems.[26] Zewe commented that as the various difficulties became evident, " . . . I diverted a lot of my attention to those items while they [Scheimann and Frederick] were looking at the primary plant." (41)

CONDITIONS NOT UNDERSTOOD

At around 4:20 a.m., Zewe left the control room and went to the turbine building to try to fix some condensate polishing equipment. (42) He did not return until sometime between 4:50 and 5:00 a.m. (43)

He described his general perception of the severity of the accident at the time he left. His statement shows that plant conditions were not understood at this time:

> . . . very soon into the accident and I'm just saying within the first 5 minutes we knew that we had an abnormal situation. Then again there has not been a trip that has really been textbook so to speak . . . I didn't feel at this point in time, that the situation that we had, alright, was . . . [a] very serious problem. But that we did have an unusual situation with the low pressure and a high level, . . . I didn't feel that we had anywhere near the scope of seriousness of the accident that we later developed into. . . . (44)

Faust did not realize what was happening either:

> The primary [system] at the time seemed to have stabilized out with not a desirable condition, but with—I only remember as being a high steam generator or a high pressurizer level, and a low pressure, but holding. (45)

Such perceptions and responses—the operators and managers incorrectly diagnosing the seriousness of the accident, people being absent from the control room and attention focusing on relatively less important systems or components while failing to recognize the significance of other conditions—would recur during the day.

It would be some time before anyone became really concerned. For Zewe, it was not until

> . . . we got into the point to where we had to secure the cooling pumps or where we chose to secure the reactor coolant pumps.[27] (46)

[22] Following the accident at Three Mile Island, the NRC issued a requirement that all operating reactors install primary coolant saturation meters to provide readings on saturation conditions. Ironically, on February 26, 1980, Florida Power Corporation's Crystal River-3 reactor was forced to shut down as a result of a loss of power related directly to the installation of the instrument. The loss of power was apparently caused by a short in the electronics installed in response to the post-TMI NRC requirement. The accident resulted in dose rates up to 60 R/hr in the containment building. They declined to less than 0.2 R/hr in five hours. (34) See "Radiation Effects and Monitoring," p. 43, for a description of the units of measure for radiation.

[23] Closing the valves during testing while the plant is in operation was a violation of the Technical Specifications to which the utility was legally obligated to adhere. The NRC has fined Met Ed $155,000 for this and other violations. See "Recovery at Three Mile Island," pp. 210–211.

[24] On the basis of an FBI investigation, which found no evidence of sabotage, and because of limited staff resources, the Special Investigation did not pursue the possibility of sabotage.

[25] Cooldown involves removal of decay heat so that low temperature, low pressure conditions can be established in the primary system.

[26] See Addendum 4, p. 153, for a description.

[27] This occurred between 5:15 and 5:41 a.m. See pp. 104–105.

For Scheimann that recognition came at about 6:30 a.m.:

> . . . probably at the point where we were starting to get the radiation monitors and the different alarms . . . That was the point where I was concerned that it was more than an ordinary trip that we had seen in the past. (47)

TOO MANY ALARMS

Within the first few minutes of the accident, more than a hundred alarms had activated on the overhead panels in the control room. (48) The difficulties posed by this and other features of the alarm system were familiar to the control room personnel.[28]

In Faust's opinion, the alarms "got in the way" of the operators' efforts to diagnose the accident. (49) Frederick said the operators ". . . disregard[ed] generally the annunciator [alarm] system as a whole, because it was not giving us useful information." (50) Zewe, when asked how useful the alarm system had been in diagnosing the accident, replied, "Not very helpful." (51)

As noted in the previous chapter, the operators had decided not to acknowledge the alarms activated during the initial stages of a complicated transient until they had a chance to read them.[29] (52) However, in Zewe's words:

> . . . the transient was so severe from the standpoint of alarms, that [for] several minutes, it was just intolerable to go through each of the flashing alarms, so I then acknowledged the alarms to silence the alarm in the control room and just try to handle the casualty based on plant parameters, more so than alarm responses. (53)

Frederick said that after the first five minutes, the alarms were activating at a much slower rate. (54) Even at that slower rate, the control room personnel differed on the usefulness of the system. Zewe found that it was helpful:

> Any new and subsequent alarms that came in after that then were a lot more meaningful because they came in at a time fashion to where we could acknowledge them and take action based on the new incoming alarms. (55)

Frederick, on the other hand, said that it was still "hard to tell" when new alarms were activated because so many were already lit and the alarm noise does not change with additional annunciators. (56)

THE COMPUTER IS BACKLOGGED

The plant computer also proved of little use, again as control room personnel had anticipated.[30] During the early stages of the accident, the computer could not keep pace with the volume of incoming alarms, and developed a one-and-one-half hour backlog. (57) In addition, the paper in the alarm printer jammed. (58) A post-accident review revealed that none of the alarms activated in the computer from 5:14 a.m. to 6:48 a.m. was printed out. (59) Zewe hypothesized that the record of those alarms, which should have been stored in the computer's memory, were erased by a technician when trying to fix the printer. (60)

THE DRAIN TANK RUPTURES

Still unknown to the control room personnel, steam and water were continuing to pour out of the PORV and into the reactor coolant drain tank, located in the containment. The tank was not designed to collect flow for long periods of time, since normally the valve opens for just a few seconds.

About 4:04, pressure in the tank reached 150 psi, the point at which the tank's pressure relief valve lifts. It did so, and steam and water, which were at this point very slightly radioactive, escaped into the containment. Pumps in the containment sump channeled the water into a waste storage tank in the adjacent auxiliary building. (61)

When the relief valve on the tank opened, pressure in the tank leveled off for several minutes. Then it began to rise again, (62) as water continued to pour in. When, 15 minutes into the accident, the pressure reached about 200 psi, an 18-inch rupture disc at the top of the tank blew as it was designed to. Pressure in the tank immediately dropped to just under 20 psi. (63) More slightly radioactive water spilled onto the floor of the containment. It, too, was pumped into the tank in the auxiliary building. (64)

These very low-level radioactive releases were the first from the containment.

As a result of the blown rupture disc and the release of coolant into the containment, temperature and pressure in that building began to increase. Pressure did not, at this time, reach the point at which the containment automatically seals itself, closing off the pathways, including the sump pump lines, to the auxiliary building. Had the Unit 2 containment been designed to seal automatically upon actuation of the HPI, as it is at some plants, the radioactive water would not have

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[28] See "Prior to the Accident," pp. 67–70.
[29] See "Prior to the Accident," p. 69.
[30] See "Prior to the Accident," p. 71.

been automatically pumped outside the containment.[31]

Within 30 minutes, the tank in the auxiliary building overflowed, releasing small amounts of radioactivity into the building itself. Some of this, in turn, escaped out the stack into the atmosphere. At this time there was inadequate means of measuring offsite releases.[32] It has since been calculated that the releases were minimal and posed no health hazard.[33]

Response to Conditions in the Drain Tank

Many control room personnel were aware of the increases in temperature and pressure in the containment and deduced that they had been caused by the rupture of the tank. However, they failed to recognize this as an indicator of an ongoing loss of coolant through the PORV. (66)

Ken Bryan, a TMI–1 Shift Supervisor who arrived in the control room about 4:08 a.m., recalled that shortly after he came into the room,

> Somebody came around the corner and said that the reactor coolant drain tank was full and how about pumping it down? I walked around to pump it down and it was empty. I looked and there wasn't any water in it. The indication was downscale all the way. I said oh! oh! and then I sort of walked around front again. (67)

Bryan also recalled that at some point after he noticed the loss of level in the tank, he heard the containment fire alarm. (68) He said the operators checked the temperature in the containment and found it was rising. (69) According to Bryan, ". . . I think about this time we figured that we blew the rupture disc on the drain tank." [34] (70)

Zewe also was aware that something had happened to the drain tank. He recalled that at approximately 20 to 25 minutes into the accident he checked the gauges and noticed that the temperature in the drain tank was high, while pressure and level were low. (71) Zewe surmised, "We either had lifted the relief valve on it and it was still open or we blew the rupture disc on it. Or something else happened to the tank . . . I didn't know at that point." (72)

In another interview, Zewe said he also had noticed that the pump which circulates water from the tank through a cooling system ". . . had a very low discharge pressure [which] means that we ruptured the RC [reactor coolant] drain tank." (73) A low discharge pressure means there is little or no water in the tank. Frederick also was aware of the low discharge pressure: "It didn't seem like the pump was pumping." [35] (74)

George Kunder, the TMI–2 Superintendent for Technical Support and the Duty Officer that day,[36] arrived in the control room at 4:50 a.m., having been called about the turbine trip and reactor scram. (75) He said that when he checked the containment pressure strip chart, it read "around 2, 2.2 pounds," (76) an indication ". . . that we did have a pressure rise in the containment which likely had come from the reactor coolant drain tank rupture disc blowing. . . ." [37] (77)

On the other hand, others did not conclude that the drain tank had ruptured. When Frederick checked the instrumentation for the drain tank about 40 minutes into the accident, pressure had already returned to normal. (78) He said he did not know that the rupture disc had already blown,[38] (80) and he thought the monitoring instruments in the tank had been damaged:

> I assumed that we just damaged all those instruments by blowing the relief valves in there. Okay. We either blew it dry or, you know, a sudden surge of pressure was too much for the instruments. Then they failed. (81)

Temperature and pressure in the containment continued to rise steadily after the rupture, going from 120°F to 170°F and 0 psi to 2.5 psi, respectively.

The control room personnel failed to recognize that the abnormal conditions in the drain tank, and the resultant increases in temperature and pressure in the containment, were caused by continuing loss of coolant through the stuck-open PORV. Their statements indicate that many were unaware of all the symptoms or of their sequence. It should be noted that the instrumentation showing the temperature, pressure and water level in the reactor coolant drain tank was located on the back of a panel in the control room, out of the line of sight of the main console. Further, there was no

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[31] At TMI–2, the containment did not seal until 7:56 a.m., in response to high pressure. (65)

[32] See "Radiation Effects and Monitoring," p. 44.

[33] The releases were estimated through back-calculations that were supported by evidence developed by the Food and Drug Administration. See "Radiation Effects and Monitoring," pp. 44–45.

[34] See Addendum 5, p. 153, for other statements by Bryan.

[35] Ordinarily, the pump operates intermittently to remove water that collects in the tank from various leaks normally occurring around pumps and valves in the primary system.

[36] He was licensed on Unit 1 and was studying to obtain his license for Unit 2.

[37] For further statements on this matter, see Addendum 6, pp. 153–154.

[38] In an interview conducted several weeks after the accident, Frederick said that "a few minutes" after the accident began, he checked the instruments and noticed that pressure and temperature were high and the level was "down." (79) If so, and had he believed the instruments, then he could have deduced that the rupture disc had blown when, 40 minutes into the accident, he saw that pressure in the tank was normal.

strip chart which recorded conditions in the tank over time, making it difficult to reconstruct trends and to connect the rupture of the drain tank with the long-term loss of coolant through the PORV. Without knowing the sequence, an operator aware of one abnormal condition would not necessarily see it in terms of a progression of events indicative of an ongoing loss of coolant. Further, as is evident from Frederick's statements, when the indicators were checked subsequent to the rupture of the disc, some conditions, such as pressure, were back to normal. (82) Some personnel said they were misled by this into thinking nothing was unusual. Frederick, for example, later explained that since the pressure in the drain tank did not appear to be elevated, he did not suspect the PORV was still open. (83)

In this same time frame, at about 24 minutes into the accident, Zewe asked Bryan to get readings of the temperatures in the discharge line leading from the pressurizer relief valves. (84) The temperatures were high and were a further indication of flow into the drain tank. The actions and statements of the control room personnel provide no evidence that they understood the cause of what they were seeing.

HIGH WATER LEVEL IN THE SUMP

The continuing loss of coolant led to another symptom which appeared at this time, but, again, its implications were not understood. Water had been flowing into the auxiliary building for about half an hour. At this point, an auxiliary operator noticed that both sump pumps were running. The auxiliary building storage tank was overflowing onto the floor, and a control panel in the auxiliary building showed that the water level in the sump was high. (85) He reported these facts to the control room. (86)

Frederick got a sump level reading from the computer; it showed 5.999 feet, the top of the scale, suggesting that the actual level was off-scale.[39] (87) When Zewe heard this—it was about 40 minutes into the accident—he ordered Frederick to shut off the pumps. (88) Zewe said: ". . . and we knew at that point that . . . the water from the RC drain tank was going into the sump."[40] (89)

Persistent low pressure in the primary system is another indication that a LOCA may be in progress. Control room personnel had noticed this symptom, but again they did not attribute it to an ongoing loss of coolant. (90)

One reason for the confusion over primary system pressure was that it had stabilized at a low point about 30 minutes into the accident. Zewe, for one, said:

> I really did not feel that we had a loss of pressure, anyway . . . [A]t this point in time, we had a rather stable pressure configuration, even though it was low. We did not have a continuing loss of pressure. (91)

Kunder, who had arrived at 4:50, said that he found the situation confusing because he had never seen pressurizer level pegged in the high range with a concurrent low primary pressure. He recalled that before these two parameters had always performed consistently. (92)

The operators were later to describe the accident as a combination of events they had never experienced, either in operating the plant or in training on simulated emergencies. (93) All stated they knew the combination of high pressurizer level and low system pressure indicated an unusual transient. (94) Zewe and Scheimann, however, said they would have been more concerned had pressure not stabilized, albeit at a low point. (95)

Zewe said that when he returned to the control room just prior to 5 a.m., the operators began "trying to put our heads together" to come up with an explanation for the accident. (96)

> . . . All of us were talking together . . . trying to come up with why the strange indication. Everything looked very good except pressure was low, and level was high. . . . (97)

POSSIBLE ACCIDENT SCENARIOS

For about the next half hour the control room personnel considered different scenarios, based on symptoms described in the emergency procedures that appeared to match the symptoms being exhibited.[41] These symptoms included high pressurizer level, low primary system pressure, elevated containment temperature and pressure, and an off-scale high water level in the containment sump.

Radiation did not appear to be a key symptom at this time. Control room personnel recalled only one radiation alarm during this period—at 5:18. (98) It was activated by an intermediate let-down cooler radiation monitor that normally measures radioactivity in the water in the secondary side of the let-down heat exchanger. (99) Zewe did not consider it significant. (100) He said he knew that

[39] This scale, like others, was calibrated for normal operating, not accident conditions.

[40] See also Addendum 7, p. 154.

[41] Emergency procedures are written instructions designed to assist the operator in responding to specific transients and accidents. The procedure for a particular event lists the symptoms that that event is expected to produce. It also specifies immediate actions and followup actions that the operator must take to respond effectively to the situation. Statements by control room personnel on the use of the procedures appear in Addendum 8, p. 154.

the monitors had very low setpoints, were very sensitive and were located near the sump into which the slightly radioactive water from the drain tank had flowed. (101)

The four possible scenarios (102) the control room personnel remembered considering were:

- A rupture in the steam line running from the "B" steam generator;
- Leakage from the primary to secondary system through the tubes[42] in this steam generator;
- A break in the emergency feedwater line; and
- A LOCA.[43]

CONSIDERATION OF A LOCA

With respect to a LOCA, the control room personnel had differing recollections about whether they explicitly considered it. Zewe said he never did:

> It really did not enter my mind that we had a loss-of-coolant accident. I didn't fully understand what I had, but I always think, in terms of a loss-of-coolant accident . . . that your pressurizer level is a big key. But I had the reverse of what it would have been for a loss of [coolant] level. (103)

He also misinterpreted another symptom:

> I never really considered that we had a LOCA. The automatic actuation of the engineering safety feature system [high pressure injection], I felt at the time was because of feedwater initiation. (104)

Kunder likewise never considered that they had a loss-of-coolant accident. (105)

However, Faust and Frederick said they postulated a LOCA. Faust noted, ". . . we were looking at possibilities of a LOCA for one thing." (106) Others recalled referring to the LOCA Emergency Procedure, (107) although it is not clear exactly when. Frederick said they discussed the LOCA Emergency Procedure in order to determine whether the accident involved a steam line break or a loss of coolant. (108)

In the course of the accident, the operators referred to emergency procedures dealing with possible types of accidents. The procedure for LOCAs appears to have been based on the assumption that specific symptoms would become apparent almost simultaneously at the beginning of the accident. In effect, the procedure took a "cookbook" approach which assumed that all the symptoms of a LOCA would be present unambiguously. It did not tell how operators should interpret an ambiguous or different set of symptoms, nor did it state which symptoms were the most important, to be responded to even if other symptoms were absent or seemingly contradictory.

However, it should be noted that procedures are based on certain foreseeable circumstances and are not meant to cover all possible situations or to substitute for operator training and judgment in unforeseen situations. In several other respects the operators found the procedures to be vague, confusing, incomplete and hard to understand.[44]

A LOCA Is Rejected

The conclusion reached, according to Frederick, was that the accident was not a LOCA. (109)

There were several reasons why operators failed to interpret the symptoms as a LOCA. For one, in their diagnosis of the situation they stressed the importance of the seemingly unusual sequence of three of the key symptoms of the accident: low primary system pressure, high containment pressure and water in the containment sump. (110) They expected that these symptoms would occur almost simultaneously during a LOCA. (111) Zewe explained that their training for LOCAs led them to look for these symptoms to occur "within seconds of each other." (112)

In this case, there was a delay between when the PORV was to have closed and when two of the symptoms of the LOCA occurred. Because of the size and location of the source of the LOCA—the stuck-open PORV—the water and steam from the leak remained in the reactor coolant drain tank for 15 minutes, at which point the drain tank rupture disc burst, leading to high containment pressure and water in the sump. By that time, the reactor coolant system pressure had stabilized. Thus when the operators became aware of symptoms such as the high water level in the containment sump, they did not relate them to the drop in primary system pressure. (113) Instead, their statements indicate they viewed them as unrelated, possibly caused by an event different from that which caused the initial drop in pressure. (114)

The Emergency Procedure states that one of the symptoms of a LOCA is a "rapid continuing decrease" in reactor coolant system pressure. The procedure does not explain, however, when or even whether that decrease will level out. In a LOCA involving a relatively small-sized break such as the March 28 accident at TMI, the primary system pressure would be expected to stabilize at a relatively high level at some point after the accident began, as it in fact did. (115) Not realizing this

[42] A break in a small primary pipe in the steam generator which releases radioactive primary water into the secondary system.

[43] For further details on the choice of possibilities, see Addendum 9, pp. 154–155.

[44] See Addendum 10, pp. 155–156.

was typical, the control room personnel interpreted it to mean that a LOCA was not taking place.

Second, although both Faust and Frederick agreed that all the symptoms listed in a procedure need not be present for the procedure to be considered applicable, (116) the absence of one key symptom described in the LOCA Emergency Procedure (117) led the operators to believe that the accident involved something other than a loss of coolant.

The Absence of a Key Alarm

A key symptom referred to in the LOCA Emergency Procedure—it is described as a "unique" symptom—is the HP–R–227 radiation monitor alarm. (118) It is critical, though not essential, for diagnosing a LOCA, since the monitor measures particulate and iodine gas radiation in the atmosphere of the containment.[45]

Zewe, when asked what significance the HP–R–227 alarm would have had during the first two hours of the March 28 accident, replied:

> [O]ne of the things you look for if you do have a LOCA is that you have activity indicated on the atmospheric monitor in the building, so that certainly would have been a key. (120)

Further, this symptom generally does not appear in the event of either a steam line break or a tube rupture.

None of the control room personnel said they recalled the alarm from the HP–R–227 radiation monitor coming on (it did not do so even around 6:45 a.m., when most of the other radiation monitors were activated). (121) They said they had specifically checked for it. According to Zewe,

> I looked at the panel several times during the first two hours into the accident and the alarm would have been very evident. Plus, I had a shift foreman [Scheimann] that was right at the primary plant controls which is directly across from the alarm panel and I'm certain that he would not have missed an alarm, because you would have had to acknowledge it and it has its own alarm sound. (122)

Frederick stated that according to the control room personnels' interpretation of the emergency procedure, the radiation alarm was the feature by which LOCAs could be distinguished from two other accidents having some characteristics similar to a LOCA: a primary to secondary system tube leak in the steam generator and a steam line break. (123) Frederick said that when the operators referred to the "Symptoms" section of the LOCA Emergency Procedure,

> We had to decide whether what we had was a large steam leak or a loss of coolant. The difference between the two, according to these procedures, is a radiation alarm in the building, and a radiation alarm never came in. (124)

Frederick said further:

> We decided it was a non-radioactive leak, therefore, it must be the steam system and not the reactor coolant system. The symptoms are identical except for the radiation alarm. (125)

Faust gave a similar explanation:

> If you look at the diagnostic chart for determining whether you have a steam leak, or a primary leak, there is only one difference, and that is the radiation level. And whether or not you're going to fall into a LOCA procedure is determined by whether or not you have a direct radiation alarm. That's how the procedure reads. There was no radiation alarm, we were not in the LOCA procedure. That's how it is. (126)

Problems with the Monitor.—According to two NRC inspectors who analyzed the failure of the alarm to sound, it may have been miscalibrated. (127) Their post-accident review of the strip chart for the monitor showed that from 5:05 a.m. to 5:25 a.m., it was detecting levels of radiation above the point at which the alarm was to activate. Larry Jackson, an NRC inspector who studied the strip chart, told the Special Investigation staff that it is possible the level of activity detected by the monitor did not go far enough past the alarm setpoint to activate it in that period. (128) He also said that if the alarm setpoint had been even slightly miscalibrated, it would have prevented the alarm from coming on. (129) He stressed that he had not checked the monitor to determine if it was miscalibrated.[46] (130)

A second possible reason the alarm may not have gone off was found later that morning, at about 5:50 a.m., when the core was first becoming uncovered. (131) Joseph B. Logan, Unit 2 Superintendent, and Richard W. Dubiel, Supervisor of Radiation Protection and Chemistry, had joined Kunder in the control room. Dubiel said that just after he arrived, Kunder asked him to remove the

[45] The monitor is located in the auxiliary building; (119) its readings appear on a gauge and strip chart in the control room. If the readings go above a certain level, an alarm light on the control panel and a high-pitched horn will be activated.

[46] The radiation monitor has been inaccessible because it is located in the auxiliary building, an area of high radiation levels.

charcoal filter in the HP–R–227 monitor. (132) Dubiel described what he found:

> He [Kunder] . . . was very interested in getting a reactor building [containment] atmosphere sample and in making preparations for a reactor building entry. I got the technician, went down and we tried to get a sample of HP–R–227, which is the reactor building atmosphere monitor.
>
> As we opened up the iodine monitor holding a charcoal cartridge, a large amount of water came out. I immediately closed it back up, and with the amount of water in there, my first thought was that we had some type of a steam environment in the reactor building atmosphere causing some condensation in the sample lines, and getting water into the monitor. [S]o I called George and told him we could not get a sample off that monitor because it was full of water. (133)

Larry Jackson, the NRC inspector, said that water in the sample line would both have blocked the air flow into the monitor and would have had a shielding effect. Either would have reduced the levels of radioactivity detected by the monitor. (134)

A review of the monitor strip chart after the accident provided support for this explanation. (135) It showed that the amounts of radioactivity detected by the HP–R–227 decreased until just prior to 6:00 a.m. (136) A decrease would not have been likely, given conditions in the containment during that time. A steady increase would have been more probable. That decrease could have resulted from the water in the monitor. (137)

The HP–R–227 monitors should perform well in a steam environment, since they are relied upon for diagnosing a LOCA, an accident which exposes them to steam. This apparent design weakness is of concern to the Subcommittee.

The Emergency Procedure Misinterpreted

The control room personnel focused on the HP–R–227 radiation alarm monitor as the determinant of a LOCA because the procedure characterized it as a "unique" symptom of a LOCA which could be used to distinguish between a LOCA and a steam line break. The control room personnel said they interpreted this to mean that, other than for the alarm, the symptoms of a LOCA and a steam line break were identical. (138)

The control room personnel were interpreting the emergency procedure to mean that the absence of this radiation alarm was conclusive evidence that a LOCA was not taking place. This interpretation is incorrect. Although a LOCA and a steam line break inside the containment would produce many of the same symptoms in the primary system and the containment atmosphere, the secondary system would behave quite differently. For example, pressure on the secondary side of the steam generator would be expected to drop substantially during a steam line break, but not during a LOCA. In short, there were symptoms other than the HP–R–227 alarm that operators could have used to distinguish the two accidents.[47]

On the other hand, the Special Investigation staff found that the wording of the procedure does imply that an alarm on HP–R–227 is an extremely significant symptom of a LOCA and that the wording is broad enough so that the control room personnel's confusion is understandable in that context.

In another respect, the control room personnel used the Emergency Procedure inappropriately. Although the radiation alarm was not present, neither was the "unique" symptom of a break in the main steam line. (139) If the procedures had been followed strictly, both a LOCA and a steam line break would have to have been precluded because of the absence of their unique indicators.[48]

STILL MORE SYMPTOMS APPEAR

Around 5:00 a.m., two more symptoms arose.

First, not long after 5:00 a.m., the four reactor coolant pumps began to vibrate excessively. As noted, the coolant had become saturated, meaning that steam bubbles had formed in it. To protect the pumps from possible damage, plant operators turned the first two off at 5:14 a.m.—74 minutes into the accident. (140) They did not take any corrective actions to return the coolant to an unsaturated state, as they were not aware of that condition. (141)

Then, at 5:15 a.m., a reactor coolant sample was analyzed to determine, among other things, the concentration of boron in the water. The results showed less boron than prior to shutdown, even though the operators had been adding it continuously since 4:00 a.m. (142) When the operators and managers started getting higher neutron counts from the source and intermediate range monitors,[49] they interpreted them as confirmation of the low concentration of boron. (143) They said

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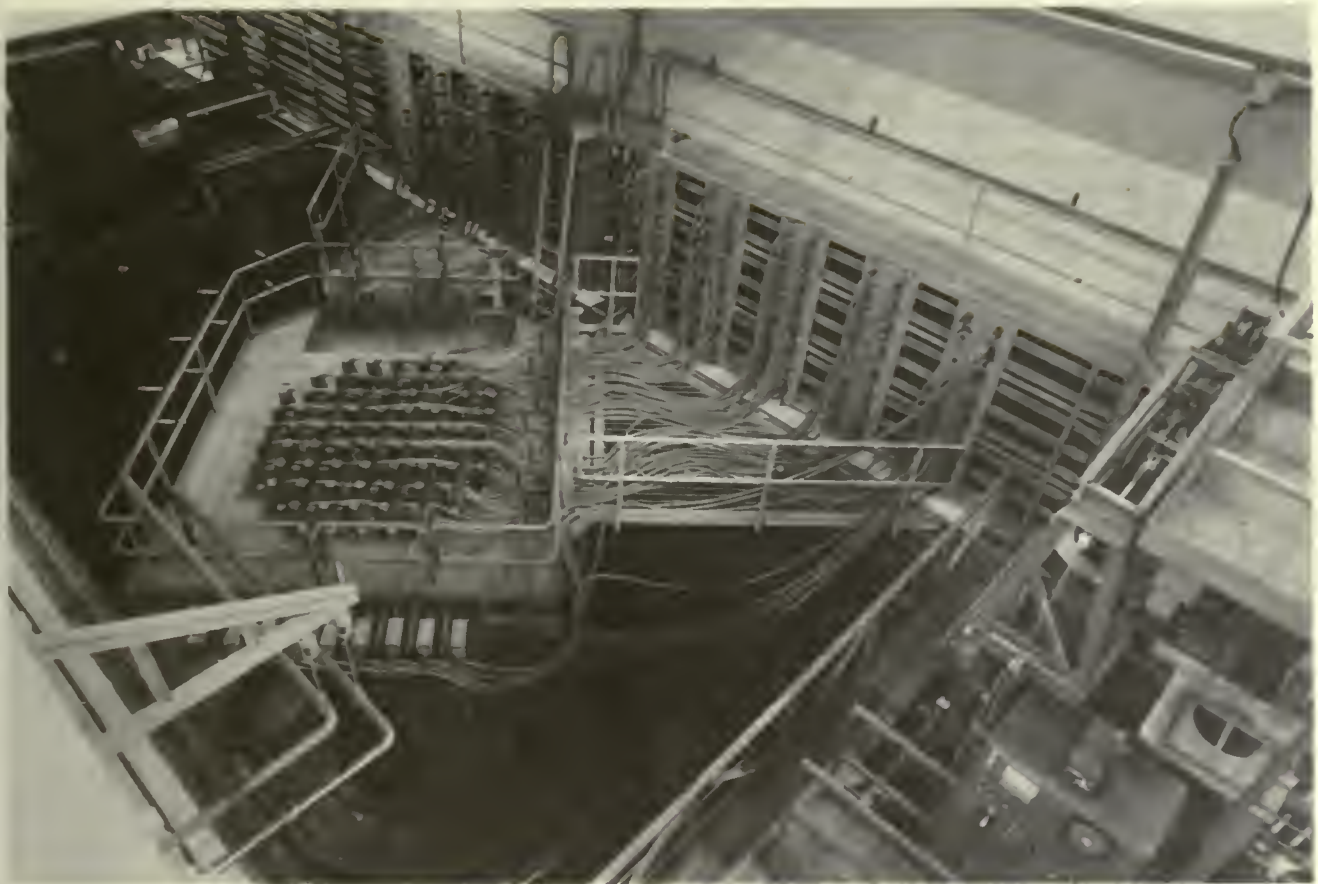
[47] This fact is reflected both in LOCA Emergency Procedure ("NOTE: 3," on pp. 6–7) and in the steam line break Emergency Procedure. The unique symptoms of a steam line break are 1) low condensate storage tank level alarm, and/or low hot well level alarm, and 2) Feedwater Latch System Actuation.

[48] See also Addendum 11, p. 156, for another example of inappropriate use of the emergency procedures.

[49] The nuclear instrumentation includes source and intermediate range monitors that measure the extent of neutron activity (or flux) that is occurring in the core. The monitors are located outside the reactor vessel.



Top of the reactor showing instrumentation cables

they feared they were somehow diluting the boron, thereby raising the possibility of recriticality. (144)

Shortly after the operators isolated the "B" steam generator at 5:27 a.m.,[50] pressure in the containment began to decrease slowly. (145) The change was coincidental, but led some control room personnel to conclude that a steam line rupture had in fact been causing the increase in pressure. In Zewe's words, "So I said; I'll be darned, the leaking generator was leaking into the building." (146) Scheimann commented, "I, myself, thought that when we isolated the generator, we might have stopped the leak." (147)

At about 5:15 a.m., Station Manager Gary Miller called the Unit 2 control room and spoke with Kunder. According to Kunder, he told Miller he did not understand what was going on in the plant. (148) As a result of this conversation, Miller directed that a conference call be established between Miller, Kunder, Met Ed Vice President for Generation Jack Herbein, and Lee Rogers, B&W's site representative.[51]

THE CORE IS UNCOVERED

At 5:41 a.m., still unaware that a LOCA was in progress, the control room personnel took a critical step. They shut down the last two reactor coolant pumps, which also were vibrating excessively. (149) This ended the forced flow of cooling water through the core. So long as the pumps had been running, the combination of water and steam flowing through the core removed enough heat to protect it even though coolant was being lost. (150) Once the pumps were stopped, the steam separated from the water and rose to the top of the hotlegs—the so-called "candy canes"—and the water level in the reactor vessel dropped.

The uncovering of the core began very soon after circulation stopped. Water was continuing to escape out the PORV, at the same time that HPI was being throttled, so that the lost coolant was not being replaced. The water level continued to decline, temperatures to increase, the coolant to boil. Not only did the boiling release saturated

[50] See Addendum 9, pp. 154–155, on isolation of the "B" generator.
[51] See p. 109.

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steam, which continued to rise toward the higher portions of the system, such as the hotlegs, but the steam displaced more coolant forcing it into the pressurizer and out the PORV. This process would continue to uncover the core.

The control room operators tried to remove the heat by establishing natural circulation (i.e., convection flow)[52] through the primary system, a method that would not require the reactor coolant pumps. (151)

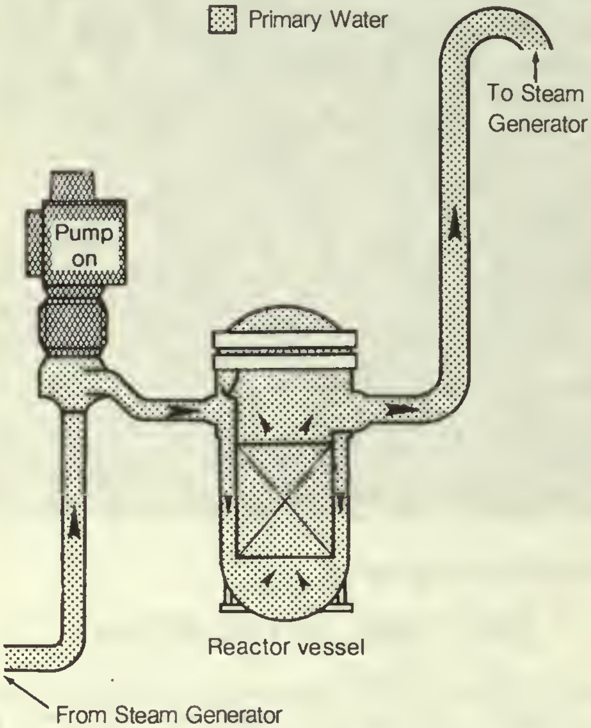

Figure A: Normal Conditions- Primary system contains water

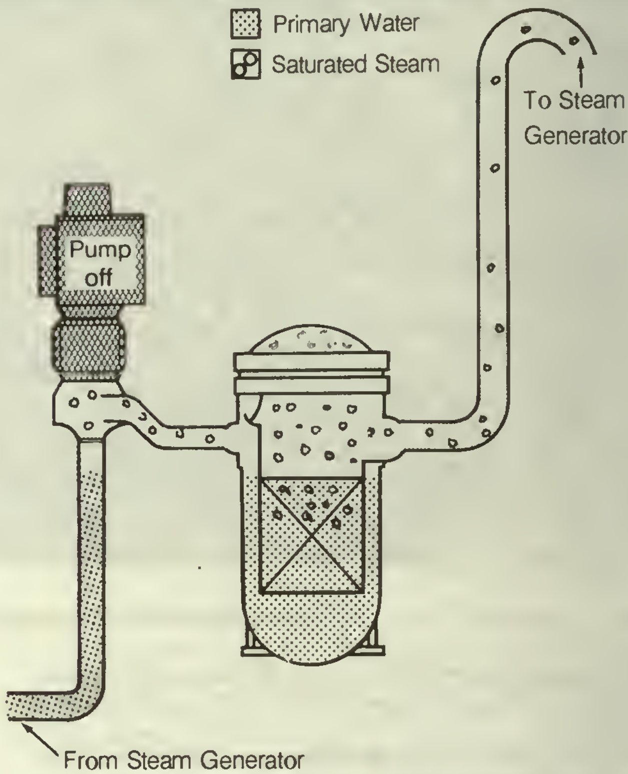

Figure B: Primary system contains water and saturated steam

Adapted from: Nuclear Safety Analysis Center

Neither Zewe, Faust, Frederick nor Scheimann had ever used natural circulation to cool down the TMI-2 reactor. (152) Although they had practiced initiating it at the Babcock & Wilcox simulator, the practice did not continue long enough for them to observe how a plant would respond once natural circulation was established.[53] (153) Their efforts proved unsuccessful because steam had accumulated in the hotlegs, blocking the passage of any flow.

With saturated steam in the hotlegs and no flow, a large difference in temperature developed between water in the pipes going into the reactor vessel—the "coldlegs"—and water in the pipes coming out—the "hotlegs." Based on the evidence reviewed by the Special Investigation staff, the control room personnel did not interpret this condition to mean that there was no flow.[54]

While the control room personnel were trying to establish natural circulation, they lost a key indicator needed to determine if it was taking place. The hotleg temperatures went offscale: the temperatures in the "A" loop reached the high point on the scale of 620° F at approximately 6:10 a.m., the "B" loop at 6:30 a.m. (154)

Frederick, trying to determine whether natural circulation had been established and having lost a key indicator, said that at that point:

> . . . the only thing I figured I could do was watch, hold the steam generator levels up and watch the temperatures in the steam generator and try and deter-

[52] See "Technical Glossary," Appendix E, p. 372.

[53] See Addendum 12, p. 156, for Zewe's comments on the usefulness of the emergency procedure in connection with natural circulation.

[54] In order to determine whether cooling of the core is taking place by natural circulation, the "coldleg" temperature is subtracted from the "hotleg" temperature. The result is called "delta T," meaning the difference in temperature between water in the hotleg and in the coldleg. If delta T falls within an appropriate range, it indicates that water is flowing through the system, that the steam generators are not dry, and that they are removing heat.

mine a change in the delta T across the core. Now we sat like that for I don't know how long. (155)

WHAT WAS HAPPENING IN THE CORE

By piecing together the many analyses that have been carried out since the accident, the actual course of events during this period was reconstructed. Normal reactor conditions are illustrated in Figure A. Primary coolant fills the reactor vessel and flows smoothly through the system. Once the coolant began to boil, however, saturated steam was produced.[55]

Within minutes of shutting down the last two reactor coolant pumps, at around 5:41, the top of the reactor vessel was no longer filled with water, but rather only with steam (see Figure B). As the boiling continued, the water level in the vessel dropped, progressively uncovering the core. Thus, boiling water surrounded the lower part of the core, steam the upper part. The exposed fuel above the water level began to heat up rapidly.

While steam will remove some heat, it is inefficient for this purpose. As the steam moved past the ever hotter exposed fuel, it removed some of the heat, becoming "superheated" in the process—that is, heated beyond the boiling point.

Water turns to steam and steam to superheated steam at precise temperatures and pressures. The American Society of Mechanical Engineers publishes standardized steam tables that show the properties of steam whether saturated or superheated, at varying temperatures and pressures. Steam tables were available in the control room at Three Mile Island on March 28.

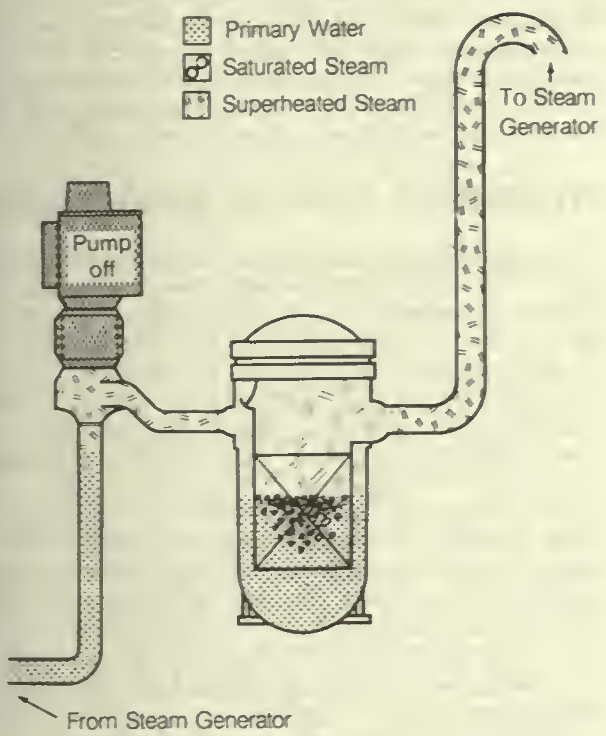

Figure C: All pumps off, reactor core drying out and heating up, superheated steam flowing to hotlegs.

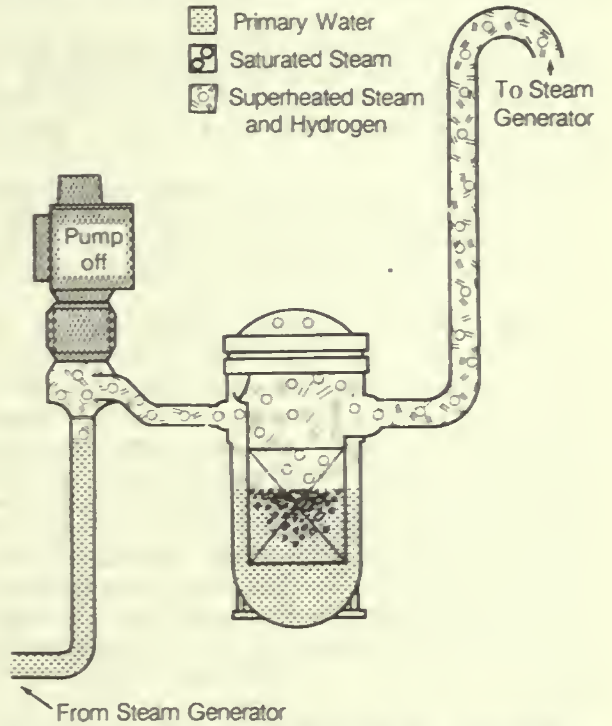

Figure D: Core dryout and heatup continuing. Superheated steam and hydrogen generated by zirconium/water reaction collecting in hot legs.

Adapted from: Nuclear Safety Analysis Center

The superheated steam rose to the higher parts of the system, including the hotlegs (Figure C). As a result, temperatures in the hotlegs rose sharply. Once trapped in the hotlegs, even if coolant is injected into the core in sufficient quantity to cover it again, the superheated steam may remain in the hotlegs, as it did at TMI.[56] The very high hotleg temperatures that result are unique signals that the core has been uncovered. (155)

Thus superheated steam in the hotlegs can only be interpreted to mean that the core has been uncovered at some time, although it might not necessarily be uncovered at the moment.

Because the steam was not removing heat as efficiently as water, the exposed fuel rods continued

[55] Steam bubbles in a boiling pot of water are "saturated" steam.
[56] Superheated steam can be condensed into water by increasing pressure or lowering temperature.

to heat up. Within a short time, the Zircaloy cladding around the rods reacted chemically with the steam, severely damaging the cladding. The reactions—which were to reach their peak by about 6:30 a.m.—generated significant quantities of hydrogen,[57] some of which also collected in the higher portions of the primary system, particularly in the hotlegs (Figure D). This hydrogen, together with the superheated steam in the hotlegs, contributed to the blockage of circulation through the system. The remainder of the hydrogen escaped into the containment through the PORV and the ruptured drain tank. (158)

As the cladding around the fuel rods deteriorated, radioactive gases normally contained by the cladding were released into the coolant. (159) As the coolant flowed out the PORV, so did the radiation.

If hotleg temperatures and primary system pressure are known, steam tables can be used to determine if superheat conditions have been reached in the system. Control room personnel knew by 6:10 a.m. that the hotleg temperature in the "A" loop had reached at least the upper limit on the scale, 620°F. At the same time, pressure in the primary system was below 1,000 psi. At 620°F, any pressure below 1,780 psi is indicative of superheated steam conditions in the system. By using the steam tables, the control room personnel had the means available to deduce that there was superheated steam in the system.[58] Since it is not possible to have superheat without the core having been uncovered, the control room personnel also could have deduced that some portion of the upper part of the core had been uncovered. (160) At this time, however, these conditions went unrecognized.[59]

As the morning progressed and the LOCA went undetected, there was a continuing loss of coolant, greater uncovering of the core, additional damage to the fuel, and further release of radiation to the coolant. (161)

RECRITICALITY A CONCERN

Because of the low boron concentration and high neutron readings, the control room personnel said they became concerned about increasing nuclear activity in the core. (162) In addition, alarms indicating low level radiation in the containment were sounding periodically. The number of these alarms increased considerably about 6 a.m.

At about that time, Michael Ross asked Scott Wilkerson,[60] a nuclear engineer who had been on duty at Unit 1 at the time of the accident, to look into the possibility of recriticality—that is, the resumption of the nuclear chain reaction, a development that could have serious consequences. (163)

After Ross asked Wilkerson to look into the possibility of recriticality, Kunder asked Wilkerson to have Michael Benson, Unit 2's lead nuclear engineer, was called and asked to come in to do a post-trip review.[61] When Benson arrived about an hour later, Wilkerson, another employee, and he looked into the question of recriticality. (164)

STUCK-OPEN PORV IS RECOGNIZED

Around 6:00 a.m., Brian Mehler, a Met Ed Shift Supervisor, arrived in the control room. He noticed that the pressurizer was full, or "solid," but that system pressure had decreased, and concluded that "at that point we had steam in the hotlegs." (165)

Mehler also noticed that the temperature in the discharge line connecting the PORV and the reactor coolant drain tank was 229°F, an abnormally high reading. (166) This temperature was a crucial indicator that the PORV was stuck open.

The PORV had been leaking since October 1978, and the control room personnel had become accustomed to abnormally high temperatures during normal operations. Further, they knew the PORV had lifted in the early stages of the accident. Therefore, they did not conclude that the higher temperatures were indicating a stuck-open PORV.[62] (167) Although, in accordance with the emergency procedure for PORV failure, the operators had requested temperatures for the PORV and code safety valve discharge lines from the control room computer twice before, they had discounted the abnormally high temperatures.[63] (168)

The emergency procedure requires that the block valve be closed if temperatures exceed 200° F. (169) The utility personnel failed to do so, even

[57] At 1,600° F, the Zircaloy cladding of the fuel rods will react chemically with steam to produce hydrogen in an oxidation process called a "zirc-water" or "zirconium-water reaction." (157)

[58] See p. 107.

[59] See pp. 117, 124–126.

[60] For the first three hours, Wilkerson was one of three engineers in the control room. This may have been significant, since engineers have different training, are qualified to perform different types of work, and might have provided a different perspective on the problem, all of which could have assisted the control room personnel in diagnosing the situation.

[61] A review of plant data following a reactor trip.

[62] There is evidence that one operator used an incorrect method for diagnosing the failed PORV, using discharge line temperatures. See Addendum 14, pp. 156–157.

[63] A post-accident analysis revealed that the readings were requested at 4:24 a.m., 24 minutes into the accident (the PORV was 285° F, the code safety valves were 275° F and 263° F); at 5:20 a.m., 1 hour and 20 minutes into it (the PORV was 283° F, the code safety valves were 211 °F and 218 °F); and at 6:17 a.m., 2 hours, 17 minutes into it (the PORV was 229° F). See Addendum 13, p. 156, for further details.

though the readings they requested in the first minutes of the accident were over that figure.[64]

At 6:22 a.m., some two hours and twenty-two minutes into the accident, and about a half hour after he had arrived in the control room, Mehler concluded the PORV was stuck open.[65] He recalled that:

> . . . what I saw was the pressurizer being solid and no pressure in the system, pressure going down. It would indicate to me at that particular time that either the [pressurizer] heaters were not functioning or that we had a leak . . . And I asked . . . if they checked if the heaters were on . . . [and] I pushed out the temperature for the electromatic [PORV] and codes [safety valves], and from that point, I assumed that the electromatic was partially opened because of the temperature. . . . (174)

Mehler directed Scheimann to close the block valve to isolate the stuck-open PORV.

Bryan's recollection of the overall situation in the control room at that time was:

> . . . we were kind of just . . . sit[ting] back and started scratching [our] heads, you know, trying to put this together. That is about where we were at. (175)

Some control room personnel have made statements indicating that at the time Mehler made his diagnosis, they did not appreciate the reasoning for it. (176) Scheimann later characterized Mehler's decision as "pretty much as [a] last resort. . . ." (177) In Frederick's opinion:

> As far as I know the action to close the valve was . . . somewhat out of desperation. In other words, there seemed to be no other possible cause . . . It [was] a last ditch effort. (178)

Before the block valve was closed at 6:22, some 32,000 gallons of coolant—more than a third of the volume of the primary system—had flowed out. Damage already had been done to the fuel and would continue to occur for at least another hour. (179)

At the time the block valve was closed, the control room personnel took no immediate action to replace the coolant that had been lost, (180) suggesting that they did not recognize that the plant had experienced a loss-of-coolant accident.

Shortly after 6 a.m., Kunder at the plant and three people offsite who would later play a major role in responding to the accident—Gary Miller, the TMI Station Manager; Lee Rogers, the B&W Site Manager; and John Herbein, Met Ed's Vice President for Generation—began a 35-minute conference call. Herbein was the first utility corporate executive contacted. He later contributed to the successful effort to stabilize the reactor late in the afternoon.[66]

The four men discussed conditions at the plant. At one point in the conference call, Rogers asked whether the block valve had been closed. Someone was sent to find out and soon returned to say it was shut. However, no one asked how recently it had been closed. (181)

In fact, it had just been closed, a piece of information critical to anyone trying to determine what conditions in the reactor vessel might be.

SUMMARY: FIRST 2½ HOURS

The closing of the block valve brought the first phase of the accident to an end, but there would be further problems. The control room personnel, in failing to diagnose the struck-open valve, had responded to symptoms of the accident in ways that aggravated the loss of coolant, resulting in severe damage to the core. At this point, however, none of them realized the core was uncovered.

The key stumbling block in the early attempts to diagnose the accident emerged within the first few minutes: the conflicting symptons of high water level in the pressurizer and low pressure in the primary system. The operators opted to address the former, in effect rejecting the possibility of a LOCA.

In part, this choice was a result of their training. Operators were taught to avoid collapsing the steam bubble in the pressurizer.[67] Thus they slowed the flow of the high pressure injection to prevent the pressurizer from filling. They did so at a time when, unknown to them, there was a need to replenish the coolant being lost so that the core would not become uncovered.

Their training had not adequately prepared the control room personnel to deal with such problems as multiple failures,[68] plant behavior when

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[64] The utility has been faulted for failing to follow correct procedures with respect to the prior PORV leakage. TMI-2 Emergency Procedure #2202-1.5 ("Pressurizer System Failure") contained sections on PORV and code safety valve leakage. Operators were to respond to suspected PORV leakage by closing the block valve (170) and to suspected code safety valve leakage by recording their discharge line temperatures on an analog trend recorder. (171) Prior to March 28, the utility neither used the recorder nor closed the block valve. It also did not repair the valve. (172) As noted earlier, the NRC fined Met Ed $155,000 for these and other violations. (173) See "Recovery at Three Mile Island," p. 210–211.

[65] See Addendum 15, p. 157.

[66] See p. 151.

[67] See p. 96 and "Prior to the Accident," p. 74.

[68] See fn. 8, p. 94, and "Prior to the Accident," p. 75.

natural circulation is used to cool the core,[69] and the absence of indicators of actual plant conditions because of instruments going offscale.[70]

Further, control room personnel did not consider some of the symptoms to be typical of a LOCA, again based on their training but also on the emergency procedures, which they found to be unclear, vague and incomplete.[71] Because they neither heard nor observed a key indicator of a LOCA, the HP–R–227 radiation monitor alarm, which they mistakenly believed to be a necessary indicator, they rejected the possibility of a LOCA. Further, their training and the procedures led them to believe all the symptoms would occur within seconds of each other. During the accident, the sequence was not as expected, and control room personnel did not become aware of the symptoms as they occurred. They also failed to identify the trends and relationships among the symptoms that were indicative of a LOCA.

There were other problems: equipment malfunctions; a lack of certain key indicators, such as water level in the core; poor layout of instruments in the control room, particularly those relating to the reactor coolant drain tank; too many alarms coming on at once; and a one-and-a-half hour backlog on the computer.[72] Nor were the emergency procedures helpful. They did not provide guidance for decisionmaking in unforeseen circumstances.

Some of the problems can be traced to management. The utility knew that one or more of the relief valves on the pressurizer had been leaking for six months. In such cases, the NRC requires that the utility either close the block valve or install an analog trend recorder.[73] The utility took neither step, nor did it identify or repair the leaking valve.

Operator errors must be seen in the context of these significant problems. Yet one person did diagnose the stuck-open PORV shortly after his arrival in the control room. He did not, however, initiate actions to replenish the lost coolant.

A SITE EMERGENCY IS DECLARED

During the conference call at 6:00 a.m., a decision was made to try to restart the reactor coolant pumps. Between this time and the attempt to restart them at 6:54, the severity of the accident was to become clearer. For example, about 6:30 a radiation technician began surveying the auxiliary building. He found that radioactivity was increasing rapidly. In the control room, radiation monitors for the containment and auxiliary buildings were showing the same thing. Alarms indicating high radiation levels sounded in areas of the plant periodically. (182)

Unknown to those at Unit 2, the core was uncovered. Calculations made subsequent to the accident show that temperatures in parts of it may have reached 4,350°–4,500° F, and possibly higher. (183)

At approximately 6:40 a.m., Dubiel phoned Kunder, who was in the control room, to report that two follow-up boron samples were showing even lower boron concentrations[74] than the first sample taken at 5:15 a.m. (184)

While Kunder was on the phone, radiation alarms began coming in from all over the plant. Kunder turned to Joseph Logan, Unit 2 Superintendent for Operations, and announced, in very strong language, that they were "failing fuel." [75] (185)

At 6:45 Zewe and Kunder declared a site emergency,[76] as required by TMI's emergency plan in the event of a possible "uncontrolled release of radioactivity to the immediate environment." [77] (186)

NOTIFICATION OF OFFSITE AGENCIES

Ron Warren, a Met Ed engineer, arrived in the control room shortly after the site emergency was declared. Kunder directed that he and Richard Bensel, another Met Ed engineer, notify offsite agencies of the problems at the plant, again in accordance with Met Ed's emergency plan. Among those contacted were the Dauphin County Civil Defense Agency, the State Bureau of Radiological Protection and the Nuclear Regulatory Commission Region I office. (187)

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[69] See p. 106.
[70] See p. 106.
[71] See p. 102.
[72] See pp. 94, 96, 99–100.
[73] A device that records temperatures over time.
[74] See pp. 104–105.
[75] Fuel failure means that the Zircaloy cladding of the fuel rods had been breached, allowing radioactive fission products to enter the coolant. See p. 108.
[76] See "Prior to the Accident," p. 79.
[77] There probably had been no offsite release at this time. See p. 112.

According to Warren, he told those contacted

> . . . that we had had a site emergency and that we had possible fuel damage, which is what George [Kunder] had told me [and it] was about the only information he had relayed on to me, and we thought we had a primary to secondary leak. (188)

Warren, when questioned by Special Investigation staff as to exactly what he said, reiterated that he talked only of possible fuel failure:

> Question: Were those words used, "The core may have been uncovered," anything like that?
>
> WARREN: No, those weren't. The only words used were that we had possible fuel [failure]. When we made the telephone calls, we really didn't have that much information. (189)

Warren stated that he had difficulty getting additional information:

> . . . Every time we tried to corner George [Kunder] to get more information, he was off somewhere else talking to other people. (190)

THE PUMPS WILL NOT RUN

At 6:54 the control room personnel tried to restart (or "bump") the reactor coolant pumps. At 7:15 they gave up. Although the pumps started, they would not run properly, since they were still pumping mainly steam, rather than water. (191) The inability to keep them going led to increased recognition that there was steam in the primary system. As Kunder told the Special Investigation staff:

> . . . I guess it was within maybe the next 15 minutes, half an hour, when I, along with everybody else, recognized that we had significant steam void[ing] inside the reactor coolant system. [The reactor coolant pumps] did not produce any flow . . . it's apparent that it [the pumps] was just spinning in a steam environment. (192)

During the attempt to restart the pumps, another confusing set of indicators became apparent. There was a sharp decrease in neutron activity in the core and, at the same time, there appeared to be a sharp decrease in the boron concentration in the coolant. (193) Ordinarily, neutron activity would increase as the amount of boron, a substance that absorbs neutrons, decreases.[78]

Kunder, recalling the drop in boron concentration from the 1,000 parts per million (ppm) measured before the accident to the 400 ppm at this time, described his confusion during this period:

> That really alarmed me . . . I was grasping at straws trying to assess what was happening. So, initially, there I was feeling we had a possible de-boration [[79]] of the coolant system, and then we had the 400 ppm sample come in. I said, "Oh, my goodness, it's still going." When we bumped the reactor coolant pump, apparently we let enough water into the core [that the] intermediate range [neutron] indications went down and source range [neutron] indication went down, and I said, "Ah ha, it's turned around." As things evolved, it became apparent that the indications were very confusing and very misleading.[80] (195)

NEUTRON ACTIVITY

Around 7:15 Wilkerson turned to the issue of recriticality that Kunder had raised with him just before 6:00 a.m. He and two newly arrived engineers, Mike Benson and Howard Crawford, walked around the control room checking the instrumentation panels and calling up information from the computer. (196)

Benson described what he found to Special Investigation staff. The hotleg temperature was off-scale high, while the coldleg temperature was abnormally low. (197) Pressure in the primary system was down, and there was no flow because the reactor coolant pumps had been turned off. One set of neutron indicators outside the core suggested normal levels of activity, but the computer was providing high readings for another set inside the core. Normally, at the reduced power level of the plant, the computer would not provide any readings.[81]

In an attempt to resolve these contradictory readings of neutron activity, Benson checked a backup set of neutron detectors that also took readings from directly inside the core. The backup detector strip chart printed out data that also showed high neutron activity. Benson concluded

[78] The decrease in neutron activity was signalled by the neutron monitors. One explanation for the decrease is that the core, which initially had been partially voided, was refilled to a certain extent when the pumps were started. While the core was partially voided, the neutrons had been able to escape the reactor vessel. When the core was refilled, they were trapped, leading to a decreased signal. The converse may also be true: when the core was gradually becoming uncovered, the neutron level rose proportionately as more neutrons escaped. (194)

[79] Decrease in the concentration of boron in the coolant.

[80] See Addendum 16, p. 157, for Logan's reaction to the behavior of the source and intermediate range monitors.

[81] See Addendum 17, p. 157, for Benson's description of what was happening.

that the incore detectors had been made inoperable by excessive heat and that that had resulted from a steam void in the core:

> When I looked at the back-ups it indicated to me how [the incore neutron detectors] had slowed going back [down]. They had already gone through the void and they had [seen] the worst case. They couldn't recover. There is a temperature limit [for the incore detectors] . . . I just assumed when the void went through that it wiped them out.[82] (199)

OFFSITE RADIATION

Meanwhile, Crawford had, as required by Met Ed's emergency plan, calculated a projected radiation dose rate for Goldsboro, Pa., located directly across the Susquehanna River. Using the procedure prescribed in the plan for projecting doses, Crawford made an extremely conservative projection, hypothesizing a high rate of radiation leakage from the containment (0.2 percent of the atmosphere in the containment per day) and abnormally high pressure in the containment (55 psi). (200) The rate came out at 10 rad per hour (10 R/hr),[83] twice the level at which protective action is mandated according to the EPA Manual's Protective Action Guides. Had that been the actual release rate, it would have necessitated protective action for Goldsboro and probably other areas downwind of the plant.

At around this time, radiation monitoring teams were sent to the site's perimeter and to Goldsboro to monitor actual offsite dose rates, again in accordance with the utility's emergency plan. (201) The releases, according to onsite measurements, were small. Furthermore, containment pressure had not been greater than 3 psi. (202)

EMERGENCY COMMAND TEAM SET UP

Gary Miller arrived in the control room around 7 a.m. As specified in the emergency plan, he assumed the role of emergency director and over the next hour set up an emergency command team to carry out TMI's emergency plan and to handle the accident. (203)

Mike Ross, Unit 1 Supervisor of Operations, was put in charge of plant operations, with Zewe reporting to him. Dubiel was assigned the task of radiation protection and monitoring. Logan was to make sure that emergency plans were available and being followed. Kunder was assigned to supervise technical support and communications. Lee Rogers, Babcock & Wilcox's Manager of Site Operations,[84] who had also just arrived, was asked to serve as the liaison with B&W and to provide technical assistance. James Seelinger, Unit 1 Superintendent, who would arrive later, was to head the Emergency Control Station, which, after 10 a.m., was located in the TMI–1 control room. (204) In addition to the members designated by Miller, others such as Zewe and one or more of the NRC inspectors who arrived later that morning participated in the team's meetings from time to time.

A GENERAL EMERGENCY IS DECLARED

While taking over as emergency director and assembling the emergency command team, Miller also focused on radiation monitoring. (205) Radiation levels inside the plant were continuing to increase, and a potential for releases to the atmosphere existed.

At 7:24, based on the radiation levels in the containment measured by the containment dome monitor, Miller declared a general emergency.[85] (206)

By approximately 7:30 a.m., control room personnel were increasing the amount of coolant being supplied to the core. That action was producing little additional flow. It was being inhibited by the superheated steam and hydrogen gas trapped in the hotlegs, which continued to prevent establishment of natural circulation. The trapped steam and gas sustained the big temperature differential between the hotlegs and the coldlegs. (207) Moreover, the reactor coolant pumps could not be turned on because of the blocked pipes. Primary system pressure, which stood at about 1,500 psi, down from the 2,100 psi registered at around 7, was being kept at that level by periodic venting through the block valve into the containment. (208) Damage to the core was already severe, unknown to those at the plant.

[82] The extent to which the incore detectors were knocked out during the early hours of the accident may not be known until the core is removed. Another device—the movable incore detector—could have been used to determine the operability of the fixed neutron detectors and as an indicator of the extent of uncovering. No one thought to use it until three days into the accident, partly because utility personnel considered it to be property of the reactor-vendor and partly because of its status as "experimental." (198)

[83] See "Radiation Effects and Monitoring," p. 44.

[84] Babcock & Wilcox had provided the reactor. It is common for a reactor-vendor to assign a representative to a plant using its reactor.

[85] See "Prior to the Accident," p. 79.

INCORE TEMPERATURES

Sometime between 7:30 and 8 a.m., Miller decided to use the incore thermocouples[86] for more accurate temperature readings. (209) He said he needed them in part to judge how effectively existing plant systems were removing heat from the core, given that the operators had been unable to establish natural circulation: (210)

> . . . The context of what I was looking for was a temperature indication that would have some accuracy or be on a scale of the instrument that I was reading . . . I was looking for a temperature on the hot end to help evaluate heat removal from an action standpoint. (211)

About 7:30, Miller asked his senior instrumentation engineer, Ivan Porter, to get readings for the incore thermocouples from the computer. (212)

The computer printed out nothing but question marks. This meant either that the temperatures in the core were greater than 700° F (the top of the scale) or that the monitoring and readout equipment was malfunctioning. (213) In fact, the temperatures were greater than 700° F. There was no other means in place for getting actual incore temperature readings from the control room equipment. (214)

The resistance temperature detector that measures hotleg temperatures also was registering off-scale. It only told Miller that temperatures were equal to or greater than 620° F. (215)

Eventually either Miller directed or Porter volunteered to find another method of obtaining accurate incore temperatures. Between 8 and 9 a.m. Porter, Bill Yeager and Thomas Wright, two instrumentation technicians, and Douglas Weaver, an instrumentation foreman, went down to the cable room. They were going to try to tap directly into the wiring leading to the computer with a device called a thermocouple reader.[87] (216) Porter returned to the control room while the instrument technicians tapped into the wiring.[88]

Soon they were joined by another instrumentation technician, Bob Gilbert, and another instrumentation foreman, Skip Bennett. Weaver and Wright left to install yet another measuring device. Known as a "resistance bridge," it was to be connected to the hotleg temperature detector in order to extend the range of hotleg temperatures that could be read from the control room. (222)

IS THE CORE UNCOVERED?

When Porter returned to the cable room, the others had finished hooking up the thermocouple reader. They got five initial readings (the device could accommodate five thermocouples at a time). These ranged from 200 to over 2,000° F. (223).

When Yeager saw the 2,000° F reading, he said he concluded the core was uncovered. (224) He told NRC investigators that he made that statement to those present. (225) Bennett concluded that the core had been uncovered, but no longer was. (226)

Wright and Gilbert, on the other hand, stated that they did not think the core had ever been uncovered. (227) Wright thought the thermocouples had been damaged.[89] (229) Gilbert, along with Porter, believed the readings simply meant the thermocouples were not functioning properly. (230)

According to Porter, someone in the cable room suggested they take additional thermocouple readings by means of another instrument, a digital voltmeter. (231) It provides a direct reading of the voltage being produced by the thermocouples. With the aid of a conversion chart, these readings can be translated into temperatures. Porter, believing the thermocouples had been destroyed, told the others he did not think it would be worthwhile to use the voltmeter. (232)

The others did so anyway. Between 8 and 9 a.m., they took all 52 incore thermocouple readings with the meter. (233)

THE INCORE READING IS DISCOUNTED

Just prior to 8:15 a.m., Porter had a brief conversation with Miller about the incore thermocouple readings. Miller told the Special Investi-

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[86] Temperature measuring devices located in the reactor vessel a few inches above the core.

[87] The incore thermocouples transmit their information to the computer through wiring in cables going from the containment to the cable room, one floor below the control room.

[88] Recollections of who went down to the cable room with whom and when vary slightly. Wright recalled that initially he and Yeager went down to the cable room alone and were later joined by Porter and perhaps Bennett. He recalled Gilbert having been involved originally in providing the thermocouple reader, but did not recall his presence in the cable room. (217) Yeager also recalled going to the cable room to install the thermocouple reader with Wright, having been directed to do so by Weaver. Subsequently, according to Yeager, Bennett, Gilbert and Porter arrived. (218) Gilbert recalled going down with Bennett and finding Porter and two technicians taking readings. According to Gilbert, by the time he and Bennett arrived, the readings taken off the thermocouple reader had already been acquired and the digital voltmeter had been set up. (219) Weaver said he went down with Porter and had taken two or three readings before Bennett and Gilbert arrived. (220) No one else recalled Weaver's presence in the cable room. Porter stated that he went down with Bennett, Wright and Yeager, went back to the control room while the thermocouple reader was being hooked up, then returned to the cable room and learned of the five readings. (221)

[89] He said he thought the thermocouples had formed junctions with neighboring ones and that those reading over 2,000° were reading twice the actual temperatures in the core. He knew that temperatures of 1,000°, while high, were not high enough to indicate core uncovering and damage. (228)

gation staff that at the time, he was focusing on Crawford's high projected offsite dose rate and was waiting for a report from the offsite monitoring team at Goldsboro. (234)

His conversation with Porter was brief. According to Miller, Porter gave Miller the five readings taken off the thermocouple reader but said he did not believe the thermocouples were reliable. (235) Porter said that because he did not see any value in the use of the digital voltmeter, he did not wait for a full set of readings.[90] (239) Nor did Porter tell Miller that two of his instrumentation staff had concluded the core was then or had been uncovered. However, Porter said he did not recall having heard them make those statements. (240)

HOTLEG TEMPERATURES

Sometime between 8 and 9 a.m., Porter, Weaver and Wright finishing hooking up the resistance bridge in the control room to the hotleg temperature detector. They then obtained actual hotleg temperatures, which ranged between 680° and 720° in one hotleg and between 760° and 790° in the other. (241) Although these temperatures indicated superheated conditions in the hotlegs and therefore uncovering of the core, the control room personnel did not interpret them that way. (242)

It is unclear precisely when Miller and other control room personnel received the hotleg temperatures—critical indicators of the condition of the core. For example, the Special Investigation found no record that established whether the temperatures were available to Miller at 8:15 when, having established the utility's emergency management structure, he assembled his key advisors for the first of a number of "think tank" meetings, a caucus approach to managing the accident that was characteristic of much of the first day. Until interviewed by Special Investigation staff on September 28, 1979, Miller said that he was not even aware that the two devices had been used to acquire thermocouple readings. (243)

THE EMERGENCY COMMAND TEAM

The meetings of the emergency command team took place in the shift supervisor's office at the rear of the control room. The first occurred at 8:15 a.m., four hours after the reactor had tripped, three hours after Kunder informed Miller that he was concerned that he did not know what was going on in the plant, two and a half hours after the core was first uncovered, and nearly an hour and a half after the declaration of a site emergency.

At this early caucus, the management team established three general goals for handling the emergency and bringing the plant to a safe and stable condition: (244)

- Protect the public
- Keep the core covered
- Protect Met Ed plant and personnel.

HPI: DEALING WITH UNCERTAINTY

In hindsight, the issue of greatest significance at the meeting was high pressure injection, since it was the only means of cooling the core. Earlier in the day the operators had been confused by the conflicting signals of high water level in the pressurizer and low primary system pressure. Responding to the former, they had turned off one of the HPI pumps and throttled the second.[91]

Early in the meeting of the emergency command team, someone in the group, without Miller's knowledge, had decided to turn off the remaining high pressure injection pump. As a result, for about five minutes there was no flow of coolant to the core. (245) Subsequently in the meeting, Miller made a crucial decision: HPI should not be turned off completely from that point forward.[92]

Two weeks later Miller was to attribute his decision to uncertainty: "Based on the instruments we had we didn't know whether the core was covered." (246) However, in interviews he has made ambiguous statements about when he first realized the possibility that the core was uncovered.[93]

Two weeks after the accident, control room personnel were not sure how the decision to stop HPI came about and whether, in fact, HPI had been completely turned off: [94]

> SEELINGER: There was a period, though, after one of the caucuses, we were in the middle of a caucus, and we sent somebody out to secure the makeup

[90] Bennett had transferred all 52 incore thermocouple readings to a computer sheet sometime between 9 a.m., when the last measurement was taken, and 10 a.m., when nonessential personnel were evacuated from the Unit 2 control room. Wright said he saw the computer sheet in the instrument shop when he left the cable room. (236) Bennett said he returned the conversion tables to the console in the control room, during which time he spoke to Porter and informed him there were "several thermocouples that were extremely hot, in the neighborhood of 2,000 degrees." (237) The computer sheet was not discovered until several weeks after the accident, when Bennett returned from vacation. (238)

[91] See pp. 96–98.

[92] For most of the day, HPI remained the most effective and, to a large extent, the only means of cooling the core.

[93] See pp. 124–129, for his other statements.

[94] Plant data indicate that it was stopped at this time. (247)

pumps.[95] And we talked and they secured the makeup pumps. We talked for about two more minutes and Gary [Miller] came to the conclusion, we just decided and I think it was through his impetus, that's the wrong thing to do. We didn't totally understand it . . .

ROGERS: Right, I do remember that.

SEELINGER: . . . Let's go start the makeup pumps again. That [sticks] in my mind.

MILLER: In the room there I said [not to] secure [expletive deleted] HPI.

ZEWE: We didn't secure the makeup pumps we just secured HPI . . .

* * *

ROSS: Make sure that goes on the tape, we never stopped the makeup pumps.

SEELINGER: We never did stop the makeup pumps?

ROSS: Never stopped the makeup pumps.

SEELINGER: Okay.

ROGERS: No, that's true.

SEELINGER: We sent somebody out of the room with that intention and then we changed our mind within a very short period of time.

ROSS: Yeah, never did that, never did that.

MILLER: Yeah, I was strongly in disa . . . not in favor of stopping the HPI pumps. . . . (249)

Special Investigation staff later questioned Miller about his recollection of what had transpired at the 8:15 meeting.

Question: Can I ask who the individual was who was sent out of the room to do it [secure HPI] and how the information was gotten to him or whomever not to do it?

MILLER: My memory is that the shift supervisor, Bill Zewe, and Mike Ross, were both in the room when that direction was given. The man would have been Bill Zewe who was in charge of the operation from the standpoint of the senior watch supervisor.

Question: How was the information gotten to him after he left the room that he should not secure those pumps?

MILLER: Mike Ross, who was in charge of operations.

Question: And it was Ross who said in the transcript, "Never stopped the makeup pumps."?

MILLER: Yes.

Question: And then Seelinger says, "Yes, we sent somebody out, but then we changed our minds?" So that would be what actually happened. Zewe went out with the instruction to do it [secure HPI], and then you changed your minds and Ross was sent out to inform Zewe not to do it, or to himself take the action necessary to make sure that those pumps were not secured.

* * *

. . . [M]aybe you can explain what you do recall with respect to people coming and going and what may have occurred during that first caucus.

MILLER: During that caucus, the command group, as I have called it, were making reports to me of activities in their respective areas of responsibility. I believe during the caucus the shift supervisor, Bill Zewe, came into the room and talked to one of the members of the group and not to me and then he exited the room and subsequent to that I was informed that high pressure injection was going to be secured, and at that point I directed Mike Ross to go inform and direct Bill Zewe that high pressure injection pumps were to be turned on and left on and only turned off with my personal permission. (250)

WHO KNEW WHAT AND WHEN

Miller said his decision was based on the possibility that the core was uncovered. (251) In the same timeframe, others also had concluded that it probably had been uncovered.

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[95] The make-up pumps are actually the same as the HPI pumps. In industry parlance, make-up refers to a manually controlled flow rate, high pressure injection to the automatically delivered flow rate, which at TMI-2 was 500 gallons per minute per pump. "Securing HPI" means bypassing the automatic injection rate and operating the pumps manually at a lower (make-up) rate.

The control room operators' actions make clear that they interpreted the direction "not to secure HPI" differently. They neither increased the flow rate to the full-flow rate at which HPI comes on automatically, nor did they leave the full-flow rate on when the high pressure injection system actuated at various points later in the accident. Prior to the directive "not to secure HPI" having been issued, the operators had been using one pump to provide coolant to the primary system. After the directive, the operators began using two pumps in a consistent fashion for the first time since the accident began.

Their actions lead to the conclusion that they interpreted the directive "not to secure HPI" in terms of a distinction between one pump ("make-up") and two pump ("HPI") operation. (248)

John Flint,[96] a Babcock & Wilcox engineer who had arrived in the control room around 9 a.m., (252) and Bennett and Yeager, the two instrumentation technicians who had been in the cable room, indicated that they believed independently, and with varying degrees of certainty, that the core had been uncovered. (253) In fact, as noted before, Yeager said he believed the core was then uncovered.[97] Flint told staff of this and other investigations that he told Lee Rogers, his manager, of his conclusion shortly before 10 a.m. that morning:

> Question: Did you have any conversation about core damage with Lee Rogers?
>
> FLINT: Yes, I did.
>
> Question: Was he in general agreement with you?
>
> FLINT: We didn't discuss it in any depth. I mentioned that we had core damage, possible uncoverage of the core. At that time, he was on his way to go into a meeting in the shift supervisor's office. We didn't discuss it further. (254)

Rogers was vague when questioned by the Special Investigation staff on this point:

> ... [Flint] indicates that he mentioned to me that he was sure we had uncovered the core. And I did not recall that he ever said that to me; again, not thinking that that was information that was going to help me get the plant back to a stable condition. I must reinforce that, because he may very well have said it to me and may have been very strong in his saying it to me, but I did not recall that shortly after [the accident], and I did not recall quite a few months after. . . . (255)

According to Kunder, several others in the control room had surmised that the core had been uncovered as early as 6:54 a.m., when the unsuccessful attempt was made to restart the reactor coolant pumps:

> ... We were concerned at that point that we might be uncovering the core . . . I was concerned . . . that with the vapor lock [the trapped steam] I just wasn't sure in my own mind that all the flow was going in through the core . . . So I think we were concerned for some indefinite time, which may have been an hour or two, that the core was indeed uncovered. (256)

THE ROLE OF THE INCORE READINGS

Not everyone recognized the core was or had been uncovered. One possible reason was the extent to which control room personnel doubted the reliability of the incore thermocouples, which were the only direct indicators of temperatures in the core. At least four of Miller's six advisors—Ross, Logan, Kunder and Rogers—were aware that Porter had advised Miller that the incore thermocouples should not be considered reliable. Logan said:

> . . . He [Porter] had some [incore thermocouple readings] that were high, some low, and they didn't make any sense. (257)

Kunder concurred:

> . . . Based on the variation [in temperature values] he [Porter] didn't feel . . . that the indications were reliable enough to base any judgment or action on. (258)

Ross commented,

> . . . [He said] not to take anything concrete off of them, that's what I deduced from the conversation I heard. (259)

Rogers and Ross recalled actually overhearing the discussion between Miller and Porter as it occurred. (260) In an interview with Special Investigation staff, Rogers described how the information was conveyed and how it was received:

> . . . [The readings were conveyed] with various given numbers relating to temperature; as high as 2400, as I recall, and as low as a couple hundred degrees, with a lot of them not reading, not giving any indications at all, both with the individual readout and with the computer readout. And discussions, of course, being, "Well, can we believe them? Do we know what they are telling us? Are they really good for this kind of an indication?" That, again, when entered into somebody's thought process—once you interject into your thinking are you sure you can believe them, is there any knowledge or information you know that they will perform in the kind of conditions we have in the plant right now, you then start not believing that any of them are right. (261)

Miller said he had accepted Porter's opinion that the incore thermocouple readings were un-

[96] Flint had been assigned by B&W to the plant in connection with Unit 2 start-up operations.
[97] See p. 113.

reliable. (262) Further, shortly after the 8:15 caucus with his senior advisors, he had gotten accurate hotleg temperature readings, which met his need for data to assess heat removal. He explained,

> . . . I accepted [Porter's] advice and did not go back and evaluate the specifics of why he had said that [the incore thermocouples were unreliable]. I accepted his advice and at the same time I had an indication of hot temperature that was on scale on an instrument that I felt I could depend on . . . and a normally used instrument, as opposed to the incore instrument, which is not recognized or was not recognized at that time in any [of our] procedures or training or testing. So I didn't go back and question his technical advice on that basis. (263)

Subsequent to the accident, Ross said he concluded that the incore thermocouples probably were the most reliable indicator at the time of conditions in the core. (264) He explained why he thought they were discounted:

> . . . we have never trained our people [to use them] nor do we use them, nor do surveillance or readouts on those, saying, "Hey, this is what you ought to be looking at." We have never done that. I think that's probably why it was easy to discount them . . . It was easy to discount them, also because in many units [they] are not even hooked up. In my unit [Three Mile Island Unit 1] that's not even connected, incore thermocouples. (265)

THE MEANING OF WHAT IS KNOWN

Some control room personnel said they were aware of conditions that clearly indicated the core was uncovered, but that they did not make that connection. For example, Miller, unlike Zewe and Rogers, said he was relying on the hotleg temperatures as an indirect measure of coolant temperatures in the core. (266) The hotleg temperatures that he said he had accepted as reliable were over 700° F. Given primary system pressure, which Miller also had, those readings showed clearly the presence of superheat conditions. (267) Miller's subsequent actions in directing a futile attempt at collapsing the steam by repressurizing the plant lead to the conclusion that he did not deduce that superheated conditions existed or view the hotleg temperatures as corroborative of the incore thermocouple readings at that time.[98] Similarly, engineers Benson and Crawford, who had been focusing on the issue of recriticality, said they did not equate significant steam voiding with uncovering of the core. (268)

The evidence suggests another reason that some control room personnel did not recognize the core was uncovered: not everyone realized that there was steam in the system or steam in the hotlegs. According to Flint, as late as 9 a.m., Miller and some of his advisors, may not have been convinced there was steam in the hotlegs. Flint had discussed this condition with some members of the management team and did not believe at that time it was generally accepted there was steam in the hotlegs:

> Question: . . . at that time, was the belief that there were bubbles in the legs shared by everybody else in addition to yourself and Ed Frederick?
>
> FLINT: No.
>
> Question: And do you recall having any conversations with any non-believers regarding the existence of such bubbles in the legs?
>
> FLINT: Yes, I spoke with Lee Rogers, Gary Miller, George Kunder, Bill Zewe.
>
> Question: And all of those individuals did not think that there were bubbles in the legs . . . ?
>
> FLINT: . . . [Prior to this] I did not have the impression that they thought there were steam bubbles in the legs. (269)

Kunder, however, said control room personnel had deduced earlier, when they had failed to get the reactor coolant pumps running, that they had steam in the system. (270) Flint had also had a discussion with Frederick shortly after arriving. Based on the hotleg temperatures, the neutron detector readings and other plant conditions, he said the two had decided there was steam in the hotlegs. (271)

RECRITICALITY NOT A PROBLEM

In this same general timeframe, Frederick and Zewe spoke to Flint about the earlier concern over possible recriticality. Flint said he concluded that there had been voiding in the core and that it had led to excessive leakage of neutrons from the core which, in turn, had caused the sharp rise and fall on the source and intermediate range neutron monitors.[99] According to Flint:

> . . . [Ed Frederick, one of the control room operators] mentioned that they had earlier thought they had started to go critical again. So did Bill Zewe [the control room shift supervisor] and one or two

[98] See pp. 124–125.
[99] See pp. 112–113.

> other people. When I looked at it, I told them that was not my opinion. I felt there had been a change in the [neutron] leakage path from the core and that's what the detectors were seeing. (272)

The source and intermediate range monitors and other indicators were not signaling recriticality, the main concern up to then, but simply a period of time when there had been less shielding of the monitors because of a steam void in the core.[100] Benson had recognized this:

> . . . The problem had come up . . . "Well, do you think you have [gone] critical again?" You know, they were throwing around boron numbers like 700 ppm. I said, "That's ridiculous" . . . I assumed the void going through [the core as] being the [cause] for the source range being erratic. I also assumed the void had messed up the incores . . . We shouldn't have been critical at 700 ppm with all the [control] rods in. (273)

According to Benson and Crawford, Flint was present when the two of them were discussing the excess leakage of neutrons from the core. In fact, according to Crawford, it was Flint who led them to conclude that the probable cause was voiding in the core:

> . . . It wasn't until . . . we talked to John Flint that we actually thought about voiding in the core causing the excess neutron leakage . . . We were just kind of talking and he said, "Well, that could be one of the causes." We kind of agreed that that would be a good cause. (274)

The Met Ed nuclear engineers—Benson, Wilkerson and Crawford—not only concluded there was voiding in the core, but also deduced the effect that condition was having on hot and coldleg temperatures. Benson said:

> . . . The hotleg was really hot and the cold [leg] was really cold, [and] that also tended to make me feel that somewhere up [in] the hotlegs . . . was the void. It had already gone through the core and it was somewhere up in the . . . hotlegs. Everything seemed to look like that. I went over [and] I talked it over with Scott [Wilkerson] awhile and Howard [Crawford]. We both tended to agree that that's what had happened. (275)

Neither Benson nor Crawford concluded the core had been uncovered. (276)

In summary, by 9:30 a.m. certain control room personnel had realized that the core had been uncovered and that superheated steam had been produced. However, many others, including nuclear engineers and the head of the emergency team, still failed to recognize what was happening in the plant. Thus at around 7:45, when the utility began communicating information on the accident and on plant conditions to the NRC and State officials, many did not know the extent of the damage to the core.

NOTIFICATION OF THE NRC

When Miller announced the general emergency, Warren and Bensel went through the same notifications as before, again according to Met Ed's emergency plan.

NOTIFICATION OF REGION I

Met Ed first called the NRC Region I office at 7:10 a.m., but it was not until 7:45 a.m. that Region I learned of the difficulties at TMI. When Warren called, he had gotten only the answering service, with whom he left a message. When the Region I switchboard opened at 7:45 a.m. and the operator called in routinely, she got a message from the service that a general emergency had been declared at TMI, there was a primary to secondary system leak in the "B" steam generator, and there had been an offsite release of radioactivity.[101] The utility did not mention the stuck-open PORV. (277)

The operator immediately called Eldon Brunner, Region I Branch Chief, in his office. As he had been told there had been an offsite release, he went to the office of George Smith, the Region's chief health physicist. (278) According to the Region I Plan, in the event of a radiological incident, Smith was the "appropriate branch chief" to take primary responsibility for initiating the Region's radiological incident response program; Brunner was the designee for operational incidents.[102] (279)

In fact, the TMI accident involved both classes of incidents. The plan did not specify who should take overall responsibility in such a case. But this did not lead to confusion, as Brunner and Smith shared the responsibility. (280).

On his way to see Smith, Brunner stopped by the office of the Regional Director, Boyce Grier, and informed him of the general emergency. He also directed that arriving personnel report to Smith's office. (281)

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[100] When steam replaces water in the core, there is less shielding of neutrons, causing greater penetration of the reactor vessel by the neutrons, which is picked up by the out-of-core neutron detectors.

[101] In fact, there was no evidence of a release by that time. See "Radiation Effects and Monitoring," p. 44.

[102] Incidents involving the operation of a reactor, in contrast to safeguard accidents or a release of radioactivity without ongoing problems with the reactor itself.

From that office, both men returned the call to the site and began recording information about the accident. (282) They took the information down on white notepads, rather than on the "incident notification information" forms prescribed by the Region's Plan. These forms specified what information was to be obtained: "the cause of the incident," "the present status of the material, facility or operation" and "actions taken or proposed to be taken by the licensee." (283) This kind of information was later not readily available to NRC headquarters.

While Brunner and Smith were recording the information, Donald Haverkamp and Richard Keimig, respectively the Region I Project Inspector and Project Section Chief for TMI, arrived in Smith's office. Their arrival permitted Brunner to go back upstairs at approximately 8 a.m. to activate the Regional Incident Response Center. (284)

At some point the information Brunner had obtained earlier was transferred from the note pads to a blackboard, which served as the Center's status board. From then on, all information was put onto "Incident Messageforms," designed for use in the Response Center. (285)

An open line was set up with the TMI-2 control room at 8:10, and Warren began transmitting information to the Region over it. (286)

NOTIFICATION OF NRC HEADQUARTERS

When Grier received the news from Brunner, he called NRC headquarters in Washington, D.C. and spoke with John Davis, Acting Director of the Office of Inspection and Enforcement (I&E) and a member of the NRC's Executive Management Team (EMT). Grier advised Davis of the general emergency and of the steps taken to set up the regional Response Center. Davis then activated the headquarters Incident Response Center, comprised of IRACT and the EMT. (287)

At 8:24, a direct line was established between IRACT and Region I. The region transmitted data from TMI to IRACT over this line.

One of the earliest pieces of information to go from Region I to NRC headquarters was the temperature in the primary system. At 8:25 a.m. Grier informed Norman Moseley, IRACT Director, that primary system temperature was 571° F. (288)

This temperature was misleading, as it was an average of both the cold and hotlegs ("T_{ave}"), rather than the significantly hotter temperature of the hotlegs ("T_h")—the primary system temperature normally used to diagnose conditions in the core. (The hotleg temperature in the "A" loop was actually in the neighborhood of 680° F,[103] which, as noted, was indicative of superheated steam, given the pressure in the primary system.) (289) Headquarters had no way of knowing it was receiving an average reading.

NOTIFICATION OF THE COMMISSIONERS

Beginning at 8:37 a.m., Davis tried to notify Chairman Joseph Hendrie and the other Commissioners. Hendrie was at a hospital in the Washington area where his daughter was having her wisdom teeth extracted and for this reason was out of the office all day. (290) He had infrequent contact with the Commission and generally was not directly involved in the agency's response during the first day.[104] (292)

Davis did not reach Commissioner Richard Kennedy until 8:53 a.m. at his office; Kennedy said that when Commissioner Victor Gilinsky arrived, he would give him the news. Gilinsky was Acting Chairman in Hendrie's absence. At 8:57 a.m., Davis notified Commissioner John Ahearne, who decided to go to the Response Center in Bethesda. Shortly thereafter, Acting Chairman Gilinsky called the EMT.[105] (294)

A Diagnosis of Core Uncovering

When Davis spoke with Commissioner Ahearne, he told him that "a bubble was pulled into the vessel." (295) Davis had given that same information to Commissioner Kennedy a few minutes earlier. Ahearne asked that Edson Case, the representative of the Office of Nuclear Reactor Regulation on the EMT, be called to the phone to explain what that meant. Case told him:

> What it seems to signify to me is that they lost enough coolant out of the pressurizer, and generally throughout the system, that it apparently uncovered part of the core and popped [the cladding]. And I think probably the activity so far is due to popping the fuel elements. The real question is—is that the entire problem and have they regained control over the primary system pressure and level with their safety injection system? (296)

Case's deduction and the question he put to Ahearne were important. Not only did he diagnose uncovering of the core; he also raised the next step—regaining control over the primary system

[103] The offscale high reading was 620° F; actual temperatures were 680° F.

[104] Hendrie was aware of the accident as early as 10:05 a.m. when he spoke with Commissioner Gilinsky over the phone about it. (291)

[105] The content of this conversation is unknown, as it was not present in its entirety in the IRACT/EMT tape transcripts. (293)

by using the emergency water injection system. (297)

There was no discussion at this time of the need to consider evacuation or other protective action in light of the possible consequences of an uncovered core.[106] This is particularly relevant because, prior to Three Mile Island, it was believed that prolonged uncovering of a nuclear core would lead inevitably to a core meltdown. As Chairman Hendrie testified in hearings before the Subcommittee:

> . . . I think I would have told you on the 27th of March that if you had a core substantially uncovered for some hours that I would have to assume that major damage, and probably some melting, was beginning to go on; and I couldn't tell you with any confidence that it wouldn't continue to go on. (298)

THE FLOW OF INFORMATION

Warren continued to serve as the link between the regional office and the plant:

> . . . As long as I was up in the Unit 2 control room [until about 10 a.m.[107]], most of the morning was spent on the phone with the NRC relaying messages back and forth with them. . . . (299)

Assigned to the phone, Warren said he was never fully briefed. He was unaware of important discussions that were occurring in the control room. Because he himself only suspected as much, he did not tell the NRC of the concern that the core was uncovered:

> Question: Were you aware on the morning of the 28th that the core had been uncovered at some point previously?
>
> WARREN: No, I suspected that it had . . . as soon as . . . George [Kunder], my boss, related that we had possible fuel damage, I thought that there was a possibility that we may have uncovered the core. (300)

Core uncovering was not the only information being mishandled. Misinformation about natural circulation would be transmitted throughout the day, starting at around 9 a.m. Even as Case was posing the question about regaining control over the primary system with the plant's safety injection system, Kunder was answering it in a simultaneous conversation he was having with the regional office. Kunder reported to Region I that there was a vapor lock in the hotlegs and that the plant was not getting proper flow. Moreover, he informed the NRC that utility management was concerned the core was not being cooled. (301)

Within 10 minutes, this information was transmitted to IRACT. (302) However, 10 minutes later, the crux of Kunder's report—that the utility was having problems establishing natural circulation—was contradicted. Region I's George Smith reported to IRACT that natural circulation was being used to cool the primary system. (303)

Then, less than 15 minutes later, Smith's report was contradicted. Grier told Davis at the EMT that the reactor was not being cooled through natural circulation and that the only mechanism for cooling the core was high pressure injection. He again informed headquarters that steam binding was preventing natural circulation. (304)

Throughout the day, the transmittal of this sort of contradictory information characterized communications among the site, the Region and NRC headquarters. Communications at times became so confused that NRC headquarters was transmitting contradictory information simultaneously. For example, in one conversation at 1 p.m., IRACT reported that there "seems to be all kinds of bubbles in the thing; in one or two hotlegs and in the core itself," (305) while at the same time, on another phone, Victor Stello, NRR's IRACT representative, was telling an aide to Congressman Morris Udall that the reactor's primary system was "water solid." (306)

There is evidence that the assumption that accidents would be of short duration also contributed to the communications problems. When the Response Center was activated, IRACT was able to open only one line of communications. (307) The need for both radiological and operational information quickly overburdened that single channel. Around 2 p.m. on the first day an unidentified speaker at IRACT would make the following observation:

> This [accident] is interesting in the broad sense that generally we always considered . . . an event happening and then a release. And this was a strange one because we've got both going at the same time. And it did create a problem at one point . . . some people have said that the reactor people were asking questions and [the radiological] people were asking questions, and they all had to wait in line and there was some competition. Instead of having a field [communicator] who was [conversant in both], the field [communicator] they had . . . was good, but he wasn't that conversant in health phys-

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[106] See pp. 132–135.

[107] At that time, radiation levels in the control room forced non-essential personnel, including Warren, to evacuate the Unit 2 control room for Unit 1.

ics stuff . . . there was a waiting in line kind of thing [that] ended up [occurring], and he never thought about whether they were both primary.[108] (308)

NOTIFICATION OF THE STATE

At 7:02 a.m. the utility had contacted Clarence Deller, the duty officer at the Pennsylvania Emergency Management Agency (PEMA), the designated lead agency of the State for emergency response, to inform him of the site emergency. Deller in turn called William Dornsife, duty officer that morning for the Bureau of Radiological Protection (BRP), PEMA's technical arm, at his home. (309)

Dornsife said he did not have the TMI phone number and had some difficulty contacting the Unit 2 control room. (310) Around 7:15 a.m. the shift supervisor got a message from Dornsife and returned his call. (311)

Dornsife was the only nuclear engineer in the Pennsylvania Department of Environmental Resources and therefore the only official in Pennsylvania's State emergency organization who was technically qualified to assess the status of the reactor. (312) When the plant finally contacted him, Dornsife went through a checklist of questions contained in the BRP emergency response plan for the TMI site. It was designed to aid offsite officials in assessing severity. (313) According to Dornsife, he:

> . . . asked other questions like status of safeguards. Had the High Pressure Injection operated as designed? Had the reactor tripped? And they told me [yes] in all cases. (314)

FLOW OF INFORMATION TO THE STATE

On the whole, Dornsife said he found it difficult to pin down what type of accident had occurred because the utility was not sure what had happened. (315) This difficulty also would reoccur throughout the day.

The answers Dornsife received pointed to a "Type 3" accident, as spelled out in the BRP site-specific plan for TMI. (316) This type of accident involved a release of radiation to the atmosphere as a result of system failures and included "design basis" accidents, such as loss of coolant, and abnormal transients such as steam line failures or steam generator tube failures. (317)

By the time Dornsife was notified, the TMI operators had already closed the block valve to isolate the PORV, although they had not recognized that the plant had experienced a loss of coolant accident. Dornsife did not receive any information indicating a "failure of the primary coolant pressure boundary,"[109] a symptom of a "Type 4" accident "major failure with failed safeguards." (318) Nor did the plant conditions he was given suggest to him a failure of "engineered safeguards or mitigating features,"[110] another Type 4 accident. (319) Accordingly, he said he did not consider a "Type 4" accident. (320) At this point, Dornsife said he saw no need to consider protective actions seriously, nor did the utility recommend that the State do so. (321)

NOTIFICATIONS BY THE STATE

In addition to notifying the BRP, PEMA also notified others. A call was made at 7:08 a.m. to the Dauphin County Office of Emergency Preparedness,[111] which had already been contacted by TMI at 7:02. At 7:45, Col. Oran K. Henderson, the Director of PEMA, spoke with Governor Richard Thornburgh, who at 8:10 called Paul Critchlow, his Press Secretary, requesting that he start checking into the incident. (322)

At 8:20 a.m. PEMA notified Lt. Governor William Scranton. Scranton was Chairman of PEMA and the person whom Governor Thornburgh put in overall charge of State response to the emergency. (323)

Throughout the early morning hours, Critchlow and other aides in the Lt. Governor's office, along with David Milne, Press Secretary of the Department of Environmental Resources, and Dornsife, began to assemble facts about the TMI crisis for a previously scheduled news conference on energy. (324) These individuals loosely formed what amounted to an ad hoc emergency management structure that, as the day progressed, had the effect of minimizing PEMA's role in dealing with the accident, as described below.

At 8:45 a.m. PEMA's operations officer, Dick Lamison, notified the Federal Defense Civil Preparedness Agency Region II of the accident at TMI–2. That agency placed its health physicist on alert and fed information to the other States within Region II and to its national office. It offered PEMA assistance, but Lamison said none was needed. (325) PEMA also was in touch with the Federal Protection Agency Regional Office in Philadelphia. Again, it did not request Federal assistance. (326)

As the day wore on, PEMA and BRP were to call on outside resources, as did the NRC. Some time after 11, Margaret Reilly, Director of

[108] For two additional problems, see Addendum 18, pp. 157–158.
[109] A breach somewhere in the primary system, such as the stuck-open PORV, permitting a loss of coolant.
[110] These include safety features such as the Emergency Core Cooling System.
[111] This is another name for the county civil defense unit. Three Mile Island is located in Dauphin County.

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BRP's Division of Environmental Radiation, accepted a second offer of assistance from Brookhaven National Laboratory (BNL), which had a radiological assistance plan under the aegis of the Department of Energy. (She said she had rejected their first offer of assistance at midmorning because she assumed the incident would be over before a BNL team could arrive.) (327) Brookhaven sent a team to assist with radiation monitoring. The BRP also relied on the National Weather Service to trace and forecast wind speed and direction. The NRC Region I requested teams from several other DOE field operations; these were coordinated through DOE's local command post, established at Capitol City Airport, New Cumberland, 10 miles northwest of the plant. (328)

PEMA'S ROLE

From the beginning, PEMA as an organization played a relatively minor role in the accident, despite its designation as the lead agency and overall coordinator of the State's emergency response. (329) There were several reasons. For one, PEMA had no technical experts. After notification of the accident by TMI, as outlined in PEMA's emergency plans, PEMA no longer spoke directly with the utility. (330) Instead, PEMA personnel were to rely on BRP to provide and interpret data from the site and to recommend the need for protective action such as evacuation. (331)

However, the link between BRP and PEMA proved very weak. PEMA logs reveal that PEMA operations personnel received no new information from BRP between 9:40 a.m. and 12:30 p.m. on March 28. (332) According to Dornsife, BRP was generally so busy with radiation monitoring that staff often forgot to brief PEMA. He acknowledged that BRP was supposed to keep PEMA informed

> ...and get back to them and tell them what the situation was to begin with... [but] we were so involved in tracking, we forgot to inform PEMA. (333)

Reilly agreed that, amidst its monitoring activities, BRP may not have kept PEMA sufficiently informed. She said she surmised, in addition, that BRP's data may not have been understood by PEMA personnel because it was too technical. She said:

> I think we probably, to some extent, [fell] down on the job with them in that we didn't tell them information as to what was going on. Our stance was that if we perceived something they needed, we would tell them ... you try to tell them in the language we speak, and it [the information] doesn't go through the conduits into PEMA too well. (334)

Conversely, PEMA's Deputy Director, Craig Williamson, recalled that much of the information PEMA received from BRP was general in nature and unrelated to a determination of the need for protective action:

> We experienced difficulty [Wednesday and Thursday] with getting information in the form that we would disseminate it to the emergency system in the affected area. Much of the information was very general in nature and lacked the specifics that we really needed to inform the field. (335)

In addition, PEMA was understaffed. According to John Comey, the PEMA Public Information Officer, in an extended emergency, he, for one, needed "trained personnel" who were aware of the requirements of the press and in a position to assist him. (336) In the past, the Governor's Press Secretary had assigned him public information counterparts from other State agencies. This time, that assistance was not forthcoming. (337) He explained the situation:

> . . . it was about two and a half months into the administration . . . Members of the Commonwealth press office, the Governor's press office, were not aware of what our function was as far as the public information piece of it is concerned. They were not aware of our capabilities, the limitations, and the need to coordinate, the fact that we had a history, a good history, of providing this type of service to the members of the working press. (338)

A major problem for PEMA, however, was relations with the Governor and Lt. Governor's offices. When Comey and his temporary assistants wanted to tell the press that PEMA was in an "advanced state of readiness," that approach conflicted with the Governor's. According to Comey:

> This type of descriptive adjective [advanced state of readiness] the Governor did not want to use. He wanted it very low-keyed . . . [T]o give the press the confidence that we could accomplish this, which I knew we could, the [our] descriptions were a little more aggressive and this was quite contrary to what the Governor had in mind. And for that reason, he was critical in the very early stages of what we were doing down here. (339)

Critchlow restrained PEMA's public information function:

> Question: What was the thinking behind what appeared to be a rather hampered ability on [Comey's] part to deal with the press?
>
> Critchlow: Early on . . . Comey was overloaded—some of the people he was drawing in to help were making some potentially panic type inciting statements—so we moved [in] to make sure any statements they did make were cleared through me and my office. (340)

Comey commented:

> . . . My hands were tied. I was not permitted to conduct press conferences . . . to conduct daily press briefings. So it was [on] a one to one basis and that one to one often would include as many as one hundred to one hundred and fifty members of the National and International Press here physically in the office. (341)

There was also some question within PEMA at the beginning of the accident as to the accident's severity. Upon notification, PEMA Director Henderson's first reaction was that it was a test. (342) After the Lt. Governor's first briefing, Henderson said he came away feeling the accident was small, isolated and insignificant. (343)

The extent to which PEMA was excluded as an active participant is evidenced by the fact that it did not activate its Emergency Operations Center until Friday. Until then, according to PEMA's Operations Officer, PEMA had received no indication that the problem at TMI was serious. (344)

Given this situation, it was impossible for PEMA to work effectively with local agencies. Kevin J. Molloy, the Dauphin County Emergency Preparedness Director, said the information from PEMA was either so general, it was useless, or so technical, it told the lay county civil defense official nothing. (345)

Comey pointed out, however, that he did not believe PEMA was supposed to transmit details on TMI to the counties, even had PEMA had that information. Nor did he believe the information was needed:

> The information provided to the Counties throughout this period was the type of information they needed by and large to perfect their responsibilities in the evacuation process . . . Where we could, mention was made of what conditions were at the facility . . . The only thing that was required was that they know the task to be placed upon them, and also know the time frame that we are talking about. (346)

AD HOC STATE MANAGEMENT

The Lt. Governor's ad hoc management structure took over PEMA's role. (347) This group was located in the State Capitol building and drew on resources from State agencies, including BRP and PEMA. The briefings and news conferences often involved PEMA Director Henderson, BRP Director Thomas Gerusky and Dornsife.

There was criticism of the failure or inability of the ad hoc emergency group to transmit information to others. Comey said, "The information coming from the Governor's office was almost non-existent." (348) Molloy put it even more strongly. First he described the actual chain of command:

> . . . The accepted chain of command is local-to-County-to-State-to-Federal . . . When this procedure is followed, emergencies are handled expeditiously and professionally . . . Basically, through the entire incident the chain of command information-wise, went something like this: TMI/NRC/Governor's Office, at the top block, the next block was the news media and the public, and last but not least, the Pennsylvania Emergency Management Agency and County and local emergency personnel. (349)

Molloy commented that often he and others got their news from the radio and television and that he was very dissatisfied with the flow of communications:

> . . . We did not have time to listen to the radio and T.V. etc. Yet this was the way the information was coming out of the Governor's office. It was not being given to PEMA, who could have filtered it down to us, etc. So information-wise from the Governor's office, I feel it left a lot to be desired. (350)

Molloy and others complained often, on one occasion directly to the Lt. Governor, when he visited Molloy's office in the Dauphin County Courthouse. Although Scranton promised the flow of information would be improved, Molloy did not recall that happening. (351) He said he blamed the Governor and Lt. Governor's offices for undermining both the flow of information and the predesignated chain of decisionmaking. (352)

DECISION TO REPRESSURIZE

As noted, between 9 a.m. and 10 a.m., only a few people in the control room at TMI–2 had realized the core had been uncovered.[112] General agreement had finally been reached that steam was present in the primary system, though there was less agreement as to its location within the system and whether it was superheated. Some believed the steam was only in the hotlegs, others that it was in the core as well.

Mehler, as noted, had concluded there was steam in the hotlegs at about 6 a.m. Wider recognition that there was also steam in the core had come with the onslaught of radiation alarms at 6:40 a.m. and the unsuccessful attempt between 6:54 and 7:15 a.m. to get the reactor coolant pumps to run. (353) Yet Miller, who was in charge of emergency operations, replied that he was only aware of steam in the hotlegs:

> . . . By 9 a.m. I was convinced that we had steam phase in the hotlegs because of the [hotleg] . . . temperatures plus the start of the reactor coolant pumps which showed us they were not pumping water. So I would say we were aware of a steam condition. . . . (354)

There is no evidence that he deduced the core had been uncovered.

On the other hand, John Flint said he recognized that the steam in the reactor was so hot (that is, so superheated) that it could not be collapsed back into the coolant.[113] He also said he deduced that the core probably had been uncovered. (355) At the time it was generally known that the only way superheated steam could be produced in a reactor was through core uncovering.[114] (356)

Between 9 and 9:30 a.m. the Emergency Command Team decided to repressurize the reactor in an effort to collapse the steam[115] and establish natural circulation. Flint said he argued against this strategy, recognizing that the superheated steam was so hot—in excess of 700° F, according to the hotleg temperature readings—that pressure could not be raised high enough within the capability of the system to collapse the steam back into water:

> . . . That morning I had recommended against the repressurization because, if the temperatures were true, we could not, in fact, collapse the [steam] bubble. (357)

Nevertheless, the Emergency Command Team directed the operators to repressurize.

REPRESSURIZATION FAILS

To raise pressure, the amount of makeup was increased and the block valve kept closed. By 9:45 a.m., pressure was about the same as at the start of the accident—2,100 psi. However, the steam bubbles did not disappear.

Flint had been right—with temperatures at 700° F or greater, pressure would have to have been raised around 3,000 psi to collapse the superheated steam, a pressure that exceeded the NRC Technical Specifications and approached the maximum test pressure for the system.[116] (358)

Superheat Went Unrecognized

The fact that the Emergency Command Team attempted repressurization shows that its members had not recognized there was superheated steam in the system. There is no evidence to suggest that superheated steam was ever discussed at any of the emergency command team meetings.

Two weeks after the accident, when the management team gathered to record its recollections, Rogers, Miller and Ross discussed the decision to repressurize and the lack of insight into superheated conditions. The following exchanges clearly indicate that this condition had not been a consideration.

> ROGERS: . . . Somewhere around 9:30 you [the utility] started raising pressure trying to collapse the steam bubble. In our stupidity, we thought we could collapse a superheated steam bubble and we weren't even thinking it was superheated at the time.
>
> ROSS: No, we were just trying to pour water into the [legs].
>
> ROGERS: We weren't even thinking about it. We were just trying to push the pressure up with [high pressure injection water] being injected to try and get the thing solid [with water]. We knew we had steam in the loops, and we knew we had to get it moved somehow. And that was our attempt, after a meeting in the supervisor's office, . . . to raise pressure

[112] See pp. 113–114, 116.

[113] See fn. 115 below.

[114] The thesis that the only proximate cause of superheated conditions is core uncovering is now being challenged as a result of events at TMI. Some analysts contend that, following uncovering of and damage to the core early in the morning, superheat was produced in the afternoon by fission products in the primary system hotlegs. See pp. 142–143 on conditions in the afternoon.

[115] One way to rid the system of steam is to subject it to enough pressure that it is forced back into solution in the water. This can be done by adding water to the system, which will cause pressure to increase, or by closing the system, allowing pressure to build as heat to the system is increased.

[116] The pressure at which the reactor coolant system was designed to operate was 2,500 psi; the maximum pressure allowable during hydrostatic testing was 3,125 psi. The Technical Specification limit set by the NRC was 2,750 psig.

to try to inject [high pressure injection water] to move the steam. (359)

It was only after the system reached high pressure without collapsing the steam that some, but not all, members of the emergency team concluded there was superheated steam in the hotlegs. Rogers stated,

> . . . [We knew they had superheat] from the time when they got up to normal system pressure and had the resistance bridge to the RTD's (resistance temperature detector) hooked up] . . . During that period of time with high pressure we concluded and . . . essentially we all agreed we were at superheat. (360)

Miller also indicated repressurization led him to recognize they had superheated steam in the hotlegs:

> . . . We were considering going higher in pressure but by that time we had discussed steam conditions and going higher wouldn't help us . . . We were pumping . . . as high a pressure as we had decided to go, and the water level [was] not charging the system solid, and in fact we were losing water to the reactor building floor.[117] In other words, very hot superheated conditions. (361)

Zewe also said he recognized superheat. Following repressurization, he had consulted the steam tables [118] in the control room from which the properties of steam in the hotlegs could be determined and had concluded that superheated steam was present. (362) However, he said that because control room personnel realized there were steam bubbles in the hotlegs, they were not sure that the hotleg temperature readings were correct. (363)

On the other hand, Logan and Ross said they were not aware of the superheated conditions, suggesting that Miller, Rogers and Zewe did not share their conclusions with the whole team.

Logan said that such a condition was never made evident to him. (364) Ross, who was directly under Miller in operational control of the plant, stated:

> . . . I don't think I ever personally put it together and said, "Jesus, superheated steam." I knew we had a problem; we couldn't fill the loops. I don't think I ever made it to, "Gee, we're superheated."
>
> . . . I don't think I ever deduced anything about superheated steam. (365)

This is a further indication that superheated conditions were not discussed by the entire team. Beyond that, there is no evidence that those who recognized superheated steam in the system ever discussed its origin, its consequences or its meaning in terms of returning the plant to stable conditions.

Why Superheat Was Missed

The control room personnel gave a number of reasons for their failure to analyze the implications of superheat. Zewe explained that he did not know the true temperature of the core itself; he was not aware of the earlier incore thermocouple readings Porter had given Miller. (366) Further, while both Zewe and Rogers said they realized that the hotleg temperatures they were getting, and which they considered reliable, were good indicators of superheated steam in the hotlegs, their statements indicate they also knew their hotleg temperatures were not necessarily useful for understanding the properties of steam in the core. (367)

Rogers explained:

> Question: And you weren't relying on the hotleg temperature as an indicator of the reactor coolant system?
>
> ROGERS: You could not.
>
> Question: Why couldn't you?
>
> ROGERS: Because there was no water passing through the core getting to the hotleg RTD [resistance temperature detector]. (368)

In addition, unlike senior NRC officials later in the afternoon, both Zewe and Rogers indicated they understood that the core could be covered even when temperature readings in the hotlegs signified superheated steam conditions in the higher regions of the reactor.

Zewe was questioned on this point:

> Question: But if you had the core covered would you have expected to have seen that [superheated] condition in the hotlegs?
>
> ZEWE: . . . I think that it is conceivable we could still have water in the core, but still have steam voids in the hotleg because they were above the elevation of the core, and we could have bubbles formed high in the hotleg and have [water] in the vessel; yes. (369)

Rogers explained how he reached a similar conclusion:

> . . . Let me say something that helps [explain] that. In this plant, several months previous to [the accident], dur-

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[117] Water was lost through the stuck-open PORV as the operators opened and closed the block valve to regulate pressure.

[118] See p. 107.

> ing the [hot] functional testing program when the core [was] not installed, a phenomenon had occurred where we had trapped a lot of hot water in the hotlegs, and subsequently had the rest of the system colder. And without the ability to run the reactor coolant pumps, which we did not have at that time, we could not get the heat out of those hotlegs; even with the system filled with water, we could not move any heat from that. It's in a natural trapped condition. So this is not something that really startled me, that I had hot conditions in the hotlegs and the rest of the system lower temperatures. That was not something new to us . . . It was accepted as a condition because of the layout of the plant . . . It has happened at other B&W plants, so it was not a brand new problem.[119] (370)

Neither explanation, however, addresses why they did not discuss past uncovering as the source of the superheated conditions.

Unlike Zewe, Miller did know of some of the incore thermocouple readings, but had discounted them as unreliable.[120] He said he was relying on hotleg temperatures, which he believed were the hottest temperatures in the system:

> . . . The resistance temperature detector I have spoken of was reading around 720 degrees. The cold temperature was reading I think, less than 200. The steam [generator] downcomer temperature was around 500 or so at various times; the RTD [resistance temperature detector] in the hotleg being the hottest . . . At that time I would probably assume the core was somewhere below . . . 700 without knowledge of specifically why. (371)

At the same time, Rogers had incorrectly interpreted the pressurizer temperature as the best indicator of core temperature. He believed it was a better indicator of core temperatures than the hotlegs:

> . . . I accepted that the temperature in the pressurizer was a result of the water coming in through the core and going out through the surge line to the pressurizer. I accepted [it] myself, and a lot of other people were accepting the same thing. . . .[121] (372)

None of the other control room personnel interviewed by the Special Investigation staff mentioned this position. Miller, for example, implied that pressurizer instrumentation as a whole could not be relied on:

> . . . We really didn't trust the pressurizer instrumentation because we knew the condition of the loop being [having] steam bubbles. (374)

Rogers also told Special Investigation staff that he was unaware of any steam condition in the core itself, either during repressurization or at any other time in the day. Nor, Rogers said, was it likely he or others would have deduced that:

> . . . No, I would not say that I knew that we had [steam and water] conditions in the core. We were totally convinced we had steam in the loops, and I believe with what we knew we were putting in there, we would not have assumed that we had steam in the core at that point in time, and probably wouldn't through that day with the information we had anyway. (375)

Both Miller and Rogers gave as a reason for their not recognizing core uncovering as the source of superheated steam their preoccupation with identifying a strategy for returning the plant to stability:

> MILLER: The only action I considered was to maintain core coverage. I don't think I went back and asked myself how we had gotten to this point . . . (376)
>
> * * *
>
> Question: What led to superheat?
>
> ROGERS: . . . in the control room at that point in time and probably throughout the rest of the day we didn't have the luxury nor the need to go back and look at how we got to where we were. (377)

This failure by the utility to establish trends or to look back at causes of conditions was a serious analytical weakness that would be repeated again during the day. It was an obstacle to an effective response by outside agencies, in particular the NRC.

Differing Recollections

Based on the collective recollections of Kunder, Logan and Ross, concern about a steam bubble

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[119] This design problem was recognized by GPU and B&W during hot functional testing of the plant, but apparently was not communicated to operators prior to the accident. See "Prior to the Accident," p. 65.

[120] See pp. 112–113.

[121] In fact, pressurizer temperature was not a good indicator. The evidence suggests that pressurizer temperatures during the accident were hundreds of degrees below actual core temperatures. The relief valves on the pressurizer, as well as the loop seal and the isolation of the temperature measuring devices from the pressurizer vessel, would tend to prevent these devices from registering superheat. Other evidence suggests that Rogers was led to focus on pressurizer temperature as a result of a recommendation from a Babcock & Wilcox task force in Lynchburg, Virginia. (373)

on top of the core and uncertainty over whether the core was uncovered was one of the motivating factors in the next step they would take—depressurization. Logan said, "The determination was made that we . . . had a bubble in the top of the vessel." (378) Ross recalled that this determination was made during the planning for depressurization. (379) Yet Miller, who recalled a concern that flow from HPI was bypassing the core, (380) did not recall any discussion of steam in the core:

> Question: Were you confident there wasn't steam in the core?
>
> MILLER: I don't believe we were confident of that, but I can't honestly remember discussing that . . . We talked about heat removability, I think, more than steam bubbles in the core. . . . (381)

In hindsight, there was an unwillingness among some control room personnel to believe the worst and inadequate communication among those present.

Two weeks after the accident Miller stated that during that first day he "did not admit the reality of failed fuel." (382) Flint has said repeatedly that he told Rogers that morning that the core probably had been uncovered. Rogers, however, said he did not recall hearing that significant information.

Similarly, when Flint expressed his doubts about repressurization, given his belief that the steam in the hotlegs was superheated, he said his advice was not heeded. (383) He was proven correct, but that did not lead to a general awareness of that condition. Nuclear engineers in the plant also had concluded there had been voiding in the core, but members of the emergency command team have not indicated they were aware of that information. Similarly, there is no evidence showing that the opinions of the instrument technicians, who took the incore thermocouple readings and from them deduced core uncovering, ever reached the team. Thus, as the above discussion illustrates, there were both physical indications of the condition of the core and several clear statements about those indications, yet many members of the utility's emergency command team apparently remained unaware of them.

It is also important to recall that some two hours prior to depressurization, Edson Case of the NRC had surmised on his own that part of the core had been uncovered and had expressed this opinion to Commissioner Ahearne. (384) Yet neither the Commissioners nor the NRC emergency response staff pursued this concern directly with the utility or discussed the need for protective action with the State.[122]

FAILURES IN COMMUNICATIONS

At 9:26 a.m., during the time that the utility was repressurizing, Kunder spoke on the telephone with Donald Haverkamp at Region I.[123] Haverkamp asked Kunder to "go through the scenario" of what had happened earlier in the morning. (385) During the conversation, Region I and, through it, IRACT in Washington received some important information.

Kunder told the regional office that the reactor coolant pumps were off and that there was no flow through the primary system. Part of Kunder's explanation went as follows:

> . . . The pressure came . . . all the way down to about 1,000 pounds and that was roughly over a 15 minute span. I think it was during that condition that we . . . got a bubble [or] some such through apparently the heating in the core up in the loops and . . . it apparently had an effect of vapor locking . . . It looks to me [like] we had that vapor locking effect being fed by the heat in the core . . . The problem [then was] trying to get the pressure down low enough so we are sure that the flow is going down into the reactor vessel annulus [124] and up into the core. Vapor lock is apparently preventing that from occurring. (386)

Region I did not report to IRACT that there were steam conditions in the core at that time. This was a serious breakdown in communications that adversely affected the NRC's potential ability to understand the accident. However, Kunder did not specifically tell Haverkamp there was steam in the core; he mentioned only that vapor locking was causing the problems with flow.

When Special Investigation staff read him parts of his conversation with Haverkamp, Kunder responded:

> . . . That's interesting. That's more accurate than I have been recalling. My perception at that time, I think, was, I guess, pretty accurate in the sense that I was aware we had steam in the core and in the hotlegs. (387)

About 15 minutes after IRACT learned that the reactor coolant pumps were off and there was no flow, Region I Director Grier called John Davis. Davis asked whether, given this condition, Grier

[122] See the discussion of evacuation, pp. 132–135.

[123] Fifteen minutes earlier Region I had begun tape recording communications between the site and its office. Thus, there was a record of the conversation.

[124] The space between the reactor vessel wall and the core.

had any concerns about adequate cooling of the core. He replied, "not as long as pressure and temperature continue to come down." (388)

At that very moment the utility was trying to repressurize—to *increase* pressure in the primary system, not bring it down. (389) Grier's statement, viewed in the context of what was actually happening at the plant, typified the communications problems that hampered the NRC's response throughout the morning and early afternoon.

WHAT THE NRC HAD LEARNED

By 9:30 a.m., IRACT had received the following information from the region:

—There was a failure of nuclear fuel. (390)

—There was high radiation in the containment. (391)

—There was increased containment pressure. (392)

—The reactor coolant pumps had been shut off. (393)

—There was boiling water in the reactor coolant system. (394)

These facts indicated that the plant had had significant problems, was still in an abnormal condition and had, earlier in the morning, experienced some problem with cooling the core. This was, in fact, the essence of Edson Case's interpretation of the situation just before 9 a.m. (395) However, NRC headquarters lacked the data the utility and its own Region I personnel had that provided a clearer indication of core uncovering. (396)

THE NEXT STEP: DEPRESSURIZATION

Between 9:45 and 11:30 a.m., the emergency command team decided to depressurize the reactor. (397)

A number of concerns prompted this strategy. Because attempts to achieve natural circulation had failed, control room personnel had been using the make-up pumps to provide water to cool the core. Several said they were becoming worried the supply of cooling water would become depleted. According to Ross,

> . . . We were getting concerned that we were going to run out of water soon . . . [Depressurization] was kind of a rash move, we felt at the time. But we felt it was necessary. . . . (398)

Miller concurred,

> . . . I was concerned with the amount of water. We had hours of water left, but were talking about bringing in the ultimate water sources at the time. (399)

Another reason control room personnel gave for depressurization was that repeated operation of the block valve, used to regulate pressure during repressurization, might cause it to fail. (400)

The most significant reason, however, was uncertainty whether the core was uncovered. The discussion regarding depressurization did not focus on superheat, but rather on the possibility that a saturated steam bubble atop the core might be inhibiting flow through the core. (401)

As Miller recalled,

> . . . We knew there were steam bubbles within some of the pipes. We looked at elevation diagrams, and I remember some of that kind of analysis. There were people in the group throughout the morning who postulated that the high pressure injection [of coolant water] possibly could be by-passing some of the core. (402)

Rogers had the same recollection.

> . . . At some point in time in the meeting which preceded our reducing the pressure again, the question was brought up, "Are we absolutely sure that the high pressure injection water is getting to the core?" "Are we absolutely sure that the core is indeed being covered?" (403)

Following the accident, Kunder recalled a concern of his—that chemicals in the coolant water might be concentrating in the core and blocking the passage of water:

> . . . I know another thing that I was worried about, and I think we all shared the same concern: were we concentrating boric acid in there? (404)

Not all the control room personnel shared the various concerns. Miller, for example, responded to Kunder's statement about the concentration of boron by saying "that never bothered me at that time." (405)

The weight of the evidence suggests that the primary concern was the possibility that the core was uncovered.[125]

[125] The NRC's Special Inquiry Group stated: "At 11:30 a.m., because no one can think of anything else that has not been tried, the decision is made to depressurize the system. Later, it will appear that there are several different perceptions of the precise reasons for depressurizing." (406)

Although parts of this conclusion are correct, on the whole it is misleading. In contrast with this Investigation, the Special Inquiry Group did not point out that there were two separate attempts to depressurize, each with separate

INTERPRETING THE CORE FLOOD TANKS

Some control room personnel said they were looking for a way to assure themselves the core was covered. They had no means of measuring water level directly, and they had long since discounted pressurizer level as a reliable indirect indicator. They reasoned that by depressurizing they could force the core flood tanks to come on and inject water onto the core.

Several members of the management team, in interviews with Special Investigation staff, described how they expected to be able to interpret the behavior of the core flood tanks.

> MILLER: . . . if the core was significantly dry and pressure differential existed, we felt we would push a lot of water into the core. (408)
>
> ROSS: We assumed that if the core was, in fact, very, very empty, and we lowered pressure, that the core flood tanks would inject and cover the core again. (409)

If, on the other hand, the water level was already high, they believed the tanks would inject only a small amount of water, meaning that the core was covered.

Miller, though he said he did not agree with all the concerns, decided to depressurize:

> . . . During that morning the group that I assembled were discussing the fact that we wanted . . . double assurance that the water we were pumping in was covering the core . . . I didn't believe the core was uncovered but I listened to people in my group [who were] looking for double assurance. (410)

DEPRESSURIZATION INITIATED

At about 11:30 a.m., the operators began to depressurize by opening the block valve and decreasing HPI. One hour later, at about 12:41 p.m., the pressure at which the core flood tanks are activated—600 psi—was reached, and they injected water into the core. (411) This continued for 30 minutes. Pressure continued to fall to about 435 psi, just above the 430 psi level that the NRC had been told was the point at which the decay heat removal system would come on.[126] (413) Only a minimal amount of water was dumped onto the core before the tanks shut off—approximately 750 gallons—equivalent in volume to only a minute and a half of flow from one HPI pump.[127] (414)

DEPRESSURIZATION TERMINATED

At 1:10 p.m., the operators closed the block valve, thereby terminating depressurization. The control room personnel said they were convinced that the minimal amount of water injected into the core meant it was covered. Miller, for one, commented:

> . . . We had a foot, foot and a half, of water decrease [in the core flood tanks] and that convinced most people in the group that we didn't have major uncoverage at that point. (415)

Rogers noted:

> . . . That [core flood tank injection] occurred in a way that everyone agreed was an indication of water in the core . . . that was conclusive evidence that there was a water phase in the core knowing full well they had a steam-noncondensible phase in the hotlegs. (416)

According to Rogers, he and some other control room personnel went a step further and concluded that, since the tanks did not dump all their water at once (an event that clearly would have indicated that the core was uncovered at the time), it had never been uncovered at all. As Rogers told the Special Investigation staff:

> . . . I will readily admit that that statement [that the core had never been uncovered] was made quite a few times in the control room at that point in time when we deliberately went down to the core flood tank float condition, the objective being assuring the core is covered. When that occurred more than one person in the control room said, "Hey, the

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objectives. The purpose of the first depressurization, when it was planned, was to ensnre the core was covered, not to bring into operation the low pressure decay heat removal system. As Rogers told Special Investigation staff:

> . . . There was no deliberate action to go to low pressure injection conditions at that point. It was agreed that at some point in time we will want to get there . . . [Bnt] the concern over whether the core was covered is why that action was taken . . . We would want to get the water phase (in the hotlegs) before we [went] to decay heat. (407)

The objective of the second depressurization—to use the low pressnre decay heat removal system—was stated in a conversation between Miller and Ross; the content of their discussion was not generally known, even to control room personnel, until two weeks after the accident. This wonld explain the differing recollections of control room personnel about the purpose of depressurization.

[126] In fact, the setpoint was 320 psi. (412)

[127] It is unclear why so little water was released from the core flood tanks. It could be that the core was covered at that point, or it could have been the result of the effect of steam and gas in the reactor coolant system. See pp. 142–143.

core's covered and it probably has never been uncovered." (417)

It is clear, in hindsight, that they were wrong. Furthermore, there is no evidence that the command team took into account how the core flood tanks would behave in a situation where the core was only partially covered or being cooled by steam. In both cases, depressurization would tend to increase boiling, since water boils sooner at lower pressures. The boiling would in turn increase the volume of steam in the system, which would in turn raise pressure in the system. This would inhibit the flow of water from the core flood tanks, as they empty only if pressure in the reactor vessel is lower than in the tanks. Thus, with a core that was partially uncovered, the core flood tanks would only be able to discharge a portion of their contents, since the injected water would quickly flash to steam, raising pressure and thereby reducing the pressure differential between the core flood tanks and the reactor vessel.

Further, the NRC has pointed out in an early investigation of the accident, that because of the layout of the core flood tank piping, minimal injection by the tanks cannot be interpreted to mean the core is covered. (418) When there are saturated or superheated steam conditions in the system, the core flood tanks can become cut off from the core. The steam can form loop seals in the core flood tank piping which can prevent the tanks from injecting water onto the core even if the core is totally devoid of water. (419)

HPI THROTTLED AGAIN

Shortly after 1:10 p.m., a control room operator's log showed the entry: "Stopped HPI." (420) While the meaning of this entry has never been explained, the evidence shows that over the next several hours the amount of water being added to the system was again throttled to low rates of flow. (421)

THE NRC ONSITE

A five-member NRC inspection team arrived onsite at 10:10 a.m., when radiation in the Unit 2 control room had reached levels that required evacuation of non-essential personnel. Personnel were moved either to the Unit 1 control room, where the Emergency Control Station was being transferred, or to the Three Mile Island Observation Center, a facility for visitors adjacent to the plant on the east bank of the Susquehanna. Those who remained in the Unit 2 control room had to use respirators periodically for the rest of the day. (422)

Miller directed the NRC inspectors to the control room at Unit 1. (423) The NRC team had been sent by emergency vehicle at 8:45 a.m. from the Region I office near Philadelphia, about 85 miles away.[128] It was comprised mainly of health physicists; there was only one operations inspector. (425)

According to the Region I plan, the Project Inspector for the facility "normally" is to be a member of the inspection team and to serve as its leader. (426) However, according to Brunner, because of the erroneous information about radiation releases that morning, the Region thought the problem was largely radiological. (427) The TMI Project Inspector therefore was not included on the team. (428) Instead, the Region decided to monitor the operational problems by telephone from the Regional Incident Response Center. (429)

Once again, misinformation had been transmitted and resulted in an inappropriate response. Further, as will be seen, the presence of NRC representatives onsite did little to improve the flow of communications or the accuracy of the information that was transmitted.

Shortly after the inspection team was dispatched, a two-man back-up team with a second operations inspector left for the site. Later in the afternoon the Region I Project Section Chief for TMI was sent. (430)

INADEQUATE REGIONAL PROCEDURES

The NRC's overall goal is to protect the health and safety of the public. To meet that goal, it is essential that the NRC have the ability to respond quickly in the event of an accident. This basic premise was a lesson the NRC had learned from its analysis of its inadequate response to the Browns Ferry fire of 1975. (431)

Despite that overall goal, the procedures in the Region I plan allowed up to 6 hours before an NRC team had to be onsite, even in the case of the most serious category of nuclear accident. (432) There was, however, another procedure Region I could have followed, given the conditions of the TMI accident. This procedure provided for the dispatch of the inspection team by two predesignated modes of transportation—both by emergency vehicle and by either helicopter or chartered aircraft. (433) Region I decided to use an emergency vehicle only, (434) and although the reactor is located only about 85 miles from

[128] The Plan specifies that emergency vehicle *and* "rotary or fixed wing aircraft" transportation are appropriate in the case of a Level I incident (defined as "an event which has an actual or imminent serious threat to public health and safety, the environment, property, or security and safeguards of licensed facilities and materials) under certain conditions." Those conditions relate to weather, time of day and distance from the regional office. (424)

the regional office, the inspection team did not arrive until nearly two and a half hours after notification. (435)

In correspondence with Special Investigation staff, Boyce Grier, Director of Region I, noted that the second procedure relating to transportation of the inspection team was not a requirement but merely "guidance on selection of the transportation mode." (436) He also wrote:

> . . . Since the team departed Region I at 8:45 a.m. [one hour after notification] and arrived at the TMI–2 control room at 10:05 a.m. [2:20 after notification] the intent of the Plan was met. (437)

In fact, the onsite inspection team did not set up operations in the Unit 2 control room until about 11:30 a.m., nearly an hour-an-a-half after their arrival at the plant during the evacuation of the Unit 2 control room.

Had Region I used air transportation to the site, along with the simultaneous dispatch of an emergency vehicle, the NRC could have mitigated the communications difficulties that were a direct result of the team's arrival during evacuation of the Unit 2 control room.

MORE COMMUNICATIONS PROBLEMS

When non-essential personnel were evacuated to the Unit 1 control room, the original phone connection between the Unit 2 control room and the Region was broken since Warren, the individual manning the phone there, was among those evacuated.

Although a line was established between Region 1 and the Unit 1 control room shortly after the arrival of the NRC onsite inspection team, for a period of about an hour-and-a-half there was no direct communication between the Unit 2 control room and either the Region or NRC headquarters. (438) This was a critical period, a time when there was uncertainty about whether the core was covered, when a new strategy was being planned, and when the dimensions of the accident and what the utility intended to do or was doing to achieve stability should have been communicated directly to offsite agencies.

It was during this period of no direct contact with Unit 2 that the Commissioners asked for hourly briefings from the EMT, unless a significant development necessitated a more immediate call. (439)

Prognosis at NRC Headquarters

At about 10:16 a.m., the Commissioners at headquarters—Gilinsky, Kennedy and Bradford—received the first collective briefing from EMT members Davis, Case and Lee Gossick. With respect to the status of the reactor, Case told the Commissioners:

> I think right now we have the situation under control and we'll have to keep getting information to make sure that continues. (440)

After this briefing, Commissioner Bradford decided to join Commissioner Ahearne at the Response Center in Bethesda. This meant that there were two Commissioners at the Response Center, one at a local hospital and two at NRC headquarters in Washington, D.C.

Others in IRACT and the EMT were conveying the same favorable information about the status of the reactor. At 10:32 a.m., IRACT's Brian Grimes briefed the Director of the Office of Nuclear Reactor Regulation, Harold Denton. Grimes told him that as far as he could tell, the reactor's core was in "a fairly normal status," although it was not clear to IRACT that the operators had reestablished the proper water level in the pressurizer. (441)

During the next briefing of the Commissioners, around 11 a.m., Gilinsky asked whether the reactor was "under control." (442) Case told him:

> The signs are encouraging, Vic. Pressurizer level is up . . . we have coldleg temperature measurements of 220, which is good. We have indications that one steam generator is being used for natural circulation and transferring heat outside the primary system. So signs . . . continue to be good.[129] (443)

IRACT member Harold Thornburg made similar statements when briefing the Regional Directors of the Office of Inspection and Enforcement at about the same time: "They're getting the situation under control," (444) "it looks like the damn thing seems cool now," (445) "it does look like they are cooling the thing." (446)

The Flow of Misinformation

Part of the reason for the transmittal of inaccurate information was that IRACT was getting the wrong information about a key condition—natural circulation. This was contributing to their incorrect analysis of the accident. In addition, they were not getting the proper data on hotleg temperatures. Following repressurization at 9:30 a.m., hotleg temperatures in the "A" loop had increased from about 680° F to 730–740° F, where they remained until about 11:30, by which time the utility had reversed its strategy and was attempting to reach stability through depressurization. (447) There is no evidence that NRC headquarters was made aware of this upward trend in tempera-

[129] On the accuracy of this account, see p. 132.

tures. In fact, for two-and-a-half hours IRACT continued to receive only the hotleg-coldleg *average* temperatures, mistakenly reported either as hotleg or as primary system temperatures. (448)

Misleading conversations between Met Ed employees and NRC officials in Region I contributed to the confusion between average temperatures and hotleg temperatures. Typical was an earlier conversation at about 10:15 a.m. between Kunder in the Unit 2 control room and Region I's Haverkamp.

Kunder told Haverkamp that the unit superintendent in charge of operations, Mike Ross, was certain the core was covered. (449) It is now evident that some control room personnel were, at that time, concerned whether the core really was covered; it was this concern that had led to the decision to depressurize.[130] Kunder did not mention any of these doubts concerning core coverage. Although he did convey the control room personnel's doubts about the hotleg temperatures, in doing so, he mistakenly characterized the average temperature reading of 571°F as the hotleg temperature:

> KUNDER (to Mike Ross in Unit 2 control room): Mike, how does the core look?
> KUNDER (to Haverkamp): [I'm] talking to Mike Ross—he's looking at the indications; his assessment is that he's surely . . . got the core covered and we are getting water . . . into the core. The only thing though is that the T_h [hotleg temperatures] are still high and that's what bothers us; the pressure, and getting control of it, and . . .
> HAVERKAMP: What is your pressure and temperature now?
> KUNDER: The pressure is still up around what I told you, it's holding there, okay: We got a bubble in the pressurizer . . . But he is still baffled by the T hot [hotleg temperatures]; we are really trying to access that. T hot right now is reading 571 degrees F but, again, I am not sure how real a number that is. (450)

At about 11:40 a.m., IRACT received both hot and coldleg temperature readings. The Region reported the hotleg temperature to be 620°F. (451) It did not tell IRACT that 620°F was not a real measure of temperature in the primary system, but merely the upper limit on the scale on the control room console and that the instrument was reading offscale high.

The actual temperature at that point was about 730°F. While the control room personnel knew the reading of 620°F from the strip chart on the console in the control room was inaccurate, there is no evidence that the NRC inspectors who were in the control room or that IRACT in Bethesda knew this until 4 p.m.

The Meaning of Coldleg Temperatures?

IRACT was, at this time, getting accurate coldleg temperatures—in the neighborhood of 220°F. However, IRACT and EMT members interpreted the accuracy of these readings differently. During the 11 a.m. briefing of the Commissioners, Edson Case of the EMT reported the coldleg temperature without mentioning hotleg temperatures or the difficulty in acquiring them. He also told the Commissioners he believed the coldleg reading was "good." (452) Twenty minutes later, in a briefing of NRC Region IV, IRACT's Harold Thornburg stated that the coldleg temperature did not "look right." (453)

EVACUATION

RADIOLOGICAL DATA

Transcripts of telephone conversations between Region I and IRACT show that at 9:08 a.m. the Region informed IRACT that a Met Ed radiation survey team had reported measurable levels of radioactive iodine at the plant's perimeter. (454) The survey team was said to have detected the iodine while measuring a radioactive plume released from the plant. James Sniezek, who was at IRACT that morning assembling and analyzing incoming radiation measurements, concurred with Special Investigation staff that a reading of radioactive iodine from a plume at the site's perimeter would indicate a subsequent offsite release. (455) Indeed, a 9:22 a.m. air sample taken in Goldsboro on the west bank of the Susquehanna River opposite the site was reported to contain measurable levels of radioactive iodine. (456)

Although IRACT learned about the radioactive iodine in the plume over an hour before the NRC issued its first press release at 10:30 a.m., the NRC informed the public in its press release that:

> Measurements are still being made to determine if there has been any radioactivity detected off the site. There is no indication of a release off the site. (457)

Joseph Fouchard, Director of NRC's Office of Public Affairs, was with the EMT throughout March 28. Fouchard said that the information in the NRC's press releases was based on conversations he had with members of the EMT. (458) As noted, the EMT was receiving reports on site

[130] See pp. 128–129.

Personnel plot wind directions to assist in radiation monitoring

status and radiation from IRACT. Fouchard did not recall clearing the press releases with Sniezek at IRACT, but Sniezek indicated IRACT personnel saw extracts of them. (459)

Inaccurate radiological information was transmitted at other times on Wednesday and disseminated to the public, reflecting the inadequacy of both the radiation monitoring around the site and the communications system set up by the NRC to receive data. But, as is discussed below, these problems only partially explain why so little attention was paid to the possible need for protective action in the earliest hours of the accident.

RESPONSIBILITY FOR EVACUATION?

At 11:09 a.m., the EMT reported to the Commissioners by telephone that radioactive iodine had been detected offsite and that the sample was going to be analyzed.[131] Gilinsky, as he would during subsequent briefings, questioned who was responsible for evacuation of the public. (460) This important issue had not been addressed seriously by any group up to this point, despite the recognized uncertainty over core covering.

Davis explained:

> . . . of course, the licensee will analyze them. We will see what the levels are. They'll flow in here, and at some point, as they begin to increase, they would move into emergency measures such as evacuation. But we are a long way from that from what we've got now . . . And that would be through the state.
>
> GILINSKY: But I want to understand who has responsibility here?
>
> DAVIS: Okay. That's through the state.
>
> GILINSKY: So it is the licensee dealing through the state at this point. (461)

It is clear from this conversation that on the first day of the accident, the EMT did not believe

[131] This was the same iodine release Dornsife reported. See p. 135.

the NRC had any role to play in determining the need for evacuation.[132]

During a later briefing, at 1:45 p.m., Gilinsky would learn for the first time of onsite readings of radioactive iodine *above* minimum detectable levels. He again asked what levels of radioactivity would trigger mandatory protective action initiatives:

> GILINSKY: . . . At what sort of levels do you begin to start talking about moving anybody from where they are.
>
> DAVIS (to Brian Grimes in background): At what sort of levels do you begin to evacuate?
>
> GRIMES: Evacuate? Thousands of times higher.
>
> GOSSICK: Thousands of times higher than what we're getting now.
>
> GILINSKY: I see. Okay.
>
> DAVIS: 5 Rem whole body, 25 Rem thyroid type numbers.[133] (464)

PROCEDURES ARE NOT UNDERSTOOD

The above and subsequent conversations reveal a serious deficiency in the NRC's emergency response: its limited knowledge concerning responsibility for protective action and the correct procedures to be followed in determining its need. Two points become clear from the questions and answers. First, the Commissioners had little understanding of who was responsible for recommending or ordering evacuation. Neither they nor EMT saw the Commission as having a role. The Commissioners expressed no awareness of the new guidelines EPA was in the process of issuing with respect to procedures for estimating projected doses and evaluating the need for evacuation.[134] Rather, both they and the EMT were considering the need for protective action only in terms of the relation between the Protective Action Guide (PAG) dose—the "projected dose to individuals in the population which warrants taking protective action"—and an actual offsite radiation reading. This meant, in effect, that they would only have considered evacuation in the event of an actual release of radiation at or above a certain level specified by the PAG. Neither at this time nor at any subsequent time did the Commissioners or the EMT use as criteria for evacuation reactor system status, present or future.

The EPA made clear that PAGs were to be used "*only in an ex post facto effort*" to minimize the risk from an event which is occurring or has already occurred and that under no circumstances were they to be considered as "acceptable doses." (466) In fact, according to the EPA,[134] "there is no direct relationship between acceptable levels of societal risk and Protective Action Guides." (467)

The EPA specifically recommended that PAGs be applied, and decisions of protective action reached, in conjunction with ongoing estimations of *projected* doses. (468) The latest EPA guidance stipulated that these projected doses were to be determined on the basis of specific information, including "reactor system status" or "plant conditions." (469) Implicit in the use of this criterion, and explicitly stated elsewhere in the Manual, is that protective actions such as evacuation can and obviously should be taken before the hazard is already present. (470)

Gilinsky has since acknowledged that the NRC did not clearly understand the EPA guidelines on protective action:

> Question: Was the executive management team, as far as you could determine based on your conversations with them on March 28, in a mode in which the question of evacuation was, one, [solely] a matter of state responsibility; and, two, to be determined on the basis of the EPA [Protective Action] Guides?
>
> GILINSKY: I think the answer to the first part is yes. I don't know that everyone was clear on the EPA guidelines. In fact, I think the answer is they were not. Some people certainly were because there had been a joint task force with EPA in which they participated. (471)

A VACUUM IN RESPONSIBILITY

That there was a vacuum in responsibility at this time concerning determination of the need for

[132] On Friday, the NRC recommended evacuation. Significantly, when that recommendation was made, it stemmed from a single measure of radiation released from the plant, a release (1,200 mR/hr) that was actually smaller than one on Thursday afternoon (3,000 mR/hr). IRACT personnel were aware of Thursday's reading, but apparently the EMT was not because it made no recommendation for evacuation at that time. On Friday, EMT officials recommended evacuation without consulting their support staff at IRACT. Friday's recommendation had no relation to EPA guidelines on projected doses; it was based on a one-time-only reading from a puff release monitored by a health physicist in a helicopter hovering directly above the plant's vent stack. (462)

[133] These PAG dose rate levels are maximum levels at which protective action is mandatory. However, the PAGs also specify that lower range levels (1 rem whole body and 5 rem thyroid) are applicable if there are no local constraints on protective action. Moreover, even lower levels pertain for "sensitive populations" such as women of childbearing age and children. (463)

[134] The EPA had held numerous meetings and discussions on the proposed revised guidelines. The NRC participated on at least one joint task force relating to them. (465) Therefore, the NRC should have had some familiarity with the new guidelines.

protective action is apparent. The NRC saw itself as having no role; it assumed that that function was the State's. Those people within the State responsible for protective action said they saw no reason seriously to consider the matter throughout the day, based on their comparison of the EPA Protective Action Guides and the data on offsite releases they had available. (472) The State was not aware of the new EPA guidelines, nor was it assessing plant status on its own in order to formulate protective action.[135] Moreover, throughout the day, it received assurances from the site that the plant was stable. Dornsife never questioned whether the reactor core was covered. Based upon this belief and the assurances from the utility, the BRP told the Governor that no protective action was necessary. (473)

Had Dornsife known of the uncertainty of utility personnel and the NRC officials about the core being uncovered, he said he would have asked more operational questions, since he believed that extended uncovering of the core was a reason to consider evacuation. (474)

For its part, the utility was monitoring onsite and offsite levels of radioactivity and focused too heavily on them as its criteria for evacuation, rather than on plant conditions. (475) It should be noted, however, that the utility was confused as to actual plant conditions. It is unclear whether the utility would have considered its uncertainty a plant condition to be used as a criterion in considering the need for protective action.

The lack of understanding on the utility's part is exemplified by Dubiel's misreading of a significant indicator of plant conditions—the wide differential in temperatures between the hot and cold legs.[136] Dubiel was in charge of supervising the utility's implementation of the TMI Emergency Plan with respect to radiation protection. Yet he told Special Investigation staff he was not "overly concerned or worried about that condition." (476) Similarly, he believed that because the core flood tanks, when activated that afternoon, had injected only a limited amount of water, the core was covered.[137] (477)

COMMUNICATIONS WITH THE STATE

The difficulties in communications between the State and the utility were the result of an inadequate number of technically qualified State personnel and the utility's deficiencies in transmitting information, as discussed below.

DISJOINTED FLOW OF INFORMATION

A typical example of the disjointed flow of information was Lt. Governor Scranton's 10:55 a.m. press conference. The State was receiving the same kind of misleading information as the NRC, and Scranton expressed optimism about plant conditions, just as the NRC had been. He read a press release that Paul Critchlow, the Governor's Press Secretary, and David Milne, Department of Environmental Resources' Press Secretary, had helped prepare earlier that morning. It stated that "no increase in normal radiation levels have been detected." (478) He had been told that at an earlier briefing; (479) the information was based on what Miller had told Dornsife earlier in the morning.[138] (480)

After the statement was read, Dornsife was called upon to answer technical questions from the press. (481) Just before the press conference, at about the same time the Commissioners learned of the release, Dornsife had heard from Thomas Gerusky, the Director of BRP, that detectable levels of radioactive iodine had been found in Goldsboro. Dornsife had not had an opportunity to tell the Lt. Governor and other State officials before the press conference, but he announced the release at this time. Dornsife said the Lt. Governor and his staff were both surprised and disconcerted. (482)

PERSONNEL AND COMMUNICATIONS

Several things contributed to the communications difficulties between the utility and the State. For one, the State did not have enough technical people who were capable of collecting, coordinating and disseminating radiation information on a 24-hour basis. (483) When TMI wanted to relay field survey data to BRP, often the only person available to take the information was the BRP secretary. (484) The utility personnel who had been evacuated from Unit 2 to Unit 1 said that having to give technical data to a lay person impeded the efficient flow of radiation information to BRP. According to Benson,

> Question: When you were talking with the State, who were you speaking with?
>
> BENSON: I don't recall. Sometimes I felt the person at the State was not too educated in engineering fields. I felt it was a secretary, because she would ask me, was that "gamma." It was really just

[135] See p. 134 for the implications of this condition.
[136] See p. 106.
[137] See p. 130.
[138] Before going to the Capitol Building to brief Scranton, Dornsife had called Miller for more detailed information. Miller explained to Dornsife that the high radiation readings reflected "gap activity" caused by a low-level pressure transient. (A gap exists between the fuel pellets and the Zircaloy cladding surrounding them. Gaseous fission products tend to collect in this space. Once the cladding has been breached—"failed fuel"—these gases are released into the coolant.)

some of their reactions . . . I don't feel the person was up to par on health physics and that sort of thing, more like a secretary. (485)

As pointed out earlier, Dornsife was the sole nuclear engineer in the State's emergency management structure.[139] He had to handle several responsibilities. Among them, he was supposed to assist Margaret Reilly, in charge of environmental matters at BRP, with the radiation monitoring program. BRP's limited resources were being overwhelmed by the sudden influx of radiation data. (487) However, Dornsife also was called on to assist at briefings and press conferences. Accordingly, he was frequently called away from his office and had trouble keeping current. As he noted,

> Sometimes Tom [Gerusky] and I were off at meetings, and it was difficult to—after being away from the office—to come back and get current with what was going on which led to the problem of keeping current with what the plant status was. (488)

Reilly said she found the comings and goings troublesome, especially because she needed their assistance in handling the radiation tasks for which she was responsible:

> . . . Dornsife and Gerusky spent a lot of time out [of the office] going to the Governor's office, briefings, and things like that. I was essentially trying to keep the environment thing going, but one thing I would like to find a way to avoid in the future is having people snapped away like that. (489)

UNCERTAINTY OVER STATE NEEDS

Another factor affecting communications between the State and the utility was uncertainty over what information TMI was to transmit. Dubiel said that he tried to convey the general tone he picked up from the operations people, in addition to relaying radiation information. (490) He noted, however, that it was unclear what information was to be provided and that the plant conditions to be conveyed in the course of making offsite notifications were not clearly delineated in the Met Ed Emergency Plan or its implementing procedures. (491)

Indeed, the plan focused primarily on measurements of radioactivity onsite and offsite and dealt very little with plant status. (492) Transmission of information about plant conditions had been largely restricted to the operability of certain plant systems at the time of initial notification.[140] (493) Further, the plan focused on current levels of radiation, and not on the potential for worsening ones, given changes in plant status. (494) As Dubiel explained:

> . . . There is not explicit guidance to state that if one believes the conditions are going to get significantly worse, or whatever, that additional or more conservative protective actions may be taken. (495)

Throughout the day, the TMI personnel relaying information to BRP were primarily non-operations personnel.[141] Sometimes Dubiel, in charge of radiological protection for TMI, would talk over the Unit 2 phone line, but with the exception of Miller's conversation with Dornsife, (497) Unit 2 operations people were generally not talking directly to the State. Furthermore, as was the case with the NRC, most of the communication was from the Unit 1 control room.[142] (498)

Dubiel described his contact with the State as periodic but not systematic: (499)

> Well, I was periodically talking to them. I don't think there was anything that you would call systematic, . . . I tried to present the status of the plant to the degree that I could understand it, to the degree that any of us could understand. (500)

Dornsife told Special Investigation staff that early on discontinuity in terms of the TMI people with whom he spoke compromised the accuracy of the information he was receiving:

> . . . I was aware that up until I was briefed by Gary Miller [around 9:30 a.m.] that I was getting somewhat disjointed information . . . I was aware I wasn't getting real accurate continuous information. (501)

Finally, Dornsife noted that at times it was difficult for BRP to get through to TMI. BRP personnel continuously monitored their end of the open line over a speaker phone, but TMI employees only picked up their end every 15 or 30 minutes. (502) Sometimes BRP would have to get their attention by shouting into the phone or by calling an outside line and asking a Met Ed employee to pick up the open line. (503)

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[139] In addition, Dornsife had worked more than six months in the Burns and Roe home office on the TMI-2 design, and then spent more than six months onsite in 1976. During the licensing process for TMI-2, all of Dornsife's time was spent reviewing TMI-related licensing documents. (486)

[140] For Miller's assessment, see Addendum 19, p. 159.

[141] See also Addendum 20, p. 159.

[142] After the evacuation of Unit 2, nearly all communications were with non-operations staff in Unit 1. (496)

QUALITY OF THE DATA

Despite these problems, Dornsife did not question the veracity of the information he was receiving:

> We think the utility was being perfectly candid with us. We were asking questions and they were giving us what we still feel was accurate information. (504)

But the utility's ability to respond was limited by its confusion over plant conditions, the rapidly changing parameters and the state of crisis. Gary Miller recalled two weeks later:

> One thing . . . that stands out clear in my mind, is that as the emergency director and station manager during that day, I was consistently pulled to the phone by senior persons in the State Government, the NRC, and my own management, both here and in remote locations. This caused the pressure to be intense, as it was very hard to concentrate on what I considered to be a very serious situation . . . I felt strong in my obligation to the public and to making sure that there was no [radiation] emissions and that there was evacuation in plenty of time if that was required. But the phone, the pressure, the fact that the plant was in a state that I had never been schooled in combined to make it almost intolerable. (505)

NRC'S INTERNAL COMMUNICATIONS

Meanwhile, the NRC was still having difficulty with its internal communications, difficulties that did not diminish until late in the afternoon. Because of delays in getting briefed on what had occurred, in setting up the utility's Emergency Control Station in Unit 1, and a shortage of respirators in both units, an hour-and-a-half had passed before two members of the onsite inspection team could enter the control room at Unit 2, where the accident was being managed. (506)

Once they arrived in Unit 2, communications were reestablished between Region I and the Unit 2 control room, with the NRC inspectors manning the link. This link would be NRC headquarters' only one with Unit 2 until 4:30, and, again, it was indirect. At 12:30 it finally established a direct, 3-way line that incorporated both the region and the site, but the link-up at TMI was to Unit 1. (507)

Both these communications channels were to prove unsatisfactory. For example, for the first time, shortly after 12 noon, the NRC asked that the regional office inquire about incore thermocouple temperatures.[143] (508) Three-and-a-half hours passed before there was any follow-up on this question. The NRC headquarters was unable to get incore thermocouple readings, the direct indicator of core temperatures, and continued to receive inaccurate hotleg temperatures, the indirect measure.[144] (509)

The NRC's problems in communicating with the plant through Unit 1 are illustrated by an exchange at 12:27:

> REGION 1: What are some of their [the operators] ideas that they are using, you know, relative to handling this situation, you know?
>
> INSPECTOR IN UNIT 1 CONTROL ROOM: I have no idea because we are in the other control room, you know, that's all going on [in] the other unit's control room. (510)

Erroneous information was transmitted even after the three-way communications link was setup. In an early conversation over this line, Chick Gallina, one of the NRC onsite inspectors, reported the following from Unit 1:

> GALLINA: Okay, the reactor pressure is 500 [psi].
>
> IRACT: Got it.
>
> GALLINA: Temperature—250 [°F]. Okay?
>
> IRACT: Got it, thank you. (511)

The information was in error. Temperature in the primary system at 1:30 p.m. was not 250°F; only the coldleg approximated this temperature. The hotleg was hundreds of degrees higher.

This incorrect information was quickly transmitted to the Commissioners. At their 1:45 briefing, Case and Davis, on the basis of the last erroneous hotleg temperature readings, told Commissioner Gilinsky and several members of the Commission staff the following:

> CASE: . . . system pressure has gone down from 2000 [pounds] to . . . 500. Temperature is 250 degrees. Shortly they ought to be going on the [cold] shutdown decay heat removal system which can be activated at 450 pounds [sic] . . . So they are reaching the point where things will get stable in the primary system.
>
> GILINSKY: Okay. So how do you feel about the fate of the reactor?
>
> CASE: I feel good. Now I get the impression that it's stabilized or directly approaching a stabilized situation. (512)

* * *

[143] See Addendum 21, p. 159, for the text of the conversation.
[144] See Addendum 22, pp. 159–160, for an example of the inaccurate transmission of hotleg temperatures.

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NRC STAFF: . . . the hotleg, coldleg situation, is there anything new on that?

DAVIS: As I understand they're both reading 250 degrees. (513)

Throughout the early afternoon, IRACT was receiving its information from, and relaying questions almost exclusively through, NRC inspectors in the Unit 1 control room or in the regional office.[145] Region I was having difficulty acquiring accurate information from the onsite team and transmitting it to headquarters. And neither was responding effectively to State needs, as reflected by communications among the State agencies, or to the public.

A DECISION TO DEPRESSURIZE AGAIN

Sometime after 1:10, the emergency command team again decided to depressurize; on this occasion, the intent was not to assure the core was covered, but rather to reach the point at which the low pressure decay heat removal system could be used.

This objective was not widely known within the control room at the time. Miller, Ross and Rogers, in a meeting two weeks after the accident, discussed their perceptions of the motive behind the second depressurization:

> MILLER: We were kidding ourselves. We were hoping for decay heat, you know it?
>
> ROSS: That's where we were going . . .
>
> MILLER: That's [expletive deleted] [un]believable!
>
> ROSS: . . . I was just making a run for decay heat.
>
> ROGERS: No. No. We didn't want to go to decay heat, not with those legs full of steam.
>
> MILLER: Ross and I did.
>
> ROSS: We talked about it.
>
> MILLER: We say that as our . . .
>
> ROSS: . . . our only hope. (515)

THE HYDROGEN BURN[146]

At 1:50 p.m., Zewe directed the operators at the front panels in the control room to open the block valve to begin depressurization. As it was opened, pressure in the containment shot up dramatically, reaching 28–31 psi, according to a strip chart.[147] Since the start of the accident, containment pressure had never been greater than about 4 psi. (516)

Mehler was in the shift supervisor's office at the time. He looked out into the control room:

> What I noticed [was] the people started to move a little faster, they were securing pumps. So essentially, I thought we had an ES again, which is an emergency safeguard [actuation], but I didn't know whether it was [due to] low pressure [in the primary system] or reactor building [containment] pressure. I have never seen reactor building pressure go that high. We went out to see what was going on. (517)

The Spray Pumps Come On

Mehler left the office and went over to the control panels where Zewe, Shift Supervisor Joe Chwastyk, Mike Ross and the operators were standing. There he saw something he said he had never seen before. (518) Indicators showed the containment spray pumps were running. He explained:

> . . . To start spray pumps [in the containment building] you need 30 pounds of pressure . . . and they were running. I couldn't believe that. I looked at them [the spray pump indicators]. I walked over and looked at the [pressure strip] charts and that's when I saw the line straight up and straight down. It looked like somebody played with the transmitter. It couldn't have been that [because] we wouldn't have gotten the spray pumps. (519)

The spray pumps never before had come on at Three Mile Island, and by the afternoon the news had spread to Unit 1. (520)

Mehler told Special Investigation staff that when he was at the control panel, he was standing beside an NRC inspector, whom subsequently he said he could not identify.[148] The inspector asked why the pumps were running. Mehler explained that they were designed to lower containment pressure and were activated at 30 psi. (522) He pointed out the spike on the pressure chart. According to Mehler:

> . . . He [the inspector] asked me why I was concerned because the spray pumps

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[145] IRACT personnel were aware, at the time, of the limitations in the communications system. (514)

[146] Because of conflicts in the recollections of those present, it is not possible to reconstruct a consistent account of what occurred in the control room at 1:50 p.m. In general, evidence adduced by the Special Investigation supports the findings of the NRC's Special Inquiry Group, which explored the issue in far greater depth than any of the other investigations. What follows is a synthesis and summary of a large body of contradictory evidence.

[147] The chart is difficult to read at a glance and has been interpreted variously as having read 28–31 psi. The containment is designed to withstand a pressure of 60 psi.

[148] Mehler attempted to identify the inspector for the NRC Special Inquiry Group. His description did not fit any of the inspectors in the control room. (521)

were running. I told him they would only start at 30 pounds. I walked over to the chart; 31, it was straight up. I looked at it and said, "That's impossible." I showed it to him. He didn't know what was going on. All he did was write down what we told him . . . Then he went back in the office after we secured from all that. (523)

The Pressure Spike

As noted, there had in fact been a sharp increase in containment pressure—a so-called containment pressure "spike," and pressure had gone to 28–31 psi. With the containment spray pumps running, containment pressure decreased rapidly, and in about five minutes the spray system was shut off.

Most of those who were aware of the pressure spike attributed it to an electrical malfunction in the instrument. (524)

Zewe said:

> . . . My first reaction was I stepped back and looked at it [the pressure spike] and said "What in the world was that?" to all that were there . . . I conversed with the other shift supervisor there and also Mr. Ross, who was there, and we concluded that it was just some phenomenon, some voltage spike or transfer that affected the recorder or pressure indication. (525)

The spike had resulted from the rapid combustion of hydrogen within the containment. The hydrogen had been produced during the earlier period of core uncovering, when core temperatures were in excess of 2,500° F.[149] Hydrogen was released to the containment when the block valve was opened to vent or control pressure.

A Strange Noise

There were other symptoms of the burn. Miller, Logan, Dubiel, Rogers, Flint and a Met Ed engineer named Walter "Bubba" Marshall also were in the control room, but not at the front panels. At the time of the pressure spike, they heard a noise that was inaudible to the people at the control panels. (527)

Whether the noise was caused by the hydrogen burn has been the subject of considerable post-accident analysis. Miller and Dubiel stated they commented on it at the time:

> MILLER: . . . I was aware of a noise . . . and in fact, I believe I asked, "What was that?" in fairly strong language. (528)
>
> DUBIEL: . . . I said, "It sounded like the ventilation system." (529)

According to Ross, Miller then spoke with him:

> . . . [Gary] said, "Did you feel that or hear that," something to that effect. I said "no." In fact, I remarked to him, "This is not the time to get nervous . . ." I speculated the noise he heard could have been the ventilation. He seemed to think it was right above him in the duct work. (530)

To Miller, that explanation seemed reasonable:

> . . . I did not closely evaluate [it] because I was told, I believe, that it was a ventilation system which was changing modes and did make a thud-type noise [when that occurred]. (531)

Others who heard the noise also concluded it was the ventilation system. (532)

The Special Investigation staff found that the noise probably was made by the ventilation system. There are butterfly valves directly over the control room which could have been thrown shut when the emergency safety system was actuated because of the high pressure in the containment building:

> Question: Well, if the ventilation system were on at that point in time, and ESFAS [emergency safety systems] came on, wouldn't that close the dampers?
>
> Ross: That would put it on recirc[ulation], yes.
>
> Question: Might that have been what he heard?
>
> Ross: It's possible, very possible. I hadn't even thought about it, but it's very possible. (533)

After hearing the noise and concluding that it was the ventilation system, Flint glanced over the control panels, where he learned that the operators were concerned about a pressure spike. He noted that they were checking "the possibility of an electrical problem." (534)

Dubiel also had moved closer, over to the far left panel on the console. He overheard the operator in front of the spray pump controls indicate that they had come on. A short while later he looked at the strip chart and noticed the spike. (535)

Ross, after speaking with Miller, looked over at the control panels. He found the same things as the others. Since the pressure immediately went back to zero, he said, "We didn't try to analyze or deduce. We wrote if off." (536)

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[149] See p. 108 for a description of the production of the hydrogen. The 2,500° reading is known from the incore thermocouples (see pp. 113–114). However, core temperatures were certainly much higher. The President's Commission estimated temperatures in the core to have reached 4,350–4,500° F. (526)

The Symptoms Are Not Understood

Rogers said that "just about everyone in the control area heard the noise." (537) Zewe said he could not understand how anyone could have overlooked the other indicators—the pressure spike and the activation of the spray pumps:

> . . . I cannot honestly see how . . . anyone that was there that had any concern at all could overlook [those indications] because we certainly stopped everything, and that was the main thing that was in progress at that point in time. (538)

Yet Zewe, Ross, Mehler, and operators at the console said they heard no noise, and Rogers, Miller and Logan stated they were not aware of either the pressure spike or the spray pumps. (539) George Kunder and the two NRC inspectors in the control room said they were unaware of any of these phenomena. (540) The evidence suggests that Flint, Marshall and Dubiel were the only ones in the control room to have heard the noise and who also were aware of both the spike and activation of the spray pumps. (541)

Only Chwastyk and Mehler have said they recognized that the spike reflected a real increase in containment pressure. Chwastyk was the only one who said he concluded it was the result of a "hydrogen explosion." (542)

There is conflicting evidence as to whether Miller was made aware of the pressure spike or the actuation of the sprays before he left for a briefing of the Lt. Governor at around 1:55 p.m. He has consistently maintained that he was unaware of either event.

The contradictory evidence stems in large part from testimony and statements made by Chwastyk and Mehler that they believed Miller was informed of the hydrogen burn or related phenomena. Chwastyk testified before the NRC Special Inquiry Group (SIG) that his "best recollection" was that he told Miller they had experienced "some sort of explosion." (543) He stated that he believed his conversation with Miller occurred in the context of discussing an attempt to reestablish a bubble in the pressurizer.

Miller and Ross both testified before the SIG that they were unaware of any such attempt, which appears to have led the SIG to doubt whether Chwastyk actually mentioned the burn to Miller that afternoon.[150] (549)

Similarly, although Mehler and Chwastyk recalled discussing the event with an NRC inspector, neither of the two NRC inspectors in the Unit 2 control room at the time recalled being aware of the pressure spike, actuation of the pumps or any of the other phenomena related to the hydrogen burn. (550) One, James Higgins, who indicated he would have been the more likely of the two to look at the panel with the strip chart, said his first knowledge of the spike came on Friday morning, March 30. He noted that at the time he might have looked at the strip chart, visible through a window approximately four inches wide, shortly after the spike was recorded:

> ... and the spike would have been there and I would not have considered it significant. I may have just looked at where the reading was at that time, knowing that it had been 2 pounds the last time I looked at it and it is now reading 1 [to] 3 pounds ... It was always the type of thing where I had a backlog of about 40 questions I was supposed to answer for the people in Washington. (551)

There is evidence suggesting that Higgins did look at the chart. A Region I "Incident Messageform" shows that at 3:45 p.m., Higgins reported containment pressure of 0 psi to the NRC, five minutes before the segment of the strip chart showing the spike would have disappeared from view. (552) In his report to the Region he made

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[150] Rogers told Special Investigation staff that when he was looking at the steam tables (presumably in the afternoon), it was in relation to an attempt to redraw a bubble in the pressurizer, lending credence to Chwastyk's recollection of the timing of his discussion with Miller. (544)

Mehler told the SIG that he thought he had informed those who were in the shift supervisor's office of the spike, and that Ross and Miller were among those present. (545) However, Ross told Special Investigation staff that he was out in the control room at the time of the spike, where he discussed the thump with Miller. (546)

The matter is further complicated by other contradictory evidence. See, especially, NRC Special Inquiry Group, Vol. II, Part 3, pp. 138–152. The SIG concluded:

> Based on the weight of the evidence, it appears more probable that if Miller learned of the reactor building pressure increase, it was in the context of an indication that was not understood or was discounted as an electrical malfunction, rather than as a possible hydrogen explosion. If Miller was in fact informed of the pressure increase or was aware of it at 1:50 p.m. on March 28, it is impossible to determine from available testimony whether it is most likely that he subsequently forgot the event, or if he simply failed to take account of what was happening, or if he has testified falsely about not recalling learning of it at the time. (547)

On March 21, 1980, the NRC Commissioners directed the Office of Inspection & Enforcement to review the transfer of information between the utility and the NRC to determine whether a further civil penalty to Met Ed is justified. (548)

no reference to a spike, even though it would have been visible at the time.[151]

The Hydrogen Burn Is Real

Days later, when the control room strip charts were analyzed, the utility concluded that there were too many redundant indications from the control room instrumentation for the hydrogen burn to have been anything but real. (554)

The containment building had automatically isolated again, the containment sprays had come on, emergency core cooling was initiated automatically at full flow, and the wide-range pressure recorder, which is tied to containment pressure, had a small spike on it. (555)

Each of these indications appeared on instruments in the control room. The evidence suggests that confusion in the control room over the source of the thump and over persistent electrical problems around that time diverted attention away from those indicators. (556)

There is no direct evidence of any deliberate effort by utility personnel to conceal from the NRC, the State or the public information on the hydrogen burn or on uncovering of and damage to the core.

Rather, failure to recognize the hydrogen burn and its meaning can be partially explained in the context of several other factors. One was a disruption in the management of emergency operations at the plant when, around 1:55, Miller and Kunder left to go brief Lt. Governor Scranton in Harrisburg.[152] Another involved the incore thermocouple readings. As noted, Miller and Porter had discounted them as unreliable. At the higher temperatures indicated by the thermocouples, fuel failure was inevitable, as was the generation of hydrogen. Instead, the hottest temperatures of which Zewe, for one, was aware were the hotleg readings in the neighborhood of 800°F. He and some of the other control room personnel said, therefore, they did not suspect that the threshold temperature for a zirc-water reaction (1,600°F) had been passed. (557)

ARNOLD QUESTIONS CORE STATUS

At approximately 2 p.m., 10 minutes after the spike, Rogers and one of the plant managers were in the shift supervisor's office talking by telephone with GPU Vice President Robert Arnold. The conversation centered on his concern whether the core was covered. Arnold recalled speaking with Rogers and someone else, whom he believed to have been Logan. (558) This telephone call might explain why Rogers and Logan said they did not learn of the pressure spike or activation of the spray pumps during the first day.

Arnold was assured by the two the core was covered on the basis of the experience with the flood tanks. As he recalled:

> ... They felt at the time that they [had] sort of passed the crisis, as it were, and the core flood tanks were indicating that the core was covered, the system was full [of water]. (559)

Arnold said he questioned their conclusions:

> ... I believe I indicated to [them] at that time my uneasiness as to whether that, in fact, was that reliable an indication and told them I thought they ought to review very carefully whether or not in fact they had the core uncovered ... certainly my impression was both a plant staff member and Lee Rogers were confident the core was covered. My recollection was the comment was made they didn't think it had ever been uncovered. (560)

DEPRESSURIZATION FAILS

Ross and Miller's attempt to bring reactor pressure down to the point where the decay heat removal system could be brought on lasted a little over an hour. At 2:34 p.m., pressure fell to 410 psi, 25 psi below the lowest pressure achieved previously. The core flood tanks again injected water onto the core. It is estimated that this injection lasted two minutes and added another 165 gallons of water to the primary system. Pressure, however, not only stopped falling, it rose 10 to 15 psi, leveling off at 420–425 psi. It remained at that level until operators closed the block valve at 3:08 p.m., terminating the attempt. (561) The inability of the utility to bring pressure lower was not reported to the NRC for several hours.[153]

Why Pressure Stabilized

One of the continuing mysteries of the accident is why pressure could not be lowered further, even with the block valve open. A number of plausible theories has been advanced.

One is that superheated steam was being produced while the core was uncovered, tending to keep pressure up.[154] (562)

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[151] There were a number of electrical instruments that malfunctioned at about this time because of a loss of power in two electrical busses.

In explaining to the Special Investigation how he might have looked at the four-inch-wide pressure strip chart without noticing where the needle had gone before, Higgins referred to spikes on other monitors caused by electrical malfunctions in plant instrumentation. (553)

[152] This is discussed further on p. 144.

[153] See p. 143.

[154] See p. 107 for an explanation of the phenomenon.

Another, held by analysts at the Nuclear Safety Analysis Center (NSAC),[155] is that the amount of cold water being added to the core through HPI was sufficient to balance the steaming in the hotlegs, causing pressure to stabilize. (563)

The primary difference between these two theories is where they say the interaction of steam and water occurred—in the core or above it.

As on previous occasions, control room personnel had differing recollections about the purpose of depressurization and why pressure would not go lower. Rogers said he was not aware that pressure could not be taken lower because he was not aware that Miller and Ross were attempting to bring on the decay heat removal system.[156] Rogers told the Special Investigation staff:

> ... I am saying that [the fact that pressure could not be taken lower] was not information that was readily known at the time [because it was not readily known] that we were going to go any lower. (564)

Zewe, on the other hand, attributed the inability to lower the pressure to saturated conditions in the primary system:

> ... as I recall, we were unable to get below 410 to 420 pounds ... We kind of deduced [that was] because of saturation pressure in the cooling system at the time. (565)

Ross, Zewe's supervisor, had no recollection of analyzing the difficulty in those terms:

> I was aware we were hot; I don't think I was aware that we were actually superheated in the steam. I don't think I ever deduced anything about superheated steam. (566)

Ross could not recall any analysis that afternoon of why pressure could not be brought lower during depressurization:

> ... I don't think we ever said, "Why won't the pressure go any lower?" I don't think we ever sat down and said, "Why won't it go any lower?" I don't think we ever analyzed that. (567)

HOTLEG TEMPERATURES

Another related mystery concerns the measurements of temperatures in the hotlegs during this period. These temperatures had fallen dramatically after the hydrogen burn. Those in the "A" loop dropped sharply from about 715°F at 1:45 p.m. to about 460°F by 3:15 p.m. When they reached 620°F, they came back onscale on the control room console monitor. They also fell between 3 p.m. and 3:15 p.m. to the point where superheated steam was no longer indicated in the hotleg. However, after 3:15, following closure of the block valve, they increased to the point where superheated conditions were again indicated. They remained there until about 5 p.m.[157] Still unresolved is whether this indicated a second uncovering of the core or is attributable to other factors.

In the judgment of Special Investigation staff, neither the President's Commission nor the NRC Special Inquiry Group has fully explained this phenomenon.

Analysts at Battelle Columbus Laboratories, who performed the analysis for the NRC Special Inquiry Group, postulated that the return to superheated conditions resulted when the hot piping in the system heated the steam and gas in the hotlegs to that point. (568)

According to analysts at NSAC, the temperature fluctuations can be explained by the heating effect of fission products plated along and throughout the primary system—fission products that were distributed throughout the system, including the hotlegs, following uncovering of and damage to the nuclear core early in the morning.[158] (569) The effect of such plating would be to provide a source of heat for the production of superheated steam throughout the system, and not just in the core. This plating

[155] See "Glossary of Organizations," Appendix F, p. 381.

[156] See p. 138.

[157] The correlation between the hydrogen burn and the simultaneous temporary unblocking of the hotlegs has not been explained.

An analysis of the plant data shows that the hotleg temperatures began to converge with the temperatures of the coolant in the surge line (the pipe running from the hotlegs to the pressurizer) following the hydrogen burn. By 3:08 p.m., when the second attempt at depressurization was concluded, both the surge line and the hotleg temperatures were at the boiling, or saturation, point. Thereafter, the hotleg again showed superheated steam conditions, while the surge line remained superheated or at the boiling point until a later decision to repressurize.

The hydrogen generated during core uncovery early in the accident is assumed to have accumulated in the hotlegs and to have mixed with the superheated steam there, helping to block the flow into the steam generator and contributing to the stagnant, superheated temperatures in the hotlegs. Special Investigation staff theorize that when the pressure spike occurred at 1:50 p.m., after the opening of the block valve, hydrogen gas in the hotleg may have been vented out through the pressurizer, allowing flow to return through the hotleg and causing the temperatures to fall. Readings once again appeared on the resistance temperature detector, the hotleg temperature measuring device, which for awhile may have reflected temperatures of coolant flowing through the core.

[158] See p. 124 for further details on plating.

could have further heated the water and steam in the hotlegs to superheated temperatures.

Analysts from Battelle Columbus Laboratories find this theory to be implausible. (570)

A POSSIBLE SECOND UNCOVERING

It is also possible that the superheated temperatures reflected a second uncovering of the core. That could explain why the hotleg was filled first with saturated steam and then again with superheated steam.

In analyzing the question of a second core uncovering, the staff of the Special Investigation attempted to calculate the rate at which coolant was injected onto the core.

The second depressurization took place from 1:15 p.m. to 3:08 p.m. Using the NRC figure of an average flow rate of 150 gpm for the entire period from 1:15 p.m. to 5:20 p.m.,[159] along with other data, the staff estimated that the average net flow rate for the first two hours was about 100 gpm of water. (571) This is only 30 gpm greater than the net average flow during the morning hours when the core is known to have been uncovered.

There are, however, several considerations about conditions during this time. First, decay heat was lower during the afternoon. Second, the amount of water then being released through the let-down system is not accurately known. Finally, in general it is very difficult to estimate and compare flow rates at various times based on the available data. Thus, it is hard to use the estimated rate of flow to determine whether the core was uncovered.

There is insufficient evidence for the Special Investigation staff to conclude which, if any, of these theories is correct.[160] Such a determination may be possible when the core can be examined directly.

WHY HPI WAS THROTTLED

While the calculations of the NRC and Special Investigation staff provide only estimates of actual flow rates, they still raise the question of why utility personnel throttled the amount of water delivered to the core to such an extent.

After the first depressurization, a number of utility personnel had concluded (based on the minimal injection of water from the core flood tanks) that the core never had been uncovered. Thus the control room personnel believed they could use the make-up pumps to cool the core, even at low rates of flow:

> Ross: We felt that we had the core covered; we felt that we were cooling the core with the High Pressure Injection which we maintained throughout this time. (573)
>
> Miller: That day, I don't feel from 7 in the morning on[,] that we felt we had uncovery or maintained uncovery. I don't think we had the time to think about the hours before that and what they might have done to the condition of the core. We knew they damaged it, and we knew the systems we had [High Pressure Injection] were the only systems we had, and they were working effectively.[161] (575)

RIGHT HOTLEG TEMPERATURES . . .

The transcripts of the NRC tapes show that IRACT received another report on hotleg temperatures at 2:20 p.m. According to the evidence, this was the first accurate one received since the beginning of the accident. The temperature was said to be 600°F, reflecting the return to onscale readings on the control room console.[162]

Even that lower temperature, when viewed in conjunction with primary system pressure, indicated superheated conditions.

Thirty minutes later a hotleg temperature of 550°F was reported; it also reflected superheated conditions. This report was to be the last received by IRACT over the next several hours.

. . . BUT OTHER MISINFORMATION

Although the NRC was at last getting accurate hotleg temperature readings, it still was not getting accurate information on natural circulation. At about 3:15 p.m., TMI Unit 1 Shift Supervisor Greg Hitz informed IRACT that the plant was being cooled with natural circulation at a rate of 3°F per hour. (576) In fact, for the next four-and-a-half hours, there was little or no heat transfer by natural circulation through the steam generators.[163] (577) More important, there was a pe-

[159] See Addendum 23, p. 160, for the NRC's calculations.

[160] There was also an unexplained slight upward trend in the source range neutron monitors during the afternoon hours. However, the monitors do not appear to have behaved as they did in the morning when there is no doubt the core was uncovered. If the core were uncovered again during this period, it was probably a result of depressurizing without providing sufficient high pressure injection to the core. (572)

[161] At this writing, NSAC is in the process of preparing a report, to include estimated high pressure injection flow rates during the accident. (574)

[162] See p. 142, text and accompanying footnote.

[163] There was very minimal natural circulation, not enough to state it was successfully established.

riod after 3:08 p.m., when the core was not being cooled at all by natural circulation. As noted, the hotleg readings indicated the core may have been uncovered again: temperatures in the hotlegs returned to stagnant, superheated conditions, and there was no flow through the primary system. (578)

COMMAND TEAM FRAGMENTED

As described earlier, during the second attempt at depressurization, Miller, the Station Manager and Emergency Director, and Kunder, Superintendent of Technical Support, left the plant and joined Jack Herbein, Met Ed Vice President for Generation, to go to Harrisburg to meet Lt. Governor Scranton. (579) As part of Scranton's efforts to understand what was happening at the plant, he had requested that Walter Creitz, President of Met Ed, provide an authoritative report from someone with firsthand knowledge of plant conditions. (580) Scranton's office had not asked for any particular individual, and it is unclear who decided that Miller was the appropriate person, despite his role at the plant. Herbein said:

> I felt it was appropriate to take any member of the plant staff with me for response to any detailed questions regarding plant status that might arise in our session with the Lt. Governor.[164] (583)

BRIEFING STATE OFFICIALS

According to Paul Critchlow, the Governor's Press Secretary and Communications Director for the State, the meeting was strained because it appeared that Herbein was not planning to tell the State of radiation releases that had occurred earlier that day. (584) At a press conference at the TMI Observation Center prior to leaving for the State Capitol, Herbein had not mentioned them. (585) Critchlow said that State officials were very concerned, as they believed they should have been notified so that they could take whatever precautions were necessary. (586) As it was, they had received the information from the Bureau of Radiation Protection, which had detected the radiation.

At the briefing, Herbein was confronted on this issue. Critchlow described the situation:

> [Herbein] was asked, "Why didn't you tell the press?" He said he had never been asked, or the question did not come up, or something like that. That immediately led to a very quickly developing caution on our part in dealing with Metropolitan Edison. (587)

Miller was noticeably upset and said very little at the briefing, according to Mark Knouse, Scranton's Executive Assistant. (588) Miller remembered spending much of the time in the Lt. Governor's office on the telephone, talking to the Unit 2 control room where he had left Logan in charge:

> Most of the briefing was done by Jack [Herbein]. I was there initially . . . and for the most of that meeting I believe I was on the phone to the plant . . . I was probably missing from half of that meeting. (589)

Dornsife had not been invited to the 2:30 p.m. briefing and did not learn of it until it was in progress, (590) even though he was the only State official equipped to deal with the technical information being provided by the utility's operations staff. His absence is even more noteworthy because Dornsife accompanied Scranton to a television interview at 2 p.m. in the Capitol building. He then returned to his office across the street. (591)

DISILLUSIONMENT WITH MET ED

At 4:30 p.m. Scranton conducted his second press conference. He wanted to place the population on alert without alarming them. (592) He made it clear at the press conference that he had become disillusioned with Met Ed and was suspicious and mistrustful of the utility. (593)

Until then, Met Ed had been Scranton's primary source of information. Having lost confidence in the utility, Scranton and his staff sought another source of reliable information. They turned to Gallina and James Higgins of NRC Region I, who would later provide briefings for the Lt. Governor.

The first such briefing occurred at 8 p.m. Nat Goldhaber, Lt. Governor Scranton's Administrative Assistant, indicated that the State found the two NRC officials to be a great improvement:

> . . . we felt that we were getting more accurate information, more complete information, and more technically qualified information than we had been getting earlier during the day . . . The presence of those specialists from a governmental agency lent a certain feeling of confidence in the reliability of the data that they were providing. (594)

[164] Herbein's recollection differed from those of both Miller and Kunder. Miller told the NRC that Herbein had directed him to leave the plant for the briefing and that he had expressed his concern about departing. Kunder also recalled that Herbein had "wanted Gary to go along and Gary said he wanted me to go along so I could back him up with any answers to technical questions." (581) Herbein told the Special Investigation, however, that he "asked Gary to release George Kunder" and that Miller "felt [that] if George was going to go, then he ought to accompany me also." (582)

THE NRC AND PLANT CONDITIONS

By 4 p.m., at least one senior NRC official—Victor Stello—believed the information received by IRACT in the afternoon indicated the core might be uncovered. (595) Since around 1 p.m., IRACT had been receiving hotleg temperatures and primary system pressure readings that, if true, indicated to Stello that the reactor core was uncovered. (596) He was still waiting for the incore thermocouple readings he had requested before noon to verify the hotleg temperatures and confirm or invalidate the indications of superheated steam in the hotlegs and whether or not the core was uncovered. (597)

INCORE TEMPERATURES REQUESTED

At 4 p.m. IRACT had still not received any word on the incore thermocouples. Via the three-way IRACT-Unit 1-Region I telephone line, Mike Wilber, the IRACT Field Communicator, at Stello's request, raised the issue again with the regional office. Donald Caphton was manning the phone there:

> WILBER: Some time ago we asked about the incore thermocouples . . .
>
> CAPHTON: No, I have no information. (598)

Shortly after this conversation, Caphton had an NRC inspector in the Unit 1 control room ask TMI Unit 1 Shift Supervisor Greg Hitz to come to the phone. IRACT asked Hitz to get the incore thermocouple readings. (599)

THE QUESTION OF SUPERHEAT

While Hitz was still on the line, Stello asked to speak with him. He raised the issue of the various readings and their implications:

> STELLO: Let me bounce a question off you. If you really have 550 degrees on that hotleg, it's clear that you're getting some superheat. If you're getting superheat, there's a chance the core could be uncovered. The only way you're going to get rid of that problem is to find a way to get more water in that vessel and get that core level back up. Have you thought about what problem you've got, if indeed you've got 550 degrees on that hotleg at 450 psi?
>
> HITZ: Yeah, I see what you're saying. Okay? . . . They . . . do have the BWST [Borated Water Storage Tank] lined up and 175 inches indicated in the pressurizer, which means that the core would be covered. They've also got the core flood tanks floating on that.
>
> STELLO: But that doesn't necessarily mean that they don't have a steam bubble in there.
>
> HITZ: Oh, okay, you're talking about a steam bubble in the core.
>
> STELLO: Yeah, and if you have a steam bubble in the core, you've got the top part of the core which could be uncovered superheating the stuff coming out of there, and that's what's giving you the reading. (600)

Hitz said he would raise the issue with his counterparts in the Unit 2 control room. (601)

Hitz also explained to the regional office and IRACT that he had spoken to Mike Ross and that Unit 2 control room personnel believed that minimal injection by the core flood tanks meant the core was covered. (602)

Ross recalled speaking with Greg Hitz during the day over the telephone connecting the Unit 1 and Unit 2 control rooms. However, he stated that he had had no conversations with Hitz or anyone else in which he was told that the NRC wanted to know whether the utility had considered superheated conditions in the reactor. (603) He said he was certain that Hitz had never mentioned superheated conditions and that he would have remembered it had Hitz done so. (604) He explained:

> . . . If someone came in and said we were superheated, "you ought to do something," I think we would have moved in on it. It wasn't total bedlam. (605)

More generally, both Ross and Gary Miller told Special Investigation staff that the NRC never recommended that day that the utility pursue a particular course of action. (606)

Incore Readings Not Available

Several minutes later, Hitz spoke with Richard Keimig at the regional office on the three-way line:

> HITZ: First of all, I can't get the incore temperatures, okay?
>
> KEIMIG: You cannot get them?
>
> HITZ: They [the computer] print out question marks . . .
>
> KEIMIG: Okay, what's that mean?
>
> HITZ: That means that either the computer point is messed up—okay.
>
> KEIMIG: Yes.
>
> HITZ: Or that the line—you know, the—where you sense it, that line's broken or something's messed up with that line . . . They're trying all of them to see if we can get any of them to print, okay?
>
> KEIMIG: All right. (607)

Hitz could not recall subsequently who gave him that information. (608) It did not correspond to, or indicate awareness of, the existence of data from equipment set up earlier in the day to acquire readings of incore temperatures directly from the thermocouple leads in the cable room. In fact, there is no evidence that anyone had used that instrumentation since around 9 a.m.

HOTLEG TEMPERATURE ANALYZED

At 4:14 p.m., still questioning the status of the core, Stello called Eisenhut and asked him to contact Babcock & Wilcox to try to get a better understanding of the hotleg temperature readings. (609)

Eisenhut replied that B&W was on the telephone at that moment but "said they don't have enough information to straighten it out either." (610) Stello then spoke with Thomas Novak at NRR and asked him to consider alternative ways of increasing flow through the core to eliminate a steam bubble. (611)

By 4:24 p.m., statements by EMT members concerning the status of the reactor were no longer as optimistic as they had been throughout the morning and early afternoon. Gossick told Edward Fay of the NRC's Office of Congressional Affairs, "we're still all right, but we still don't have this core the way we want it . . . we just can't say that we're stabilized yet." (612)

Stello again spoke with Eisenhut, who said that the question mark readings for the incore thermocouples were at that moment being raised with Babcock & Wilcox. He also told Stello that the reason B&W was not concluding that superheated steam was present was that their readings on system temperature and pressure were from indicators in the pressurizer, rather than from the hotleg. Stello stated his disagreement with the B&W readings and gave Eisenhut the readings he had for pressurizer temperature, primary system pressure and hot and coldleg temperatures.

Eisenhut soon concurred with Stello's opinion:

> EISENHUT: You got it man. That's it. They've got a problem.
> STELLO: You're above saturation and the only way that's possible is with superheat. (613)

Stello told Eisenhut to give Babcock & Wilcox the "right numbers." (614)

NRC: WHAT ACTIONS TO TAKE?

From the EMT office adjacent to IRACT, Gossick called Acting Chairman Gilinsky, who was at Commission headquarters. Gossick began:

> We've got a little update here I think we need to give you . . . Let me get John Davis and Vic Stello on here to give you the situation with the core that we've got. We've got I think a significant development coming up here.[165] (619)

With Davis and Gossick on the line, Stello explained to Gilinsky his concern about superheated steam. Gilinsky responded, ". . . you're saying that, in fact, the core may not be covered." (620) He asked who was in charge at the plant, but neither Stello, Gossick nor Davis knew. (621) Gilinsky then asked whether there was "anything we ought to do about that beyond having talked" with Hitz. (622)

Stello replied:

> The only thing I can think of doing is to use our minds and understanding and tell them what we think based on the facts we hear, and they must make the judgment. We cannot make the judgment here because we're relying on information that's from too many different channels. I don't have enough information myself to decide what I would do. I can only react to the facts and raise questions for them to consider. (623)

Gilinsky suggested that "the natural way to handle it" was to speak to the NRC onsite inspection team leader and have him raise the issue with the licensee "to make sure that our message gets through." (624) He suggested they "talk to the superintendent" and said, "I think we probably ought to get some feedback." (625) Then the following exchange took place:

> GOSSICK: We've got to be careful that, you know, they don't start asking us what to do and then . . .
> GILINSKY: No. They're in charge, and we can only offer something that we thought of, but they are absolutely in charge. There can't be any question about

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[165] None of the three EMT members have recalled having learned on March 28, 1979, that there was superheated steam in the primary system. In an interview with Special Investigation staff, Davis said he did not remember learning of superheat, even though the tapes indicate he was a party to the conversation with Commissioner Gilinsky and Stello concerning superheat. (615) Gossick recalled Stello's concern, but not that it arose on Wednesday, even though he placed the call to Gilinsky, put Stello on the line to brief the Acting Chairman on "a significant development" having to do with "the situation of the core," (616) and participated in the ensuing discussion about superheated steam and core uncovering.

Case testified on the subject before the Subcommittee. He originally said that he did not know about superheated steam until late in the afternoon. He said he had told the Senators during a 5:10 p.m. briefing on March 28 that "it is not completely clear to us that even though the core is covered there might not be a steam bubble someplace in the core," (617) because he had learned about the superheated steam. However, later in his testimony, he conceded that there was a significant difference between superheated and saturated steam and stated that he was only aware that afternoon that there was a steam bubble, not that it was superheated. (618)

that. And we don't want any confusion in anybody's mind, especially in their mind.

GOSSICK: That's right.

GILINSKY: And they've got to assess everything that, you know, that they need to assess.

STELLO: We'll make it very clear to them that the decisions that are being made are theirs, and that the only thing we're doing is asking questions. (626)

CONCERN ABOUT SUPERHEAT

While Stello, Gossick and Davis were speaking with Gilinsky, IRACT established its first direct communications channel with the Unit 2 control room. (627) It was 4:36 p.m., over 12 hours since the accident began. When Stello returned to the IRACT office from the EMT office, he asked Moseley to raise the issue of superheated steam with James Higgins, the NRC inspector in the Unit 2 control room. While Moseley spoke with Higgins over the telephone, Stello stood next to Moseley (Stello's voice was also recorded on the tape):

> STELLO (to Moseley): Let's get somebody to explain the 580 degree hotleg temperature.
>
> MOSELEY: The high hotleg temperature, [do] you conclude that there is superheat there?
>
> HIGGINS: The hotleg?
>
> MOSELEY: Yes.
>
> HIGGINS: There probably is. I'm not sure.
>
> MOSELEY: How do we know there's not a steam bubble in the reactor itself and what the level is in the reactor; is all the fuel cool?
>
> HIGGINS: They're not positively certain that there's not a bubble in the reactor vessel . . . they're not 100 percent certain. (628)

Higgins explained, as Hitz had, the command team's interpretation of the partial injection by the core flood tanks. (629) He also said they had ruled out any attempt at rapid depressurization [166]—the step which Stello and Moseley had believed would have to be taken. (631)

Stello, Moseley and Higgins continued:

> STELLO: Does the licensee understand 580 degrees in the hotleg?
>
> MOSELEY: It means that it is superheat; they concede that.
>
> STELLO: They agree to that?
>
> MOSELEY: Yeah.
>
> STELLO: Do they have any way to explain superheat without the core being uncovered?
>
> MOSELEY: Not to my satisfaction, no.
>
> STELLO: Did you ask?
>
> MOSELEY (to Higgins): Have you pursued with them this question you and I talked about a little earlier, and that is, how do we know that the core is not uncovered, partially?
>
> HIGGINS: We have talked that over. Actually, most of the discussion on that was between the people here on site—the unit superintendent—Bob Arnold . . . the vice president of Met Ed in a dialog of about 20 minutes or so and I listened to the whole discussion. The final result of it was that they felt very confident that the core was covered, based on indications when they were blowing down and the core flood tanks and the interactions there, although they could not really give assurance of 100 percent that the core was covered.
>
> MOSELEY: Well, the core flood tank story is not convincing to me. (632)

Moseley then turned the phone back over to the field communicator.

At the height of NRC concern over uncovering of the core, Stello and Moseley were on the phone with an NRC inspector in the Unit 2 control room. They learned that the utility agreed there was superheated steam in the hotlegs, but was nevertheless "very confident" the core was covered.[167] The evidence the TMI emergency command team gave to support its belief the core was covered was the spurious indicator of limited injection of water from the core flood tanks. Although Stello and Moseley questioned the basis for the utility's lack of concern, neither of them asked for further feedback from the utility, as Gilinsky had suggested.[168] They had the opportunity to do so. Since they had a direct line to the Unit 2 control room, they could have raised the issue directly with Miller (or for that matter any of the other utility representatives), in keeping with Gilinsky's suggestion that they speak with the plant superintendent. Thus, the NRC left hanging the crucial question of whether the core was uncovered.

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[166] Stello, Moseley and other NRC officials said they believed the utility should open the block valve and leave it open, causing pressure to plummet to the point where the decay heat removal system could be initiated. They did not know that in the last attempt to depressurize, pressure had, on its own, stabilized at a point above that for low-pressure decay heat removal. A more detailed discussion of this issue can be found in the staff report by the President's Commission, "Report of the Office of Chief Counsel on the Nuclear Regulatory Commission." (630)

[167] See p. 141.

[168] See p. 146.

The NRC Special Inquiry Group, after investigating this particular matter, found:

> There is no record of Stello having communicated this message [about superheated steam and an uncovered core] directly to the Unit 2 control room. . . . (633)

As the tapes show, Stello *did* raise the issue with the Unit 2 control room within minutes of his conversation with Gilinsky. The evidence suggests that the Special Inquiry Group simply accepted Higgins' recollection of the accident and was unaware of the contradictory evidence on the tapes.[169] Higgins' recollection was not supported by the evidence uncovered by this Investigation.

NRC'S AFTERNOON STATUS REPORTS

About 5:10 p.m., EMT members Case, Gossick and Davis took part in a conference call with members of the Subcommittee on Nuclear Regulation and Senators H. John Heinz, III and Richard S. Schweiker of Pennsylvania. The Senators had requested a briefing on the status of the reactor. Case summarized the various points of view:

> . . . The water level is above the core and is showing in the pressurizer level which is above the core. On this basis the company believes the core is covered and there is no problem of further release of fission products. It is not completely clear to us that even though the core is covered there may not be a steam bubble someplace in the core which would result in inadequate cooling to that portion of the core. We are raising this question with the licensee, suggesting that if this is still going on, it might be worthwhile to consider just lifting the safety relief valve and blowing the pressure down rapidly [depressurizing] in order to get this lower pressure system on the line. The pressure has been hung up around 500 pounds for the last four or five hours. Slowly, slowly coming down. But in the meantime, this portion of the core may be overheating so that is giving us some concern at this point in time. (634)

Case described two possibilities: either the core was completely covered or some small percentage was uncovered. He did not point out that if the core was uncovered, there were no direct means at the plant for determining to what extent. (635)

The Senators asked if there was any need for evacuation. Davis responded that offsite radiation levels "do not at this time indicate evacuation." (636) There was no mention of the uncertainty as to the degree to which the core might be uncovered and that that in itself was a reason for considering protective action. This was because, as noted, the NRC was focusing on actual radiation levels and not on plant conditions in considering the need for protective action.

The NRC's Role Discussed

The Senators then asked if the situation had been stabilized. Case told them it had not and that it might be a long time before stability would be reached. The following exchange took place:

> HART: Who determines the course of action?
>
> CASE: The licensee.
>
> HART: Under all circumstances?
>
> CASE: Under all circumstances, unless it gets to the point that if we think we know enough here, which is very, very difficult for us to conclude, that we ought to tell them to do something. Now we have direct communications through telephone into the control building of both of the units.
>
> HART: How long will you wait?
>
> CASE: Pardon me?
>
> HART: How long might you wait before you'd override them.
>
> CASE: Well, it would be at least another hour or so, I would think, Senator. (637)

Radiological Releases Reported

At about 5 p.m., the NRC issued its second press release. It stated in part:

> Low levels of radiation have been measured off the plant site. The maximum confirmed radiation reading was about three milliroentgens per hour about one-third mile from the site. At one mile, a reading of one milliroentgen per hour was measured. It is believed that this is principally direct radiation coming from radioactive material within the reactor containment building, rather than from release of radioactive materials from the containment. (638)

The Information Is Wrong

The tape transcripts show that by 4 p.m. IRACT had become aware of a 70 milliroentgen per hour reading at the north gate to the plant. They also show, when compared to Met Ed documents, that between 4 and 4:30 NRC inspectors in Unit 1 had incorrectly transmitted as an onsite measurement, a 50 milliroentgen per hour offsite reading taken opposite the north gate on Route 441. (639)

[169] See Addendum 24, p. 160, for the text of Higgins' interview with the Special Inquiry Group.

With regard to the statement in the 5 p.m. press release that the maximum confirmed offsite readings were believed to be "principally direct radiation," Sniezek, who was chiefly responsible within IRACT for analyzing radiological information, indicated that he did not recall having discussed the question of direct radiation versus releases in conjunction with the 5 p.m. press release.[170] He said that if he had been asked, he believed he would not have known whether the offsite radioactivity was more the result of one than the other: "I wouldn't know which one principally it was." (640)

There are some direct measurements that can serve as a check on whether a radiation dose is attributable to direct radiation or to an actual release. If the radiation is the result principally of direct radiation, then the dose measurements should be somewhat constant in all directions from the containment at a given distance, and they should not change substantially unless the radiation inside the containment changed substantially. The information received by IRACT prior to the issuance of the 5 p.m. press release was not consistent with either condition. Rather, IRACT was told that radiation levels inside the containment were constant; the containment dome monitor read 6,000 R/hr from 10 a.m. onward. Yet between 2 p.m. and 4 p.m. dose measurements at a given distance—at the north gate—went from 30 to 70 to 50 to 1 milliroentgens per hour. All this was known to IRACT prior to 5 p.m. (641)

With respect to the general accuracy of the press releases issued by the NRC on March 28, Joseph Fouchard, Director of Public Affairs for the NRC, stated, "... we were using the best information we had in the Incident Center when we wrote these. We were not trying to maximize or minimize the situation. We were trying to tell it as we believed it then existed."[171] (643)

More Incorrect Information

In the late afternoon IRACT also gave misinformation to Executive Branch agencies, including the White House and the Department of Health, Education and Welfare. Between 4 and 5 p.m. Bernard Weiss, the IRACT Communications Officer at the Response Center and the person responsible for briefing these organizations, reported to Clark W. Heath of the Chronic Disease Division at HEW's Center for Disease Control: "It was really never a problem with regard to loss of water and exposure to the core ... there was never a problem of keeping the core covered." (644)

Between 5:30 and 6 p.m., Weiss discussed the same issue with the White House Situation Room. He reasserted that "there was never a problem with regard to keeping the core covered." (645)

In fact, IRACT, from whom Weiss was receiving his information, had, by 4:30 p.m., spoken with the Unit 2 control room. IRACT personnel were following up on the very concerns that Weiss was telling the HEW and the White House were not at issue—that there were indications that superheat in the primary system had been preventing adequate circulation through the core, leading to possible uncovering.

Weiss, in explaining how he obtained the information that he passed on to these agencies and individuals, said the data had gone through IRACT, where it was evaluated, and then through EMT. (646) "At some point it was said that we ought to update the Commissioners on what is current at this time." (647) He said he could not recall who told him to tell the agencies that the core was not uncovered.

Dudley Thompson, Weiss' superior, said that Weiss "may not have been quite as current [on developments at the site] on a minute to minute basis." (648)

Asked to explain the apparent discrepancies between what was known at the NRC and what was being transmitted to other agencies through Weiss, Case said he did not believe Weiss was "deliberately misinforming" anyone. Case acknowledged that Weiss' late afternoon report to the White House Situation Room "simply wasn't accurate." (649) His explanation was that the report resulted from the normal confusion that arises in an emergency. (650)

THE NRC FAILS TO FOLLOW UP

On March 28, the NRC never did explore the need for evacuation or take steps to override the licensee with respect either to its diagnosis of the severity of the accident or to actions that should be taken to regain control of the reactor.[172] According to Commissioner Bradford, one reason evacuation was not addressed was that the Commission "simply did not have the information on what was going on inside the reactor." (651) While that certainly was the case in the morning, it was not so in the afternoon.

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[170] See p. 158.

[171] The NRC's Special Inquiry Group concluded: "To anyone acquainted with reactor physics, the idea of a containment building so full [of] radioactivity that it is penetrating those 4-foot concrete-and-steel walls with enough intensity to be picked up by monitors more than a mile away—well, it is not only grossly in error, bnt ridiculous in retrospect." (642)

[172] It is now believed that if the utility had pnrsned the strategy of rapid depressurization favored by the NRC, an even more serious condition could have developed.

Chairman Gilinsky explained to the Subcommittee why he took no steps to initiate discussions on protective action with the other Commissioners or with the State after he learned of Stello's concern that the core was uncovered:

> Let me tell you what was on my mind. The comparison that I made continually was with the temperatures I'm familiar with from the rules on emergency cooling systems, which require that temperatures in the reactor core stay below approximately 2,000 degrees, 2,200 degrees, during the course of [a] loss of coolant accident. This is based on the fact that oxidation of the cladding becomes rapid at about 1,600 degrees. So mentally, I was making this sort of a comparison, throughout the day in fact. And none of the temperatures that I had heard approached anything like those numbers.
>
> Now, I must say that I asked how we could be getting fuel failure if we were, in fact, nowhere near such temperatures, and I remember the response, I don't remember who gave it, that one could get a certain amount of fuel failure, pin holes in [the] fuel, if the fuel [saw] something like a thousand degrees for sometime.
>
> So clearly in my mind I had some sort of picture of either pockets of steam or some form of inadequate cooling. But it did not, to my mind, at least at that point, call for further steps with regard to evacuation. . . . (652)

Gilinsky said he recalled that the discussions centered on the extent of fuel failure, which was then estimated to have been one percent, rather than on core uncovering. (653)

This figure of one percent fuel failure, which proved to be wrong and which suggested far less serious conditions than existed, was used repeatedly not only in statements to the press that evening, but in testimony by the Commissioners the following day before the House Subcommittee on Energy and the Environment. (654) It is unknown where the figure came from.

One possible source was a previous NRC estimate that certain "design basis" accidents would result in a failure of one percent of the fuel, which would in turn produce an iodine spike.[173] (656)

Yet, even at this point the NRC had evidence showing that the figure of one percent was incorrect. As early as 4 p.m. on Wednesday some NRC staff had ruled that figure out as inaccurate. An NRC official in IRACT, and another in the main NRR offices, had discussed some NRC calculations based on the primary coolant sample the utility had drawn and analyzed earlier in the morning. It showed more radioactive iodine than would be found in the coolant as a result of an iodine spike. (657) It was evidence of fuel failure greater than one percent and suggested greater damage to the core.

The NRC has since estimated that during the first day, over 90 percent of fuel had failed, that the entire inventory of radioactive iodine in the core was released to the coolant, and that the geometry of the core was disarranged. (658)

COMMISSIONERS' ROLE IN RETROSPECT

The Commissioners played a relatively minor part on March 28, notwithstanding their prescribed policymaking function. As Eisenhut commented, "To the best of my knowledge [the Commission] really played no firm policy direction role on Wednesday." (659)

The limited participation of the Commissioners was not surprising, in retrospect. The presumption had always been that accidents would be of such short duration, there would be no time for the Commissioners to become actively involved.[174] They were clearly unprepared to do so.

Second, neither the Commissioners themselves nor the senior emergency response staff saw the Commissioners as having an operational role. IRACT's Stello noted,

> . . . my view was the decision [to direct the licensee] would be made by EMT if needed, and I didn't think very much about the Commission. If we needed to decide something, my view was that [a] decision would be made and inform the Commission rather than asking. (660)

Case, an EMT member, told Special Investigation staff that he felt the Commission members should ". . . keep out of it . . . I don't think the five-man body, whomever they may be, is the type of organization you want in an emergency." (661) He said the Commissioners' role was "deliberative" and that they should not be involved in handling emergencies. (662)

The Commissioners themselves stated that it was appropriate for them to rely on the emergency

[173] "Design basis" accidents are hypothetical events analyzed by the NRC in terms of plant response and of safety features required to handle the accident. Some design basis accidents could result in damage to the Zircaloy cladding on the fuel rods. Because of the damage, some radioactive iodine, a fission product normally contained by the cladding, would be released to the coolant. The release would show up as an increase in radioactive iodine, referred to as an "iodine spike." The size of the spike would be indicative of the amount of failed fuel. (655)

[174] See "Prior to the Accident," pp. 82–83.

response organization for technical decisions. Commissioner Ahearne commented:

> As far as the issue of what is the role of a Commissioner during emergency response, my understanding of it prior to and certainly during [the accident] was that the way the NRC system was designed was for the senior technical people in the agency to be responsible for monitoring and taking whatever action might be necessary as far as the technical issues. (663)

Commissioner Gilinsky noted:

> ... generally speaking, the technical, minute-by-minute decisions and recommendations have to be handled by our staff. And the Commissioners have got to deal with things that are more general in nature ... but the technical questions have got to be examined by the staff, and it is they who have to be in direct touch with the licensee as well as counterparts in the State. (664)

Nevertheless, there were actions the Commissioners believed, in hindsight, they should have taken. As noted, Chairman Hendrie spent the first day of the accident at a hospital with his daughter and was not heavily involved in events on the first day. He subsequently said that "it wasn't very effective for me not to be there; I should have gone to the response center." (665) Commissioners Kennedy, Bradford and Gilinsky thought the issue of evacuation would have been formally addressed by the Commission on Wednesday morning had they had information available to the utility. (666)

STABLE CONDITIONS ACHIEVED

At about 4:30 p.m., Jack Herbein had arrived at Unit 2 after briefing the Lt. Governor in Harrisburg. He decided that because of the unsuccessful attempts to depressurize and bring on the decay heat removal system, the control room operators should repressurize again, with the aim of restarting the reactor coolant pumps. Herbein discussed the matter with GPU Vice President Robert Arnold, who was at GPU headquarters in Reading, Pennsylvania. Arnold concurred. (667)

At some point between 5 and 6 p.m., Herbein, concerned that the core might not be covered, ordered the operators to stop depressurization, raise reactor system pressure and try to start the coolant pumps. (668) At 6 p.m. Higgins informed NRC headquarters of this strategy. (669)

This time repressurization was successful. The bubbles in one loop of the primary system collapsed, and one of the pumps was started at about 7:50 p.m. It forced coolant through the core and allowed heat to be removed through the steam generator. Thus, approximately 16 hours after the accident started, circulation through the core and heat removal through a steam generator were achieved. Relatively stable plant conditions were finally established. The immediate crisis had passed.

POTENTIAL FOR GREATER SEVERITY

A considerable amount of the analysis since the accident has focused on whether different sequences of events could have posed greater danger to residents of the surrounding community. The answer depends, to a great extent, on the probability that the accident could have resulted in the melting of the reactor core or in offsite releases of hazardous levels of radioactivity.

The actions of plant operators and managers did lead to substantial uncovering of the reactor core. Calculations done for the NRC Special Inquiry suggest that the core would have begun to melt within an hour after the block valve was closed *if* plant personnel had failed to close it and continued to limit the flow of high pressure injection. (670)

THE OUTCOME OF CORE MELTING

The President's Commission also looked at alternative sequences of events. (671) It concluded:

> No *single additional* operator action or equipment failure that is tied to the actual sequence of events at TMI would have led unequivocally to large scale fuel melting throughout the core or significantly larger releases of fission products to the environment. (672)

Contrary to what a recent report by the House Subcommittee on Energy Research and Production concluded, this finding leaves open the possibility that multiple incorrect operator actions—minimal or no high pressure injection, accompanied by no heat sink and continued let-down—could have produced those conditions. (673) Indeed, the staff of the President's Commission identified four possible "serious cases" in which large-scale fuel melting could have occurred. (674) However, when they studied the radiological consequences of these four cases, they concluded that even in those cases, containment integrity probably would not have been violated. (675) The President's Commission also found that there would have been no substantial radioactive releases from the plant even if the core had melted through the containment floor because the bedrock foundation probably would have contained the radioactive debris. (676) It also concluded that the release of fission products would have been greater than actually occurred, although not by a "large factor." (677)

PROBLEMS WITH THE ANALYSES

There are a number of problems with the "what if" analyses of the NRC Special Inquiry Group and the President's Commission, including the degree of uncertainty that attends all such studies of hypothetical events. The first implicitly assumed that a core melt following initial uncovering of the core in the morning would have been accompanied by isolation of the containment to prevent the escape of radiation. (678) In fact, the utility consistently bypassed containment isolation throughout the day in order to use the make-up and let-down systems. (679) The let-down system was leaking; this leakage was primarily responsible for the actual releases of radioactivity outside the containment and into the auxiliary building and then to the environment. Had a core melt occurred while containment isolation was bypassed, the releases to the environment through the auxiliary building pathways would have been greater during the period between the beginning of the melting and the eventual rupture of the reactor vessel.

An important issue that is unaddressed by these studies is whether the operators, based on the available instrumentation, would have realized that the core was melting down, and whether melting would have required protective action at a time when no one was prepared for it.

Of these analyses, only the President's Commission addressed the leaking let-down system as a pathway for releases of radioactivity from the containment building. It did so, however, in terms of what actually occurred, rather than in relation to a hypothetical sequence of events leading to a core melt. The President's Commission concluded on this basis that greater, but not significantly greater, releases would have resulted from a core melt at TMI. (680)

The President's Commission relied on a two-part qualitative argument in reaching this finding. First, it had studied the actual behavior of the radioactive iodine during the accident and its release through the auxiliary building. Its preliminary finding was that little radioactive iodine was released, much less than would have been predicted based on the scientific literature. (681)

The staff of the President's Commission issued the caveat that "anyone who thinks he thoroughly understands why iodine did what it did during the accident is following a simplistic approach. . . ." (682) They had been unable to make quantitative calculations of the likely magnitude of releases accompanying a hypothetical core melt. (683) In part, this was because they were uncertain about the chemical conditions in the reactor coolant system at TMI and how those had affected the actual releases of iodine, although their studies showed that the limited releases related closely to chemical conditions (such as the ph of the coolant). To conclude on the basis of what happened at TMI that limited releases would have resulted from a hypothetical core melt assumes that the same (unknown) chemical conditions would be present. This in turn assumes that during a core melt operators would have access to a reactor coolant sample and would again fortuitously misread the boron concentration, as the TMI operators did—a misreading that had led them to alter the chemistry of the coolant, coincidentally resulting, it now appears, in lower releases. (684)

Second, at TMI the inventory of volatile fission products (685) was mostly released to the coolant during the initial uncovering of the core. Given that fact, the President's Commission argued that the release of the remaining fission products that would occur with a melt would not have produced significantly larger releases than actually occurred. (686)

The Special Investigation staff found that this argument neglected the uncertainties of conditions in the reactor coolant system. The hypothetical cases analyzed by the President's Commission did not adequately consider many factors that need to be addressed in predicting whether melting would have caused larger release rates through the auxiliary building and, if so, how large those might have been.

Staff of the President's Commission used the Commission findings to assert that the "health effects" accompanying a core melt would have been unobservable. (687) This conclusion does not take into account either the accompanying uncertainties or the psychological impact the accident had on the local community.

The report of the House Subcommittee used the various "what if" analyses to conclude that "there was always a reasonable margin of safety during the accident at TMI." (688) For the reasons cited above, it is difficult to reach such a conclusion without postulating operator actions of doubtful probability and without setting aside the issue of psychological impact.

ADDENDA TO CHAPTER 7

Addendum 1

Ross was referring to a precaution contained in TMI-2 operating procedure No. 2101-1.1. It states:

> 1.2-01 *Absolute* maximum pressurizer *at any time* the reactor is critical is 385 inches. [emphasis added]
> NOTE: This water level is the maximum RCS [reactor coolant system] inventory used in the safety analyses for reactor building overpressure following a LOCA. It is also the maximum level at which the system can accommodate a turbine trip without causing the pressurizer safety valves to open.
> 1.2-04 The pressurizer must not be filled with water to indicate solid water conditions (400 inches) at any time, except as required for the system hydrostatic tests. (689)

Addendum 2

Zewe also noted that at one point he thought that some of the circuit breakers for the heater in the pressurizer had blown and that, as a result, the pressurizer had ". . . lost some heater capacity and we just couldn't recover pressures as fast as we should."[175] (690) He asked one of the control room operators to have an auxiliary operator check the heaters. (691) However, according to Zewe:

> I'm not sure whether he did check it and report to the operator. The operator didn't tell me, I don't remember any details of it, and I really didn't pursue it any further. (692)

Addendum 3

The plant's emergency procedures gave them no clear guidelines for making that decision, since the procedures assumed that RCS pressure and pressurizer level would trend in the same direction during a LOCA. In Ed Frederick's words:

> A combination of high T_h [176] and low pressure and a full pressurizer was enough. . . . We might not as well have an emergency procedure book once you see something like that. There's nothing that you can figure out from that point. (693)

In Frederick's words, the high pressurizer level and low RCS pressure were ". . . confusing indications that don't dictate any particular course of action." (694)

Addendum 4

The operators needed to open a valve that would allow feedwater to bypass the malfunctioning condensate polishers, (695) but the remote control switch in the control room was not working. (696) In addition, the water level in the condenser hot well was excessively high,[177] which, if not corrected, would preclude use of the main feedwater system. (697)

Addendum 5

Bryan said that when the operators first concluded that the rupture disc had blown, ". . . we figured the safety lifted on the pressurizer and blew the rupture disc you know, just overpressurized it." (698) However, in another interview Bryan contradicted himself, ". . . [I] never thought that the code safety valves opened." (699) Bryan added that since he knew the reactor coolant system pressure had not gone over 2,355 psi, he did not believe the code safety valves had lifted.[178] (701)

Addendum 6

Zewe attributed the symptoms to excessive water in the drain tank:

> I knew at this point that we either had the RC [reactor coolant] drain tank's relief valve open or the rupture disk had blown. . . . (702)

According to Zewe, an alarm indicating that the sump pumps were running had been activated at about 4:08, 8 minutes into the accident, but the operators did not notice it because of the backlog on the computer (703) which was printing out

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[175] Pressurizer heaters are normally used to enlarge the steam bubble in the pressurizer by heating the water in the pressurizer, turning some of it to steam. This in turn increases the pressure in the system.

[176] T_h is hotleg temperature.

[177] The condenser hot well is where steam condenses after passing through the turbine. If the level is high, it will inhibit further condensation of steam.

[178] The code safety valves are designed to lift at 2,435 psi. (700)

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the alarms. In Zewe's opinion, "I believe that the indication [for the reactor coolant drain tank] we have available in the control room is insufficient. . . ."[179] (705)

Addendum 7

According to Zewe,

> I felt certain that the water that was going into the reactor building sump was from the RCDT [reactor coolant drain tank] and also that's also where the [increase in containment] pressure was from. (706)

Implicit in Bryan's comments in one interview is that he thought the same things. He said that at one point the operators thought a steam line was leaking into the containment, but that "... we went right back to the assumption that we had a rupture disc blown in the drain tank."[180] (707)

Addendum 8

Operators, in using emergency procedures, may read from them or refer to them from memory (operators are required to memorize the procedures). However, according to Scheimann, operators do not necessarily refer directly to the procedures, especially in the early stages of an accident. Then they tend to focus on the symptoms and what response might correct it:

> . . . [The operators] don't just sit there and say, "Oh, mercy sakes, I got a loss of pressurizer level there", or "Mercy sakes, look, pressurizer pressure is going down. I have got to refer to emergency procedure blah-blah-blah." Your train of thought, just doing work like that in a situation of that nature, you just see a symptom and you try to correct for what that symptom's problem is. . . . (708)

Frederick described how operators determine which procedure is relevant:

> FREDERICK: The thought process is actually not one of trying to eliminate each emergency procedure that exists. What you are trying to do is assemble a certain amount of symptoms that you can apply to an individual emergency procedure.
>
> Question: But how do you know which ones to look for?
>
> FREDERICK: We don't look for particular symptoms; you wait for them to be evident, and you make a list of them in your mind, and you try and decide which of those is important and how they relate to the emergency procedures. In other words, not only the symptoms but the order in which they appear will steer you to a different emergency procedure. (709)

Frederick added,

> Usually at the beginning of a transient like that the emergency procedures that you use later on are not related to the original problem. This is exactly what happened to us. We had a loss of feedwater and many of the emergency procedures we might have used were not at all related to feedwater. And you had to pick up the symptoms along the way. (710)

Addendum 9

The control room personnel considered the first two scenarios—a steam line rupture or a primary tube to secondary system leak—to be plausible because of problems in the "B" steam generator. They had observed both low pressure and high level on the secondary side of the generator.

At 5:27 a.m. they isolated the "B" steam generator.[181] (711) The control room personnel differed as to why. Most recalled that they explicitly considered the possibility that the accident involved a steam leak. Faust, Zewe, Bryan, Scheimann and Kunder all thought a steam leak could have been contributing to the rising pressure in the containment. (712)

Zewe, Kunder and Faust said that when the pressure in the "B" steam generator dropped to 300 psi less than the pressure in the "A" steam generator ("A" steam generator pressure was about 1,000 psi) at about 5:30 a.m., they decided there was a rupture of some kind in a steam line. (713) Zewe, Scheimann and Kunder said the "B" steam generator was isolated because the control room personnel thought there was a steam line break. (714)

Faust, Scheimann and Bryan said, in addition, that the operators believed the problem was a primary to secondary tube leak. (715) In Faust's words:

> I kept pushing myself that we had, first of all, a steam generator tube leak simply because I had an increasing level in the "B" generator, and I could not terminate it. It had to be coming from somewhere. (716)

[179] However, in another interview Zewe said the sump pumps usually come on about once each 8-hour shift to remove condensation from the sump. (704) Thus, the operators might not have interpreted the sump pump alarm as an unambiguous sign of an unusual amount of water.

[180] A key symptom of a leaking steam line inside the containment is a rise in containment pressure. Bryan's statement implies that the operators first thought the rupture of the drain tank was responsible for the rise in pressure, then thought that the steam leak was responsible, and finally attributed it again to the drain tank.

[181] Isolated means they stopped flow of feedwater to it.

Bryan said they isolated the generator because they thought it had a tube leak.[182] (717) Faust said he believed there was both a tube leak and a steam line break, although "I mainly wanted to isolate the 'B' generator because I thought it has a tube leak." (718)

Faust said that he also thought there may have been a break in the emergency feedwater line as well, (719) a result of his rapid initiation of emergency feedwater flow eight minutes into the accident.[183]

The evidence indicates that Zewe was the only other person aware of this hypothesis. Faust noted that "[Zewe] didn't fully agree with me on it." (722) Faust also said he believed the break could have been the source of the water in the containment sump. (723)

Addendum 10

The control room personnel found the procedures to be vague or unclear and incomplete. TMI–2 Emergency Procedure 2202–1.5, "Pressurizer System Failure," listed the symptoms for a failed PORV. Zewe said that the control room personnel referred to this procedure during the accident, although he noted that "we did not specifically pull out that procedure until later because we did not suspect that we had the relief valve problem." (724)

Symptom 2 of the procedure—"*RC System Pressure is below 2205 psig and RC–R2* [PORV valve] *fails to close*"—implies a tautology: that PORV failure ("RC–R2 fails to close") is a symptom of PORV failure. Further, Frederick interpreted the procedure to be referring to the PORV position indicator light in the control room, rather than the PORV itself. (725) Since the absence of the light indicated a closed valve, he did not consider the symptom to be applicable. (726) Zewe, too, believed it to have closed because of the absence of the light:

> . . . we have a red light for the valve whenever it lifts of course that was still out and I didn't realize it . . . was still hung open. . . . (727)

Symptom 4: "The RC drain tank pressure and temperature are above normal on the control room radwaste disposal control panel 8A" was reviewed by the control room personnel several times during the first two and one-third hours of the accident. The procedure does not mention that pressure in the reactor coolant drain tank will rise steadily until the rupture disc bursts, at which point pressure will return to normal. The symptoms referred only to conditions which would exist immediately after the PORV became stuck open.

In addition, the procedure did not discuss how the water level in the tank would behave if the PORV were to stick open. While actual water levels could not be specified by the procedure because the drain tank collects leakage from many places in the primary system, how the level would change could have been addressed.

The operators had focused on the water level in the drain tank in their efforts to diagnose the accident. Zewe said he concluded, given the absence of a procedure on water level and without data on trends, that the low level in the drain tank indicated the PORV was not venting water into the tank and was therefore closed. (728)

Overall, the procedure described the various symptoms too generally. As a case in point, it stated that temperature and pressure would be "above normal," symptoms so broad that they also applied to those produced by a normally functioning PORV during a reactor trip.

With respect to the role emergency procedures played in the operators' decision to throttle HPI, Zewe said that when the operators manually activated the first HPI pump, he referred to TMI–2 Emergency Procedure No. 2202–1.3, "Loss of Reactor Coolant/Reactor Coolant System Pressure." (729) Sections 3.0 to 3.2.2, Part A, entitled "Leak or Rupture Within Capability of System Operations." (730) These sections describe the steps operators should follow when they manually initiate HPI. The last one (3.2.2) to which Zewe said he progressed directed operators to throttle HPI if the level of water in the pressurizer went over 220 inches:

> Bypass the SAFETY INJECTION by DEPRESSING the Group Reset Pushbuttons & "THROTTLE" MU–V16A/B/C/D as necessary to maintain 220″ pressurizer level and not exceed 250 GPM/HPI flow leg. (731)

Section 3.2.5 on the next page of the procedure contains the following warning:

> CAUTION: Continued operation depends upon the capability to maintain pressurizer level and RCS [reactor coolant system] pressure above the 1640 PSIG [pounds per square inch gauge] Safety Injection Actuation Setpoint. (732)

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[182] A tube leak would involve a break in one of the many small pipes within the generator through which heat from the coolant is transferred.

[183] Faust said that when he opened the block valves on the emergency feedwater line, a microphone near the main steam piping picked up the sound of ". . . cold water going down a hot pipe and hitting the hot-steam generator." (720) Faust noted that: "I thought then there was a break in the emergency feed line possible, not that the line sheared off, but a break somewhere due to thermal shock." (721)

Zewe missed the caution. He said,

> I never went that far [in reading the section]. I was still at the point of the procedure under the previous page of trying to throttle high-pressure injection flows to maintain levels. (733)

Zewe did not say why he stopped, but implied that, since he was unable to reduce pressurizer level to 220 inches, he never went beyond that step of the procedure. (734)

Frederick commented on the difficulty of writing emergency procedures:

> The tough part about any emergency procedure is writing comprehensive symptom type statements that'll get you started on a procedure. And it's hard to anticipate any kind of or all of the situations that would start you on a procedure. Symptoms have to be general, they have to be general and specific at the same time. You have to try and accomplish a wide number of circumstances, but they have to use specific indications to get you start[ed]. So it's a tough assignment. . . . (735)

Addendum 11

Zewe stated that at one point he was referring to Part A of the LOCA emergency procedure 2202–1.3. When the Engineered Safety (ES) system was activated at two minutes into the accident, that part of the procedure was no longer applicable. Instead, the relevant part was "B," "Leak or Rupture of Significant Size Such that Engineered Safety Features Systems Are Automatically Initiated." Zewe said he did not refer to that part of the procedure during the accident because he did not believe the activation was the result of a LOCA. Had he followed Part B, as directed by the procedure, he would have known to leave the HPI pumps running until he could turn on the low pressure injection pumps to cool down the reactor. (736)

Addendum 12

Zewe said that cooldown by natural circulation was discussed in the TMI–2 emergency procedure covering loss of offsite power.[184] (737) However, in a group interview with Scheimann, Faust and Frederick, he commented that the procedure contained

> . . . no real detail on what to look at or how long to look at it . . . or how long you'll have to wait before you start to see invalid indications one way or the other. (738)

[184] TMI–2 Emergency Procedure No. 2202–2.1.

Addendum 13

The first, and possibly the second, reading was obtained by Bryan at Zewe's request. (739)

There is reason to question whether it was Bryan who called up the readings at 5:20 a.m., 80 minutes into the accident. He recalled,

> I checked the temperatures at least twice, maybe three times within the first couple of minutes, well, within the first half hour that I was there. And each time all three of them [the PORV and the code safety valves] indicated— I forgot the numbers, but they were within 15 degrees or something like that. . . . (740)

However, many operators had poor recollections of when events occurred during the accident. Bryan's comment that the temperatures of the three valves were within about 15° of each other is consistent with the readings taken at 4:24 a.m., 24 minutes into the accident, and not with those taken at 80 minutes. At that point the PORV was about 65° hotter than the code safety valves. This discrepancy is significant, since Bryan claimed to have been focusing on the temperature difference between the PORV and the other valves. Either (1) someone other than Bryan took the reading at 80 minutes, or (2) Bryan misread the reading.

Mehler asked for the last set of readings. From them he concluded the PORV was open. (741)

Addendum 14

In interviews after the accident, Bryan recalled only that the temperatures of the PORV and code safety valve discharge lines were within about 15°F of each other. (742) Since all three valves had elevated discharge line temperatures, he concluded the PORV was not stuck open "[be]cause the other two are indicating the same." (743) Bryan noted, "I know I looked at the indications for the valves and it indicated closed." (744) When he was asked why he did not suspect the PORV was open, he replied, "It indicated shut. All three relief valve temperatures were approximately the same." (745)

Comparing the temperatures of the PORV and code safety valves for diagnosing PORV failure, was not discussed in the emergency procedure. Rather, operators were to consider only the temperature of the PORV discharge line.

Bryan did not state why he used this incorrect diagnostic method. Other operators have said, however, that during normal operations, differences in temperature between the PORV and the code safety valves could be used to determine whether a valve was leaking. (745) Bryan may have assumed the same principle applied in an accident in which a valve stuck open.

The Special Investigation staff believe, on the contrary, that in such a situation heat would be transferred to all the discharge lines, so that, at least initially, the valves would have similar temperatures.

Zewe has conflicting recollections about what Bryan told him about the discharge line temperatures and how he interpreted them. In one interview, Zewe said Bryan checked the temperatures at 4:24; 24 minutes into the accident, and that

> . . . they didn't look abnormally high since the electromatic [PORV] had lifted. It was about 228 or 230 degrees and they had been running about 170 to 180 so I figured it was still warm from when it lifted. (747)

This statement suggests that Zewe was looking at how much the temperature was elevated above normal. It also suggests that he discounted the procedure's warning that a temperature of over 200° in the discharge line was a symptom of PORV failure, both because he was aware that temperature in the line prior to the accident was elevated and that the valve had lifted.

In another interview Zewe implied that he, like Bryan, relied on a comparison of the temperatures of the PORV and code safety valve discharge lines:

> I . . . had him check the discharge temperatures of the relief valves, and he said you know the RCRV 2 [PORV] is a little high, about 30° higher. (748)

It is possible that Bryan never told Zewe what the temperatures of the three valves actually were, instead noting only that they were within 30° of each other, and that Zewe subsequently confused the 228°F reading which Mehler obtained at 5:17, 2 hours and 17 minutes into the accident, with what Bryan told him at 4:24, 24 minutes into it. This would explain Zewe's previous statements that the PORV temperature at 24 minutes into the accident was about 230°F, although subsequent analysis has shown it was 285°F.

Addendum 15

Although Mehler did reach the right conclusion about the steam and was on the right track concerning the PORV, he had not used the steam tables. Like the others, he did not deduce the steam was superheated and that the core was uncovered and being damaged. He later explained:

> . . . Up until [the radiation alarms came in at 6:40 a.m.], I thought [that they just] had steam voids in the hotlegs . . . That was the only place we had them which led me to believe we had not uncovered the core at that time. I did realize we had problems and fuel failure when all the alarms came on. Until that point there was no indication we did have fuel damage. (749)

Addendum 16

Logan was perplexed by the source and intermediate range monitors:

> . . . I might add, at the same time that we lit the pump off we had an indication of a count rate increasing. We had at the same time received a chemical analysis indicating that our boron . . . was lower than we had anticipated . . . There were several abnormal indications going through there. (750)

Addendum 17

Benson's description to Special Investigation staff was:

> . . . I basically looked at the reactor coolant temperature; the [hotleg] was pegged [high] the [coldleg] was 130 to 140 degrees; it was just the opposite . . . I look at the pressure; it was down. I noticed there was no flow; all the reactor coolant pumps were off . . . I looked at the start-up [source] range and . . . the intermediate range . . . and they had both [come] down to what appeared to be normal after they made that one pump start a little earlier.
>
> So I figure I would see what the incores [the incore neutron detectors] read. When you're below 15% power the computer won't do certain calculations, one of them being the incores . . . That wasn't the case. There were some of them printing out full scale . . . I noticed that the ones that were printing offscale were basically the hot channels or . . . [fuel] assemblies that you would expect to be at the highest [neutron] flux . . . It seemed like the information was pretty good because it was actually showing the correct assemblies I would expect to have the highest decay heat, but I couldn't believe they were offscale . . . I assumed one time we had a void go through the core. . . . (751)

Addendum 18

Two other factors contributed to the continuing difficulty the NRC had with internal communications on March 28, both outgrowths of the inadequacy of the emergency response planning and implementation of NRC's emergency response program. One was the actual flow of information between IRACT and the EMT on March 28, as compared with the intended flow, as depicted in the NRC Headquarters Incident Response Plan. Second was the failure of the Reactor Operations Inspection [185] implementing procedures, in effect during this incident, to include staff of the Office of Nuclear Reactor Regulation (NRR) as part of the emergency response organization.

Although the Response Plan specified that information between IRACT and the EMT would go through a predesignated liaison, on March 28 no set pattern was followed in the transmittal of data. The EMT received briefings from a number of IRACT support staff and team members. (752) Further, different EMT members would confer on their own with various members of IRACT, and "nearly all of the communication that took place back and forth between IRACT and EMT was verbal." (753)

Edson Case, the representative NRR had assigned to the EMT on March 28, told Subcommittee staff that the EMT never had any sort of formal meeting and that he received his information primarily from his NRR counterpart on IRACT, Victor Stello. (754)

Case's comment reveals an even broader problem—the separation between NRR and I&E staff on the EMT and IRACT. Although, as noted, the ROI implementing procedures did not call for participation by NRR, the NRC Headquarters' Response Plan did, and several NRR personnel were assigned to the two teams. The incident response organization in turn functioned to some extent as though there were two separate organizations—one of NRR staff and one of I&E. For example, individual EMT "team members were speaking to members of their respective organizations to obtain updating information on particular items of concern to them." (755)

There were also, in effect, two IRACT's—one under the Director of IRACT, who was from I&E, and one under the IRACT member from NRR. One illustration of this division involved two IRACT Support Groups—Plant Systems Effects and Radiological and Environmental Effects. James H. Sniezek, Director of I&E's Division of Fuel Facilities and Material Safety Inspection, headed the radiological group, as specified in the implementing procedures. However, according to Darrel Eisenhut, Deputy Director of NRR, Brian Grimes, an IRACT support staff person assigned by NRR, transmitted the radiological information received at the Response Center to a reactor systems team located in the building where NRR had its main offices. (756)

There is evidence that this second team was distinct from the IRACT radiological group staffed by I&E personnel and headed by Sniezek. For example, the physical layout of the Center provided a station for the radiological group's activity, but, according to Sniezek, he and Grimes did not share that location:

> Question: Mr. Grimes was working with you wasn't he, on the radiological effects?
>
> SNIEZEK: We were not working directly in the same physical location. . . . (757)

Another statement by Sniezek suggests that he and Grimes were not actually working together:

> Question: Was Mr. Grimes working with you on March 28?
>
> SNIEZEK: He was in the incident response center.
>
> Question: Was he following radiological information?
>
> SNIEZEK: He was involved somewhat in following radiological information also. (758)

Who was heading the IRACT Plant Systems Effects Support Group was an open question. According to Grimes, it was Stello:

> I think in effect Mr. Stello was . . . leading the [plant] systems evaluation as the most knowledgeable person in the field, and looked to me for radiological evaluations, as the primary source of [those kind of] evaluations, and the I&E function was communication and collection of information, as had been planned. (759)

However, according to IRACT team members Harold Thornburg and E. Morris Howard, both I&E Division Directors, Plant Systems Effects was under the direction of Norman Moseley, Director of IRACT. (760) Moseley, on the other hand, said the group was headed by IRACT's Technical Coordinator, Samuel Bryan. (761) Bryan in turn stated that while he was following operational and plant systems issues, he was not the Technical Coordinator. He thought Edward Jordan, Assistant Director for Technical Programs, had that job. (762)

Bryan at times served as back-up for the field communicator—holding the phone to the site open, receiving information and asking questions over the open line. (763) It would seem impossible for him to have been coordinating the activities of the two support groups. Nor is it apparent that

[185] The Division of Reactor Operations Inspection is within the Office of Inspection and Enforcement. Its implementing procedures were to be applied in the event of an incident involving plant operations. Thus its personnel were designated as support staff for the Incident Response Center. See "Prior to the Accident," p. 80.

Sniezek was reporting to Bryan, and, as noted, the NRR representatives in both groups tended to deal primarily with one another and with their colleagues at NRR headquarters. (764)

There is no evidence showing who, if anyone, was acting as Technical Coordinator.

The Reactor Operations Inspection implementing procedures were unclear about the role of the Technical Coordinator. They required that the two support groups coordinate the agency's entire response in their areas of responsibility. (765) However, the procedures did not stipulate how that was to be done. For example, they did not assign anyone responsibility for the task; the procedures only mentioned that members of the two groups should report to a Technical Coordinator. (766)

Addendum 19

Miller noted that except for those items on the checklist for initial notification, the utility did not discuss matters like coolant level with State people:

> Question: I am sure they were communicating radiological information to the State. I am not sure that the information regarding the plant status was being transmitted . . .
>
> Miller: . . . There is . . . a checklist for plant conditions in the Emergency Plan . . . it is geared to talking about things that need to be opened all during an accident—makeup pumps, diesel generators. I think if you look at that we would have probably conveyed that. I am not sure we would have conveyed the discussion you and I are having about the core level, the core flood tanks. (767)

Addendum 20

In answer to the question, "to your knowledge, none of the operations type people were talking to the State directly from Unit 2?" Ross stated, "There was none that I'm aware of." (768)

Addendum 21

The first conversation on the incore thermocouples involved Victor Stello and Mike Wilber, both at IRACT, and Harold Kister at the regional office:

> Stello (in background): And then I'll want to find out if they [can] give me a core element temperature. I got the impression those were not working. They had thermocouples on all the outlet assemblies on the B&W plant. Do they have any indication on thermocouples on the assembly?
>
> Wilber: Harry?
>
> Kister: Yes.
>
> Wilber: We are talking about the fuel assembly outlet temperatures. I understand they do have thermocouples on the fuel assembly outlet. Have they looked at any of those?
>
> Kister: Are you thinking about Westinghouse plants?
>
> Wilber: They are saying B&W has that.
>
> Kister: B&W does?
>
> Wilber: Yeah.
>
> Kister: Okay. Fuel element outlet temperature right?
>
> Wilber: Yeah. (769)

Addendum 22

Characteristic of the flow of misinformation concerning temperatures was a series of exchanges that occurred between about 12:15 and 12:30 p.m. on Wednesday. Donald Caphton and Eldon Brunner at Region I were speaking with NRC inspector Walter Baunack, who was in Unit 1 at the time. Baunack hypothesized that primary system temperature was at saturation even though he had no readings to go by to reach that conclusion:

> Caphton: How about "R" coolant temperature, reactor coolant temperature, Walt, anything on that?
>
> Baunack: I suspect it's probably pretty near saturated, wouldn't you think, if they got a steam bubble in the steam generator it would have to be saturated.
>
> Brunner: No reading?
>
> Baunack: Nobody mentioned what it was if that's what you are saying. (770)

NRC tape transcripts indicate that while the above conversation was occurring, Donald Haverkamp, who was in the regional incident response center with Caphton and Brunner was on another phone speaking with James Higgins in Unit 2. (771) Minutes later, Region I's communicator with IRACT provided headquarters with the following update:

> Region I: They think the temperature of the reactor coolant system has stabilized. They feel it is saturated at 550 degrees fahrenheit.
>
> IRACT: This is what is called a hotleg?
>
> Region I: They say across the board.
>
> IRACT: Isothermal?
>
> Region I: That is what I'm telling you right now. (772)

In this communication Region I reported that hot and coldleg temperatures were both about 550°F, when, in reality, hotleg temperatures were around 700° and coldleg temperatures some 450° lower than temperatures in the hotleg.

Circumstantial evidence from the tape transcripts suggests two possible reasons for the above misinformation being conveyed. One is that Higgins erroneously reported to Haverkamp "T_{ave}" (average) readings for hotleg or primary system temperature. That mistake had been made earlier in the morning. Another possibility is that based on Baunack's speculation that primary system temperature was at saturation, Region I personnel derived and reported a primary system temperature which they had obtained by comparing the known system pressure with standardized steam tables. Either method would have produced the erroneous information that system temperature was about 550°F.

Addendum 23

The NRC did an analysis of HPI flow rates based on changes in the level of water in the Borated Water Storage Tank from which the HPI water was drawn. (773) Its analysis showed that over the four-hour period between 1:15 p.m. and 5:20 p.m., the average net rate of flow into the core was 150 gallons per minute (gpm). During four other periods of the day the rates were:

(1) 4 a.m. to about 7:30 a.m. (corresponding to the period when the core was first uncovered)—70 gpm;

(2) 7:30 a.m. to about 11 a.m. (corresponding to the period when the core was again covered and repressurization occurred)—at least 680 gpm;

(3) about 11 a.m. to about 1:15 p.m. (the period of the first depressurization)—360 gpm; and,

(4) about 5:23 p.m. to 6:41 p.m. (the period after the decision was made to repressurize the system again)—470 gpm.

Addendum 24

Higgins had told the Special Inquiry Group:

Question: Do you recall any questions or suggested questions coming in from Region I or from Bethesda relating to saturation conditions or relating to the core being uncovered?

Higgins: No.

Question: Do you recall anybody over the phone saying, "Hey, we think there's a core coverage problem?"

Higgins: Definitely not.

Question: You don't recall that?

Higgins: Definitely not, because there were discussions among the caucuses that went on as to Gary Miller saying the type of thing: Does anyone here feel we're not providing adequate core cooling or adequate core coverage? I didn't feel at that time there was a problem. I didn't have an indication the people on the other end of the phone in Washington felt that either. I guess I can add here things I found out afterwards?

Question: Sure.

Higgins: Afterwards, that Mr. Stello called the Unit 1 control room and talked to an operator there sometime in the afternoon and asked that operator to pass on to their management the NRC's concern about core coverage, which if that happened, it just never did get to the caucuses, never did get to the right people, and in fact, was really not the right way to get it to management because, first, coming from Mr. Stello at that point, that's certainly a significant comment because that represents some type of NRC caucus, I would think, some type of NRC consensus that had that feeling. If I had heard that, I would have certainly taken some steps to find out why they felt that and tried to communicate that to Met Ed. (774)

Addendum 25

Another specific weakness in emergency planning was the lack of procedures for internal plant communications during an accident, particularly with regard to diagnosing plant conditions. The TMI–2 Emergency Plan provided no guidance to the emergency director about how to assess the condition of the plant during an emergency if it should be determined that the plant was in a state that was not covered by the plant's emergency procedures. The plan merely delegated the responsibility for developing internal plant communications procedures to the emergency director. Nor were there any provisions in the Emergency Plan for marshaling the technical and scientific advice of outside agencies and groups. In fact, there was no procedure in the Emergency Plan for participation by the reactor-vendor, the NRC or the architect's engineer in assessing plant conditions. (775)

Chapter 8

Recovery At Three Mile Island

Cleanup workers at Three Mile Island gain access for the first time to the airlock leading to the containment. Beyond the second door are the damaged reactor and other major components of the plant's primary system

Chapter 8

Recovery At Three Mile Island

INTRODUCTION

One aftermath of the accident has been the enormous and complex task of recovery. It can, in fact, be considered a continuation of the accident.

Recovery involves two phases: cleanup of the TMI-2 facility, principally decontamination and disposal of the radioactive debris, including the damaged core; and the future disposition of Unit 2—whether to refurbish it as a power plant or to decommission it.

The Special Investigation emphasized the cleanup phase of recovery. Cleanup is of deep concern to the utility, the NRC, the local population and the Congress. It is unprecedented in scope and complexity and is likely to have a substantial impact on the future of nuclear energy in this country.

The complex and uncertain steps involved in cleanup are reviewed in this section not only in terms of the technical difficulties, but also in terms of financial, social, legal and regulatory considerations.

The technical challenge is without parallel among privately owned commercial nuclear power plants. Coping successfully with the radioactive debris, especially the core, is a very large and difficult part of the task. There are also health and safety questions, such as the exposure of workers to radiation and the proximity of TMI to a densely populated area. However, based on the evidence reviewed by the Special Investigation, including prior recovery operations at government reactors in the United States and other countries, the Subcommittee believes that the technical challenge can be met.

The technical questions are interwoven with financial, social and legal factors. For example, the potential cost to the licensee is great, and the financial future of Metropolitan Edison (Met Ed), the plant's operating utility, is unclear. Local elected officials testified that the communities near Three Mile Island are extremely apprehensive about cleanup for many reasons, and very distrustful of both the NRC and the utility. There has been substantial opposition to many of the initial cleanup proposals. Some of the legal and regulatory questions are without clear precedent. The NRC has never dealt with a similar cleanup, and it faces many unresolved issues. Especially important are the circumstances under which it may take immediate action in authorizing cleanup tasks, before the required deliberative decisionmaking procedures have been completed. Another issue is the environmental review procedure to be followed.

Within the context of these various issues, cleanup poses a difficult dilemma. Cleanup requires careful planning, but there is the pressure of the unknown. The reactor's present condition is not without risk, and the status of components vital to the integrity of key systems is uncertain and unpredictable. Further weakening and failure of important equipment can be expected with the passage of time, and accidental releases of radioactivity and recriticality of the core are possible. The various methods for venting the radioactive gases, disposing of the radioactive water and removing the radioactive waste—all of which are required for cleanup—could result in uncontrolled releases to plant workers and surrounding communities. Even in cases where the NRC and GPU have concluded that health hazards are minimal, some members of the nearby communities view any releases as hazardous.[1]

To date, cleanup has followed established legal and regulatory procedures that, while deliberate, provide for orderly decisionmaking through careful consideration of options and through public participation. Decisions should involve the consideration of timing and a careful weighing of the risks and benefits of alternative courses of action.

[1] See "Social Issues in Recovery," pp. 198, 199–200.

TECHNICAL ASPECTS OF RECOVERY

THE NATURE OF THE TASK

The accident at Three Mile Island badly damaged the Unit 2 nuclear core and released radioactivity into the primary system coolant water. As of June 1980, the containment held hundreds of thousands of gallons of the highly contaminated water, whose lower layers have been described as "flocculent in appearance, gelatinous, dark green color," (1) the result of chemicals released when the fuel failed. The dominant radioactive isotope in the water is cesium 137,[2] with a relatively long half-life of 30 years.

The amount of water in the containment is still increasing because of leaking pump seals. It may threaten two motors which operate valves critical to maintenance of the primary cooling system and to removal of the radioactive water. Those valves are also necessary for assuring the operation of the new, long-term cooling equipment needed for cleanup. Assuming plant conditions remain as they were in April 1980, the valves should not become submerged for at least a year.

The atmosphere in the containment consists of various radioactive gases. Some accidental releases have already occurred, and there is a possibility of further ones. However, the potential amount is slowly decreasing with time, as radioactive material decays naturally.

Thus the atmosphere, walls and water in the containment are all contaminated with radioactivity. As of early June 1980, personnel were unable to enter the building to survey it, and estimates of the levels have been based on indirect measurements and analyses. The unsuccessful initial attempt to enter the containment in mid-May raised the question of whether corrosion would make decontamination more difficult.[3]

Although actual levels of radiation are high, they are much lower than originally projected. In July 1979, it was estimated that gamma radiation would reach 2,400 rad/hr by December. (2) In December it was calculated to be less than 1 rad/hr. (3)

There are two principal reasons for the substantial differences between projected and actual levels. The earlier estimates (4) had intentionally been made very conservatively. In addition, they were based on radiation levels as measured by the containment dome monitor. (5) Later independent measurements[4] and tests of the dome monitor showed that it was not functional.

Most of the isotopes with short half-lives already have decayed into their stable forms and no longer emit radiation in the containment. This has reduced the radiological hazard substantially. Especially important is the decay of iodine 131 (I–131), a volatile element that concentrates in the thyroid gland. Because it has a half-life of about eight days, virtually all of it has decayed. The dominant radioactive isotope still present as of June 1980 was krypton 85 (Kr–85), which has a half-life of 10.7 years.

Radioactive water is also present in the auxiliary building; again, cesium 137 is the dominant radioactive isotope.

The damaged and highly radioactive core continues to generate relatively low levels of heat that must be removed continuously.

The amount of radioactivity still present at the site is substantial and consists principally of long-lived isotopes. The condition and reliability of the equipment and systems that must contain this radiation are uncertain, particularly in the containment. The viability of critical electrical and mechanical systems may have been affected by the exposure to steam and moisture, the continuous operation of equipment for much longer than designed for, the cumulative effects of radiation, severe thermal cycling[5] and the hydrogen burn that occurred on the afternoon of the first day of the accident.

Because the containment has been inaccessible, the utility has been unable to evaluate the equipment and systems directly. It has been impossible to determine whether the elastomeric[6] seals and the building air coolers[7] are undamaged.

SAFETY CONSIDERATIONS

As a result of the unknown and uncertain condition of plant systems and equipment, the poten-

[2] Cesium 137 has been emitting most of the gamma radiation in the water. Gamma radiation is similar to, but more penetrating than, X-rays. See "Radiation Effects and Monitoring," for a description of radiation and its measurement, pp. 43–44.

[3] See p. 184.

[4] A combination of techniques was used to make the measurements, including scans through a nine-inch hole bored into an access port in the containment.

[5] Thermal cycling—the unusual hot and cold oscillating conditions during the accident—may have altered the mechanical strength of some of the system components.

[6] This is a special pliable material used throughout the plant to prevent leaking.

[7] The air coolers insure that air pressure inside the containment building is lower than outside in order that no outward leakage will occur.

tial for some problems has been analyzed. These include:

- **Leakage of krypton**

If the elastomeric seals or air cooling units were to fail, krypton would escape at ground level. It could also escape if temperature in the containment could not continue to be lowered sufficiently to keep pressure down in order to offset the increase in pressure that results from inward air leakage.

In response to questions by the Subcommittee, then-NRC Chairman Joseph Hendrie [8] said he did not think the krypton was a "pressing danger or urgent risk." (6) However, he added, ". . . the longer these materials are allowed to remain . . . in the containment building, the more chance there is that somebody will open the wrong valve or something else will happen and some of it will get out." (7) Because the krypton did pose "some increment, however small it may be, to the public risk," he concluded, "We need to get on with [removing] it." (8)

- **Leakage of water through the containment walls**

Results of a radiochemical analysis of the water indicate that there is no short-term risk of corrosion attacking the 3/8″ steel lining of the building. Nonetheless, localized concentrations of caustic chemicals could produce leaks. It is not known how long they might take to develop.

In April 1980 radioactivity was detected in one of the eight wells drilled into the bedrock around the plant in order to monitor the water continually for leakage from the containment. The well was located 60 feet from the Borated Water Storage Tank.[9] A radiation level of 2,500 picocuries per liter was measured, as compared with the normal 500 picocuries per liter attributable to natural background radiation,[10] as measured prior to the accident.

At the time the radioactivity was detected, the GPU Service Corporation [11] did not know the source of the contamination. Spokesmen said it could have resulted from nothing more than fluctuations in the natural background radiation level. (9) It could also have been the result of leakage from the Borated Water Storage Tank, since some of the same radioisotopes were present in both the tank and the well sample. (10) Another possibility was leakage from the primary containment, since, again, some of the same radioisotopes were present both in the containment and in the well sample. (11)

General Public Utilities Corporation (GPU) considers the groundwater contamination to be important and has been investigating the source. (12)

If the containment building is leaking, little can be done except to accelerate processing of the water, although that action might involve some risk and be undesirable.

- **Recriticality of the core, leading either to limited melting of the fuel, or a core meltdown**

Both the NRC and the Special Investigation looked into this possibility. (13) The NRC study concluded that the most likely cause of recriticality would be dilution of the boron concentration in the water.[12] (14) According to the NRC, this process would occur slowly enough that the approach to criticality could be detected in time to take corrective action, assuming the necessary instrumentation, procedures and equipment were available. (15) The study further concluded that recriticality most likely "[would] not result in significant offsite radiological consequences." (16) Even in the worst and least likely case—a meltdown within an unisolated containment with no means of removing heat from the containment or no containment sprays—the latent risk of cancer to individuals offsite would be negligible compared to the normal incidence of that disease. (17) However, recriticality could produce radiation levels in the containment at least 10 times higher than existed in April 1980. (18) Those levels would constitute an increased risk to the onsite workers involved in cleanup. That risk would be reduced at the time of recriticality by evacuating the workers, a protective action that is feasible because such an accident would take place over 10 hours and radiation would be released gradually. (19)

At its November hearings, the Subcommittee asked Richard F. Wilson of General Public Utilities Service Corporation, then-Director of Cleanup at TMI–2, about the possibility of core melting. He testified,

> I don't believe [that with] the current heat production in the core, there's any credible set of circumstances which would lead to melting of the core. (20)

Several NRC officials also testified. Harold R. Denton, the Director of the Office of Nuclear Reactor Regulation (NRR), said ". . . there's no possibility that there would be a core melt through the reactor vessel. . . ." (21) However, he raised

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[8] Hendrie was replaced by Acting Chairman John F. Ahearne on December 7, 1979.

[9] See "How the Plant Works," p. 31.

[10] See "Radiation Effects and Monitoring," p. 45.

[11] GPU Service Corporation performed engineering functions for GPU, such as TMI–2 cleanup, etc. Recently, GPU formed a new entity, GPU Nuclear Corporation, in part to improve coordination among the member utilities.

[12] See "How the Plant Works," p. 29.

another possibility—that hot spots[13] would develop within the core, leading to localized melting:

> . . . I'm not quite so sanguine about whether or not . . . temperatures might not approach melting somewhere in the fuel rods themselves. . . . (22)

Since the core's configuration is badly distorted, some areas may not be getting cooled. Richard H. Vollmer, then-Director of TMI Site Support and Assistant Director for Systems and Projects, Office of Nuclear Reactor Regulation, NRC said that the consequences of the hot spots would be minimal, as most of the fission products in the core that have high volatility had already been released from the system or had decayed. Thus, according to Vollmer, ". . . even if a small portion of the core were to attain high temperatures, it would not pose the usual threat to the public health and safety." (23) He went on to say, "It would . . . basically [involve] solid fission products which, if released from the core, would likely condense [in] the primary system or containment and not pose an outside threat." (24)

As noted, dilution of the boron concentration could cause recriticality. Vollmer testified that the boron concentration could accidentally decrease as a result of "boron precipitation, which usually occurs on the colder portions of the surfaces in the primary system. . . ." (25) However, he said it was unlikely that the precipitation would occur near the core, since it was the hottest part of the system. (26) He also noted that because of temperature considerations, "It [boron] should be expected to stay in the solution." (27) Chairman Hendrie likewise said, "I am not very concerned about losing boron out of that reactor water." (28)

However, their analyses did not describe difficulties in detecting decreases in boron concentration, as pointed out in an NRC memorandum. (29) First, as of April 1980, there was only one operational neutron detector. If it were to fail, monitoring any increase in power, a signal of recriticality, would be severely hampered. Second, an unforeseen rapid decrease in boron concentration would require equally rapid operator action in turning on the decay heat removal pumps. (30) The NRC memorandum pointed out a third factor. As of April, the boron concentration was being measured at a point 200 feet from the core. The amount at that point would not necessarily reflect the concentration in the core.

- **Inability to remove decay heat**

If circulation should stop, so that decay heat is not being removed, and assuming the water level is maintained, the temperature of the coolant water would not reach the boiling point so long as adequate pressure is maintained in the system. (31) The core would heat the primary coolant until a balance is established at the point where natural heat losses[14] equal the heat generated within the reactor. If this condition is reached, temperature in the reactor would remain steady. At the level of decay heat in November, this balance would occur when the temperature of the system reached 500°–600° F (260°–315° C). (32) Since fuel melting occurs at greater than 5,000° F (2,760° C), the likelihood of fuel melting from this sequence of events is extremely low.

INCIDENTS SINCE THE ACCIDENT

There have been several problems at the plant since the accident.

On December 21, 1979, the NRC issued a preliminary notification that small amounts of krypton 85 were being released from the main condenser; they were detected by the condenser radiation monitor.[15] The amounts were measured at 0.0002 microcuries[16] (two-tenths of a billionth of a curie) per milliliter and represented no health hazard.[17] (33)

GPU explained that because pressure was higher in the containment than in the secondary system piping, it believed the gas was leaking from the containment into the steam line of the steam generator "A" through degraded valve seals. The gas was then picked up by the steam traveling through the line from the generator to the condenser.

On February 11, 1980, coolant was released from the primary system during surveillance testing of the make-up pumps. By the time the leak was verified and stopped, between 600 and 1,000 gallons had drained onto the floor of the make-up pump cubicle in the auxiliary building. The water contained a small concentration of dissolved krypton 85 in addition to 50–100 microcuries per milliliter of cesium 137. (34) It gave off krypton 85 gas, and an estimated 200–300 millicuries (two-tenths of a curie) were released to the atmosphere through the ventilation system exhaust of the auxiliary building. (35) However, the station exhaust vent radiation monitor registered no increase in radiation.

[13] This means that localized melting might occur, but that progression to a full meltdown is unlikely.

[14] Natural heat losses from the reactor occur through conduction, convection and radiation. An analogy is a light bulb. The bulb heats up until its temperature reaches a point where the heat losses equal the heat generation—all without the aid of a fan or cooling water. It reaches this temperature and stays at that temperature until the light is switched off.

[15] The condenser is designed to release some radioactive gas during normal operation. The amount is regulated, and anything over it will be picked up by a radiation monitor.

[16] The curie is a unit of measurement that describes the amount of radiation present or released (see Technical glossary). One microcurie is one millionth of a curie. One picocurie is one millionth of one millionth of a curie.

[17] See "Radiation Effects and Monitoring," p. 45.

and the water itself drained into a sump from which it was routed into one of the auxiliary building tanks.

Several of the 12 workers who entered the cubicle to locate and stop the leak were exposed to the radiation. The maximum individual whole body dose received was about 160 millirem, (36) within the limits set by the NRC.

On February 12 and 13, there was an additional release of krypton gas. Approximately 4 curies were emitted to the atmosphere while workers were collecting a sample of air from the containment.

The NRC concluded that the leak on February 11 was the result of equipment failure. (37) During a briefing February 15, Victor Stello, Jr., Director of the Office of Inspection and Enforcement (I&E), explained that a discharge pressure instrument line valve became dislodged when one of the make-up pumps was restarted. (38) An NRC inquiry found that the releases on February 12 and 13 occurred because "The shift engineer who implemented the air sample procedure did not use the effective procedure . . . because the individual did not obtain a controlled copy of the procedure. . . ." (39) The inquiry concluded that the failure to follow document control procedures would be subject to subsequent enforcement action. (40)

These incidents and the continued uncertain status of important equipment in the plant highlight the need for prompt attention to planning cleanup and for improvement in the utility's radiological monitoring and protection program.

THE STEPS IN RECOVERY

There is still no carefully structured, overall plan for the cleanup at TMI, in part because of technical, regulatory, legal and financial uncertainties, compounded by the inability of the utility to enter the containment to conduct a detailed evaluation. Thus the specific steps are still undefined.

Generally, recovery will take place in two phases:

- Cleanup, which involves
  - —maintaining plant stability and preventing releases of radiation;
  - —decontaminating the plant and disposing of waste materials; and
- Deciding on the future of the facility.

These are summarized below briefly and are discussed in greater detail later in this section.

MAINTAINING STABILITY

Reactor stability must be maintained while preparing for and conducting cleanup. Two factors are essential in controlling the reactor core: assuring subcriticality and continued cooling.

Because some control rods are believed to have melted, and the shape of the core is distorted, subcriticality can only be accomplished by maintaining a sufficiently high concentration of boron in the coolant. (41) Proper cooling requires that the core remain covered with coolant. Further, the decay heat being generated by the core must be removed continuously, which is accomplished by circulating the coolant around the core. In addition, the coolant must be kept from boiling, which requires keeping pressure in the primary system at a certain level. Hence, a functional system for controlling pressure is important to stability. Finally, the primary coolant system (including the reactor vessel, piping and pressurizer) must remain intact in order to maintain the needed water level. A large break in the piping, for example, would lead to a release of coolant and thereby threaten reactor stability.

If all coolant were lost, and the core remained uncovered, it would gradually heat, but not melt. In an interview with the Special Investigation staff, Richard H. Vollmer, Office of Nuclear Reactor Regulation, NRC, explained:

> If you lost all the water, . . . in the primary system, I think even then, [the licensee] would be able to take the heat out because the core would go up to elevated temperature where it would start to radiate to the vessel . . . and you would have your conduction that way. (42)

As noted, the rising level of water in the containment could eventually submerge and cause failure of two valves that are important to the new long-term cooling equipment to be installed. This poses a threat to stability.

CLEANUP

The first step in cleaning up the plant is to decontaminate the auxiliary building. Prior to decontamination, a buildup of radioactive water in the auxiliary building caused the greatest short-term possibility of a release of radiation to the environment. (43) As a stopgap measure, the water has been stored in tanks, but ultimately it must be processed, both because the radioactivity must be removed and because the capacity of the tanks is limited. Furthermore, much of the equipment necessary for controlling the stability of the plant is in the auxiliary building. If this equipment is left near the highly radioactive tanks, the workers who must operate it will receive unnecessarily high dose rates of radiation and would have to be replaced frequently by other workers.

The next major step in cleanup is to remove the krypton 85 gas inside the containment to provide safe access to equipment inside the building, such as the reactor and steam generators, and to permit decontamination.

Next is removal of the highly radioactive water inside the building. This water represents a health hazard to workers who will have to spend long periods inside the building and also impedes overall decontamination.

After removal, the water will be processed to rid it of radioactive debris, using filtering equipment similar to that used in the auxiliary building (see pp. 184–185).

To gain access to the core, the next step in cleanup, the reactor head must be removed. Workers must first disconnect components such as the control rods that run through the head and into the core. This job will be difficult if these components are jammed or entangled as a result of the distortion of the core. However, techniques have been successfully applied to similar tasks in previous recovery efforts. (44)

Next is removal of the core.[18] Removal of the head and core is difficult to plan at this stage because the specific damage is not known. The actual steps will be based on visual examination and mechanical tests that cannot be performed until there is unrestricted access to the containment.

Although cleanup is technically challenging and represents a hazard to workers, comparable tasks have been carried out successfully at other plants severely damaged by accidents.[19]

Much of the technology to be used in cleanup is based on that developed principally at government-owned facilities for other applications, including previous accidents. In the previous accidents, however, cleanup could be accomplished relatively quickly and at minimum cost because government plants were typically self-sufficient complexes where administrative support, personnel and disposal sites were readily available, as was decontamination technology. In addition, prior accidents in the United States involving releases predated the deliberative requirements of the National Environmental Policy Act of 1969 involving environmental impact statements and direct public participation, as applicable to the area of atomic energy.

The technology already developed in these prior cleanup exercises is being made available for the Three Mile Island cleanup. (45)

Two matters that will have to be addressed in relation to cleanup are the disposal of radioactive wastes and the worker-safety program. Both matters are also discussed in detail below.

No matter what is ultimately done with the plant, the cleanup must be completed. The plant is now unsafe in comparison with a normal reactor, and the likelihood of further accidents accumulates with time.

FUTURE DISPOSITION OF TMI–2

Once cleaned up, TMI–2 may be decommissioned (taken out of service permanently) or rebuilt either as a nuclear or as a coal-fired facility.

A decision on the plant's future cannot be made now. Its overall physical condition must be better understood, and there are financial, social, legal and regulatory issues that must be resolved.

COST AND SCHEDULE

Soon after the accident, General Public Utilities Service Corporation (GPU Service Corporation) [20] hired the Bechtel Power Corporation to perform an analysis of the recovery of Unit 2. (46) The study, begun shortly after the accident, involves three phases. The first, completed in July 1979, outlined a technical plan for cleanup through the stage of building decontamination (excluding core removal) and estimated the costs of recovery through recommissioning. The study was necessarily based on very preliminary information and involved best guesses in many cases.

Bechtel estimated the cost of recovery, including refurbishment of the TMI–2 plant and replacement of the core, to be about $400 million,[21] excluding energy replacement [22] and certain other costs. It assumed a period of 4 years for the entire recovery from the time workers first entered the containment,[23] and a manpower requirement of approximately 4.1 million man-hours. Cleanup alone would involve more than 1,000 persons at any one time, to be drawn from the national pool of radiation workers. Decontamination would necessitate large amounts of protective clothing and equipment. For example, an estimated 1 million each of plastic coveralls and hoods, breathing cannisters and rubber gloves would be needed.

For cleanup alone, Bechtel projected a schedule of about 2 years and a figure of about $200 mil-

[18] The half-life of the fissionable uranium 235 (U–235) in the reactor is 713 million years. This explains in part the need to remove the core. This task will be one of the last and most difficult.

[19] Serious reactor accidents that have been cleaned up include: the SL–1 facility in Idaho; two at the Chalk River facility in Canada; Enrico Fermi in Michigan; Windscale in England; and the SRE in California. These accidents and aspects of their cleanup are described in "TMI in Perspective: Other Nuclear Accidents," Appendix A, pp. 221–226.

[20] See "Prior to the Accident," p. 51, for details on GPU Service Corporation.

[21] In early June, GPU indicated that final costs of cleanup and refurbishment could far exceed its initial $400 million estimate. See "Financial Aspects of Recovery," p. 190, and see fn. 86, p. 191.

[22] Purchase of energy from other utilities to supply customers of the GPU system.

[23] Since workers still have not entered the containment, the 4-year period has not yet begun.

lion.[24] It should be noted that this figure did not include the costs of in-service inspection (to requalify undamaged equipment), reconstruction, refurbishing of major equipment, radioactive waste disposal and miscellaneous cleanup tasks. Nor did it include the expense of replacing the core, estimated to be between $60 and $80 million.

An independent study of the costs of recovery performed for the President's Commission on the Accident at Three Mile Island estimated decontamination and fuel removal at $90–$130 million. (47)

The final cleanup figure may vary substantially from the estimates of both Bechtel and the President's Commission. Since the plant must be cleaned up, the associated costs for that portion of recovery are unavoidable.

The second phase of the Bechtel study, scheduled for completion soon, is to cover removal of the reactor head and disposal of the core. The third and final phase will address recertification and recommissioning—the steps necessary to put the plant back into operation. The study of this phase is incomplete, since it requires a detailed assessment of the plant, which cannot be finished until the containment is entered.

PLANNING FOR CLEANUP

All planning for cleanup and recovery must be coordinated with the NRC. The agency must approve the cleanup plan and is responsible for establishing the requirements governing cleanup, including limits on worker exposure and radiation releases. Because this is the first major commercial accident in the United States [25] involving large-scale cleanup and recovery, mechanisms for coordination between the NRC and the utility are being developed as recovery proceeds.

As of June 1980, the NRC had not approved an overall plan for cleanup. GPU Service Corporation prepared a plan and schedule in response to a subcommittee request. The NRC reviewed the plan and provided three alternate schedules, reflecting three contingencies.

With no approved plan, there can, of course, be no final target schedule or timetable for completion of the cleanup. The NRC's most conservative estimates of time for the cleanup run nearly 5 years, (48) more than twice the Bechtel projection. The lengthy NRC schedule allows time for environmental reviews and the application of more stringent restrictions on radiation releases.

The NRC also had not, as of March 1980, issued interim guidelines on acceptable releases from the plant. Normally a nuclear power facility is allowed, and does, release a specified, non-hazardous amount of radiation per month. Nonetheless, a "zero-release" standard had effectively been imposed by the NRC, which made any action on cleanup difficult.

The lack of an NRC-approved plan and schedule for cleanup and of new NRC requirements governing the work became major issues. At the November 8, 1979, Subcommittee hearing, the Special Investigation staff reported that "more than 7 months have elapsed since the day of the accident, but there is still no overall plan for recovery." (49) The subcommittee chairman stated:

> Our preliminary findings indicate that the Nuclear Regulatory Commission appears to be withholding guidelines for such a plan until the utility makes its proposal, while the utility position is that such a plan cannot be developed until specific regulatory guidelines are provided by the NRC. So we now seem to find ourselves in a situation where the NRC and Metropolitan Edison are each waiting for the other to make the first move.[26] (51)

As noted, a year after the accident, there were four possibilities: three schedules developed by the NRC, and one unapproved plan developed by the utility.

With no plan and no guidelines, no major progress had been made toward full-scale cleanup as of early June 1980. Using that date as a starting point and taking the most optimistic timetable, removal of the core—a principal health and safety concern—would not occur until sometime in 1982. According to GPU Service Corporation, in order to meet even that target and other cleanup schedules, portions of its plan should have been set in motion early in 1980. (52)

On November 9, 1979, the Subcommittee requested that the NRC supply a best-estimate plan by December 20, 1979, to include a timetable for the entire cleanup and, in addition, its plans for coordination with GPU. The NRC submitted to the Subcommittee material that did not include a best-estimate plan, but instead outlined four pos-

[24] This includes a 33 percent contingency. The contingency allows for the preliminary nature of the facts upon which estimates of cleanup were based, the potential for pricing changes and an assessment of productivity. The report maintains that productivity is a variable which depends on conditions in the containment, administrative controls, required support, worker dose limits and, finally, availability of special materials, equipment and many other items.

[25] There was also an accident at the Enrico Fermi reactor, a small commercial, power-producing "fast" reactor dissimilar to TMI–2. The accident was contained within the primary system and hence was not as serious as that at TMI. See "Three Mile Island in Perspective: Other Nuclear Accidents," Appendix A, p. 225, for further discussion.

[26] The Subcommittee Chairman's statement was based upon two internal memoranda generated by the Special Investigation staff (50).

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sible cases with widely differing schedules ranging from 38 to 58 months. The Commission explained:

> Because of the impact on schedule that could result from environmental reviews and subsequent equipment and operational restrictions, four decontamination program cases were compared to bound the likely duration of the decontamination process. (53)

The schedules provided by the NRC did not allow time for public hearings:

> It was also assumed that no hearings would be held for any steps during Phase 1 and Phase 2 [the cleanup phase of recovery]. (54)

In a discussion between John Ahearne, the new Chairman of the NRC, and Richard H. Vollmer during a meeting of the Nuclear Regulatory Commission on November 29, the mechanics of the environmental review process were outlined:

> AHEARNE: Do you have embedded anywhere in there the concept of—will there be any hearings?
>
> VOLLMER: Hearings were not really embedded in here and as I indicated our estimates of the environmental assessment and perhaps, more particularly, the environmental impact statement are probably as skinny as they could get. (55)

Regarding guidelines on releases, a point also raised by the Subcommittee, the NRC said, in its response:

> We intend to solicit public comment, within the context of the draft programmatic environmental impact statement for the TMI decontamination and cleanup activities, on whether these limits, which were developed for effluents resulting from normal operations, are appropriate for the TMI cleanup activities in light of the differences in the volume and duration of the release of such effluents. (56)

Finally,

> The staff anticipates that existing Commission regulations, guidelines and criteria applicable to a normally operating facility, will continue to be applied to cleanup activities at TMI–2. However, we recognize that although certain activities would otherwise be permitted at a normally operating facility, it may be warranted, in the public interest, to prohibit them at TMI–2 even though they could be conducted in full compliance with existing effluent limitations in the operating license or NRC regulations, until further evaluation of them is undertaken. (57)

In its response to the Subcommittee, the NRC made reference to two other key issues that have a bearing on adoption of a plan and determination of a schedule.

First is the reference to a programmatic environmental impact statement. On November 21, 1979, the NRC decided to prepare such a statement, a task requiring at least a year. (It is scheduled for completion in September 1980.) If no "emergency"-type situations occur in the interim, it is likely that all decisions on cleanup will be deferred until then.[27]

The second reference was to the possibility of more stringent requirements being placed on TMI–2, for example, in connection with releases. Herman Dieckamp, President of GPU, had testified on this point on November 8, 1979:

> If we were to be able to proceed on the basis of existing regulations and specifications, one would be able to proceed to discharge some of the water which was contaminated in the accident after having been processed. But the whole process, institutional process, has, in effect, frustrated that. (58)

The NRC Task Force Report

Early in February 1980, two small, uncontrolled releases of radiation occurred at the site, as noted. During the week of February 11, Commissioner Gilinsky sent Victor Stello, Director of the Office of Inspection and Enforcement (I&E), to the site to assess the situation. As a result of Stello's visit, a task force on the cleanup at Three Mile Island was established on February 15, 1980, under the direction of NRC's William J. Dircks, Acting Executive Director for Operations. He directed the task force to complete a report for the Commission by February 29, 1980, that would "evaluate the cleanup operations at Three Mile Island, how they are being accomplished, and the rate at which they are being accomplished to insure that the public health and safety is being protected." (59)

Selected findings of the Task Force (60) were that:

> The maintenance of TMI–2 in a stable condition cannot be accomplished with zero radiation releases....
>
> The November 21, 1979, Policy Statement of the Commission is being interpreted by the NRC staff as a "zero release" requirement insofar as it affects cleanup....
>
> Both NRC and the licensee have allowed what was once a relatively high

[27] See pp. 201, 204–207 for further details on the Programmatic Environmental Impact Statement.

priority on developing and implementing TMI-2 cleanup plans to erode. . . .

The full extent of approval authority of the NRC TMI Support Staff is unclear. . . .

* * *

The Commission's Policy Statement provides sufficient flexibility so that prompt actions which are shown to be in the best interest of the public health and safety may be undertaken by the Commission prior to completion of the PEIS [Programmatic Environmental Impact Statement] . . . If such prompt actions become numerous and must go to the Commission for approval, delays will be introduced. . . .

Neither the NRC staff nor the licensee has proposed a set of criteria that would provide an interim envelope for the conduct of day-to-day activities . . . pending completion of the PEIS. . . .

* * *

The completion of the PEIS has become an important milestone in the cleanup of TMI-2. However, the Commission's intended use of the PEIS after completion is not clear to the NRC staff. . . .

* * *

Neither NRC nor the licensee has given sufficient consideration to concerns related to the waste form for ultimate disposal of TMI-2 waste off-site. . . .

The recommendations of the Task Force were that the:

Commission announce a commitment to proceed with the cleanup of TMI-2 in as expeditious a manner as possible. Schedules for staff and licensee actions should be established and closely monitored by EDO [NRC's Executive Director of Operations]. . . .

* * *

Commission establish and EDO enforce priority system that places cleanup and PEIS preparation higher than issuing new operating licenses. . . .

* * *

EDO ensure cleanup has adequate review for long-term waste impacts by having full staff coordination on all waste disposal actions. . . .

Staff immediately propose for Commission approval rational, conservative interim criteria to permit releases associated with plant maintenance and data-gathering for future cleanup requirements while awaiting completion of PEIS. An environmental assessment would be prepared for establishment of of these criteria, and CEQ would be consulted. The need to provide opportunity for public comment should be considered.

On April 7, 1980 the Commission approved a set of interim radiological effluent criteria, allowing some work to proceed. (61)

Pennsylvania Governor's Commission

On February 26, 1980, Governor Richard Thornburgh of Pennsylvania issued the report of the Special Governor's Commission on Three Mile Island. (62) One of the topics covered was cleanup. The Commission cited the various risks present at the plant and raised several of the major issues:

. . . decontamination of the water stored in these [the auxiliary building] tanks is essential. . . .

* * *

The major advantage of the controlled [krypton] venting option is that it can be accomplished in a relatively short period of time and it is a *permanent* disposal solution. *The alternative disposal systems create large volumes of intensely concentrated waste material which must be stored on-site or transported to a permanent disposal facility. These are not permanent solutions, and would continue to impose a potential public health hazard.* [Emphasis in original]

* * *

[Limited access to low-level radioactive waste repositories in South Carolina and Washington State] may evolve into a severe problem for Pennsylvania.

During the week of April 7, 1980, the Union of Concerned Scientists agreed to a request by Governor Thornburgh to perform an independent study of krypton venting. The NRC was not required to await the outcome of the study but did so.

DOE and EPA Involvement

The Department of Energy (DOE) concluded, independently, that controlled purging was the preferred alternative for removing the krypton. On February 5, 1980, G. W. Cunningham, Assistant Secretary for Nuclear Energy, DOE, sent a letter to Dircks, which stated:

The purpose of this letter is to urge the Commission to act promptly on the matter [of krypton venting], . . . (63)

The Environmental Protection Agency (EPA) is also involved in the cleanup. Herbert Feinroth of DOE explained that:

. . . shortly after the accident, the White House asked the Environmental Protection Agency to coordinate the roles of the several agencies, including DOE, NRC, and the State in a long-term environmental monitoring plan on [TMI]. . . .

They [EPA] published a long-term surveillance plan which they have been conducting in the last year. This past week, they have initiated an activity to update that plan to include specifically what extra things should be done should the Commission approve the venting proposal. (64)

RADIOACTIVE WASTE DISPOSAL

Storage, shipment and ultimate disposal of radioactive wastes produced and accumulated during cleanup present additional problems, as does disposal of the highly radioactive core. There are only three available commercial disposal sites for low-level wastes (one each in Nevada, South Carolina and Washington), and none for high-level wastes.[28] Both Nevada and South Carolina have requested that TMI–2 wastes not be sent there, and all three States have a reciprocity agreement that bars disposal in all three should a shipment be found in violation of the requirements of any one of the States. (65)

In the State of Washington, nuclear waste became a major 1980 campaign issue. Governor Dixy Lee Ray has said that no out-of-state low-level wastes should be allowed in after December 31, 1982, a three-year period that was to allow States time to develop other options. (66) In addition, the Governor of South Carolina has imposed graduated limits on the amounts of low-level wastes that will be permitted into that State, according to testimony before the Nuclear Regulation Subcommittee on January 25, 1980.

Taken together, all three provisos raise serious questions about the availability of disposal sites for the substantial quantities of low-level wastes that will be generated over the next several years as part of the TMI cleanup.

In the case of high-level waste, the problems are compounded. Because commercial reprocessing of spent fuel has been deferred indefinitely in the United States,[29] the Unit 2 fuel may have to be disposed of unaltered. However, no commercial disposal sites are available for high-level transuranic wastes. In remarks before the Subcommittee, NRC's Denton said:

> Some of the waste will be high-level waste, as opposed to low-level waste. And I'm sure you're aware there's considerable difficulty in the country today with disposal of low-level waste. It's not clear to me that the depositories for high-level waste will be available in the time frame of cleanup, and it may become necessary that some of these [will have to] be stored onsite until that issue is resolved. (67)

At present, low-level waste at TMI is being handled in two ways. First, interim facilities have been constructed onsite to meet the immediate need for the storage of those low-level wastes extracted in the processing of radioactive water with EPICOR. However, the capacity will not be sufficient to accommodate all the anticipated wastes from cleanup. Moreover, the TMI site cannot be used for long-term storage, since it fails to meet requirements as to the depth of the water table and geological characteristics necessary to assure that any accidental leakage of radioactive material will not spread in the environment.

Second, some waste is being disposed of offsite. The Nuclear Engineering Co. (NECO), which operates disposal sites in Richland, Washington, and Beatty, Nevada, is accepting the TMI–2 wastes at its Richland facility. TMI also has a contract with the Chem-Nuclear Company to transport, handle and deliver wastes generated by decontamination of the auxiliary, fuel handling and diesel generator buildings and other areas as "requested by Met Ed."

How many truck shipments will ultimately be required is uncertain. During the Subcommittee's November 8 hearing, Wilson of GPU Service Corporation said:

> I don't think we have the total number of that [shipments], because to some degree it depends what form it [waste] will eventually be removed from the site, but certainly will amount to be in the many, many hundreds of shipments. (68)

The Bechtel study had made a rough estimate of 2,440 truckloads (see Table 1). (69)

[28] High-level waste is legally defined in 10 CFR 50 Appendix F. Generally speaking, it is that concentrated liquid or dried waste obtained from the first cycle of extraction during the reprocessing of irradiated reactor fuels. Low-level waste is everything that is not high-level.

[29] Reprocessing is a technology in which spent fuel is chemically processed to remove plutonium and depleted uranium for recycling as fresh fuel. President Carter has placed a moratorium on commercial reprocessing. Consequently, spent fuel is now stored at the various sites in spent fuel pools.

TABLE 1.—Estimated number of radioactive waste shipments for different categories

Type of waste	*Number of standard weight truck shipments*
High-level resins	370
Intermediate level—4 to 7 drums at 10 curies per drum, per truckload	500
Low level—15 to 18 drums at less than 1 curie per drum, per truckload	300
Dry compacted low-level wastes—50 to 60 drums per truckload	1,250
Major components—(air coolers, pump motors, etc.) (approximately)	20
Total shipments	2,440

This table was developed based on the assumption that the krypton 85 and processed water would not need shipping and does not include shipment of the core.

Because of its limited volume, the water from the auxiliary building can be stored and disposed of with only minor difficulty. However, when the entire cleanup task is considered, the volume becomes substantial. For example, about 1 million gallons are in the auxiliary and containment buildings combined—250,000 and 700,000 gallons respectively.[30] In addition, the utility estimates another 7 to 9 million gallons will be used for cleanup. Of this amount, up to about 5 million gallons of processed water will have to be disposed of. The rest will be purified and reused during cleanup.

By May of 1980, the water in the auxiliary building tanks was being processed by EPICOR–II at an average rate of 3 gallons per minute. This system operates much like a home water softener. It contains a series of demineralizing filters, each of which in succession removes radioisotopes from the water and traps them on a resin bed. The bed is attached to a liner that is removed and stored once saturated.

The processed water is being held in clean water storage tanks, in part because of public opposition to its discharge into the Susquehanna River.[31] Other options being considered for its disposal include reuse in other decontamination tasks onsite, evaporation or solidification in cement.

Waste solidification will have its first TMI–2 application in connection with the saturated resin beds of the EPICOR–II system. When these are changed, the water is drained from the system, but a small amount remains behind. Ordinarily, this residual water is partially removed prior to shipment by vacuum de-watering techniques.[32]

The States which regulate commercial radioactive waste disposal sites have set a standard that less than 1 percent of the volume of the radioactive waste received can be water. While this standard can be met with vacuum de-watering, errors in de-watering sometimes result in greater than acceptable percentages of water. Consequently, as an additional step toward safe handling and shipment of these TMI wastes, the NRC has ordered that the resins from EPICOR–II be solidified in cement to immobilize the radioactive waste completely. (70)

The licensee plans to install cement solidification equipment sometime in 1980 and will put the wastes into 55-gallon drums. (71) These can either be stored in underground silos onsite or shipped offsite for burial.

Nonetheless, the NRC maintains that the licensee has, or can construct, enough radioactive waste storage areas onsite to preclude the need for shipping the solidified EPICOR–II waste offsite. (72)

As noted, one commercial low-level waste site was still available in June 1980, and disposal of low-level wastes should not pose a problem in the near future. Further, despite concerns expressed by the communities surrounding TMI (73), the NRC has said that onsite storage of some wastes from the cleanup will not pose any greater health hazard to the workers, the public or the environment than it does at other commercial plants. (74)

The longer term storage of TMI wastes is, however, a problem. The NRC has not yet dealt directly with the possibility of the closure of the remaining low-level waste disposal sites, although it has asked DOE to prepare a contingency plan for that event. (75)

The issue of closure goes beyond TMI. Permanent closure after 1980 would directly affect all nuclear power plants. Onsite storage would quickly become exhausted, and eventually the plants would have to close down.

With respect to the core, while the Federal Government is seeking solutions to long-term storage (e.g., through DOE), TMI may require a nearer term solution. GPU has asked for DOE's assistance in determining how the reactor fuel can be transported and what can be done with it, since that Department is presently responsible for finding solutions to the overall nuclear waste problem. DOE is studying various options for storing the TMI core, to be completed by July 1980.[33] Poten-

[30] These figures reflect the volume in April 1980.

[31] See "Legal and Regulatory Aspects of Cleanup," pp. 201–204, 207.

[32] Vacuum de-watering is accomplished by lowering the pressure to a point where the water will naturally boil off. The resulting vapor is condensed into non-radioactive water, leaving behind the radioactive resin beds.

[33] The Subcommittee staff was informed by Herbert Feinroth, Chief, Nuclear Reactor Evaluations Branch, Division of Nuclear Power Development, DOE, that his division is funding the study and that only the technical feasibility of storage options is under review.

Storage vaults for radioactive wastes resulting from cleanup

tial interim technical solutions being considered include:

- Storage in fuel pools onsite or elsewhere;
- Storage in shielded facilities;
- Reprocessing.

An additional problem affecting interim fuel storage is the abnormal chemical state of the debris, which consists of a combination of zirconium, hydrides, oxides. fission products and possibly various alloys and other chemical compounds. Its corrosive characteristics must be determined before the long-term integrity of storage containers can be assured. When asked by the Subcommittee about these problems, Denton said:

> I think they [core materials] will present some very interesting technical questions. In what form . . . these high-level wastes should be solidified. How should this really high-level waste be contained . . . you need to know . . . what type of environment are they expected to be in over their lifetime, in order to put them in proper form to begin with. (76)

Commissioner Hendrie also commented on the storage options for the core:

> . . . there are about two options in the time frame we are talking about. One of them is to keep the casks onsite for some period . . . and the other one would be for one of the major Government processing centers to accept those casks . . . until we finally get on to solving the high-level waste problem in this country. (77)

In summary, the large quantities of low-level wastes being generated by the ongoing cleanup at TMI–2 pose substantial challenges in terms of long-term storage, shipment and disposal. There are uncertainties regarding the continued availability of offsite disposal sites. Storage and disposal of the highly radioactive, damaged reactor core pose even greater difficulties, given the uncertain future of high-level waste disposal in this country.

WORKER SAFETY

A principal focus of the Special Investigation was the safety of workers performing the cleanup operation. As noted, the immediate threat from any further accidents at the plant is principally to the workers.[34] Further, several health physics [35] problems have already occurred.

One instance involved violations of health physics regulations. On March 29, 1979, radioactive samples were drawn without using standard health physics protective procedures. This event marked the first of a series of such problems. The NRC, in the cover letter to its notice of violation and intent to impose civil penalties on Met Ed, commented that "there was a significant departure from normal health physics procedures and practices." (78) It went on to say, ". . . we believe that insufficient measures were taken to control health physics actions and decisions during the course of the accident." (79)

Then, in late August 1979, five workers performing maintenance work on a contaminated water storage system in the TMI–2 auxiliary building were exposed to levels of beta radiation in excess of NRC limits. The exposure was to their skin and extremities. Personnel monitoring the radiation were apparently not aware of the potential for high beta radiation. (80)

After a preliminary investigation, the Subcommittee sent a letter to NRC Chairman Hendrie on September 27, 1979. The letter, referring to comments made by Denton and others, stated:

> Mr. Denton also said that "even today we are still continuing to experience problems with the utility's [Metropolitan Edison's] attention to health physics." He expressed specific concern about the utility's "failure to make adequate survey and [in] understanding the radioactive environment in which they are operating." [36]
>
> Lending further credence to Mr. Denton's expressions of concern is a recent NRC critique of the utility's follow-through to correct radiation protection problems identified at the site. In an NRC report obtained by the investigation. D. R. Neely, Region I Lead Radiation Specialist, and J. R. White, Radiation Specialist, stated that the company "is not able to effectively administer the radiation protection program commensurate with the degree of radiological risk which is presently being encountered. Such risk is expected to increase as the recovery efforts expand." (82)

Acting Chairman Kennedy responded to the Committee, saying:

> With regard to a related matter, your letter of September 27 correctly points out

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[34] See pp. 165, this section.

[35] The discipline of protecting people from unwarranted exposure to nuclear radiation is called health physics. Health physicists seek to devise means of providing protection. In this instance, these protective steps broke down and led to safety problems.

[36] Problems with Met Ed's radiation safety program were highlighted as early as March 20, 1979 (prior to the accident) when Met Ed contracted with the NUS Corporation to perform a study of its health physics program. (81).

> that the staff has in the past identified a number of deficiencies in the licensee's radiation protection program which, as yet, have not been corrected. As discussed in more detail in enclosure 2, the staff has been pursuing these matters over the past several months and will continue to do so. Neither they nor the Commissioners will permit expansion of the recovery program until these important issues are suitably resolved. Again, the principal concern related to these deficiencies is in providing adequate protection for the workers on the site. (83)

In October 1979, GPU Service Corporation began upgrading its health physics organization and contracted with Rockwell International to perform engineering studies for an onsite health physics and radiochemical analysis laboratory. It has been putting together a health physics team and intended to have the entire organization in place by the summer of 1980.[37]

The NRC also responded to the health physics problems. Denton organized a "blue ribbon team" (84) of nationally prominent U.S. health physicists to advise the Commission. Its report, dated December 1979, outlined the special health physics requirements of the cleanup and assessed GPU and Met Ed's radiation protection program. (85) The team concluded:

> The panel confirmed several management and technical deficiencies in the program. Recent major GPU/Met Ed committments [sic] and actions demonstrated a major change in management attitude.
>
> The panel concluded that exposures to personnel can be maintained to as low as is reasonably achievable while limited preparatory recovery work continues and when further needed improvements are implemented as needed, the radiation safety program will be able to support major recovery activities. (86)

At the same time the NRC panel also stated that "The present radiation safety program has substantial deficiencies and requires significant corrective action to support major recovery activities." (87)

Four factors contributed to its conclusions. First, NRC staff had identified a number of managerial and technical weaknesses in the program. Second, Robert C. Arnold, a Senior Vice President of GPU and Met Ed, told the panel that despite all the comments and recommendations the utility had received from various sources, including its own contractors and consultants, it had been unable to establish an effective radiation safety program. (88) Third, the panel's interview with utility personnel at all levels revealed a common feeling that safety was not respected. (89) Fourth, the utility's program lacked organization and direction. (90)

The Panel was unable to evaluate the merit of the utility's plan to upgrade its program. It noted that "The upgrading of the radiation safety program for major recovery activities is not complete. The Panel cannot judge the capability of this future program." (91) The Panel, however, did state that the management of GPU and Met Ed had demonstrated a strong commitment to improve the radiation safety program and that work could proceed safely on a limited basis under existing management. (92)

The significant problem of protecting workers will continue. The number of technicians at the site is far greater than during normal operations. Usually, plant personnel, even during a refueling outage, number only about 800.[38] As of April 1980, there were about 1,100 people onsite to work on TMI–2. Sixteen contractors were involved in onsite radiation protection alone, and more than twice this many contractors were onsite for all purposes. (93) There were also numerous representatives of various government and industry groups.

In addition, the magnitude of contamination and radiation with which individuals must work is many times greater than previously faced. Further, there is an unusual aspect to the situation at TMI—a preponderance of beta radiation, a result of the cesium–137 and strontium–90. It is more common, around operating reactors, to have predominantly gamma radiation.

A team of three health physicists was scheduled to enter the containment in mid-1980. They would be exposed to this beta radiation. If the krypton in the containment were not vented, the field would be expected to be approximately 400 rad/hr. If it were vented, it would be significantly less. The actual dose received would also depend on where in the containment the team goes. Exposure could, in any case, be limited by wearing layers of special protective clothing, and only the extremities would receive significant doses.

Protective clothing does not block penetration by most of the gamma radiation at the Unit 2 facility. The level of this radiation, however, was estimated to be low enough that workers could tolerate it for a few hours at a time. Thus manned entry into the highly radioactive containment was

[37] As of December 1979, the organization consisted of 194 people: 55 assigned to dosimetry, 89 to field operations, 15 to radiation technical support and 35 to bioassay and management.

[38] Refueling is done periodically to replace fuel that has reached its design life and to reshuffle good fuel in the core. During refueling of the reactor, many more people than normal are onsite. Normally, TMI–2 has around 200 people onsite.

"Trailer City": Temporary offices set up during the accident have been needed for recovery operations

considered possible if sufficient care were taken and the period spent there was brief.

When asked during the November 8 hearing what the total radiation dose to workers would be for the entire recovery, Wilson of GPU Service Corporation said:

> We don't yet have a total estimate of what we might expect of what I would characterize as a total man-rem dose of the recovery operation. I would expect we would anticipate there would be no workers in the absence of any incident that would receive what's called a maximum allowable dose. (94)

THE TECHNICAL STEPS

MAINTAINING STABILITY

Subcriticality must be maintained in the core to prevent possible release of fission products or melting of the core. Subcriticality is maintained by keeping the core covered with water that has an adequate concentration of boron. As long as the primary cooling system remains intact, it is unlikely that the water level will decrease to the point of uncovering the core. Further, some control rods may not have melted; if they are in place, they will help insure shutdown.

Maintaining Boron

Boron in solution can surround a core whose normal geometry has been lost. Calculations show that between 3,000 and 4,500 parts per million (ppm) of boron in the water will insure subcriticality no matter what the geometry of the core. (95)

As of March 1980, a concentration of around 3,500 ppm was being maintained, controlled through the use of the Borated Water Storage Tank and the make-up and let-down systems. The sample of the water from the primary system is analyzed weekly for boron, gross radioactivity and acidity. GPU has stated that as long as the reactor fuel and control materials remain in their present abnormal and uncertain arrangement, the boron concentration must be maintained within that prescribed range to guarantee subcriticality of the core and to avoid excessive heat. (96)

Cooling the Core

Decay heat removal is achieved by circulating coolant around the core. This heat naturally decreases with time. At the end of April 1979, it was 41 million watts; by April 1980, it had dropped to 180,000 watts,[39] still enough to heat around 7 homes on a winter day. If this heat were not removed, the reactor would heat up a few degrees Fahrenheit per day until the balance point referred to earlier was reached.[40]

As of April 1980, natural circulation was the method being used to remove the heat. The water was circulating only within the containment; as the building was still sealed, the chance of spreading contamination or releasing radiation was reduced. Further, natural circulation lessened the exposure of workers to radioactivity.

On the primary side, natural circulation involved only the core and steam generator "A"; no pumps were being used. On the secondary side, the principal pieces of equipment relied upon were the condenser and feedwater system. Together they turned the steam produced by the heat absorbed from the primary system into water and pumped the feedwater back to the steam generator, where it again absorbed heat from the primary side. For "steaming," as this process is referred to, to take place, the primary system, including the piping, seals and pressure vessel containing the core, must remain intact.

If difficulties should arise with natural circulation, two back-up cooling systems are available immediately. A third system was scheduled to be ready for operation in March 1980.[41] (97)

According to GPU, one such difficulty would be a leak in steam generator "A." (98) If it was between the primary and secondary sides of the generator, radioactive contamination could get into the water flowing through the secondary system, creating additional radiation hazards and increasing the potential for contamination spreading through leaks in the secondary system. Because of these hazards, other means of cooling the reactor would be sought and the steam generator shut down.

Steady cooling through natural circulation could be disrupted by temperature changes. As of April 1980, the bottoms of the steam generators were submerged in the pool of water in the containment. As decay heat decreases with time, the coldest point in the system will shift location, leading to fluctuations in the flow paths of the coolant. These oscillations, which would take place in the primary loops, could lead to lesser oscillations of flow in the core, with a resulting fluctuation in core temperature of a few degrees Fahrenheit. Although the amount of this temperature fluctuation is very slight and tends to be self-correcting, it is undesirable because prudence dictates that steady cooling should be maintained.[42]

When coolant flow becomes unstable, temporary stagnation of the flow results, potentially leading to boron stratification—differing concentrations of boron in the water at various levels or regions of the core. According to GPU, calculations indicate that the fluctuation in boron concentration from this phenomenon is only minor, and concern over any resultant recriticality is unwarranted. (100)

The NRC and GPU indicated that boron stratification was not expected to be a problem, (101) since the utility could provide adequate flow to mix the concentrated boron solution injected into the reactor coolant system so that the stagnant regions would not become depleted. (102)

Backup Cooling Systems

The first back-up system would involve the "B" steam generator. It uses water flow as opposed to steaming—water is pumped through the system and absorbs heat from the primary side with conventional heat exchangers. The leak that was identified in the "B" steam generator during the accident apparently has not recurred, and the "B" generator could be used. Because this option takes place in part outside the containment, it is a less desirable method for cooling, as it increases the possibility of spreading contamination in the plant and exposing workers to higher levels of radiation. The risk of a release of significant radiation to the environment is minimal with this system.

The second back-up method involves the regular Decay Heat Removal System, which also operates in part outside the containment. It involves pumps and heat removal equipment and is the one normally used after a reactor shutdown. It, too, is not being used so as to limit the spread of contamination and exposure to workers.

The third alternative—the Mini Decay Heat Removal System—had been scheduled for operation in March 1980, but was still not being used as of June 1980. In that month the NRC and GPU decided to install a long-life filter. (103)

[39] Heat and electricity are both forms of energy. The rate of energy production can be expressed in watts.

[40] See p. 166.

[41] This system—the Mini Decay Heat Removal System—will eventually become the principal means of cooling; it is discussed in detail later. In order to bring this system into operation, GPU Service Corporation has had to submit to the NRC proposed changes in the Technical Specifications of its license. The NRC must approve these.

[42] In April 1980, such oscillations in flow actually occurred. They resulted from the occasional use of the so-called "pressure-volume control system." The system caused just enough imbalance to start the oscillation. The oscillations occurred over a period of 17–18 hours and led to a maximum temperature drop of 40–50°F across the core during periods of complete stagnation. Eventually, the oscillations disappeared and steady cooling was re-established. (99) The importance of these oscillations has not been thoroughly investigated.

This system is smaller than the regular decay heat removal one, as it has been built to accommodate the low levels of decay heat being generated in 1980. If nothing unusual happens, it will be more than adequate to handle existing levels of heat.

The Mini Decay Heat Removal System also functions in part outside the containment. However, it has much smaller piping and other equipment than the regular Decay Heat Removal System, and the volume of radioactive material to be pumped through it will be smaller. The associated radiation hazard would decrease proportionately. Nearby workers would be exposed to significantly less gamma doses than result from the regular system, which would involve several hundred rem/hr. Further, use of the Mini System would allow external control and monitoring of coolant conditions (both temperature and pressure) and permit access from outside the containment to the primary coolant, a capability that will be important during cleanup of primary system water.

Construction of the Mini Decay Heat Removal System is the first of a series of actions that would establish independent, external control of the reactor environment. According to Wilson, it "will be the mode of cooling until such time as the [reactor] head is removed and the fuel extracted." (104) GPU plans to rely on this system because, as noted earlier, the utility believes that natural circulation could be impeded in the future.[43] Moreover, once the reactor head is removed, natural circulation will no longer be possible, and a different method of cooling must be used.

EARLY CLEANUP STEPS

Major decontamination of the plant began in April 1979, when Met Ed started processing the water that had been transferred from TMI–2 to the TMI–1 auxiliary building for storage. The processing was done with a system called EPICOR–I.[44] The water contained relatively low levels of radioactivity (less than one microcurie per milliliter).

In April, decontamination of the diesel generator building was undertaken. In May, work was begun at the TMI–2 auxiliary and fuel handling buildings. It involved principally dry and wet vacuuming, mopping and wiping to remove contamination. Workers were required to use special clothing and respirators.

The accident and cleanup as of April 1980 already had produced a variety of slightly radioactive solid wastes, such as clothing, rags, ion-exchange resins, swipes and contaminated air filters, much of which has been buried at the Richland, Washington site. (105)

Radioactive Water in the Auxiliary Building

Cleanup of this building has been progressing well. (106) As a result of decontamination efforts, surface contamination in selected areas had been reduced by a factor of between 100 and 1,000 between May and October 1979. Since October, more of the building has been cleaned in order to achieve levels of radioactivity comparable to the already decontaminated areas. Although the water in one tank in the building was still reading more than 1,000 rad/hr, most of the others were reading from 20–30 rad/hr. (107) Processing of this water is being done with EPICOR–II.[45]

The cumulative exposure of workers in the auxiliary building through November 1979 was 50 person-rem. (108) By comparison, approximately 45 person-rem are received per year by workers at a plant which is being refueled. (109) The amount of radioactive water in the auxiliary building had been increasing prior to November 1979 [46] because of non-radioactive water leaking into the system. While the additional non-radioactive water has had a diluting effect, it too has become contaminated, thereby adding to the volume of water needing to be processed.

The leakage is mostly from pumps in the building that are part of the river water service system. (110) At present, these pumps cannot be sealed because they are too close to high-radiation areas. Prior to November 1979, the amount of leakage had been fluctuating from as low as 300 gallons per day to as high as 2,000 gallons (the average was 800–1,000 gallons/day), depending on the use of various systems on any day. By April 1980, the leakage was better controlled, and the average ranged between 200–450 gallons per day. (111) The water drains into the contaminated sumps in the auxiliary building where it is collected and added to the new tanks that were installed in the fuel handling building to contain contaminated water.

The total usable capacity of the storage tanks to contain this leaking water is 415,000 gallons. (112) One week after the accident, the design of the EPICOR–II water processing system was begun, in part to address the growing problem of storage of radioactive water. The system was scheduled for use in mid-May 1979. At that time, the city of Lancaster, Pennsylvania, brought suit [47] to gain an injunction against the discharge

[43] See p. 178.

[44] Similar in design to EPICOR–II, EPICOR–I was brought to the site immediately after the accident.

[45] See pp. 181, 182.

[46] In November 1979, with EPICOR–II operating, the water could be processed faster than it was leaking in, and the total amount of radiation was being reduced.

[47] See "Legal and Regulatory Aspects of Recovery," pp. 201–204.

Decontamination underway

of processed water into the Susquehanna River. (113) (Lancaster is about 23 miles from TMI and gets its water at a point 8 miles downstream of the site.) Another suit was filed by the Susquehanna Valley Alliance against both the utility and the NRC. (114) As a result, the NRC prohibited any further water processing and discharge without its authorization. The NRC's action raised a potential problem of storage of the contaminated water.

The Subcommittee recognized the need for a decision on the issue of water storage. On September 28, 1979, it sent a letter to the Chairman of the NRC, stating:

> We understand that the currently estimated capacity for storing this water in Unit 2 will be exceeded in approximately 40 days. We understand that alternate storage options exist, including pumping the contaminated water into tanks in Unit 1 or bringing additional storage tanks on

to the Island. Please advise us what options are being considered and how they would be implemented.

* * *

We bring these matters to your attention because of the serious public policy issues they pose, not only for the Three Mile Island region, but also with respect to NRC's ability to handle this matter. (115)

By October 1, only 28,600 gallons of storage capacity remained in the tanks installed in the fuel handling building. On October 16, GPU said that approximately 23,000 gallons of storage capacity remained. (116)

The NRC, after receiving the Subcommittee's letter, held a meeting on October 4, 1979. NRC staff told the Commissioners that any significant further delay in decisionmaking could lead to several problems. (117) First, the tanks could overflow, spilling water into the auxiliary building sump, from which it would flow back into the full sump tank system and ultimately begin to fill the building. Second, the contaminated water from Unit 2 might have to be transferred to the uncontaminated tanks in the TMI–1 unit (the two units share certain water storage facilities), thus spreading contamination to Unit 1.

Possible solutions besides further processing included acquisition of additional tanks or pumping the water in the auxiliary building back into the containment. (118) Both options had serious drawbacks. (119)

On October 22, the NRC decided to permit Met Ed to process the contaminated water with EPICOR–II.[48] However, the Commission also decided that the processed water would have to be held up pending a later decision on disposal. (120) The clean tanks, also located in the nearby fuel handling building, now hold processed water.

Because the EPICOR–II system was basically a new design, the extent to which it could remove radioactive contamination was uncertain.[49]

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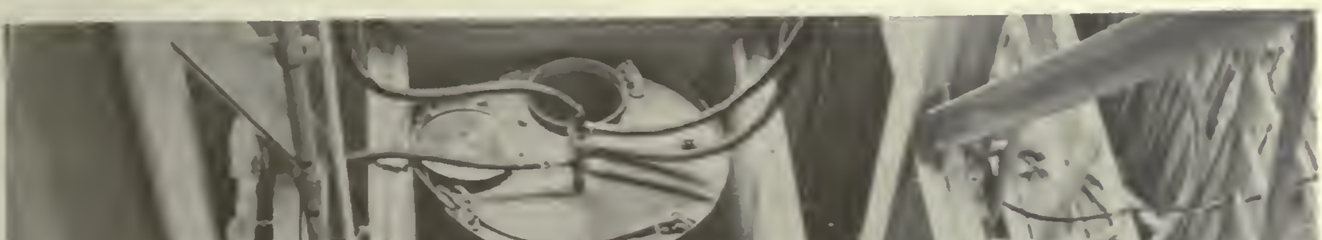
[48] See "Legal and Regulatory Aspects of Recovery," pp. 201–203, 206–207, concerning the claim that the NRC illegally "segmented" cleanup decisions in violation of the National Environmental Policy Act of 1969 and other regulations.

[49] This capability is expressed by a quantitative measure of effectiveness called the decontamination factor for the process; that measure is the ratio of the concentration of radioactivity in the contaminated water to that in the processed water.



EPICOR–II water purification system

In testimony on November 8, Wilson told the Subcommittee that the decontamination factor for EPICOR–II was better than anticipated:

> The decontamination factors [of cesium 137] are about two orders of magnitude [50] better than the design basis of the system. We expect to be able to continue to process with this system and are putting in place on the site the additional storage tankage for the clean water. (121)

He also said,

> We are not now, or do we have immediate plans to discharge that water. In fact, they are under a probation [sic] from the NRC to not do so. (122)

THE NEXT STEPS

The Containment Atmosphere

The next step in recovery of Unit 2 is removal of the estimated 45,000 curies of krypton 85 in the containment atmosphere. (123) GPU Service Corporation has considered several options, including controlled venting to the atmosphere, cryogenic processing, charcoal adsorption, and gas compression. In addition, selective absorption has been proposed. Venting has become a very controversial step, as it involves releasing the gas to the atmosphere. While the last four options would avoid direct releases, they have other drawbacks, as described below.

Controlled Venting

In the first option, the gas would be released from the building by venting it at a controlled rate over 34 days, through the plant vent stack, 160 feet above ground level. Venting would take place at times when wind and other meteorological conditions are most favorable for atmospheric dispersion. (124)

GPU has maintained that this controlled release can be performed in compliance with all current Federal radiation standards.[51] (125) Its estimate is that the highest calculated dose to an individual would be 0.1 millirem of gamma and 5 millirem of beta radiation for the total purge (the standards are 10 and 20 millirem, respectively).[52]

The NRC discussed the magnitude of the release at a meeting on November 29, 1979. One issue was comparative doses: how much radiation would be released in the venting at TMI–2 in comparison with normal releases from either a pressurized water reactor (such as TMI) or a boiling water reactor.[53]

The NRC staff told the Commission during the meeting that the controlled venting of krypton from the TMI–2 plant would have fewer radiological consequences than do the releases of krypton and all other noble gases [54] over 1 year from a single, normally operating boiling water reactor. (126) The release would also be 10 times less than the annual routine releases from certain Federal military installations.[55]

On August 22, the Critical Mass Energy Project, a public interest group that opposes nuclear power, petitioned the NRC to prevent the controlled venting. Richard Pollock, its Director, sent a letter, dated August 22, 1979, to Chairman Hendrie, saying:

> According to the Bechtel Corporation consultant's report for the licensee, "controlled" venting of radioactive gases could lead to contamination levels for persons at the boundary site reaching .14 millirems of gamma radiation and 14.8 millirems [56] of beta radiation during a 30-day period. NRC criteria sets the yearly maximum dosages for the general population at 10 millirem for gamma radiation and 20 millirem for beta counts.
>
> * * *
>
> . . . if there was an accident during venting, the TMI–2 area residents conceivably could receive much larger dosages than those contemplated by Bechtel and GPU. (129)

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[50] Two orders of magnitude equal a factor of 100.

[51] 10 C.F.R. 60, Appendix I, § B.1, states "The calculated annual total quantity of all radioactive material above background to be released from each light-water-cooled nuclear power reactor to the atmosphere will not result in an estimated annual air dose from gaseous effluents at any location near ground level which could be occupied by individuals in unrestricted areas in excess of ten millirads for gamma radiation or 20 millirads for beta radiation."

[52] The safety analysis discussed here pertains to an estimated inventory of 44,000 curies. In its environmental assessment the NRC used a figure of 57,000 curies, based on weekly sampling of the reactor building atmosphere since the accident. The licensee's figure (44,000 curies) is based on the measured concentration at the time its report was issued (November 13, 1979). The conclusions reached by the licensee would not probably not be significantly different if the higher figure were being used.

[53] See "Technical Glossary," Appendix E, pp. 367, 373.

[54] Noble gases routinely escape from reactors and include helium, neon, argon, krypton, xenon and radon.

[55] For example, the Savannah River facility located in South Carolina releases 4.3×10^5 Ci of Kr–85 per year. The maximum calculated whole body dose to an individual at the plant perimeter from the krypton is 0.0026 millirem. (127) Standards for those facilities are set by DOE.

[56] These radiation dose predictions were based on preliminary estimates made by Bechtel Corp. in its July 1979 Planning Study for containment entry and decontamination. (128) Hence, they should not be expected to agree with the later estimates cited above.

The projected population dose from an accidental release is uncertain, as it depends on the extent of the leak and prevailing wind and other weather conditions. However, according to Vollmer, who spoke at a meeting of the NRC on November 29, 1979:

> . . . if you are involved in an accident where you released all the krypton currently in containment, using average meteorology, you would get a whole-body dose in the environment of less than 10 MR [millirem] and a skin dose on the order of 200–500 MR, so even if all [the krypton] were released in an accident case, the offsite consequences would be not large even with respect to perhaps Part 20 [the Federal Guidelines]. (130)

Hence, although there is strong public distrust about venting, NRC estimates indicate minimal radiation effects for the surrounding population, even in the event of an accidental release at one time of all the krypton in the containment. (131)

Because the discussion of venting has led to considerable public pressure to evaluate other options (see "Social Issues in Recovery," pp. 199–200, 201), Governor Thornburgh asked that the Union of Concerned Scientists perform an independent study. It concluded, ". . . direct radiation-induced health effects from exposure to krypton 85 even from the Met Ed/NRC proposed venting would be absent." (132) However, the report stated, "UCS recommends against any procedure that would result in citizens . . . being deliberately exposed to radiation . . . at levels comparable to those expected from . . . the venting proposal." (133) Citing a desire to diminish public stress, UCS made two proposals for elevated venting, each of which had the potential of greatly reducing the radiation exposure. One option involved construction of an incinerator stack to create a buoyant plume, and the other involved use of a tethered balloon to support an extended stack made of thin polyethylene, one foot in diameter, 1,000–2,000 ft. high. (134)

Cryogenic Processing

The second option for krypton removal involves cryogenic processing. The Kr–85 would be liquefied, distilled and stored in bottles. An advantage of this method is that it could significantly decrease or eliminate the radiation released from the plant at the time of removal. However, the utility has estimated that it would take 20 to 30 months to build the necessary equipment. (135) Further, it is unclear what would be done with the bottles.

A safety analysis and environmental report prepared by GPU outlined the disadvantages:

> The system produces highly concentrated [Kr–85]. Any leakage or component failure could result in significantly greater amounts of uncontrolled radioactivity release than the other systems. (136)
>
> * * *
>
> There is no significant operating experience with a cryogenic distillation system at any operating light water reactor. Accordingly, this is not a proven technology for reactor application. (137)

The study concluded that—

> When compared to controlled purging of the containment building, the alternate cryogenic treatment system is considered to be less safe—it is less reliable, and clearly has the potential for uncontrolled releases of radioactivity with higher radiation exposures. (138)

During the November 29 NRC meeting, the issue of cryogenic cleanup was also addressed. NRC estimated that if this option were selected, it would take 20 months to become operational after a decision was made to proceed. (139)

Charcoal Adsorption

The third option, charcoal adsorption, could also minimize radiation releases from the plant. During the same Commission meeting, Vollmer explained its use:

> The technology . . . is one simply of putting the contaminated gas over charcoal, preferably in a chilled state, preferably under some higher-than-atmosphere pressure, to get maximum effectiveness, and then the charcoal which would adsorb the krypton gas, but not retain it indefinitely, would have to be encapsulated and then you would have to [dispose of it]. (140)

Vollmer continued:

> I might indicate that the charcoal volume required for this would be about the same as the size of the volume of the containment building, about two million cubic feet. What the staff tells me is something on the order of a third of the charcoal available in the country. (141)

Gas Compression

According to GPU, the fourth option, gas compression, similarly would greatly lessen the amount of krypton–85 released into the atmosphere. On the other hand, as the GPU safety analysis report noted:

> Storage of krypton at high pressure for long periods of time in 28 miles of piping increases the likelihood of uncontrolled release compared to purging containment.
>
> * * *
>
> The extensive time required to build and install a gas compression system would increase the likelihood of inadvertent and uncontrolled leakage from the existing

containment building, and thereby cause higher exposure to personnel. (142)

The report concluded:

> When compared to controlled purging of the containment building, the alternate gas compression system is considered to be less safe—it is less reliable and clearly has the potential for uncontrolled release of radioactivity with higher radiation exposures. (143)

This option would require construction of a $50–$75 million facility over a two- to three-year period. (144) The facility would include a 160-foot high building to house the equipment and approximately 24 miles of 36-inch diameter high pressure piping. (145)

Selective Absorption

In a briefing before the NRC on April 25, 1980, representatives of the Department of Energy and Oak Ridge National Laboratory presented a technical assessment of an alternate method for treating the krypton. (146) The selective absorption method, instigated four years ago by a DOE request that a mobile radwaste disposal system be developed, is partly a spinoff from technology developed for the removal of krypton from reprocessing facilities.

A report written by Oak Ridge National Laboratory (ORNL) estimates that development of such a system for use at TMI–2 would require 13 months and from $9 to $12 million, on a crash priority basis. (147)

In testimony before the Commission, ORNL stated that it believed venting was the preferred option. (148) The selective absorption method is, in principle, a zero-release system according to ORNL, but venting would still be preferable since it would allow early entry into the containment. (149)

The selective absorption method was independently assessed in two other studies. A professor at the Michigan State University wrote in a letter to Commissioner Gilinsky. "I have tentatively concluded that the best method of those available is the selective absorption process system. . . ." (150)

Science Applications, Incorporated, also performed a review and found that there was little basis to choose between selective absorption and controlled purging with regard to physical health effects and that the purging option was preferred because it would be less stressful to the population than the selective absorption method. (151)

NRC Consideration of Options

On March 12, 1980, as planned, the NRC staff submitted their environmental assessment of the venting option. They concluded that controlled purging was the preferred alternative. They proposed a period for public review, to be followed by a meeting at which the public's views would be heard. Thereafter, the Commission was to make a final decision on venting.[57]

Containment Cleanup and Core Removal

The containment must be decontaminated so that it can be entered and the highly radioactive core dismantled and removed. The water in the containment also poses a health physics and safety problem.

Containment Entry and Water Removal

The plans outlined in the July 1979 Bechtel report considered the use of robots for entering the containment. (152) The utility has since concluded that radiation levels will be low enough to allow manned entry for brief periods. (153)

A team of three health physicists, two GPU employees and three backup members, was trained for this job. The individuals had been selected on the basis of their knowledge of the layout of the containment and of health physics, understanding of the operations to be performed and physical fitness. The team will carry out a number of tasks, such as surveying for radiation, assessment of contamination and observation of the conditions inside the containment. Their analysis will be the basis for planning further entry and decontamination. The team had completed its training by mid-March 1980 (154) and was awaiting NRC approval of its procedures.

On May 20, 1980, workers encountered an unexpected problem when they attempted to enter the containment for a 30-minute inspection. Entry was thwarted after 15 minutes of effort when the containment door beyond the equipment airlock failed to open. (155) The door depends on functioning of an electro-mechanical system. As of June 1980, the NRC had not determined whether the door was stuck because of the failure of electrical equipment, mechanical equipment, rusting inside containment, or combinations of these. Testing on a similar airlock door was underway in order to attempt to identify the problem.

After the team conducts its assessment, the next step will be to clean up the radioactive water within the containment and the reactor.[58] The utility is planning to process these highly radioactive liquids (between 100 and 275 microcuries per cubic centimeter) using a submerged demineralizer that

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[57] See "Social Issues in Recovery," pp. 199–200, 201, and "Legal and Regulatory Aspects of Recovery," pp. 206–207, for a discussion of events subsequent to the staff's venting recommendation.

[58] Although the core will continue to leak radioactive contamination into the coolant, cleaning the water will greatly reduce the amount of radiation and thus lessen exposure of workers to it.

was originally developed for defense application. (156) The system is much like EPICOR–II, but uses inorganic rather than organic resins. It will be placed in the spent fuel pool where the water will shield it from the radiation.

In testimony before the Subcommittee on November 8, Wilson said that specialized engineering and development of this system for use at TMI is underway. He said it is expected to be operational in late 1980. (157) One existing system that might be suitable for use at TMI consists of a self-contained unit within a shipping cask that is licensed for shipments of up to 300,000 curies. It would allow direct shipment of the wastes, thereby minimizing handling. (158)

An evaporation system will be required to clean up the liquids used in decontamination. These liquids contain a soap-like material on which EPICOR's ion exchange technique does not work well. The evaporation system being procured by GPU Service Corporation can process 30 gallons per minute. It boils the water; the steam is then condensed and sent through a polishing demineralizer [59] designed to produce very pure water. This water will be reused during decontamination.

As noted, there were 700,000 gallons of radioactive water in the containment as of December 1979, a level that has been increasing because of the leaking pump seals inside the containment. In testimony before the Subcommittee on November 8, Vollmer said:

> . . . [given] the leakage rate of about 500 gallons per day, and I believe it's actually lower than that now, we would project approximately a foot or so rise in six months. (159)

A more precise estimate by GPU established the rate of leakage at less than 230 gallons per day, equivalent to a one-half to one inch increase in the water level per month. (160) The leaking cannot be reduced until the new primary coolant pressure control [60] and heat removal systems are operable.

The rising water, as noted, threatens the motors that operate two critical isolation valves. Based on photographs taken before the accident that show the height of the motors, it was calculated that, as of November 1979, the motors were approximately two feet above the water level. In November Vollmer told the Subcommittee:

> . . . I don't see anything in the near term, say within a year, that would have any influence on the safety of operations. (161)

By April 1980, the bottom of the valve bodies were in contact with the water [61] and a failure of the valve, given the humid environment, is possible. If the valves become submerged or if the electric actuators fail in the humid environment, (162) control over them will be lost, and they will remain in whatever position they were prior to failure. As they have been kept closed, they would fail in that position. Access to primary system coolant would then be lost, and neither the decay heat removal system nor the new Mini Decay Heat Removal System could be used. This would be undesirable because it would leave only the existing deteriorating equipment for core cooling. In addition, decontamination of the primary system water would be greatly inhibited.

Met Ed frequently measures the water level and continuously monitors (meggers [62]) the electrical leads on top of the valves. (163)

Since it is important to the long-term cooling of the core and treatment of the primary system water to have one of the valves open, if difficulties arise, the utility will open one of the two valves so that it will fail in that position. If such action has to be taken before the NRC approves the Mini Decay Heat Removal System,[63] radioactive water will flow into the regular decay heat removal system, spreading contamination in the facility. That spread can be limited by closing an isolation valve located outside the containment building.

There also is radioactive material within the reactor vessel and its associated piping. The amount continues to increase as the coolant moves around the damaged core and fission products in the fuel are leached from the fuel. (164) This process is counteracted to a certain extent by continual replacement of the leaking radioactive water with clean water, which dilutes the radioactivity somewhat. The activity level in the primary system water is now 275 microcuries per milliliter, essentially the same as that in the water in the containment.

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[59] A polishing demineralizer is the final filtering stage of the evaporator system. The relatively decontaminated water is "polished" in this final step.

[60] The coolant pressure control system located in the fuel handling building is also used to provide make-up coolant to compensate for the leakage and to control the chemistry of the coolant, particularly the concentrations of boron and oxygen. It includes a pressurized nitrogen supply that controls pressure, and a borated water batching tank, charging water storage tank and independent charging pumps. It was added for the same reason that the new heat removal system was added: to avoid reliance on reactor systems that may have been damaged during the accident and that are inaccessible because of their proximity to high radiation fields.

[61] The valve bodies are about one foot below the actuators.

[62] Meggering is the electrical monitoring of the leads. Presence of water will lead to a change in the electrical signal, which would be detected on a readout instrument, alerting personnel to possible degradation of the equipment electronics.

[63] According to GPU, if the NRC requires a long-life filter on the Mini Decay Heat Removal System, four to six months will be required for installation.

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Because of the continued leaching, GPU Service Corporation intends to install continuously operating purification equipment, once the reactor head is removed, to minimize the dose to workers. (165)

Building Decontamination

The next step in the cleanup process is manual decontamination of the inside of the containment. A containment recovery service building will be constructed adjacent to the containment equipment hatch to provide health physics control and isolation from the environment.

Many techniques are likely to be employed in this stage of recovery, including wet and dry vacuuming, mopping, wiping and the use of semiportable equipment such as degreasing units, ultrasonic cleaners and electropolishing machines. (166) Conventional contamination control techniques are the technological basis for this activity. A decision on specific methods will be made once the observations and measurements taken in the earlier manned entry are analyzed.

Radiation Inside the Containment

The work force will face the greatest radiation hazard in this phase. Early after the accident, the NRC and the utility had been concerned that cesium 137 (Cs–137) might have been released from the water into the atmosphere of the containment and then might have become extensively deposited on the walls of the containment,[64] adding significantly to the cleanup task. (168) The radiation dose to workers would have made the health physics problems substantially more difficult, and it would have been necessary to wash the Cs–137 off the walls remotely, using the building spray system in conjunction with solvents and detergents or foaming agents.

Information obtained prior to the Subcommittee hearing on November 8 showed that the extent of airborne Cs–137 and of surface deposits was much less than anticipated, since less cesium was released into the air than estimated earlier. This means that the cesium is in solution in the water and can be cleaned up by other techniques such as EPICOR or the submerged demineralizer.

As of June 1980, GPU's plans called for manual decontamination of the walls. In remarks before the Subcommittee on November 8, Wilson said,

> . . . a part of the plan originally conceived by Bechtel used the containment building spray system as a means of remote decontamination inside containment prior to entry. The current data suggest that's not required. . . . (169)

The feasibility of this plan will depend on surveys performed by the team in the containment.

Although attempts at direct measurements have been inconclusive to date, (170) preliminary indications of the condition of the containment wall have been obtained. A two-inch and a nine-inch hole were drilled through the end plates of the access pipes leading into the building. (171) As of June 1980, Oak Ridge National Laboratory had finished analyzing the cut-offs from the holes. Results have not yet been released. Swipe tests[65] around the inside perimeter of the hole and radiation surveying are also planned. These tests will help determine the concentration of Cs–137 near the hole, while the analysis of the cut-outs will be used in determining the efficacy of various decontamination techniques.

Finally, the inside of parts of the containment has been videotaped, using equipment inserted through the holes. According to the NRC, the pictures show no significant damage or disruption as a result of the hydrogen burn that occurred on March 28, 1979. (172) No visible evidence of the accident can be seen on the portion of the containment filmed except for some paint blistering and droplets of condensed water falling from the walls.

On the basis of the limited measurements available, the utility has estimated the radiation environment inside the containment building; (173) its figures are shown in Table 2. The figures in this table were estimated based on the assumption that neither the radioactive gases nor the liquid inside the building had been removed.[66]

TABLE 2.—*Estimated dose rates at various elevations in reactor building*

Elevation	Location	Dose rate (rad per hour) Total gamma	Total beta	Total
282 ft	Sump	120.0	720	840
305 ft	Equipment hatch	3.0	400	400
347 ft	Operating deck	.5	400	400

If the krypton and water are not removed first, manned entry will be possible only for relatively short times. Because of the estimated high level of radiation, containment cleanup (krypton and water removed and walls decontaminated) must be finished before the reactor head and core can

[64] This is similar to what happens when soot adheres to buildings, discoloring them. While there is no evidence that cesium has migrated into the steel liner of the building, there is still a concern that some painted surfaces may have to be stripped to remove cesium contamination. (167)

[65] A swipe test is a means of determining the level of contamination on a radioactive surface. A small piece of cloth-like material is rubbed on the wall and taken to the laboratory for radiochemical analysis. The test allows determination of the relative amounts of radioactive species present.

[66] Values in the table were current through March 1980.

be removed. The estimated radiation dose will come predominantly from gamma and beta radiation and will differ according to the elevation within the containment. The radiation environment at the 282-foot level is primarily the product of radiation emanating from the pool of water. At the higher elevations (305 and 347 feet), it is largely the product of emissions from the krypton. If the containment sump is drained and the krypton 85 removed, gamma dose rates inside the building are projected to drop sharply to between 0.2 and 10 rem/hr.

For purposes of comparison, the occupational whole-body dose limit for an individual, as established by the Code of Federal Regulations, is 3 rads per quarter year from all sources. (174) The dose permitted to the hands and feet is approximately 18 rads per quarter year (hands and feet have a greater tolerance for radiation). (175)

Using the radiation estimates, the amount of time that an individual can remain in each area of the plant without the aid of additional shielding can be determined. If, for example, the gamma radiation level were 3 rem/hr, an individual could work no longer than 1 hour in that region.

Reactor Head and Core Removal

This phase of the cleanup is the most uncertain, since the condition of the severely damaged core is unknown and because subcriticality of the reactor must be monitored and maintained while work proceeds on the core. A plan for removing the reactor head [67] and core was being prepared by Bechtel. (176)

Barring legal and economic difficulties, GPU's goal was to begin removing the head 11 months after the containment was entered and to begin removing the fuel 20 months after entry. The NRC's preliminary estimate, based on GPU's plans, was that core removal might not be complete until March 1984 if the krypton in the containment were treated cryogenically instead of being vented.

The plan for removal of the head and core has been slow to develop. Certain steps are fundamental to the job, but the specific techniques to be employed will depend upon now uncertain details. (177) For example, it is clear that the reactor head must be removed to gain access to the core. It is less clear, however, whether special tools and procedures will have to be developed to disengage entangled control rod drives. That will only become clear once the containment can be entered and tests performed. The special tools can only be designed once the nature of the problem is defined.

According to GPU, the Bechtel report on the removal of the head (which was released in May 1980) contains initial planning for the removal of the reactor vessel head and core, describes some of the available technical options and also identifies the preferred general approach to the job.

Two steps are necessary before the reactor head can be lifted off. First, a means of removing decay heat other than by natural circulation must be established, since natural circulation will not work with the reactor head removed. As noted, the Mini Decay Heat Removal System will probably be used. Second, the coolant must be decontaminated and a continuous filtration system hooked up in order to reduce the radiation field for workers. Once the containment building and primary water are decontaminated, access to the reactor head area needs to be unencumbered by high radiation levels.

Head Removal.—Ordinarily, for example during reactor refueling, removal of the reactor vessel head is relatively straightforward. In the case of Unit 2, however, the control rod drives that penetrate the head may be entangled with the damaged core. GPU Service Corporation plans to place boroscopes [68] into the instrument or control rod thimbles (penetrations made for control rods) so that their condition can be evaluated visually. If there is resistance when the control rods are lifted, the drives will have to be disconnected prior to removing the head. This task will involve, if necessary, the removal of those head penetrations which are not jammed first, in order to create openings in the reactor head through which the entangled drive-trains can be reached. The problem rods can then be cut loose and the head removed.

All activities involving head and core removal will be tested on mock-ups. As noted, special tools will have to be designed and built, based on needs to be defined as the cleanup proceeds. This type of specialized tool design has been carried out successfully during core removals at other reactors which have experienced accidents.[69]

Core Removal.—The largest single source of radioactivity is the reactor core, estimated to contain 6 billion curies. Although it is generally easier to control the spread of contamination from solids such as the core than it is from liquids or gases, the core at TMI has been severely damaged and poses hazards that will require special handling.

The physical configuration of the core is unknown. As a result of the accident, at least 90 percent of the fuel rods have burst. (178) Periodic injection of cold water into the extremely hot core

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[67] The reactor head is bolted on the pressure vessel. It is massive but is designed to be removable.
[68] A boroscope is a device similar to a periscope, which allows remote viewing of objects. It has its own light source.
[69] See "Three Mile Island in Perspective: Other Nuclear Accidents," Appendix A, pp. 221–226.

(close to 4,000° F in some regions) probably caused both the cladding and the reactor fuel itself to shatter like glass. Some of the materials in the core are thought to have melted.[70] This material includes some of the silver-indium control rods as well as the stainless steel in which these rods were enclosed. These molten metals may have slumped to the lower portions of the core and solidified there, forming a casting of sorts.

It is difficult to determine with certainty what the core looks like today. Some analyses suggest the core resembles an empty bowl with fragmented pieces of fuel and Zircaloy interspersed between intact remnants of the fuel pins at the bottom of the core. (179) The fuel assemblies further from the center may be entirely intact, forming the walls of the bowl. The upper portion of the fuel in the radial center of the core was probably destroyed and displaced, forming the cavity of the bowl.

Great caution will have to be taken during core removal to guarantee subcriticality. The boron concentration must be maintained continuously at 3,500 parts per million until the core is out. While the exact procedures that will be used are uncertain, past experience points to some possible approaches.

All handling and manipulation of the core will be performed remotely and under clean, borated water, with the aid of underwater television. Intact fuel assemblies, damaged assemblies and loose debris will be encased in metal cans underwater and their ends welded shut with underwater welding equipment. The cans will then be moved through the fuel transfer port to be placed in either a shipping or storage cask. Several independent neutron monitors will be put in place to detect any increase in neutron activity, a sign of recriticality.

With respect to the cost of fuel removal, the July 1970 Bechtel estimate for fuel removal equipment and disposal was $23 million. (180)

Worker radiation dose rates during core removal are expected to be comparable to those encountered during normal plant refueling.[71] (181) Since more workers will be exposed over a longer time, however, the collective dose to the work force will probably be greater than for refueling. Nonetheless, the dose for this phase is expected to be less than during decontamination of the containment.

Removal of the core is the last step in cleanup. At this point the full degree of damage can be assessed and a decision made as to the plant's future.

FUTURE OPTIONS

Four options have primarily been studied in connection with TMI–2's future.[72] (182) This section discusses some of the technical factors.[73]

Decommissioning—retiring the plant permanently—is a step normally taken after 30–40 years, the projected life of a similar plant. If, however, the facility can be reused, the utility has several options including: to repair the existing nuclear unit; to replace it with a new nuclear unit; or to convert it to a coal-fired or other fossil-fueled unit.[74]

Obviously, the decision will depend in part on the condition of both the nuclear steam supply system (NSSS)[75] and the rest of the plant. While rough estimates of the extent of the damage to the NSSS and the plant exist, an accurate assessment will not be possible until cleanup is complete. At that time, radiation levels should allow relatively unrestricted access throughout the containment, and a detailed evaluation can be made.

The technical decision will also depend on other factors, most particularly finances. In considering the financial factor, it should be noted that some basic costs pertain to all options. As GPU's President, Herman Dieckamp, noted in response to questioning by the Subcommittee:

> . . . cleaning up the plant . . . has a cost associated with it of at least $200 million out of that estimated $320 million for the total . . . costs. So that is there irrespective of return to service. (184)

As of April 1980, GPU maintained that damage to the facility was within a range that would permit the plant to be recommissioned either with a nuclear or a coal-fired steam supply system. (185) Bechtel had estimated the physical effects of the accident in its report, issued July 1979. (186) The report stated:

> Excluding the conditions that existed during the hydrogen detonation, the physical effects of elevated containment pressures and temperatures during the

[70] The presence of any previously molten materials can only be guessed at until the core can be viewed.

[71] During refueling, many workers are inside the containment. The resulting dose to the work force is therefore higher than in normal plant operations.

[72] This section is intended to provide an idea of what the final stage of recovery—disposition of the facility—entails and generally what options have been considered most seriously.

[73] See subsequent subsections for details on financial, social and legal and regulatory factors.

[74] Gilbert and Associates performed a study for GPU Service Corporation that included cost estimates for natural gas-fired units, but noted that "Coal would be the primary fuel due to current and proposed restrictions on oil, and the unknown availability of natural or synthetic gas in the quantities needed for the installation." (183)

[75] The reactor, steam generator and primary system piping, etc.

March 28, TMI–2 accident on the containment structure, systems and components were probably minimal.

In localized areas, the possibility of some instrumentation damage, hydraulic snubbers leaking, grease fittings/lubricated fittings dripping oil, etc., does exist. The pressure and temperature . . . conditions that existed . . . do not appear to be detrimental to the equipment in the containment for the short time period in question. (187)

The extent of damage done to the primary system by thermal shock had not yet been determined. Similarly, the extent to which hydriding [76] of the steel had led to embrittlement was not known. These factors can only be known after entry of the containment.

There is also the possibility further damage to the plant has occurred or will occur subsequent to the accident. It includes radiation damage to the insulation on the electrical wiring and corrosion of components submerged in the pool of water. However, if the damage is relatively limited, as anticipated by Bechtel, replacement of many of the major components within the plant will not be necessary.

DECOMMISSIONING AND REPLACEMENT

Adequate experience is available on decommissioning plants. (188) Studies on the costs of decommissioning plants of comparable size, at which accidents have not occurred, are about $30 million. (189) The study prepared for The President's Commission on the Accident at Three Mile Island put the cost of decommissioning TMI–2 at $192 million, with a range between $157–$241 million. (190) According to the study, about half the expenditure would be associated with the disassembly and removal of structures.[77]

If the plant is decommissioned and retired, the utility would still have the option of replacing Unit 2 with a new facility. The cost of a nuclear unit, including interim replacement power costs, is estimated at between $2.3 and $3.1 billion. (192) The comparable cost of a coal-fired plant is estimated at between $1.9 and $2.6 billion, in 1979 fixed dollars, reflecting the lower construction cost of that type of plant.

RECOMMISSIONING

GPU has stated that it would prefer to put Unit 2 back into operation using fully the undamaged portions of the facility, but has not decided whether a nuclear or coal-fired unit will be selected. (193) Its investment in TMI–2 was over $1 billion, and the plant had been in commercial operation for only 1 year at the time of the accident. Decommissioning would mean retirement of an essentially new facility. Thus, the utility has an economic incentive to reuse the plant.

The cost of repairing the unit and returning it to nuclear service was estimated by consultants to The President's Commission at between $1.0 and $1.9 billion, with construction running from 45 to 69 months (the figure includes the costs of replacement power). (194) The higher figure is based on replacement of the entire nuclear steam supply system.

GPU has looked into converting the plant to a coal-fired unit. Dieckamp explained the utility's conclusions during the November 8 hearing:

> . . . with respect to the study of alternatives to returning it as a nuclear plant, we have felt that . . . it was going to be important for us to have good solid detailed studies that had, indeed, evaluated the options. And so, we have been looking at an option that would convert the plant to coal firing.
>
> * * *
>
> It becomes possibly a very complex unwieldy configuration, and perhaps, not a very productive plan. (195)

Insofar as environmental constraints and costs were concerned,

> We are . . . looking at . . . the capacity of that local air basin to handle coal firing, and in addition, there are the problems of handling ash and scrubber sludge . . .
>
> * * *
>
> I think it's probably true that the incremental cost to get the next 900 megawatts of power is probably less if one reconverts or maintains it as a nuclear plant. (196)

Gilbert and Associates, Inc. studied the coal conversion option [78] for the GPU Service Corporation. (198) It estimated the cost at between $0.7 billion and $1.0 billion, with a construction time of

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[76] Hydriding is similar to oxidizing; it is a chemical reaction at the surface of the steel. It causes embrittlement of the steel.

[77] The study cautions that ". . . our assessment should be interpreted with the caveat that the present assessments may change as better data become available in the future." (191)

[78] The report contains the following caveat: "Moreover, the numbers presented in the report are subject to major changes in the course of the detailed analysis which is expected to be made in the Phase II study. Consequently, no judgement as to technical or economic feasibility can be reached on the basis of this report." (197)

from 42 to 48 months.[79] Their estimate did not include energy replacement costs, the expense of offsite sulphur dioxide removal equipment and facilities, decommissioning and other items.

According to the various studies, repairing the nuclear plant is the least costly, followed by replacement with a coal-fired plant, followed by replacement with a nuclear plant. These figures are summarized in Table 3.[80]

TABLE 3.—*Cost in billions of dollars*

Option	
Repair or replace nuclear reactor in existing facility	$1.0–$1.9
Replace nuclear reactor with coal in existing facility	$0.7–$1.0*
Decommission existing facility, build new coal plant	$1.9–$2.6
Decommission existing facility, build new nuclear plant	$2.3–$3.1

*Excludes large energy replacement costs.

FINANCIAL ASPECTS OF RECOVERY

Recovery has raised a number of financial questions, such as who will pay for cleanup, the financial condition of the GPU companies, the possibility of bankruptcy and the effect of bankruptcy on cleanup. More than 1 year after the accident, there were still no clearcut answers to any of the issues.

THE PROBLEM OF CASH FLOW

The two nuclear facilities at Three Mile Island are 50 percent owned by Met Ed, 25 percent by the Pennsylvania Electric Company (PENELEC), and 25 percent by Jersey Central Power and Light Company (Jersey Central), three utilities which are in turn owned by GPU.[81] (200) The NRC licenses authorize Met Ed to operate the two units and to receive, possess and use special nuclear material for that purpose. (201)

The major electrical generation transmission and distribution facilities of the three utilities are physically interconnected, and the GPU companies operate as a single, integrated electric utility system. Thus, the energy generated at TMI–1 and TMI–2 before the accident was distributed throughout the GPU system. (202)

Since the accident, the GPU companies have been facing serious financial problems, despite substantial assets.[82] The financial problems are reflected in the declining value of the parent company's common stock. Before the accident, it was selling on the New York Stock Exchange for more than $17 a share (205); in mid-May 1980, the price was between $5 and $6. (206) Bond ratings of the three GPU utilities also have fallen. Before the accident, Moody's Investor Service had given Met Ed and PENELEC bonds an "A" rating, Jersey Central bonds a "Baa" bond rating (207); in March 1980, PENELEC and Jersey Central's rating had dropped to "Ba," Met Ed's even further to "B." (208)

The GPU companies' principal financial problem has been cash flow. (209) Their problem was created by the need to pay for cleanup costs and to purchase electric power to compensate for the lost output of Units 1 and 2.

In early 1980, GPU's working estimate was that decontamination of Unit 2[83] would cost at least $200 million, and there were indicators that revised cost estimates would be far higher.[84] (211) One management consulting firm predicted that total cleanup costs could be "half a billion dollars—or much more." (212)

The major ongoing expense, however, has been replacement power. GPU reported that during 1979, the utilities' costs ran from $20 million to over $35 million each month, (213) figures that may increase.

The GPU companies' $4.9 billion in total assets do not provide a simple solution to the companies'

[79] The President's Commission did not estimate the cost of rebuilding Unit 2 as a coal facility. The estimates of schedule and cost prepared by Gilbert and Associates are not directly comparable to those of the President's Commission, since different assumptions were used in formulating the results. Gilbert and Associates also estimated the costs of conversion to natural gas. This option was found to be less desirable. The costs ranged from $446 million to $500 million. (199)

[80] The figures in this table are all approximate and do not reflect comprehensive cost analyses.

[81] See "Prior to the Accident," pp. 50–51.

[82] For 1979, GPU and its three utility subsidiaries reported more than $4.9 billion in consolidated assets, an increase of more than $300 million over 1978. Of these, Met Ed accounted for about $1.3 billion, PENELEC about $1.5 billion and Jersey Central about $2.1 billion. (203) The GPU system is the 14th largest investor-owned utility system in the nation in terms of both assets and revenues. (204)

[83] As discussed earlier, cleanup is only the first step in dealing with Unit 2. GPU still must decide whether to rehabilitate, convert or decommission the facility. Each option will entail additional costs. See "Technical Aspects of Recovery," pp. 188, 189.

[84] Pursuant to agreement, Met Ed, PENELEC and Jersey Central are jointly responsible for all operating and maintenance costs associated with TMI, including those related to the accident, in the same proportion as their ownership shares—50 percent, 25 percent and 25 percent respectively. (210)

cash flow problems. GPU's only significant assets are the common stocks of its three subsidiaries; (214) their assets in turn consist mostly of facilities and equipment and are not liquid. (215) Further, according to GPU's Treasurer, John G. Graham, neither GPU nor its utility subsidiaries have had large cash reserves to draw upon in order to help pay the post-accident costs.[85] (219)

The GPU utilities are paying for the accident-related costs from three principal sources—insurance, loans and utility operating revenues.

The companies had $300 million in property damage insurance for Unit 2, the maximum coverage available, and they expect the full amount to be available to pay for cleanup. (220)

As of May 1980, cleanup costs were well below the maximum coverage.[86] However, insurance settlements sometimes had lagged behind expenditures, contributing somewhat to the cash flow problem.[87]

The GPU companies had no insurance to cover additional replacement power costs.[88] They have been trying to meet this major expense out of their operating revenues and have requested rate relief from State regulatory authorities in order to augment that revenue.[89]

In June 1979, both the Pennsylvania Public Utility Commission (PUC), which regulates Met Ed and PENELEC, and the New Jersey Board of Public Utilities (New Jersey Utilities Board), which regulates Jersey Central, granted substantial rate increases to cover replacement power costs. Nevertheless, for at least a year after the accident, the rate increases did not match these utility costs.[90] (226) This was because State regulators had granted less than full relief and because GPU's cost estimates proved too low.[91]

In April and May 1980, New Jersey and Pennsylvania regulators granted substantial additional rate relief designed finally to provide full and current recovery of replacement power costs.[92]

Although rate increases for replacement power have been substantial, they have been offset to some extent by other decisions by the Pennsylvania and New Jersey regulators. Most prominently, the utility regulators have removed from the utilities' rate bases all capital and operating costs associated with TMI–2 and TMI–1.[93]

Since insurance and operating revenues have been insufficient to meet cash needs, the GPU companies arranged to borrow money to help cover the cash flow gap between existing expenses and future revenues. They have obtained short-term loans from a consortium of banks and some long-term financing through institutional investors.

On June 15, 1979, GPU and its subsidiaries entered into a revolving credit agreement with 45 banks, including Citibank, N.A. and Chemical

[85] According to consultants working for the President's Commission on the Accident at Three Mile Island, the GPU companies' financial structure prior to the accident was not unique. The consultants concluded that:

> GPU [and its subsidiaries] followed general industry practices and, after reconciling individual company differences, probably was not materially different in its financing practices, and results achieved, from the other electric utilities which had facilities in New Jersey or Pennsylvania. (216)

According to GPU's Graham,

> The virtually universal pattern for major electric utilities in the U.S. that own, as do the GPU companies, generating, transmission and distribution facilities is to maintain virtually no balances of unrestricted *cash* working capital . . . cash balances are generally only those required to be maintained as compensating balances for lines of credit and/or for outstanding short-term borrowings. (217)

In part, he said, this is because

> The rate regulatory process has not permitted—and is not intended to permit—an electric utility to accumulate large cash reserves to deal with the aftermath of an accident. (218)

[86] According to an NRC staff study, if Unit 2 is decommissioned, the property damage insurance will cover cleanup costs, but not the costs of decommissioning, such as dismantlement or entombment. If the unit is restored to service, restoration would be covered by any insurance remaining (up to the $300 million limit) after decontamination. (221) GPU's estimates indicate cleanup and restoration costs may greatly exceed $400 million. (222)

[87] According to GPU's treasurer, through October 31, 1979, approximately $83 million had been expended for containing and cleaning up the accident, while insurance recoveries to that date were only $20 million. (223)

[88] Since the accident, members of the nuclear industry have formed an insurance pool through a mutual insurance entity called Nuclear Electric Insurance Limited (NEIL) to help cover replacement power costs in the event of another nuclear accident. Membership in NEIL will be available to electric utilities, including publicly-owned utilities, that have an insurable interest in a nuclear power generating unit or in a nuclear unit's output. (224)

[89] See, generally, "Legal and Regulatory Aspects of Recovery," pp. 212–216, for a discussion of State regulatory proceedings since the accident.

[90] In December 1979, GPU's treasurer said that the "net outflow for replacement power purchases was running at the rate of approximately $12 million per month." (225)

[91] In June 1979, Pennsylvania and New Jersey each approved rate relief that covered only about 85 percent of the estimated replacement power costs of the three utilities. (227) The June 1979 rate increases had been based on utility estimates of replacement power costs over 18 months. (228) Since the utilities had assumed that TMI–1 would be back in service by January 1980, (229) their estimates of need over the 18-month period proved unduly optimistic. (230) The companies also underestimated price increases in oil, which adversely affected the costs of purchased power. (231)

[92] In early June 1980, GPU said that it had spent about $300 million to replace lost output at TMI but had received only $150 million of the increased costs from customers. (232)

[93] In June 1979, the Pennsylvania PUC and the New Jersey Board of Public Utilities each removed the Unit 2 costs but permitted retention of Unit 1 costs. In April 1980, New Jersey removed Unit 1 costs, and in May 1980, Pennsylvania did likewise. (233)

Bank.[94] The agreement established a line of credit, initially totalling $412 million, with sublimits for each GPU company. (235) As of late May 1980, total borrowing could not exceed $292 million without a favorable vote of the banks representing 85 percent of the credit line. (236)

The banks required that GPU put up substantial collateral to back up the loans. For example, GPU had to put up all of the common stock of its subsidiaries. According to a Citibank official, before the accident, the banks would have given GPU revolving credit without requiring collateral. (237)

The agreement authorizes the banks to suspend further credit, declare a default and accelerate the due date of outstanding loans if, in the opinion of the majority, there is a "material and adverse" change in the actual or prospective financial condition of the borrower that "substantially increases the risk" that the loans will not be repaid when due. (238) If the majority determines that "the revenues to be available" to a borrower "will be insufficient to assure its ongoing financial viability," they may suspend further credit, although they may not, for this reason alone, declare a default or accelerate the due date.[95] (240)

In late May 1980, after favorable rate rulings in Pennsylvania and New Jersey, GPU officials estimated that the loans would not reach the $292 million credit limit before the end of 1980, at which time the banks would have to vote whether to increase the credit limit. (241)

In late June 1979, PENELEC and Jersey Central each issued $50 million worth of first mortgage bonds in order to obtain some long-term financing. The bonds were sold through private placement to a group of major insurance companies. In each case, the net proceeds were to be used either to pay outstanding short-term bank loans or construction expenditures or to reimburse the bond issuer's corporate treasuries for funds previously expended. (242) In October 1979, Jersey Central issued another $47.5 million in first mortgage bonds under similar terms.[96] (244)

REGULATORY ISSUES

One effect of the stipulations on short- and long-term borrowing has been to tie continued lending to the rate-rulings of State regulators. During Subcommittee hearings on November 9, 1979, GPU's John Graham testified:

> I would say if we receive adequate and timely rate relief, I believe that Metropolitan Edison Co. and the other two operating companies of GPU will remain financially viable.
>
> * * *
>
> With that hypothetical, favorable action by the Pennsylvania Commission, I believe that the banks will stay with us; Metropolitan Edison will have access to bank credit; GPU can contribute in the form of leaving retained earnings in Metropolitan Edison Co. or by GPU using part of the revolving credit agreement to make borrowings at the GPU level and to put that money into Metropolitan Edison Co. as that might be necessary. (245)

The lending banks have given similar testimony. Officials of Citibank and Chemical Bank told the Pennsylvania Public Utility Commission in February 1980 that the PUC's decisions would "collectively determine" the lending banks' confidence in the GPU companies as viable entities to whom continued credit should be extended. (246)

The Securities and Exchange Commission (SEC) has been following GPU's borrowing arrangements closely, pursuant to its statutory duties.[97] (248) It, too, has pointed out the importance of rate relief. On November 9, 1979, SEC Commissioner Loomis testified before the Subcommittee:

> Senator HART. Does the data you have just presented indicate to you GPU is in sound financial condition overall?

[94] Before the accident, the GPU companies had informal lines of credit totalling $225 million at 89 diffrent banks. The reason for a written revolving credit agreement, according to bank officials, was that under the informal arrangement any one bank could have unilaterally ceased to fund its line of credit, which would have left the other banks "deeply concerned" and could have created a "cascading effect," with one cancellation leading to cancellations by the others. The revolving credit agreement was designed to prevent this by setting up written procedures to insure the lending banks acted "in concert." (234)

[95] The GPU companies have continued to maintain some informal credit lines with various banks. However, under the revolving credit agreement, the amount of debt outstanding under these external lines cannot exceed $15 million. (239)

[96] All bonds had a 20-year maturity; PENELEC's bore interest at 11¾ percent per year, Jersey Central's 12 percent per year (June issuance) and 11⅝ percent per year (October issuance).

All of these bonds are subject to mandatory redemption in specified situations; that is, they must be repurchased by the issuer at face value prior to the maturity date. One situation would be if a bank participating in the revolving credit agreement refuses to make advances to the utility. (243)

[97] GPU is a holding company subject to regulation under the Public Utility Holding Company Act of 1935, 15 U.S.C. §§ 79 *et seq.* According to SEC Commissioner Philip A. Loomis, Jr., one of the Act's purposes is ". . . to require that the members of holding company systems be soundly financed without too high a level of debt . . . By requiring proper financing, the act and regulations seek to keep each utility company highly solvent and most unlikely candidates for bankruptcy, except under extraordinary conditions, which may . . . [exist] here." (247)

LOOMIS. . . . I will make an introductory answer. Its capitalization is appropriate for its operations, we believe, and it seems to me . . . the particular problem of GPU and Metropolitan Edison is the fact that with both of these nuclear plants down and not operating, they have to buy electricity from other sources, and that electricity is very expensive, and the problem is whether or not their revenues will carry the cost of obtaining purchased power. (249)

The Director of the SEC's Division of Corporate Regulation, Aaron Levy, also testified on this issue.

> Senator HART. . . . assuming the replacement power costs will be covered by the rate base for the utility, in your judgment, should GPU be able to sustain the estimated $300 to $400 million cost of the TMI cleanup? . . .
>
> LEVY. On the basis of the . . . [data] we have, and if adequate rate relief is granted, I can't see any reason why the system should not be able to absorb whatever the cleanup costs may be. (250)

The regulators in Pennsylvania and New Jersey have indicated their awareness of the link between their rate-making decisions and the financial condition of the GPU companies. (251) Their decisions have reflected an attempt to provide the utilities with needed rate relief without making customers bear an unreasonable or inequitable share of the utilities' costs. (252)

Thus, for example, on April 1, 1980, the New Jersey Board of Public Utilities rendered a decision in which it said:

> It is obvious that this availability of funds [from the lending banks] is uncertain and contingent on the banks' reaction to regulatory action taken in New Jersey and Pennsylvania. (253)

It also said:

> The Board [of Public Utilities] clearly recognizes the serious financial condition of . . . [Jersey Central]. This Board will endeavor to work toward [preserving Jersey Central] . . . as an ongoing concern to avoid the potential devastating impact of insolvency or bankruptcy.[98] (254)

As of late May, rate adjustments by the New Jersey Utilities Board had raised Jersey Central's rate levels by some $293 million, roughly 48 percent over the utility's pre-accident levels. About $82 million of the increase was attributed to TMI. (257)

In May 1980 the Pennsylvania PUC granted PENELEC and Met Ed significant rate increases, stating that their decision provided "an adequate framework for Met Ed's recovery" and that it was Met Ed's burden to "convince its bank creditors that it . . . has the will and the ability to rehabilitate itself." (258)

At the end of May, rate adjustments by the Pennsylvania PUC had raised Met Ed's rate levels by some $150 million, 50 percent over pre-accident levels;[99] about $143 million was attributed to TMI. (260) The rate levels for PENELEC, which did not have to make substantial post-accident purchases of replacement power had increased about $19 million, 4.2 percent over its pre-accident levels. All of this increase was attributed to TMI. (261)

Despite the utility regulators' actions, it remained uncertain in late May how far the efforts of the utility regulators would go toward resolving the GPU companies' financial difficulties.[100]

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[98] Shortly before this decision, Coopers & Lybrand, an accounting firm, had submitted a report on the 1979 consolidated balance sheets and related consolidated statements of GPU and its subsidiaries. The auditors warned that

> The Corporation [GPU] is unable to determine the consequences of the accident . . . and of the response of rate-making and other regulatory agencies to that accident.
>
> * * *
>
> The Corporation's subsidiaries are currently not receiving a level of revenues sufficient to assure their ability to continue as a going concern. The continuation of the Corporation as a going concern is dependent upon obtaining adequate and timely rate relief and maintaining and increasing the availability of credit under the revolving credit agreement . . . The eventual outcome and effect of the foregoing on the consolidated financial statements cannot presently be determined. (255)

Similar warnings were contained in the separate reports prepared for two of the three subsidiary utilities, Met Ed and Jersey Central. The report for PENELEC, however, did not include the latter, more serious, warning quoted above. (256)

[99] At the time of the accident, Met Ed had received approval for but had not yet implemented certain rate increases. In the aftermath of the accident, these increases never went into effect. Assuming these increases had been implemented at the time of accident, Met Ed's percentage increase in rates between that time and late May 1980 would have been 30.3 percent rather than 50 percent. (259)

[100] On May 15, 1980, the banks wrote to GPU saying that rate rulings in April and May had been "significantly responsive" to many of the borrowers' needs but that "substantial questions" remained as to the borrowers' ongoing financial viability. The bank indicated particular concern over the removal of Unit 1 costs from Met Ed's rate base. (262) See "Legal and Regulatory Aspects of Recovery," p. 216, for further details.

NRC PROCEEDINGS ON TMI–1

Proceedings are underway before the NRC to determine whether Unit 1 may be returned to service.[101] If Unit 1 is returned to service, replacement power costs may drop an estimated $14 million per month. (263) Moreover, the restart of Unit 1 could well cause the Pennsylvania and New Jersey utility regulators to return Unit 1 capital and operating costs to the utilities' rate bases. (264) These costs had accounted for about $56.5 million in annual revenues to the three utilities. (265) If Unit 1 cannot be brought back to service, the GPU companies will finally have to decide how permanently to replace Unit 1's energy output at a reasonable cost.

As of late May, formal hearings were not expected to begin before the fall, and there was no firm date for a final decision. (266)

THE PROSPECTS OF BANKRUPTCY

At the Subcommittee's November 1979 hearings, GPU's Treasurer Graham stressed that he had "no reason to believe that Met Ed will become insolvent." [102] (268) Nor did GPU's President Dieckamp "see the situation where we perceive to have bankruptcy of Met Ed to be in the best interest of GPU." (269) Graham also has stated that bankruptcy would be "seriously adverse" to "investors in the securities of the GPU companies." (270)

The lending banks have indicated that bankruptcy of the GPU companies would not necessarily be in their best interest either. According to February 13, 1980 testimony of a Citibank official:

> From our background, what we do know of [utility bankruptcy] we feel very strongly it's not likely, as we've stated in our testimony, to benefit anybody but the legal profession. (271)

These statements provide some reassurance, but business considerations change, and if one or more of the GPU companies fails to pay its debts as they come due, bankruptcy cannot be ruled out.

THE EFFECT ON CLEANUP

A corporation does not necessarily close down and liquidate its assets under bankruptcy law. The company may instead go through a judicially-supervised reorganization while it continues to do business.[103] (272)

SEC Commissioner Loomis advised the Subcommittee that "as a practical matter" a utility company such as Met Ed, which is providing electric power to the public, could not "simply close down and turn off the lights and liquidate its assets." [104] (274)

Loomis also testified, however, that in the event of Met Ed's bankruptcy there was no assurance the utility's revenues would be directed to cleanup:

> . . . [Bankruptcy] would raise some very difficult, unsettled questions under the new Bankruptcy Act as to who would get whatever revenue comes in; whether it would go to cleanup or whether it goes to paying off bonds is unsettled under the present law. Though this is a brand-new law, I think the courts would decide it right, but there would be a lot of litigation. (275)

GPU's Treasurer gave similar warnings about the uncertainties of bankruptcy, noting that creditors would likely argue against the use of utility revenues for purchasing replacement power or for prosecution of the TMI–2 cleanup efforts. (276)

The question of Met Ed's bankruptcy raises the issue of what responsibility the remaining GPU companies would have for cleanup.

According to a memorandum on a staff interview, GPU's Treasurer had "committed GPU to cleaning up TMI–2 no matter what circumstances transpired." (277) When asked about this at Subcommittee hearings, Graham replied:

> As I recall the context in which we were discussing the issue with your staff, we were talking about the three operating companies working together outside of a bankruptcy or an insolvency of one of those three companies, and I was saying, and I continue to say, we would take all steps that we can and within our power to do the cleanup job. . . . (278)

During the Subcommittee hearings, GPU President Dieckamp similarly indicated that because of the "many uncertainties," he could not unequivocally commit GPU's resources to cleanup. (279)

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[101] See "Legal and Regulatory Aspects of Recovery," p. 212, for a more detailed discussion of this proceeding.

[102] A debtor corporation may voluntarily commence bankruptcy proceedings. Involuntary bankruptcy proceedings may be instituted against a debtor corporation by creditors. (267)

[103] Under 15 U.S.C.A. § 79k(f) (Supp. 1980), if an action were commenced in Federal court for bankruptcy reorganization, the SEC would have the right to be heard concerning the appointment of a receiver or trustee for a registered holding company such as GPU, and the SEC could itself be appointed. Any reorganization plan would have to be approved by the SEC before it could become effective. Even without commencement of a bankruptcy proceeding, a holding company like GPU may submit a reorganization plan to the SEC, pursuant to 15 U.S.C. § 79k(e), and the SEC would have the power to approve the plan and present it to a Federal court for enforcement.

[104] If a bankruptcy liquidation proceeding were commenced, a party in interest could ask the court to convert it to a reorganization proceeding. Moreover, the debtor would have a one-time absolute right to convert it to a reorganization. (273)

In light of GPU's stated position, the Subcommittee Chairman said:

> . . . I think what our concern is if GPU will not stand behind that obligation and Met Ed does go into insolvency or receivership what entity is legally obligated to maintain . . . that plant, and keep the core cool . . . [W]e are trying to figure out here whether it is Met Ed's responsibility, GPU's responsibility, the NRC's responsibility, the State of Pennsylvania's responsibility, the Congress' responsibility, or whose responsibilities it is. And on the answer to that question, in my judgment, could well rest a large part of the future of that industry. . . . (280)

Subsequent to the hearings, Graham sent the Subcommittee a letter setting forth the "preliminary results" of an investigation into whether GPU, PENELEC and Jersey Central would be liable for cleanup costs if Met Ed were to enter bankruptcy reorganization proceedings. (281) Without ever stating "no," he gave an assortment of reasons why the three remaining GPU companies might not be liable.[105] One suggestion was that, at most, only Met Ed might be held legally responsible for cleaning up the facility, even though the three utilities jointly own the Unit 2 facility and pay for operating expenses.

THE FUTURE

At the time of the accident, the NRC did not require that licensees have sufficient insurance or other financial resources to deal with a nuclear accident.[106] Nor did it require that a holding company's assets be legally committed to cover any cleanup costs at a subsidiary's nuclear plant. (284)

When this point was raised during the Subcommittee hearings, the NRC Commissioners expressed interest in the idea of ensuring that sufficient funds be available for cleanup of an accident, but did not indicate that they had taken any steps to that end.[107] Less than 3 weeks after the hearings, the Commission directed the agency's Executive Director for Operations to study alternative approaches to assuring such arrangements, including the possibility of requiring insurance coverage and "a commitment of a holding company's assets for accident recovery." (286)

As suggested earlier, cleanup efforts by the GPU companies would not necessarily stop in the event of bankruptcy proceedings. Those proceedings provide a method for determining the bankrupt's

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[105] Graham's letter asserted that:

"(a) The Atomic Energy Act, as amended, does not on its face impose a clear statutory obligation on the owner of a nuclear facility to clean upon the consequences of an accident and the regulations adopted by the NRC do not on their face impose such an obligation. Similarly, the license for TMI-2 does not expressly impose such an obligation. While the GPU companies do not dispute the existence of such an obligation and intend to meet it if permitted to do so, the question as to whether such an obligation exists might have to be resolved in litigation if there were to be reorganization proceedings.

"(b) Assuming that such an obligation exists, there is nothing in the Atomic Energy Act or regulations or license which would cause such an obligation to be other than an unsecured general claim and, as such, subject to the prior liens of the mortgage indentures securing the first mortgage bonds of the TMI-2 owners.

"(c) Although the licensees of TMI-2 are Met Ed, Jersey Central and PENELEC, the license grants only Met Ed the power to operate TMI-2 and to receive, possess and use special nuclear material for that purpose. Resolutions of the potential questions referred to in subparagraphs (a) and (b) without litigation would appear to be even more doubtful in the case of Jersey Central and PENELEC.

"(d) PENELEC and Jersey Central have an agreement with Met Ed whereby they have each agreed to provide 25 percent of the cost of operating and maintaining TMI-2, and Met Ed is to provide 50 percent of such costs. It is not clear whether, if Met Ed were involved in bankruptcy proceedings, it could use its revenues (which have been pledged to secure its bonds) or other mortgaged property to pay for its share of such costs. If Met Ed were able to provide for its share of such costs and Jersey Central and PENELEC were not themselves in reorganization, such contract would call for pro rata payments by Jersey Central and PENELEC, although counsel for one of the intervenors in the Jersey Central proceedings has questioned the validity and effectiveness of that agreement. It may also be argued by someone that the contract does not cover cleanup costs unless they are a part of maintenance costs incidental to restoring TMI-2 to service . . .

"(e) GPU is not a co-licensee under the operating license and does not have an agreement with Met Ed. As previously pointed out, GPU has virtually no assets other than the common stocks of Met Ed, PENELEC and Jersey Central." (282)

[106] Section 182(a) of the Atomic Energy Act of 1954, as amended, 42 U.S.C. § 2232(a), states that each license applicant "shall specifically state such information as the Commission . . . may determine to be necessary to decide such of the technical and financial qualifications of the applicant . . . as the Commission may deem appropriate for the license." Under 10 C.F.R. § 50.33(f) and Appendix C, an applicant must demonstrate that it has reasonable assurance of obtaining the funds to cover estimated operating costs and costs of permanently shutting the facility down. According to NRC staff, this regulation has been interpreted to cover a normal decommissioning operation, not the more substantial costs resulting from an accident. (283)

[107] For example, former Commission Chairman Joseph Hendrie said:

> I guess the financial side does have an interest here. You would want to have reasonable confidence that you weren't licensing a plant or a utility that was in such shakey condition that they would just go into bankruptcy and there would be some question about their survivability as an operating entity to take care of the site. Yes, I think we have to look. I am not quite sure how we treat or how well you could do any analyses, but I think we need to look at it. (285)

obligations and debts and for deciding which will be satisfied. (287) Further, the NRC's General Counsel said that if such action were necessary, the agency has the authority to run the TMI facility, pursuant to Section 186(c) of the Atomic Energy Act, 42 U.S.C. section 2236(c).[108] (288)

During the November 9 hearing, the Subcommittee Chairman asked NRC's General Counsel, Leonard Bickwit, about the possibility of an NRC takeover:

> Senator HART. If Metropolitan Edison were to go into receivership or become insolvent, and for one reason or another GPU were unable or unwilling to assume responsibility, what would be your recommendation to the Commission in this regard?
>
> BICKWIT. You want to look at the options, but at this point I would advise them, if it happened tomorrow, I would advise them to take it over, and if the expertise of the Commission was not up to the problem, contract with those who could assist. (289)

Following up on this latter point, the Subcommittee asked the NRC's Denton whether NRC staff was capable of taking over the plant. Denton replied:

> I think the answer is yes . . . I do think the NRC operation could assume a managerial, technical direction of the plant, but this is only an assumption that many of the employees of the plant who are skilled in operating individual pieces of equipment could be transferred and somehow paid by the NRC. We don't have the operational capability to replace those individual employees that are actually manning the equipment today.
>
> And to do that, would require a massive rearrangement of our own priorities and assistance from other Government agencies. (290)

At the hearings, the Subcommittee Chairman also asked if the Federal Government would have a responsibility to pay for the cleanup in the event of bankruptcy. Bickwit replied, "I don't see it." (291) Commisioner Hendrie agreed:

> . . . unless we get to some situation where it is an urgent public safety matter and there simply isn't any other institution around that is able to take action. But short of that, which I don't see as being the case, it is not a Federal responsibility, in a financial sense, I wouldn't think. (292)

In late February 1980, an NRC Special Task Force on Cleanup noted that bankruptcy of a licensee was a risk for which no contingency plans had been prepared:

> There is some risk that the licensee may go bankrupt and may not be able to complete the cleanup. There are no known plans to cover this contingency. (293)

It recommended that the

> Commission, in conjunction with other government agencies, prepare contingency plan for cleanup in case of financial failure of licensee. (294)

As a result of this recent recommendation, the agency has begun to prepare contingency plans for NRC management of the cleanup. (295)

IN SUMMARY

The financial aspects of cleanup involve the weighing of many interests. The GPU companies' financial condition has been largely tied to the decisions of utility regulators, who have had to balance the needs of the utilities and their customers. The NRC has had to fulfill its mandate to protect the public's health and safety, yet its decisions also may affect the financial condition of the utilities. More than 1 year after the accident, the financial condition of the GPU companies remained uncertain, as did the consequences of bankruptcy on cleanup.

SOCIAL ISSUES IN RECOVERY

The accident at Three Mile Island has remained a major source of anxiety for local residents. The President's Commission on Three Mile Island concluded that "the most serious health effect of the accident was severe mental stress." (296) Strong distrust and lack of confidence in the NRC and the licensee have persisted during recovery.

On November 8, 1979, the Subcommittee heard testimony from two elected officials from communities near TMI. One was Bruce Smith, Chairman

[108] Section 186(c), 42 U.S.C. section 2236(c), states,

> In cases found by the Commission to be of extreme importance to the health and safety of the public, the Commission may recapture any special nuclear material held by the licensee or may enter upon and operate the facility prior to any of the procedures provided under the Administrative Procedure Act.

of the Board of Supervisors, Newberry Township, a township located just a few miles from TMI. (297) He described himself as "an average citizen" and a "conservative," who before the accident would "invariably compare the cooling towers to the pyramids." (298) He stated:

> . . . [N]ow I am so angry about Three Mile Island that I have become one of the leaders in the movement to close TMI forever, as a nuclear plant. (299)

Smith cited a specific example of the community's ongoing distrust. Referring to Met Ed's November 1979 request to vent the krypton gas in the containment,[109] he testified:

> I personally attended the news conference when Met Ed announced their desire to release krypton into the atmosphere. Met Ed officials seemed mystified when local citizens protested; after all the krypton only had half-life of [a little] . . . more than 10 years. It was little consolation to the people of central Pennsylvania to know that Met Ed was going to select the days when wind direction and velocity were best for release of the krypton.[110] (301)

Smith said further:

> . . . [T]he bottom line of what most people say is due to their unique experience, they don't quite believe everything that they're told . . . So, the people don't know what to believe, and they're told that everything is being done safely and within the guidelines and acceptable limits. Even the word acceptable limits becomes laughable when you've been through what people in central Pennsylvania feel they've been through. (302)

Smith recommended one way to improve the community's attitude toward cleanup:

> A long-range step-by-step plan could better prepare the community as well as the community leaders with the problems and dangers to be confronted with the cleanup process. (303)

Referring to some of the many post-accident studies and surveys of local residents, Smith also noted that the constant reminders of TMI might be fueling public concern:

> [T]he inherent problem is similar to that of a hypochondriac who learns of too many potential diseases. It becomes a psychological problem which depresses the interviewer and the interviewee . . . The psychological impact of the accident at Three Mile Island is immeasurable, but it is there, in many homes.[111] (305)

A second Subcommittee witness was Albert B. Wohlsen, then the Mayor of the city of Lancaster. (306) As is discussed later, Lancaster city officials had initiated a civil action in May 1979 to enjoin the NRC from permitting the discharge of any Unit 2 wastewater into the Susquehanna River, a major source of Lancaster's drinking water.[112] The reason for the suit, according to Wohlsen, was that cleanup decisions "were being made with no opportunity for Lancaster's participation." (307)

Wohlsen gave his view of community distrust: "[t]he inaccuracies, inconsistencies and misinformation supplied by Met Ed and the Nuclear Regulatory Commission following the accident" had produced in citizens from the Lancaster area a "crisis of confidence concerning the ability of Met Ed and the NRC to protect the public." (308) He added,

> Met Ed and the NRC have made repeated assurances that their post-accident procedures are more reliable, accurate and responsive to the public's need for reliable information. That conclusion, however, is open to serious challenge. (309)

Further,

> . . . Restoring public confidence in nuclear power and our governmental ability to safety control it both in Lancaster County and elsewhere, will require more effort in the future than has been demonstrated by Met Ed and the NRC in the past. (310)

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[109] See "Legal and Regulatory Aspects of Recovery," pp. 205–207, and "Technical Aspects of Recovery," pp. 182–184, for details on Met Ed's request to vent the krypton, the NRC's response and the events that followed.

[110] Met Ed, in requesting NRC's permission to proceed with venting, addressed the problem of public concern: We are cognizant of the concern on the part of some members of the surrounding communities about the venting of the Kr-85. We are convinced, however, that this is the most prudent and safest approach . . . The Company will do whatever it can to provide sufficient information to the public to assure them they will be aware of the timing of releases and the results of the monitoring on both on-site and off-site radiation levels. (300)

[111] According to a newspaper report, psychologists consulting for the National Science Foundation recently ". . . found a direct relationship between the degree of risk perceived by laymen and the frequency with which a potential risk is mentioned in news reports. During the Three Mile Island incident, for instance, some 700 newsmen, editors, photographers, producers and support staff were on the scene—concentrated news coverage matched in recent years only by Saigon during the height of the Vietnam war." (304)

[112] See "Legal and Regulatory Aspects of Recovery," pp. 201–204, 207.

Wohlsen, too, suggested a solution:

> The public must be fully involved and informed so that it can be confident that reactor accidents are openly and properly analyzed and resolved. (311)

A third Subcommittee witness was Judith Johnsrud, Co-Director of the Enviromental Coalition Against Nuclear Power, a non-profit organization representing "individuals and citizen groups throughout the Pennsylvania and adjoining states." (The Coalition had intervened in the licensing proceedings involving TMI–2). (312) Stating that area residents were "trying to restore some semblance of sanity to their own lives," (313) she commented on the "distressing lack of . . . reliable information [available] from official sources." (314) She also said,

> We find that, in all except the most outspoken proponents of nuclear power and the most apathetic, there is a sense of unease. Although many people appear to be unwilling to discuss the persistent hazards of the plant, when pressed they admit they are sick of the matter and just wish the problem would go away. There is little sympathy expressed for Met Ed; we find few who believe in either the veracity or competence of the utility to conduct the recovery or further operation of the reactors at TMI. (315)

During the Subcommittee's hearings, GPU's President Dieckamp acknowledged the continuing concerns of the local public:

> But, the cleanup is more than a technical matter. It involves activities which have been perceived by the local public as imposing an unknown hazard. The accident has made some segments of the public so conscious and fearful of radiation that there's a great tendency to accept nothing. (316)

He added that "we certainly recognize there's a great need to inform the public and in the process, to hopefully regain some public confidence." (317)

According to Harold Denton, the NRC also was "acutely aware of the need to keep the local citizens and governments informed." (318) He suggested,

> I think we can bring this to a much better focus and lay out for the public inspection general plans so that everyone can understand what are the steps and still provide flexibility for adjusting and modifying the plan as new knowledge is gained. (319)

At the time of the November Subcommittee hearings, the NRC, Met Ed and the State of Pennsylvania were trying to restore community trust by holding biweekly meetings open to the public. (320) In addition, once the NRC decided to prepare an environmental impact statement,[113] public "scoping" meetings were held to discuss this document. (321) By early February of this year, the NRC also had set up a permanent office in Middletown, Pennsylvania, both to serve as an offsite base for NRC officials and to make the agency more accessible to the public. (322)

Nonetheless, fueled in part by the accidental releases on February 11, 12, and 13, 1980,[114] community concern and distrust persisted. On February 12, 1980, the NRC held a public meeting near TMI to solicit comments on the programmatic environmental impact statement being prepared on the decontamination and disposal of radioactive wastes at TMI. A woman who described herself as a 36-year resident of Middletown said at that meeting:

> . . . I work in mental health . . . Now, I am seeing among people I know, just local people, my neighbors, the same kinds of symptoms I am seeing in people I am treating, only we accept it as normal. We have come to a place, living here, where we have accepted high anxiety, stress, fear, and inability to sleep, restlessness, the desire to escape, a feeling of being trapped, we have begun to accept that as normal. And that is not normal.
>
> * * *
>
> . . . people are really, are being impacted on a daily basis by things that they are beginning to believe they cannot in any way change. That induces hopelessness. Hopelessness induces depression. And if we don't get cancer from radiation, then the effect of depression will probably take its toll. (324)

Some speakers stated that they could no longer rely on the licensee and the NRC, and two citizens suggested that a local citizens' advisory group be funded to conduct an independent review of the activities at TMI. (325) One commented:

> . . . [T]here should be a citizens advisory panel. I think it should be, that you

[113] See "Legal and Regulatory Aspects of Recovery," p. 201, 204–205, for further discussion of the impact statement.

[114] In a report dated February 28, 1980, an NRC Special Task Force on Three Mile Island Cleanup reported the view of on-site NRC support staff:

> . . . that there had been considerable improvement in the public's confidence in the licensee during the past 10 months, but that this confidence was severely eroded by the events that took place at TMI–2 and were so widely publicized during the week of February 11, 1980. The Mayor of Middletown expressed a similar view. (323)

> should make a real, deliberate attempt to contact some of the leaders of these local organizations, who have been active, who have tried to educate themselves, and who have a tie with the community, know what the people's concerns are, and deal with them on a day-to-day basis.
>
> I also think that that advisory panel should have funding provided so that they can solicit input from qualified, independent experts to help evaluate these assessments that you people are doing, so that we feel that we are getting the input and we are able to ask the questions and get the type of information that we feel good about. (326)

In its February 28, 1980, report to the Commissioners, the NRC's Special Task Force on Three Mile Island Cleanup noted that "[t]here exist strong feelings of fear and anxiety among citizens about the activities at TMI–2." (327) According to the Task Force:

> The public concerns for health and safety appear to stem from a lack of public confidence in either the licensee or NRC, coupled with a conviction on the part of a substantial fraction of the population that releases of any quantity are dangerous and/or that the magnitude of releases is consistently understated. These concerns have led to a high degree of stress for a segment of the population, which needs to be alleviated. (328)

The Task Force recommended consideration of a "citizen's advisory committee" in connnection with the preparation of the environmental impact statement. (329) Further,

> Staff . . . [should] take positive actions to ensure local citizens are (a) informed of the need for timely cleanup of TMI and the steps to be taken to clean up the plant, including evaluation of alternatives; (b) alerted when particular planned releases are to be made, with advice on precautions the public should take, if any; and (c) provided data promptly about radiation levels in their communities during the course of any release. (330)

Several weeks after the Task Force issued its report, NRC staff recommended to the Commission that it approve the "controlled purging" of krypton gas in the containment.[115] In doing so, the staff stated that it was

> fully aware of the public sentiment against the planned or accidental release of any further radioactive materials . . . , regardless of the dose consequences . . . [T]he authorization of controlled purging will entail some public concern and stress despite the absence of significant radiological health effects. On the other hand, if purging is not authorized . . . , based on past experience there will continue to be planned and unplanned small gaseous releases incident to the activities involved in maintaining the facility in a safe status as well as continuous low level releases from offgassing . . . Thus, even if purging is authorized there will still be a source of continued public concern and stress . . . , but the major source of public concern will have been alleviated. (331)

On March 19, 1980, the NRC held a public meeting in Middletown to discuss the staff's assessment that venting would have no significant adverse impact on public health and safety and no significant environmental impact. The meeting was punctuated by frequent interruptions by the audience. (332) One speaker from the audience explained:

> . . . people aren't very polite to you tonight and I would be willing to bet that on the whole with maybe a few exceptions, this is a pretty law abiding, polite crowd usually.
>
> But the thing is that when you push people to the wall and when you threaten people's lives, when you threaten their children's lives they are not polite. They are afraid and they are angry.
>
> These people are pretty angry tonight. . . . If that anger is so bad tonight when we are just talking about venting krypton, what is going to happen if you make that decision to do it? (333)

Another resident, who lived 3 miles from the plant, commented:

> Met Ed's alleged concern for my safety insults me. They rightly assume that I don't want any equipment to malfunction from lack of maintenance, or even relive another reactor accident.
>
> However, they assume that I would therefore willingly accept the low level—and I don't know how low level radioactive releases, a far lesser risk they say than relying on other alternatives.
>
> I have been blitzed by their PR campaigns and their charts and their fancy numbers and their smiling assurances

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[115] See "Technical Aspects of Recovery," pp. 182, 183, and "Legal and Regulatory Aspects of Recovery," pp. 205–207, for further discussion of the venting issue.

that the levels of radiation to be vented are within Federal safety limits. But who knows if the Federal safety limits are safe. . . . (334)

Two days later, on March 21, the NRC held another meeting, this time in the Commissioners' conference room in Washington, D.C. Among those present were three Commissioners and seven members of a "citizens' group on TMI cleanup." The citizens, who described the earlier public meetings on venting as "rowdy," (335) repeated to the three Commissioners an attitude expressed previously:

> . . . distrust, absolute distrust for the variety of authorities who have been hoping to be in control in the matter of TMI; that includes Met Ed, that includes the NRC. (336)

One citizen added, "we are beginning not even to trust the [State of Pennsylvania's] Department of Environmental Resources." [116] (337)

The Commissioners were told of efforts to develop a local citizens group. According to one of the community residents:

> We are talking about . . . a citizens group that can act as a buffer between the Commission and the citizens so that this does not deteriorate into something far worse and . . . get out of control. (338)

She added:

> . . . If you decide to have a citizens committee, we don't want the appointments made by any politicians or any bureaucratic offices. We can submit a list of names that I feel perhaps will meet with the approval of most of the people in the TMI area who feel that their best interests are being served. We don't want any appointments coming from the Governor, from Washington, or from anyplace else. The credibility is gone. We now feel that we have to get in control of our own lives and I would appreciate anything that you could do in that area. (339)

It should be stressed that not all area residents have opposed the cleanup proposals, including the venting of krypton. Newspaper articles in late March quoted local citizens as criticizing vocal opponents of venting as "hysterical" or "disgusting" (340) and insisting that it was "time for the silent majority to come forward." (341) One article noted that Middletown's population appeared to have risen, probably because of the influx of workers helping the cleanup, thus "belying any notion that this is an atomic ghost town." (342)

On May 12, 1980, local citizens expressed this different perspective to the NRC Commissioners. At that time the Executive Secretary of the Pennsylvania Holstein Association stated:

> It seems to us that this venting is an important, safe, and reasonable step in a job that must be done: the prompt cleanup of TMI. And actually the sooner it is done, the better not only for the members of our association, but for the entire Commonwealth of Pennsylvania.
>
> We are concerned that further delay could result in possible deterioration of the containment building and cause uncontrolled venting.
>
> Any health risks to our citizens and possible economic loss to our business community must be avoided. The agriculture community in Pennsylvania could not withstand the economic loss that would follow uncontrolled venting. (343)

This attitude was repeated by another area resident, who added:

> When is TMI going to be cleaned up? This latter question is of particular importance. With a flood or other national disaster cleanup begins as soon as the damage subsides. The man on the street can do something and within a few months things are pretty much back to normal. The disaster may be nearly forgotten.
>
> But over 1 year later Unit 2 is still not cleaned up and we are constantly reminded of the accident and the fact that it is still potentially dangerous. The longer it takes to get everything cleaned up the longer the citizenry will be subject to rumors, lies, and varying degrees of uncertainty.
>
> I feel as soon as TMI is cleaned up and either shut down or reopened concerns will begin to dissipate. However, these concerns may take a long time to disappear because people will continue to wonder where or when or if it will happen again. Fear of the unknown is a very real fear. That is not to say that the people of Middletown are in a constant state of anxiety or panic but as long as the forecast for TMI remains unknown there will certainly be fears and concerns.

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[116] As mentioned in "Legal and Regulatory Aspects of Recovery," p. 206, fn. 125, the Pennsylvania Governor's Commission on Three Mile Island had indicated in a February 1980 report that it would not oppose prompt venting provided that dose levels were "acceptable." The Secretary of the Department of Environmental Resources was a member of the Commission.

For this reason we ask you to arrive at a decision concerning the venting of krypton as soon as possible. (344)

In late March, the Governor of Pennsylvania responded to those who had expressed concern and distrust over venting. He requested that the Union of Concerned Scientists (UCS), an organization opposed to nuclear power, do its own analysis of the NRC staff's proposal. He explained that the proposal had stirred "considerable anxiety" in the area and that he wanted to ensure that the plan was analyzed "by the broadest range of experts. . . . and in the hope of assuring our people that whatever course ultimately taken is, indeed, the safest available." (345)

On May 14, 1980, the UCS released its results. As discussed in more detail elsewhere,[117] the UCS concluded that the NRC staff's proposal would not have any significant adverse health effects but recommended against the particular venting method proposed because of the anxiety it would cause area residents. (346) Two days later, on May 16, Governor Thornburgh told the NRC he would support a decision to proceed promptly with the NRC staff's venting proposal because of what he termed a "broad based consensus" among various experts, including UCS, that the proposal would not have direct radiation-induced adverse health effects. (347)

IN SUMMARY

For a variety of reasons, concern and anxiety still exist among some members of the community surrounding TMI. State and Federal officials and the licensee all have acknowledged and sought to relieve these concerns. They have not been successful. The fundamental, continuing problem is a lack of trust and confidence in those who bear responsibility for ensuring that cleanup is accomplished expeditiously, but with due regard for the health and safety of the public.

LEGAL AND REGULATORY ASPECTS OF RECOVERY

The judicial and regulatory proceedings that have followed from the accident are complex and involve many parties, among them the licensee, Met Ed, the NRC and numerous Federal and State agencies, public officials, and private groups and citizens. The proceedings are necessarily deliberative and therefore affect the pace and nature of cleanup: they also will affect the ultimate cost of the accident.

PACE AND NATURE OF CLEANUP

A difficult problem the licensee and the NRC have been facing is how to decontaminate and dispose of the radioactive solids, liquids and gases in Unit 2. Technical solutions have been complicated by legal and regulatory factors.

EPICOR–II

EPICOR–II is a water purification designed specially for TMI.[118] On May 20, 1979, as its installation neared, officials of the city of Lancaster went to Federal district court to enjoin the NRC from

> . . . approving or allowing (a) the construction or operation of any decontamination equipment or piping, and (b) the decontamination of or discharging into the Susquehanna River of any radioactive waste water from . . . reactor No. 2. . . . (348)

The city charged that the NRC had "proceeded secretly to select and approve decontamination plans" and insisted that the plans be "fully examined and subjected to public review and comment." (349)

Among its legal claims, the city alleged that before the NRC could proceed, it was required to prepare an environmental impact statement covering all plans to decontaminate Unit 2 and dispose of the radioactive water. (350) An impact statement is required under the National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. sections 4321 *et seq.*, for "major Federal action significantly affecting the quality of the human environment." It sets forth alternative approaches to the proposed project and how each might affect the environment. (351)

On May 25, as a result of the city's lawsuit, the Commissioners directed NRC staff to prepare an environmental assessment for EPICOR–II. (352) Less elaborate than an environmental impact statement, an assessment is supposed to

> . . . [b]riefly provide sufficient evidence and analysis for determining whether to

[117] See "Technical Aspects of Recovery," pp. 171, 183, and "Legal and Regulatory Aspects of Recovery," pp. 206–207.
[118] See "Technical Aspects of Recovery," pp. 179–182.

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prepare an environmental impact statement. . . . (353)

Ordinarily, the more detailed impact statement would not be required if the assessment concludes that the proposed action would have no significant environmental impact. (354)

The Commission's directive stated that pending completion of and public comment on the staff's assessment of EPICOR–II, the licensee would not be permitted to operate EPICOR–II except for testing. (355) The statement added, however, that the NRC's Director of NRR still could authorize measures he deemed "necessary" to deal with an "emergency" and that if he believed that public health and safety required the use of EPICOR–II before completion of the assessment, he would report that to the Commissioners, who might permit its use. (356)

This directive postponed operation of EPICOR-II. The City of Lancaster and the NRC then settled some of their differences. As spelled out in a court order, filed May 29, 1979, the City agreed to hold its pending motion for a preliminary injunction in abeyance. (357) The NRC was to prepare an environmental assessment in accordance with both the Commissioners' statement of May 25, 1979 and "such further terms and conditions as may be provided by this court or further stipulation by the parties." (358) Thus the order made the Commission's May 25 directive a judicial directive as well.

About the same time, four Pennsylvania residents and the Susquehanna Valley Alliance, an unincorporated association of citizens whose stated purpose is to preserve and protect the environmental quality of the Susquehanna River and its environs, commenced a second injunctive action in the same court. (359) They named the NRC, GPU, Met Ed and a number of other parties as defendants. (360)

The plaintiffs also sought an injunction against the treatment of radioactive wastewater and its discharge into the Susquehanna River. Like the City of Lancaster, the plaintiffs held that the NEPA required the NRC to prepare an environmental impact statement or to make a specific declaration that one was unnecessary. (361) Among their other claims, the plaintiffs charged there had been violations of the Federal Water Pollution Control Act, 33 U.S.C. § 1311(f), which prohibits the discharge of "high-level radioactive waste into the navigable waters," (362) and that the plaintiffs' constitutional rights had been violated. (363)

In this case, the parties did not consent to a judicial order based on the Commission's May 25, 1979 directive. The court did not grant the plaintiffs injunctive relief.

On August 14, 1979, the NRC made public the staff's environmental assessment of EPICOR–II. (364) It covered only the environmental effect of using EPICOR–II for processing radioactive wastewater, concluding that the use of EPICOR–II for this limited purpose would not "significantly affect the quality of the environment." (365)

The staff deferred the more sensitive issue—how to dispose of the wastewater processed by EPICOR–II, asserting that use of the system for processing would not foreclose any options regarding ultimate disposal. (366)

The NRC sought formal public comment on the assessment. (367) Among those who responded were the city of Lancaster and the Susquehanna Valley Alliance. Each contended that a detailed environmental impact statement was necessary, the assessment of EPICOR–II was not enough. (368) Among its arguments, the Susquehanna Valley Alliance said that the NRC was dividing cleanup into eight segments, one of which was the processing of wastewater through EPICOR–II, (369) and that

> [T]his segmentation is intended to create the illusion that no single segment has any potential significant environmental impact, thereby negating the requirement of preparing a full environmental impact statement (EIS) covering the entire [cleanup] program before the program commences. (370)

The City of Lancaster also raised the issue of improper segmentation. (371) In addition, the City complained that the NRC assessment was an

> . . . after-the-fact rationalization of the particular decontamination alternative which was chosen and constructed prior to the preparation of the assessment. (372)

The City urged that an environmental impact statement be prepared by "an agency or firm not associated with the nuclear industry or the NRC staff." (373)

Not all the comments were negative. The Governor of Pennsylvania forwarded an evaluation performed by the State's Department of Environmental Resources. It concluded that with some specific exceptions, "the environmental assessment is adequate and . . . EPICOR–II should be used as soon as reasonably possible." (374)

Given the public's comments, the NRC staff did alter some parts of the assessment; but it did not change its conclusion that the operation of EPICOR–II "will not significantly affect the quality of the human environment." (375)

After getting the revised assessment, the Commission received additional written comments, this time from the Council on Environmental Quality (CEQ). (376) A statutorily created office within the Executive Office of the President, the

CEQ is responsible for reviewing and appraising Federal environmental policies. It also prepared the Federal regulations that spell out the procedures for implementing NEPA. (377)

The CEQ observed that the NRC staff had prepared one assessment for the processing of wastewater, was going to prepare another on its disposal, planned yet another on the release of radioactive gases from the containment and still had other waste management issues to confront. The CEQ expressed its concern "that the NRC staff's review at TMI, as it is now planned, will result in an inappropriate segmentation of the issues." (378) It advised:

> . . . it appears . . . several of the alternative operations being considered for TMI Unit 2 will have significant impacts on the environment. In these circumstances, an environmental impact statement . . . should be prepared. . . . (379)

Following this, the NRC and the CEQ held meetings and then exchanged letters. One NRC letter, dated October 15, 1979, warned the Council that because of the continuing accumulation of wastewater in the auxiliary building, "there is a pressing need for action to deal with the intermediate-level waste water." (380) The NRC noted the two alternatives to EPICOR–II for decontamination, but stated that each

> . . . in effect would enlarge rather than reduce the spread of radioactive contamination and would involve potentially significant safety questions and environmental impacts. (381)

The letter also noted that the Commission had concluded that "prompt decontamination of the intermediate-level water by EPICOR–II is the best response to the situation." (382)

The CEQ responded to the NRC with a letter, dated October 16. 1979. It clarified its position concerning EPICOR–II:

> Based on the assurances made in your letter, the Council agrees that the prompt decontamination of the intermediate-level wastewater through the EPICOR–II system is an operation necessary to control the immediate impacts of an emergency situation (40 C.F.R. § 1406.11).
>
> Nothing in this letter should, of course, be taken as passing on the appropriateness of other Commission actions thus far under NEPA.[119] (383)

In its letter, the NRC had never specifically called the situation an "emergency." Yet, in testimony before the Subcommittee, CEQ's General Counsel said that the Council had been "convinced" an emergency existed, (384) warranting the immediate action.

Nonetheless, the CEQ still "pressed" for preparation of a comprehensive environmental impact statement covering all cleanup activities. (385)

The Commission issued a formal Memorandum and Order, dated October 16, 1979, directing prompt processing of intermediate-level wastewater from TMI–2 using EPICOR–II. (386) It also directed that the licensee maintain "suitable tankage" at Unit 1 that "could be used to store wastewater from TMI–2 at an appropriate state of readiness, should additional storage capacity become necessary."[120] (388) In the Order, the Commission maintained that, despite arguments to the contrary, consideration of the impact of EPICOR–II separate and apart from the overall impact of the complete decontamination program was not an "illegal segmentation." (389)

On October 12, 1979, the Federal district court had dismissed the lawsuit of the Susquehanna Valley Alliance on the ground that the plaintiffs' claims first had to be presented to the NRC for administrative review and determination before the allegations could be considered "ripe" for any form of judicial review. (390) When the NRC's October 16 directive was issued, the Alliance immediately appealed the dismissal to the U.S. Court of Appeals for the Third Circuit, asking that it review the district court's dismissal and, pending this review, issue a judicial order prohibiting operation of EPICOR–II. (391) According to an NRC attorney, the NRC opposed this request for injunctive relief by arguing, in part, that no water would be discharged into the river and, as a result, the plaintiffs would not be harmed by the use of EPICOR–II. (392)

The appellate court refused to halt the operation of EPICOR–II, although it did retain jurisdiction over the plaintiffs' appeal from the district court's decision to dismiss the entire lawsuit. (393)

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[119] The Council's narrowly drawn approval was based on the following Federal Regulation (40 C.F.R. section 1406.11):

> Where emergency circumstances make it necessary to take an action with significant environmental impact without observing the provisions of those regulations, the Federal agency . . . should consult with the Council . . . Agencies and the Council will limit such arrangements to actions necessary to control the immediate impacts of the emergency.

[120] The Commission's Order did not explain why this particular requirement was included. The NRC's General Counsel, Leonard Bickwit, and Commissioner Victor Gilinsky advised Subcommittee staff that the purpose was to ensure that additional tankage would be available for immediate use if EPICOR–II did not function properly and the existing tankage in Unit 2 became filled to capacity with radioactive wastewater. (387)

EPICOR–II was finally used to process the wastewater, some 5 months after it was ready. At that time, the auxiliary building tanks were some three weeks from capacity.[121]

THE IMPACT STATEMENT

The NRC still had to decide what type of environmental studies to prepare on decontamination and waste disposal overall. On November 21, 1979, the Commission resolved the matter by issuing a Statement of Policy and Notice of Intent to prepare a Programmatic Environmental Impact Statement.

It announced that the agency would prepare a programmatic environmental impact statement on the decontamination and disposal of radioactive wastes, observing that an "overall study . . . will assist the Commission in carrying out its regulatory responsibilities . . . to protect the public health and safety as decontamination progresses." (394) It noted that while the programmatic impact statement was being prepared, the agency was prepared to take prompt action, if needed:

> For example, should the Commission before completing its programmatic statement decide that it is in the best interest of the public health and safety to decontaminate the high-level wastewater now in the containment building, or to purge that building of its radioactive gases, the Commmission will consider . . . [the Council on Environmental Quality's] advice as to the Commission's NEPA responsibilities. . . . (395)

The policy statement commented that "any action of this kind" would not be taken without an "environmental review" and an "opportunity for public comment." The statement also said:

> . . . there may be emergency situations, not now foreseen, which . . . would require rapid action. To the extent practicable the Commission will consult with [the Council] in these situations as well. (396)

The NRC contracted with Argonne National Laboratory to prepare the statement, at an estimated cost of $2.5 million. As of early March 1980, about 50 people were assigned to the project. In late May, the draft statement was expected in June, and the final statement was targeted for release between September and October 1980. (397)

As noted, in February an NRC Task Force indicated the staff was not "clear" how the Commission intended to use the impact statement. As of late May, the Commission still had to determine how and by whom major cleanup decisions would be made after completion of the statement and the statement's expected role in decisionmaking. (398)

The programmatic environmental impact statement has created a dilemma.

On November 9, 1979, during Subcommittee hearings, the NRC's then-Chairman, Joseph Hendrie, had predicted that the venting of krypton, like the decontamination of auxiliary building wastewater, might become caught up in issues of what could or should be done before completion of an environmental impact statement.

The Chairman of the Subcommittee, Senator Hart, had asked:

> Short of an emergency, what do . . . you contemplate will happen to deal with containment water and trapped waste? What is an emergency and isn't? How much is going to be helped from an EIS [environmental impact statement] and how much is not going to be in terms of cleaning this operation in the next 6 months to a year? (399)

Hendrie replied:

> I think the place that we are going to have a pinch is in dealing with the atmosphere of the containment building as a necessary preliminary step to getting on to processing the water in the base of the containment, or a step that has to go along with the processing of the water in the containment. Now what I would like to do is to avoid the need for emergency action in the sense that we just stop the environmental review processes and say never mind, we have got to do something, and this is as good a thing as we can see to do; so we do it. We went, in effect, through that with the CEQ [Council on Environmental Quality] on EPICOR–II because things had just dragged on and there was argument about whether we—there are always people who want you to do five more analyses. (400)

The issue arose again at a Commission meeting on March 5, 1980, when Hendrie expressed his views more strongly:

> It is inconceivable to me that the laws of the United States require us to sit on our . . . [duffs] and fiddle for 1½ years waiting for that containment to leak or the primary system to finally funk out and fail to cool the core or the boron concentration to go. Don't we get . . . [recriticality]? There has to be a way to get in there and see that system is going to run

[121] See "Technical Aspects of Recovery," p. 181.

adequately for the balance of the time that is necessary to clean up all the water, and so on.

You can't sit around here and calculate environmental impact while we get ready to have a disaster in central Pennsylvania. I appeal to the staff, applicant, and God for Christ's sake to tell me how to get out of this idiocy.

Are we, in fact, compelled inextricably under the laws of the United States to sit here and wait for trouble? (401)

Although preparation of an impact statement requires extensive time and effort, it may help the agency preparing it to focus on the alternatives, and its procedures allow the public an opportunity to comment as the document is being prepared. (402) An impact statement provides one means of deciding among competing interests based on careful assessment of all alternatives. Further, it is clear that the NRC can act in an "emergency," although it is less clear under what lesser circumstances it can do so, prior to completion of the statement. As the Commission, in response to questions from the Subcommittee, stated:

> . . . an overall environmental study of the decontamination and disposal processes will not only assist the Commission in discharging its regulatory responsibilities to protect the public health and safety but also assure that the public is informed and, indeed, involved in the Commission's decisionmaking process. (403)

The Commission also noted that

> . . . it is believed that such a statement can serve as a useful planning tool. (404)

At another point in the Commission's March 5 meeting, Commissioner Hendrie elaborated on his concerns:

> This is the 1st of March and we are talking about the end of the year, that a final EIS can be out and people begin to complain about it and we will have to fight court actions. It is not today, you know, on the 5th of March. It is going to be damn near a year from now and we are still going to be sitting here . . . [staring] at that containment. [H]ow many neutron monitors do we still have on that system?
>
> NRC Staff: One.
>
> Hendrie: Anybody want to guarantee me that it will still be there a year from now? Anybody want to guarantee me we will know for sure what the vessel boron concentration is based on the low flows and taking the customary boron sampling outside the building? Anybody going to be able to guarantee me we won't have recriticality from low boron . . . in the next year? How about breakdown of the system inside? (405)

Commissioner Gilinsky also expressed some concern:

> There ought to be, it seems to me, I think a statement that deals with alternatives, but it may be that we have gotten ourselves into a very . . . elaborate statement and certainly, the price tag seems to suggest that. (406)

However, William Dircks, Acting Executive Director for Operations, made the point that ". . . the impact statement, if it serves as a document to help you plan action and carry out actions, . . . is very important." (407)

Stephen F. Eilperin, Office of General Counsel, explained to the Commission that the environmental impact statement need not delay cleanup:

> The Commission's policy statement does not [have to] await . . . the completion of the programmatic statement to get into the unit. (408)

In a meeting of the NRC on November 29, 1979, NRC staff discussed the time required for an environmental assessment or an environmental impact statement. Vollmer commented:

> The environmental assessment case would add five months, if it is presumed that one could allow venting of the containment as a method of cleanup. (409)

He went on to say

> . . . if nothing could be done for cleanup until the Environmental Impact Statement process is complete, then a minimum of nine months would have to pass before anything could happen. (410)

According to Vollmer, the environmental impact statement would

> . . . include everything that we can foresee, including fuel removal, waste disposal—everything we can see at this time. (411)

REMOVAL OF THE KRYPTON GAS

On November 13, 1979, Met Ed made a formal presentation to the NRC on another major decontamination issue: how to remove the krypton gas from the containment. The company asked permission to purge the containment of the gas over time, insisting that the "operation . . . can be done with no significant hazard or radiation exposure either to the general population or the site." (412) Met Ed argued that

> The time [required] to implement [other] alternatives to purge are such that we cannot guarantee full containment integrity and would, in fact, expect general population doses to exceed those minimum levels resulting from purge. (413)

The NRC staff moved deliberately on Met Ed's request. Denton noted:

> I thought we had made great technological strides when we found that we were able to get the releases from this plant following the accident within those of established normal operating plants. Then we were being sued by several communities not to permit releases that would otherwise be acceptable within—if the plant had never had an accident.
>
> So, we decided as a matter of policy to look further to see if there was technology available which would further reduce the impact of releases on the environment . . . [W]e wanted to delay the release of the krypton from the containment or water from the plant until alternatives could be explored and environmental assessments could be prepared to really be sure that we have looked hard at the technology that might further reduce whatever the public impact would be of release of this gas. (414)

As with EPICOR–II, the NRC staff did an environmental assessment on the question of the venting. (415) It presented the assessment at a Commission meeting on March 12, 1980, together with its recommendation that controlled purging was the preferred option. (416) Based on its assessment, the staff concluded that purging "would have no significant adverse impact on public health and safety and no significant environmental impact." (417) It also found

> . . . that it is in the best interest of the public health and safety to purge the reactor building promptly prior to completion of the Programmatic Environmental Impact Statement. (418)

The final recommendation read:

> We recommend that controlled purging of the TMI–2 reactor building be authorized and that the licensee be directed to propose a method for purging over a shorter time period than the 60 days currently proposed, but within the constraints of Appendix I to 10 CFR 50 and 10 CFR 20.[122] (419)

The NRC staff suggested that the staff of the Council on Environmental Quality might take a different view of the NRC's authority to proceed promptly with venting:

> Until . . . [the environmental impact statement] is prepared, CEQ staff believes that NRC approval of certain actions, such as purging the radioactive gas from the containment, would be a segmentation of the entire clean-up program in a manner inconsistent with . . . [the National Environmental Policy Act].[123] (421)

The NRC held a period of public comment on the staff's recommendation for venting. It met with substantial local opposition; some residents expressed their complete lack of trust in the NRC staff's recommendation.[124]

As a result, at the end of March, Pennsylvania Governor Thornburgh asked the Union of Concerned Scientists (UCS) to study the proposal to vent the krypton (422) and on April 11 sent a letter to the NRC asking that the agency's period for public comment be extended

> . . . to reflect whatever facts or opinions might emerge from this effort, and accordingly defer any final decision on the cleanup proposal.[125] (424)

The NRC extended the comment period as requested.(425)

On May 14, the Union of Concerned Scientists released its results. The group concluded that the venting proposal would not have any significant adverse health effects but recommended against the proposed venting method because of the stress it would cause area residents. (426) It recommended instead venting with the aid of a buoyant plume or an extended vent stack using a plastic tube supported by a balloon. (427)

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[122] Appendix I to 10 C.F.R. Part 50 sets the guides and conditions by which the criterion "As low as is reasonably achievable" is to be met in terms of radiation dose standards. 10 C.F.R. Part 20 defines the standards for protection against radiation.

[123] The NRC staff also noted, however, that the Council staff recognized that NEPA permitted the NRC to approve certain actions that could result in "limited radioactive effluents" before completion of the impact statement. These actions included data-gathering activities and "actions necessary to maintain TMI in a safe and stable condition." (420)

[124] See "Social Issues in Recovery," pp. 199–200.

[125] In February 1980, the Pennsylvania Governor's Commission on Three Mile Island had urged the NRC to "make a prompt decision concerning the proposed venting," adding that the Commission "would not oppose an NRC decision to vent the krypton gas, provided that [projected] dose levels . . . are acceptable." [emphasis omitted] (423)

Two days later, on May 16, Governor Thornburgh sent a letter to Chairman Ahearne, citing assessments from eight different sources, including UCS. The Governor said:

> There is, I have found, a broad-based consensus among these sources that the venting proposal now before you would have . . . "no direct radiation-induced health effects on the residents of this area."
>
> * * *
>
> Should you proceed with the venting proposal advanced by your staff, be assured that I am prepared to support that decision. (428)

In late May, the NRC staff again recommended venting, finding that it was in the best interest of public health and safety, would not have a significant environmental impact and would not limit the choice of reasonable alternatives for future cleanup steps. (429) The CEQ concluded that as a matter of procedure, based on those findings, the NRC staff's proposal would not violate 40 C.F.R. § 1506.1. which sets forth limitations on actions during the NEPA process. (430) In early June, the Nuclear Regulatory Commission formally authorized venting. (431)

THE SITUATION, JUNE 1980

On March 17, 1980, the Third Circuit Court of Appeals reversed the District Court's dismissal of the *Susquehanna Valley Alliance* lawsuit. It concluded that the lower court did have jurisdiction to hear the plaintiffs' claims under the National Environmental Policy Act and the Federal Water Pollution Control Act, as well as plaintiffs' constitutional claims. (432) So, in early June the possibility of injunctive relief with respect to the challenged decontamination activities was still open. The appellate court's decision also set a legal precedent for other parties who might want to challenge cleanup proposals and activities in Federal court, including proposals for venting.

The *City of Lancaster* lawsuit was settled in February. The NRC agreed not to allow the discharge of water into the Susquehanna River before the end of 1981 without first complying with the NRC's November 21, 1979 policy statement. The settlement spelled out the plaintiffs' right to seek judicial review of any NRC decision to permit discharges, including those authorized in the event the NRC determined that an "emergency" existed. (433)

Work was continuing on the comprehensive impact statement, a major undertaking that the Commission had only decided to proceed with in late November 1979. As of early June 1980, it remained possible that most major decisions on decontamination and waste disposal would be deferred until the statement was complete. The final statement was not expected to be completed and ready to release until some time in September or October 1980. (434)

The absence of decisions on firm plans for cleanup has caused increasing concern. In late January 1980, the Secretary of Pennsylvania's Department of Environmental Resources, as quoted in a newspaper article, announced that TMI was "on its way to becoming one of the most dangerous radioactive waste storage sites in the world." (435)

Referring to the releases on February 11, 12 and 13, the Director of Pennsylvania's Department of Environmental Resources, Bureau of Radiation Protection, was quoted as saying:

> We're going to see more and more of this happening if we don't get in there and clean that mess up . . . We still have an emergency situation at Three Mile Island, and the NRC is treating it as if it were a normal situation. It can't go on like this for long before something gives. (436)

CHANGES IN THE UNIT 2 LICENSE

In normal circumstances, maintenance and operation of Unit 2 were governed by the facility's Operating License and by the more elaborate conditions set forth in the Technical Specifications for Unit 2, a multi-volume document that detailed the requirements of the license. Following the accident, normal circumstances no longer existed. Thus the NRC and the licensee recognized the need to develop revised operating and contingency procedures to assure long-term cooling of the core and plant stability. (437)

On July 20, 1979, the Director of NRR issued a written order formally suspending the existing license. The order directed that, pending further amendment of the license, the licensee "maintain the facility in a shutdown condition in accordance with the approved operating and contingency procedures." It stated that NRC staff was preparing "a detailed evaluation" of the license modifications needed to "assure the continued maintenance of the current . . . cooling condition," modifications which would be set forth in new or revised Technical Specifications. The NRC anticipated having the specifications available in a month. (438)

On January 11, 1980, after several deadline postponements, the NRR sent the Commissioners an order and revised Technical Specifications, together with an environmental assessment, which concluded that the environmental impact of the proposals would be "insignificant." (439) The

Comissioners gave their approval to NRR's submissions and on February 11, 1980, the NRR finally issued its order and revised Technical Specifications. (440)

The order provided for the definition of operating parameters for long-term cooling and for imposition of functional, operability, redundancy and surveillance requirements concerning structures, systems, equipment and components needed to maintain shutdown. (441) It also incorporated the substance of the Commission's November 21, 1979 policy statement by directing that the license be modified to:

> [P]rohibit venting or purging or other treatment of the reactor building atmosphere, discharge of water decontaminated by the EPICOR–II system, and the treatment and disposal of high-level radioactivity contaminated water in the reactor building, until each of these activities has been approved by the NRC, consistent with the Commission's Statement of Policy and Notice of Intent to Prepare a Programmatic Environmental Impact Statement. (442)

The NRR order set forth procedures by which the licensee "or any person whose interest may be affected" could request a hearing with respect to two issues: (1) whether the new requirements were "necessary and sufficient for the maintenance of the facility to protect health and safety or to minimize danger to life and property" and (2) whether the order "would significantly affect the quality of the human environment." (443)

Requests for hearings were filed by two individuals and one organization, the Environmental Coalition for Nuclear Power. (444) ENCP noted that in April and May 1979 it had asked the NRC to hold hearings on the "very issue of changes in the Technical Specifications pertaining to the shift from Operational Mode to Recovery Mode." (445)

IN SUMMARY

Once again, a review of events—this time of the regulatory proceedings—reveals numerous dilemmas and unprecedented problems. The licensee, for obvious reasons, wants to complete the cleanup as quickly as possible, and in fact, the condition of the plant suggests a need for prompt action. Yet legal and regulatory procedures call for decisions to be made deliberately after weighing alternatives and affording opportunities for public comment. The NRC has followed the necessarily deliberate procedures established to achieve these objectives, while maintaining the right to act promptly under certain conditions. As it proceeds in this fashion, the NRC must deal, as must the utility, with the distrust and vocal opposition of many residents around Three Mile Island.

FINAL COST TO THE LICENSEE

Judicial and regulatory proceedings will also influence the cost of the accident to the licensee.

JUDICIAL PROCEEDINGS

Civil Tort Actions

Following the accident, Met Ed, Jersey Central, PENELEC and GPU were named as defendants in numerous civil lawsuits brought by private parties seeking to recover for alleged personal and property damage. (446) Plaintiffs have charged, among other things, negligence or willful misconduct with respect to the design, construction, operation and maintenance of the TMI facility and with respect to the nature of the information released to the public as events progressed. (447) Strict liability claims also have been asserted, based on the alleged "miscarriage of an ultrahazardous activity," namely the operation of a nuclear reactor. (448)

Early in the proceedings, for reasons of judicial economy, most of the lawsuits were consolidated in Federal District Court into a single class action lawsuit called *Fantasky* v. *GPU*. (449) More than 60 named plaintiffs, representing businesses, property owners and residents, are part of *Fantasky*. The plaintiffs proposed to represent not only themselves, but similarly aggrieved parties who might not bring their own lawsuits.[126]

This class action suit requests monetary damages, an order "directing that the [TMI] nuisance be abated," and imposition of a "constructive trust" on property owned by the defendants to pay for the cost of medical diagnosis and treatment of "possible cancerous and abnormal genetic conditions." (452)

Early in the proceedings the parties in *Fantasky* agreed that the plaintiffs may represent

[126] The proposed classes included: Class I—all individuals, partnerships, corporations, institutions and other business and professional entities within a 25-mile radius of TMI that suffered economic harm as a result of the accident; Class II—all real property owners and residents within a 25-mile radius who suffered economic harm as a result of the accident; and Class III—all individuals within a 25-mile radius who suffered personal injury, incurred medical expenses, suffered emotional distress or will require medical services to monitor the possibility of latent defects from exposure to radiation. (450)

The damages allegedly sustained include "a substantially increased probability of incurring cancer and/or genetic defects because of exposure to radiation; damages associated with the necessity of evacuation; reduction in the financial value of property and business; contamination or spoilage of products; and work stoppages." (451)

all aggrieved parties falling within Classes I and II. (453) The plaintiffs' attempt to represent Class III members was disputed. The issue, together with a U.S. magistrate's recommendation, has been submitted to the District Judge, but as of late May, no decision had been rendered. (454)

In addition to the *Fantasky* consolidated class action, many other civil tort actions still were pending in late May 1980. There was, for example, a second class action involving dozens of plaintiffs seeking both monetary damages of at least $560 million and also punitive damages. (455) Moreover, another lawsuit was pending involving a couple who alleged that radioactive releases from TMI during the accident had caused the stillbirth of their daughter some 5 months later. (456)

For reasons of judicial economy, all suits filed since the *Fantasky* class action have been consolidated with *Fantasky*, absent a showing that a suit should be treated separately. (457) This will permit consideration of common legal and factual issues in a single proceeding.

It is difficult to predict how long the civil tort cases will last. In late May, more than one year after the accident, the *Fantasky* consolidated class action was still in a relatively early, procedural stage. (458) Because of the dispute over Class III plaintiffs, notice to the prospective class had not yet been provided. No final adjudication of the class action litigation is possible until such notice is given so that prospective class members have an opportunity to advise the court whether they wish to be represented by the plaintiffs. Litigation could continue for years after the notice is issued.

Although the civil tort actions involve substantial sums of money, the potential financial burden imposed on the GPU companies is limited in part by the Price-Anderson Act, as amended, (459) which is designed in part to reduce the financial exposure of any one licensee in the event of a nuclear accident. Price-Anderson limits the total amount of claims that must be paid to persons injured in a "nuclear incident" [127] and provides for these claims to be covered under a system of utility-purchased private insurance, retrospective premiums assessed against the utilities, and government indemnity. (460) Under this system of financial protection, Met Ed, Jersey Central and PENELEC do not expect to be assessed more than $15 million in retrospective premiums for all the TMI-generated public liability claims.[128] (462)

Price-Anderson, however, will not necessarily limit the total exposure of the GPU companies to $15 million. According to GPU's 1979 annual report, the lawsuits for personal and property damages (including claims for punitive damages) and the injunction actions have raised questions whether certain claims "material in amount" are subject to the liability limits of Price-Anderson or are outside the insurance coverage provided pursuant to the statutory scheme. (463)

Price-Anderson has other provisions that may be pertinent to the pending civil tort actions. In a severe nuclear incident, described as an "extraordinary nuclear occurrence," Price-Anderson provides that a licensee covered by the statute's system of financial protection may be required to waive certain legal defenses. (464) When the waiver occurs, the plaintiff no longer has to prove the licensee's negligence and, in addition, may institute his action at any time within three years from when he "knew, or reasonably could have known" of his accident-related injury or damage, so long as the action is not begun more than 20 years after the incident. (465) The plaintiff still must prove injury or damage, the monetary amount of the loss and the causal link between that loss and the nuclear accident.

Price-Anderson assigns the NRC responsibility for making the critical judgment whether an accident is an "extraordinary nuclear occurrence" or "ENO." The statute defines an ENO as

> . . . any event causing a discharge or dispersal of source, special nuclear, or byproduct material from its intended place of confinement in amounts offsite or causing radiation levels offsite which the Commission determines to be substantial, and which the Commission determines has resulted or will probably result in substantial damages to persons offsite or property offsite. (466)

and adds that the

> Commission shall establish criteria in writing setting forth the basis upon which the determination shall be made. (467)

The Commission's criteria are embodied in the Federal Regulations at 10 C.F.R. Part 140.

On July 23, 1979, the NRC published a notice that it was initiating proceedings to make an ENO determination. (468) On August 17 the

[127] That limit is presently set at $560 million according to the formnla set forth in the statute at 42 U.S.C. section 2210e. (459) Price-Anderson also provides that Congress may take "necessary and appropriate" action—such as providing for additional payment to claimants—if damages exceed $560 million. 42 U.S.C. section 2210e.

[128] Under Price-Anderson, a total of $140 million in utility-purchased private insnrance is available for the accident. If that is exhausted, the utilities may be assessed a maximum of $335 million. If that, too, is exhausted the Government's indemnity program covers a maximnm of $85 million. With respect to the $335 million from utilities, the amount would be assessed equally against 67 nuclear reactor plant licensees so that each pays a premium of $5 million. (461) The licensee whose plant is involved in the accident thus is assessed no more than any other licensee. Since the GPU companies hold three operating licenses, their maximum assessment would be $15 million.

Commission formed a panel of staff to assemble the relevant information, evaluate public comments and report to the Commission its findings and recommendation. (469)

In December 1979, the staff sent its report to the Commission. The panel concluded:

> . . . that the first criterion, pertaining to whether the accident caused a discharge of radioactive material or levels of radiation offsite as defined in 10 C.F.R. § 140.84, has not been met. [The panel] . . . further finds that there is presently insufficient information to support any definitive finding as to whether or not the second criterion, relating to damage to persons or property offsite as defined in 10 C.F.R. § 140.85, has been met. Since the Panel has not found that both criteria have been met, it recommends that the Commission determine that the accident at Three Mile Island did not constitute an "extraordinary nuclear occurrence." (470)

In April 1980, the Commission made a final determination that the accident did not constitute an "extraordinary nuclear occurrence," as defined by the Price-Anderson Act and the Commission's regulations. Noting that "in ordinary parlance" the accident was "extraordinary," the Commission nonetheless found that the radiological releases associated with the accident did not rise to the levels required for an ENO determination. (471)

Even assuming the plaintiffs are not able to prove negligence in their tort actions, the Commission's conclusion will not necessarily have a decisive effect on the outcome of these lawsuits. In addition to alleging negligence, the plaintiffs have also been arguing that defendants are strictly liable under State law, that is, without regard to whether they acted negligently. (472) A finding of no ENO will have no legal effect on these separate strict liability claims. Moreover, GPU and its subsidiaries may not insist that the plaintiffs prove negligence. Court papers filed well before the Commission's determination indicated that the defendants in *Fantasky* had made an undertaking not to require any person claiming compensatory damages for personal injury to prove negligence and might be willing to make a similar agreement with plaintiffs alleging economic loss. (473)

Stockholder Suits

GPU is also a defendant in litigation instituted by its own stockholders. Two class actions were brought in Federal District Court against GPU and a number of the companies' directors on behalf of GPU stockholders. (474)

The lawsuits include charges that defendants violated the securities laws by failing to disclose to stockholders and the public defects in the design, installation and operation of TMI Unit 2, all of which allegedly were known by defendants prior to the accident. As a result of the alleged nondisclosures, plaintiffs said they purchased GPU stocks at inflated prices. (475)

For judicial economy, these stockholder class actions were consolidated in the U.S. District Court for the District of New Jersey. (476) The District Court certified a class that includes purchasers of GPU common stock from August 25, 1975 through April 1, 1979. (477) As of mid-March, notices had not gone out to the class.

GPU Suit Against Babcock & Wilcox

In one noteworthy instance, GPU instituted its own lawsuit as a result of the accident. In March 1980, GPU and its three utility subsidiaries commenced a civil damage action in Federal District Court against Babcock & Wilcox (B&W), the nuclear reactor supplier for TMI, and against B&W's parent company. (478) One newspaper article described the suit as a "jarring break in what had been a united industry front on nuclear power questions." (479)

Asserting four separate causes of action, the complaint charged (1) gross negligence and reckless disregard of foreseeable consequences or, in the alternative, ordinary negligence; (2) strict liability because of the risks and consequences of an accident resulting from defects for which B&W was responsible; (3) breach of contract; and (4) breach of implied warranties. (480)

As respects their negligence claims, the plaintiffs alleged, in part, that B&W had received "prior warnings" of problems as a result of "similar incidents" at the Davis-Besse plant.[129] They also alleged "inadequacies" in the B&W nuclear steam supply system, related equipment, limits and precautions, procedures and training. (481)

As damages, plaintiffs cited, among other items, the expense of purchasing replacement power, cleanup costs and the loss of a reasonable return on capital invested in Unit 2. Plaintiffs' complaint said that damages had exceeded $500 million with the anticipation of "very substantial future damages." (482)

NRC REGULATORY PROCEEDINGS

Civil Penalties

Seven months after the accident, the Director of the Office of Inspection and Enforcement (I&E) served Met Ed with a Notice of Violation and a Notice of Proposed Issuance of Civil Penalties. Based on its investigation of the accident, I&E described a number of instances of "apparent non-

[129] See "Prior to the Accident," pp. 77–78.

compliance" with NRC's regulations, the Technical Specifications for Unit 2 and the procedures mandated by the Technical Specifications. (483)

I&E cited six "violations," ten "infractions" and one "deficiency." Most of the proposed penalties related to a single violation—Met Ed's failure to block off the pilot-operated relief valve on the reactor's pressurizer from October 1978 until some two hours after the accident began on March 28, 1979.[130] (484) For this alleged violation, each day of non-compliance was treated as a separate offense subject to a $5,000 penalty, resulting in a cumulative civil penalty of $630,000. (485)

The total amount of civil penalties for all items added up to $725,000. (486) However, by statute, the maximum assessable civil penalty for any 30-day period was $25,000.[131] (487) Since the violations related to a five-month period from October 1978 through March 28, 1979, I&E's proposed penalty thus was reduced to $155,000. (488) It was still the largest civil penalty the NRC had proposed up to that time.

On January 23, 1980, after receiving Met Ed's response to the items of "apparent non-compliance" and proposed penalties (489), I&E issued a formal order imposing $155,000 in civil penalties. (490) On February 14, 1980, Met Ed paid the fines, foregoing its right to a hearing. (491)

Imposition and payment of the $155,000 in civil fines did not bring an end to the NRC's consideration of accident-related penalties against Met Ed. On March 4, 1980, the NRC's Special Inquiry Group, which had previously investigated and reported on the accident for the Commission, submitted a supplementary report to the Commission Chairman concerning whether Met Ed officials had intentionally withheld information from the NRC as the accident unfolded on March 28, 1979. (492) The supplementary report said that there was indirect evidence from which one could infer that information was intentionally withheld, but that the record, taken as a whole, did "not permit the unbiased observer" to reach this conclusion "based on actual evidence." (493) With this report in hand, the NRC formed a group to assess the adequacy of the Special Inquiry's work on this issue and to determine whether further action, such as civil penalties, might be required. (494) As of May 1980, this assessment was still continuing.

NRC staff members also have considered the charges of Harold Hartman, a former TMI control room operator, who alleged that for months prior to the accident, Met Ed employees had been falsifying test data on the rate of leakage of the same pilot-operated relief valve that stuck open on the day of the accident.[132] According to a report published May 15, 1980, a separate Federal Grand Jury investigation began into Hartman's charges. The report suggested that while the Grand Jury was questioning Met Ed employees as individuals, the inquiry might be expanded to include Met Ed management. Pending completion of the Grand Jury investigation, the NRC will not pursue information being looked into by the Grand Jury. (495)

In April 1980, civil penalties also were assessed by the Director of I&E against Babcock & Wilcox (B&W). It was the first time such a penalty had been proposed by NRC staff for a company's activities as a reactor supplier. (496) The proposed fine, which totaled $100,000,[133] was based on four items of non-compliance. Each cited item related to B&W's alleged failure to evaluate and report on significant safety information, including information set forth in the Michelson Report,[134] in violation of 10 C.F.R. Part 21. (497) In transmitting the charges to B&W, I&E's Director charged generally that B&W "did not have an effective system for collection, review and evaluation, and reporting of important safety information." (498) In its May 20, 1980 response, B&W denied the charges, but paid the fine, saying that further proceedings would be "time-consuming, expensive and needlessly divert" the attention of "critical personnel and resources." (499)

Suspension of TMI-2's License

Another matter pending before the NRC is the status of the Unit 2 Operating License. On July 20, 1979, the NRR, as noted, had issued an order formally suspending this license. On October 25, 1979, the Commission held a meeting at which the issue of the license was discussed. Commissioner Gilinsky recommended that the Unit 2 license should be revoked because revocation, unlike suspension, would be "a very strong statement" of the Commission's position. (500) Suspension, in his view, was only "an intermediate step between not taking action and revoking licenses." (501) Commissioner Ahearne agreed that revocation would "be seen as different by the public," (502) but argued that "revocation of TMI-2's license is not meaningful,

[130] See "Prior to the Accident," pp. 71–72, for a discussion of the leakage.

[131] Both the House and Senate, in action on the NRC authorization bill for fiscal year 1980, passed provisions that would allow NRC to impose civil penalties of up to $100,000 per violation and would eliminate any limitation on the penalty amount assessable in a 30-day period. As of mid-May the authorization bill had been agreed to in conference and was awaiting enactment.

[132] See "Prior to the Accident," p. 71, fn. 49, for more details on the charges made by Hartman.

[133] Each day of non-compliance was treated as a separate violation subject to a $5,000 penalty, resulting in a cumulative penalty of $575,000. As was true of the penalty against Met Ed, however, the $25,000 statutory limit for any 30-day period reduced the assessable penalty to $100,000.

[134] See "Prior to the Accident," p. 78, for a discussion of this report.

given the status of that system." (503) In Ahearne's view:

> I do not think it would be seen as different in substance by any of the people who are knowledgeable with the proceedings or the fact of the plant or any of that side of the nuclear industry. I think it will be perceived by the industry side . . . even . . . the public interest side who are familiar with it as an attempt by the Commission to position itself in a way that makes it look as though they're taking a strong stance. (504)

The Commissioners voted on whether to revoke Unit 2's license. Gilinsky and Bradford voted for revocation, Hendrie and Ahearne against it; Commissioner Kennedy was not present. The tie vote meant that the Unit 2 license would remain suspended. (505)

Restart of Unit 1

The agency also has to decide what to do about the operation of Unit 1. On March 28, that facility was about to resume operation after being out of service for refueling. It has remained shut down since, initially because of attention to the accident, then because it was subject to an NRC shutdown order for plants with the B&W nuclear steam supply systems used in Unit 2. The NRC subsequently permitted other affected plants to resume operation. At that time, Met Ed advised the NRC that it would not restart Unit 1 without providing advance notice. (506) Shortly thereafter, on June 28, 1979, the licensee informed the NRC of various actions it proposed to take prior to restarting Unit 1, including,

> all those [actions] . . . proposed or required in respect of the other B&W units, as well as additional actions that Met Ed believed appropriate. (507)

On July 2, 1979, the Commission ordered the facility to remain in cold shutdown until further notice. (508) On August 9, the Commission issued another order explaining its action. (509) Beyond the questions relating to the B&W design, the Commission identified several other issues requiring resolution, including the potential interaction between Unit 1 and the damaged Unit 2, Met Ed's management capabilities and technical resources, the potential effect of decontamination operations on Unit 1, and the "recognized deficiencies" in the licensee's emergency plans and operational procedures. (510)

The Commission specified short- and long-term actions needed to resolve some of the concerns. Unit 1 was to stay shut down pending "satisfactory" completion of the short-term actions and "reasonable progress" toward completion of the long-term ones. (511) The Commission designated the Atomic Safety and Licensing Board to conduct hearings and render an initial determination on the resumption of Unit 1 operations. The NRC indicated that the Board's recommendation would be transmitted directly to the Commission for its final decision. (512)

In the following months, the Licensing Board ruled on petitions from parties wanting to intervene, determined what contentions would be heard, and reviewed other pre-hearing matters. Among those permitted to intervene were the Commonwealth of Pennsylvania, the County of Dauphin, Pennsylvania, the Pennsylvania Public Utility Commission, the Union of Concerned Scientists, and a number of other organizations with members residing near TMI. (513)

When the Unit 1 restart hearings begin, the Board will take evidence on a number of issues, among them whether the licensee's decontamination and restoration work on Unit 2 can be completed without affecting the safe operation of Unit 1 and whether the licensee's financial condition might undermine its ability to operate Unit 1 safely. (514) As of late May, the Board had not decided whether it would also consider the psychological distress of citizens living near TMI.[135]

In its August 9, 1979 order, the Commission said it expected the Board to conduct the proceeding "expeditiously." It set initial "milestones," calling for the Unit 1 restart hearings to begin about February 1980. (517) Yet, as of late May 1980, it was unlikely that hearings would begin before the fall,[136] (521) and no firm date for a final decision had been set.

OTHER REGULATORY PROCEEDINGS

Met Ed and PENELEC are regulated by the Pennsylvania Public Utility Commission (PUC) and Jersey Central by the New Jersey Board of Public Utilities (New Jersey Utilities Board). As discussed earlier, the regulatory commissions have been determining how much customers must pay for their power while Units 1 and 2 are out of service.

On June 15, 1979, the Pennsylvania PUC removed from Met Ed's and PENELEC's rate bases all costs associated with Unit 2, including clean-

[135] In late February 1980, the Licensing Board recommended to the Commission that evidence on the issue of psychological distress be taken during the restart hearings. (515) The Commonwealth of Pennsylvania, among others, had argued that the psychological health of residents had to be considered in deciding whether to restart Unit 1. (516)

[136] As of early March 1980, the licensee's "target" date for restarting Unit 1, assuming a favorable decision from the NRC, was January 1, 1981, (518) a date considered optimistic by some. (519) Before the NRC decided to hold restart proceedings, the licensee had talked of restarting no later than January 1, 1980. (520)

up, repair, disposal of wastes and decontamination. (522) It stated that a utility is entitled to charge rates permitting a fair return on property that is "used and useful in the public service" and that Unit 2 was no longer "used and useful." (523) It explained:

> There is a great uncertainty with respect to when, and in fact if ever, TMI-2 will resume operation. Respondents estimate that TMI-2 will be out of service for two to four years. However, no one has been able to determine the extent of damage to the fuel core. Design and operation changes may be ordered by the Nuclear Regulatory Commission, but these are as yet unknown. Public sentiment has been expressed against the renewed operation of TMI-2; and the cost of repair, cleanup and waste removal may be so high as to make restoration of the plant uneconomic. (524)

The Pennsylvania PUC did not reach the same conclusion for Unit 1 at this time. Noting that GPU's president had said Unit 1 could be generating power "as early as August 1979, and certainly no later than January 1, 1980," the PUC concluded that "TMI-1 is at present only experiencing an outage" and would not be removed from the rate base.[137] (526) However, the PUC said it would "monitor the status" of Unit 1, and if start-up were delayed beyond January 1, 1980, it would begin proceedings to decide whether Unit 1 should remain in the rate base. (527)

At the same time as it removed Unit 2 costs from the rate bases, the PUC held in favor of the two utilities on the important issue of replacement power. Before the accident, Units 1 and 2 had provided roughly 30 percent of the energy of the GPU system. (528) After the accident, the utilities continued to provide electric service to their customers by purchasing power from other sources. (529) Among them was the so-called Pennsylvania-New Jersey-Maryland Interconnection,[138] a utility pooling arrangement that permits bulk purchases at reduced rates. (531)

In its June 15 decision, the Pennsylvania PUC granted rate relief to help meet replacement power costs.[139] The PUC reasoned that if the utilities had not bought replacement power, they would have had to reduce service to consumers or increase use of the utilities' existing plants, "many of which have higher operating costs than the costs of purchased power." (533) The PUC found the power replacement purchases "to be in the public interest," (534) and said that:

> The purchase of energy is a reasonable and necessary cost of providing service which must be recovered from ratepayers. Service cannot be provided without cost. It is equitable for the ratepayers of Met Ed and PENELEC to pay the costs of purchasing power since they are receiving service and will be paying none of the costs of TMI-2. (535)

The PUC further emphasized that:

> [T]he total rates for electric service to the customers of Met Ed and PENELEC will be no greater than the rates which would have been allowed had the incident never occurred.[140] (538)

By September 1979, it had become apparent that Unit 1 would not be back in operation before January 1, 1980. The Pennsylvania PUC therefore commenced a proceeding to determine whether costs associated with that unit should be removed from the rate bases of Met Ed and PENELEC. (539)

In their formal response, the utilities blamed the NRC, claiming they had been trying to convince the agency to adopt procedures permitting an early restart of TMI-1. (540) They charged "discriminatory action":

> Respondents have been, and are, totally unable to understand how the NRC could so disregard the national and public interests involved in permitting restart of TMI-1 as early as it can be demonstrated that such restart is consistent with the public health and safety. (541)

The utilities noted that their existing rates were neither the lowest in the Commonwealth, nor the highest. (542) The utilities also raised the problem of cash flow. They stated that they had "had to borrow substantial amounts" from the banks to provide the cash needed to purchase replacement power, and that removal of Unit 1 costs from the rate base might adversely affect the willingness of

[137] The GPU president's prediction was made before the NRC directed that Unit 1 remain shut down. The State order also predated the NRC's action against Unit 1. (525)

[138] The GPU companies also were able to make bulk purchases from other power supplies. In July through November 1979, for example, they received substantial energy from outside the Interconnection pool. (530)

[139] The relief granted amounted to about 85 percent of actual replacement power costs. (532)

[140] According to the PUC, this conclusion was based on a comparison of average revenues from the rates set in its Order with average revenues derived from base rates including the costs of Unit 2 and energy rates charged prior to the accident. (536) In November 1979, GPU's president testified that the PUC's rate decisions meant that customers were paying essentially what they would have paid had Unit 2 never been built. (537)

these lenders to continue to provide the necessary cash:[141] (543)

> Respondents will continue to take all actions available to them to continue to render adequate, reliable service to their customers. . . . But Respondents do not possess the ability to ensure that such service will be rendered. The action taken by . . . [the Pennsylvania PUC], and the response of the banks to that action, are major determinants of both the adequacy and the cost of such service. (544)

In early November 1979, the Pennsylvania PUC commenced another proceeding, this time just against Met Ed, to determine whether that utility should lose its certificate of public convenience—its franchise to provide electric power in Pennsylvania. (545) The PUC noted that Met Ed was likely to incur substantial expenses as a result of the accident, and also that the President's Commission had found "a number of important cases" before the accident in which GPU and Met Ed had been guilty of "a serious lack of communication about several critical safety matters" relating to the operation of Unit 2. (546) According to the PUC, there thus were:

> . . . serious questions about the continued ability of Met Ed to provide safe, adequate, and reliable electric service at just and reasonable rates. The Commission, therefore, finds it in the public interest to put at issue . . . the continued viability of Met Ed as a public utility. (547)

The PUC consolidated the issue of Met Ed's viability as a utility with the issue of TMI–1's "used and useful" status and also with a request made by Met Ed on November 1, 1979 for additional rate relief to cover increased replacement power costs. (548)

In December, the Pennsylvania PUC began formal hearings on the three issues.

On February 8, 1980, with hearings still continuing, the Pennsylvania PUC granted Met Ed an interim rate increase to meet its higher replacement power costs. The increase provided Met Ed an estimated $55 million during 1980, (549) but was made subject to adjustments reflecting the final results of the PUC's inquiry. (550)

The interim rate relief had followed a decision by the PUC that its proceedings would not be completed until May 23, 1980. In its interim rate order, the PUC said:

> [W]e do not intend to engage in brinkmanship. The present financial condition of Met Ed is too serious a matter and of too great importance to the public Met Ed serves to warrant the risk of further financial burden brought on by delay arising from the inability of the parties to meet the intended schedule of the Commission. We are convinced that the public interest requires that this Commission provide Met Ed's bank creditors with the requisite assurance that they can ultimately be repaid. (551)

On May 9, 1980, after twenty-seven days of hearings, the Pennsylvania PUC rendered its initial decision on the three issues before it.[142] Describing these issues as "exceedingly difficult" to resolve, the PUC said that it

> . . . has had to balance the need to explore and carefully examine Met Ed's continuing, long-term viability against the urgency to act promptly to avoid being overtaken by events. In addition, the Commission has had to resolve the competing concerns of creditors who want assurances of earnings and ratepayers who want equity in allocating the costs associated with the . . . accident; and who see an inequitable duplication in paying the costs of TMI–1 and the costs of TMI–1 replacement power; and of . . . [the utilities] who would emphasize their financial needs and other parties seeking a determination based on other economic, social, and political principles. (553)

The PUC's conclusion, it said, was that "Met Ed should continue to operate as a public utility." (554) The PUC described its order as providing

> . . . an adequate framework for Met Ed's recovery. Respondent must convince its bank creditors that it has the will and the ability to rehabilitate itself. (555)

The PUC's decision criticized the Federal Government:

> Regretably, the Commission must again decry the failure of the Federal Government to respond to the accident at Three Mile Island with financial assistance that is commensurate with its responsibility for nuclear energy . . . The people of Pennsylvania should not have to bear the entire burden—emotionally or financially—where that burden properly belongs to all those who have bene-

[141] See "Financial Aspects of Recovery," pp. 191–193, for further details about this lending arrangement and its financial implications.

[142] This was an "initial decision." After a two-week period for the filing of exceptions by the parties, a final order with changes not pertinent to this discussion, was issued on May 23, 1980. (552)

fitted from the development of nuclear energy.

* * *

. . . [W]hat is painfully clear is that an economic catastrophe has befallen the GPU Companies, and their ratepayers and investors as well. We believe that Congress has a parallel responsibility to act in this situation, noting that when the prospect of a nuclear "incident" seemed remote, Federal willingness to render assistance to the nuclear industry was free-flowing. Now that such a tragedy has become more than a remote possibility, that willingness has dissipated. Never has it been more true that victory has a thousand followers, but that defeat is an orphan. (556)

Specifically, the PUC declined to revoke Met Ed's Certificate of Public Convenience "because we find no imminent and foreseeable threat to continued provision of adequate and reliable service at reasonable rates." (557) However, the PUC left open the possibility that it would consider the issue again if necessary. (558)

Second, the PUC removed capital and operating costs associated with Unit 1 from the base rates of Met Ed and PENELEC on the ground that Unit 1 was no longer "used and useful" in the public service. In explaining its decision, the PUC noted the ongoing NRC proceedings regarding restart of Unit 1 and said that there was "substantial uncertainty" as to when or whether the facility would be returned to service.[143] It added, however, that if and when the NRC allows the restart of Unit 1, the PUC would give "priority treatment" to reconsidering its determination on this issue. (560) The PUC also said that

> Met Ed must aggressively pursue the return to service of TMI–1 or an early decision on its conversion and use of an alternative fuel. (561)

Third, the PUC concluded that Met Ed and PENELEC should have rate relief needed to permit full and current recovery of their replacement power costs.[144] The Commission said that its determination to do so was "inseparably intertwined" with its decision to remove Unit 1 costs from the utilities' rate bases; and that the rate relief should lessen the utilities' need for short-term borrowing and facilitate the utilities' efforts to obtain permanent financing. (563)

Fourth, the PUC determined that the utilities should receive additional rate relief to permit them to recover over an eighteen month period certain energy costs that had not previously been covered through rate-making, including previously unreimbursed replacement power costs. (564)

New Jersey's Board of Public Utilities has been similarly involved in rate-making issues. The Board regulates Jersey Central, which, like PENELEC, shared in the cost of operating Units 1 and 2 and prior to the accident drew power from the TMI facilities.

On June 18, 1979, the New Jersey Board of Public Utilities took much the same approach as the Pennsylvania PUC. (565) The Board concluded that TMI–2 was not "used and useful" in providing service to customers and reduced Jersey Central's rate base by $29 million; it refused to take out TMI–1 costs, finding that "the outage of this facility is of a temporary duration"; and it permitted Jersey Central to recover about 85 percent of its estimated replacement power costs. (566) The Board also ordered the utility not to pay any dividends to its parent, GPU, for the remainder of 1979. (567)

Early in 1980, Jersey Central requested additional rate increases, some but not all of which related to TMI costs. The request led the New Jersey Board to consider whether Unit 1 costs should be removed from Jersey Central's rate base and whether the utility should receive additional rate increases for TMI-related replacement power costs. (568)

On April 1, 1980, the Board rendered two related decisions. In the first, it granted a rate increase for an eleven-month period to cover replacement power expenses associated with Unit 1. (569) In the second, the Board removed costs associated with Unit 1 from Jersey Central's rate base on the ground that the facility was not "used and useful." Like the Pennsylvania PUC, the Board concluded that the NRC restart proceedings would keep TMI–1 out of service for an extended period, at least two years the Board estimated. The Board added that "if and when" Unit 1 is returned to service, the Board would "expeditiously return the unit to . . . [the] rate base." (570) Having removed Unit 1 costs from the rate base, the Board approved other action to help soften the financial effect. It

[143] Although the utilities testified to an estimated in-service date of January 1, 1981, there was testimony from the PUC's consultant that mid-1983 was a realistic start-up date for Unit 1. The PUC also noted that the NRC's restart proceedings would be considering, in part, whether Unit 1 could be safely operated before completion of Unit 2 cleanup and that a GPU official had estimated that cleanup would not likely be completed until after June 1983. (559)

[144] The PUC added that not "every dollar of purchased power costs" on the utilities books would be recoverable from the ratepayers. According to the PUC, the costs would be subject to audit and review and thereafter a Commission determination that specific amounts "were imprudently or unreasonably incurred." (562)

permitted the utility to recover through rate increases certain energy costs that had been incurred prior to TMI and had not previously been covered through ratemaking. The amount the Board authorized Jersey Central to recover was $17.9 million in annual revenues, the same amount the utility was having taken out of its rate base because of the Board's decision on TMI–1 costs. (571) In rendering these decisions, the New Jersey Board said that it was aware of Jersey Central's serious condition and would work toward its preservation as an ongoing concern. (572)

Despite the favorable relief granted, New Jersey's decision to remove Unit 1 costs from the rate base led the banks to send GPU a letter, dated April 9, 1980. In it, they said that "substantial questions" remained as to the financial viability of the utilities and that the $292 million credit limit would not be raised until there was "greater assurance" of viability, "including favorable regulatory action." (573)

On May 13, 1980, the New Jersey Utilities Board granted Jersey Central additional, immediate rate relief totaling $60 million. (574) Although this relief was not directly attributable to TMI, it nonetheless meant that Jersey Central would have substantial additional revenues.

Two days later, on May 15, 1980, the banks sent another letter to GPU. (575) This letter termed the recent rate rulings as "significantly responsive" [145] but said "substantial questions" remained as to the borrowers' ongoing financial viability. The banks expressed particular concern over the Pennsylvania PUC's May 9 decision to remove Unit 1 costs from Met Ed's rate base.

Apart from its rate-making decisions, the New Jersey Board of Public Utilities has been involved in other issues of concern to Jersey Central. On January 23, 1980, the Board decided to evaluate several issues relating to Jersey Central's relative fault for the accident, the regulatory consequences of a finding of fault, the Board's legal authority to impose those consequences and the implications for the ratepayers and Jersey Central. (577) It asked Jersey Central and other parties to set forth their positions on these issues. (578)

The Board of Public Utilities also has been assessing alternatives to Jersey Central's existing operations. In early 1980 the Board retained Arthur Young and Company to analyze a broad range of options for Jersey Central, including the transfer of part of Jersey Central's Service Territory or a State takeover of the utility. (579)

Regulatory proceedings also have been invoked as part of the attempt by GPU and its subsidiaries to modify the Pennsylvania-New Jersey-Maryland (PJM) Interconnection Agreement. The GPU companies have been purchasing replacement power from the PJM pool on a split-savings basis—each GPU utility had to pay a price halfway between the cost to the selling utility and what it would have cost the GPU utility to produce the power through its own facilities. (580) In its June 19, 1979 order authorizing rate adjustments to reflect replacement power purchases, the Pennsylvania PUC directed Met Ed and PENELEC to negotiate with other members of the PJM pool for pricing not on a split-savings basis, but at cost. (581)

Met Ed, PENELEC and Jersey Central were unable to convince the other members of the pool to agree to this. However, the members did propose to allow TMI-related purchases at cost plus 10 percent. (582) In October 1979, it was estimated that if this change were put into effect for 1980, the GPU utilities could save—and the other members of the PJM pool relinquish—as much as $32 million. As part of this proposal, the pool-member utilities were to petition their respective state and city regulatory bodies for a finding that the proposal was "in the public interest." (583) Then the matter would be turned over to the Federal Energy Regulatory Commission,[146] which has jurisdiction over the proposed PJM rate modification. (That agency regulates all wholesale power sales in the country.) (585)

As called for under the proposal, pool members began taking steps to obtain approval of the proposed PJM modification from utility regulators in Virginia, Pennsylvania, Maryland, New Jersey and the District of Columbia. Prompt approval was not forthcoming. The D.C. Public Service Commission gave indications that it might take six months before reaching any decision on the proposal, (586) which, if implemented, would have resulted in increased costs to District customers. (587)

Given the prospective delay, GPU decided in late March to abandon efforts first to get state regulatory approval of the cost plus 10 percent arrangement negotiated by the other PJM pool members. (588) GPU thus filed papers with the Federal Energy Regulatory Commission stating that it had "not been feasible to obtain an agreement with the other PJM Companies which could be implemented in a timely fashion."(589) Claim-

[145] As noted earlier, the rate relief accorded by Pennsylvania and New Jersey utility regulators in April and May led GPU to estimate that the GPU companies would not reach the $292 million credit limit before the end of 1980. A few months earlier, they had expected to reach that limit around May. (576)

[146] Since it has jurisdiction over all wholesale power sales, FERC regulates not only PJM pool rates but also the rates charged by the GPU utilities to wholesale purchasers outside this pool, including cooperatives, municipalities and other utilities. Since the TMI accident, these other wholesale rates also have been subject to review by FERC. New rates for PENELEC and Jersey Central were the subject of provisional settlements, which as of the end of February 1980 were awaiting Commission approval. (584)

ing that its unusual circumstances rendered the PJM terms unjust and unreasonable, GPU requested FERC-ordered rate modifications that would change the split-savings pricing scheme to reflect a sale at the seller's cost. (590) At least one PJM pool member specifically opposed GPU's request. In mid-May, proceedings were still continuing. No relief had been granted. (591)

SUMMARY

Cleanup is an enormous undertaking beset by uncertainty. Decontamination of Unit 2 alone will require over 1,000 individuals and more than four years. The technical task is in many ways the most certain and the most manageable aspect of recovery, though it is not without substantial hazards. The technical work is complicated by financial, social, legal and regulatory factors that pose many conflicts and have few clear answers.

Cleanup poses a difficult dilemma. The damaged facility represents a hazard, most directly to the cleanup work force, but to the public as well. For this reason, it would be desirable for decontamination to proceed as quickly as possible. On the other hand, the scope and complexity of the job are unprecedented, involving many controversial issues, and it is taking place in an atmosphere of public anxiety and distrust. Therefore, caution, careful planning, a deliberative weighing of alternatives and opportunity for public comment are also desirable.

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Appendix A

Three Mile Island in Perspective: Other Nuclear Accidents

Appendix A

Three Mile Island In Perspective: Other Nuclear Accidents

INTRODUCTION

Three Mile Island was not the first severe accident at a nuclear reactor. One earlier accident at an experimental reactor in the United States caused three deaths, and accidents here and abroad at government and commercial facilities have resulted in damage to the core, measurable releases of radiation, or post-accident contamination of comparable or greater amounts than at TMI.

Most of these accidents involved smaller, government-owned or financed reactors, rather than large commercial facilities such as TMI. Many involved more remote, largely self-sufficient complexes where administrative support, needed personnel, waste disposal facilities and decontamination technology were readily available. None in this country had the same degree of publicity as associated with TMI. All the accidents within the United States involving radiation releases occurred before enactment of the National Environmental Policy Act of 1969. Consequently, cleanup operations were not affected by the requirements of that Act for detailed documentation of cleanup alternatives and for public review and deliberation.

Although there have been a number of severe accidents and major cleanup efforts in the past, it is not possible to make a point-by-point comparison with TMI. Each prior accident had its unique aspects, and documentation was not always complete. Nonetheless, the earlier accidents provide historical perspective regarding TMI and the present cleanup task. A brief review of significant accidents follows.

SL—1, IDAHO

On January 3, 1961, the first major nuclear reactor accident in the United States occurred at Stationary Low Power Reactor No. 1 (SL–1), a military facility at the remote National Reactor Testing Station in Idaho. The site is 60 miles due west of Idaho Falls (population 100,000). The accident resulted in three fatalities. (1)

In contrast to the 880-megawatt pressurized water reactor at TMI, SL–1 was a 3-megawatt boiling water reactor with a substantially smaller core. Unlike the thick concrete containment with airlock doors at TMI, the SL–1 reactor building was a cylindrical structure with ¼-inch thick steel walls and normal doors. (2)

THE ACCIDENT

While the plant was shut down, servicemen working on the instrumentation in the reactor building apparently made a mistake that resulted in the control rods being lifted out of the core, according to an AEC investigation of the accident. (3) The reactor immediately went supercritical, leading to nearly instantaneous fuel melting, a steam explosion and jettisoning of the control rods. Two workers were killed in the building and a third died enroute to the hospital. (4) The deaths resulted directly from physical injuries, although the radiation levels also would have been fatal. (5)

CLEANUP AT SL–1

Health physics personnel established a field headquarters near the site. By late evening on January 4, a military team working in relays succeeded in recovering the body of the second victim, which was inside the reactor building. It was not until the sixth day after the accident that the third body was recovered. It had been pinned by a jettisoned control rod to the upper structure of the reactor building, directly above the reactor.

The AEC described the process of removing the body:

> The direct recovery was accomplished by eight men, paired in quick-moving relays to avoid excessive radiation exposure. No two-man team was in the building more than 65 seconds. (6)

Radiation levels in the reactor building at that time were 1,000 roentgens per hour (R/hr).[1] The time each man spent in the reactor building was timed by a stopwatch. The radiation level multiplied by the time spent determined the dose each man received. (7)

Despite the high radiation levels within the SL–1 reactor building, the steel cylinder contained most of the radioactivity. Four days after the accident, radiation levels outside the reactor building ranged between 0.25 and 5 R/hr. Radiation in the control room in the adjacent building was only 1.15 R/hr. The average around the 350 ft. square perimeter of the SL–1 facility was 0.056 R/hr. (8)

A preliminary assessment of the condition of the reactor followed recovery of the casualties. The reactor was determined to be in a noncritical condition. However, the physical state of the core, the location of the control rods, and the presence or absence of water in the pressure vessel all were unknown, and no conclusion could be drawn as to whether it was possible for the reactor suddenly to go supercritical again and to create the potential for another explosion. (9)

Because of concern about the possibility of recriticality, all operations to determine the status of the reactor core were performed remotely. Personnel installed monitoring instruments to survey the radiation. They also viewed the top of the head of the reactor vessel and the interior of the vessel and the core, and then determined the level of water in the reactor vessel. This phase was completed in May 1961. It was concluded that the reactor vessel contained no water and that recriticality could be prevented by keeping it dry. (10)

General Electric Company was contracted to gather and evaluate data concerning the accident and to complete the remaining recovery efforts. After the SL–1 core was removed, it was examined and then sent offsite, together with the pressure vessel, for further analysis and dismantling. The steel reactor building was dismantled and buried on the site.

By July 27, 1962, some 19 months after the accident, decontamination of the SL–1 site was achieved, completing the cleanup phase of operations.

From July through October 1962, additional analyses on the behavior of the reactor during the transient were undertaken to obtain improved understanding of the thermal and mechanical processes that had occurred. Chemical, metallurgical and nuclear data relative to the pre-accident performance of SL–1 also were gathered. The follow-up studies took another three months.

EXPOSURE OF THE WORK FORCE

The manned recovery operations involved about 475 individuals and 3,240 entries into the SL–1 area, for a total of 9,325 man-hours. Personnel had to wear protective clothing and respiratory equipment. A cumulative dose of 3,481 rads to the skin and 998 rems to the whole body was reported for all the recovery personnel. (11) Nearly six percent of the individuals received radiation doses in excess of the radiation protection guides then recommended by the Federal Radiation Council for exposure to external sources of radiation. (12)

A congressional investigation of the accident was conducted by the Joint Committee on Atomic Energy. (13) Regarding recovery, it concluded:

> Of over 100 people engaged in recovery operations during the first 24 hours after the incident and of the several hundred so engaged in the following week, 22 persons received radiation exposures in the range of three to twenty-seven roentgens total body exposure. Precautionary medical checkups did not disclose any clinical symptoms. (14)

The Special Investigation staff spoke with Edward J. Vallario, a member of the SL–1 emergency team that entered the building to retrieve the victims' bodies. Vallario said that he had received far more than 27 roentgens. Based on the time he had voluntarily spent in the contaminated building, he calculated he had received more than 100 rems. (15) He subsequently underwent decontamination. After 18 years, he had experienced no ill effects. (16)

Future Emergency Response

Vallario stated that in radiological emergencies there should be less restrictive dose criteria to permit longer exposure during rescue efforts. (17) He also stated that rescue workers should be free to exercise their own judgment in volunteering to receive higher doses if a human life were at stake. (18)

[1] See "Radiation Effects and Monitoring," p. 43, for definitions of radiation terminology.

According to Vallario, some of the lessons learned from the SL–1 accident, such as the need for available emergency instrumentation, are still applicable today but have not been widely implemented. (19) For example, in-place wide-range radiological survey equipment would have helped during response and recovery to the SL–1 accident. Eighteen years later, at TMI, that same type of equipment also would have been useful but was not in place during the accident.

CHALK RIVER—NRX

THE ACCIDENT

At the Atomic Energy of Canada Limited (AECL) facility near Chalk River, Ontario, are two heavy water reactors,[2] referred to as NRX and NRU. Both units, located 120 miles from Ottawa (population 500,000), have experienced accidents. The first, at NRX, which has a 30-megawatt research reactor, was the more serious, and its recovery is similar in some respects to that at TMI.[3]

The NRX accident began on December 12, 1952, when an operator at the reactor mistakenly opened several bypass valves, leading to an unexpected power surge. (20) The increased heat emitted from the fissioning fuel caused the reactor coolant to boil. As a result of inadequate cooling, the fuel sheathing and some of the uranium melted.

Because of this melting, about 1 million gallons of water, which had absorbed about 10,000 curies of long-lived fission products, flowed into the basement beneath the reactor. (By comparison, approximately 1 million gallons of contaminated water are in tanks in the containment and auxiliary buildings at TMI–2. It is estimated that this water contains about 800,000 curies of long-lived fission products.)

CLEANUP

The cleanup task involved pumping the radioactive water to a disposal area on the site. The reactor, which had a core 8 feet in diameter by 10 feet high, also had to be dismantled. TMI's core, by contrast, is 12 feet in diameter and 14 feet high. Unique tools were designed and fabricated for removing the core, since special procedures were required for handling the damaged fuel elements. (21)

In order to reduce the radiation exposure to each individual involved, about a thousand servicemen were called in to participate in cleanup and recovery. The Atomic Energy Commission also provided personnel, equipment and expertise, as did the U.S. Navy. (22)

Fourteen months later, the NRX was back in operation. (23) The radioactive debris was disposed of at a dump onsite.

EXPOSURE OF WORKERS

During cleanup, workers received an average radiation dose of less than 3.9 rems (3,900 millirems). The highest reported total dose for an individual was 17 rems (17,000 millirems). (24) At TMI, the highest reported dose between the time of the accident and early June 1980 was 4–5 rems (whole body dose), and a 150 rem dose of beta radiation to the extremities. The average dose to a worker at TMI during the same period was 380 millirems. (25)

The AECL informed the Special Investigation staff that there is no published information available on long-term health studies on the NRX workers. (26)

Water draining from the site disposal area is still being monitored continuously. No detectable radioactivity has been found offsite. (27)

CHALK RIVER—NRU

The NRU reactor, larger than its sister NRX reactor, generated 200 megawatts and had a core 11 feet in diameter and 12 feet high.

THE ACCIDENT

On May 23, 1958, during startup, the aluminum sheathing of one of the fuel rods ruptured. During attempts to remove it, the fuel rod overheated, melted and fragmented. (28) Pieces fell to the bottom of the reactor vessel, onto the reactor deck plate and into the maintenance pit, where they ignited.

CLEANUP

Personnel were evacuated from the buildings, and the fire was quenched. (29) Preliminary plans

[2] A heavy water reactor is cooled by "heavy water" (deuterium oxide), which allows natural uranium to be used as the reactor fuel. A light water reactor is cooled by ordinary water and must use enriched uranium.

[3] This reactor was not a pressurized-water type. It had an unusual design in which the coolant was also not supposed to boil.

then were made for decontaminating the reactor building.

A crew soon began checking the area outside the NRU building for contamination of the air and for fallout. Access to contaminated roads and buildings was prohibited, although within a few hours decontamination personnel had some roads and buildings back in service. (30)

Radiation fields of up to 1,000 roentgens per hour (R/hr) were found on the top of the reactor deck plate, and the radiation dose rate in the maintenance pit was calculated to be in the range of 10,000–50,000 R/hr. (31) It was estimated that the burned portion of the fuel rod contained 2 million curies of mixed fission products, 700 curies of iodine 131 and a small amount of plutonium. (32)

Because of the excessive radiation fields, a decision was made to recruit outside help from the Armed Services and the Civil Defense Organization so that the exposure of each individual could be limited. Each worker was allowed to receive a 3-rem limit. Lectures, briefings and bioassays (e.g., urinalysis) were conducted for each worker.

The morning after the fire, the burned-out sections of fuel rods were removed from the maintenance pit and from the top of the reactor using remote-handling techniques that involved NRU's permanent crane and long-handled tools. Residual contamination was removed by special vacuum cleaning and washing. Offices, auxiliary rooms and basements were systematically decontaminated.

Some 600 men were involved in the cleanup. (33) The Special Investigation staff was not able to find any data on the long-term health effects on workers. The AECL informed the Special Investigation staff that there is no published information available on long-term health studies of the NRU workers. (34)

WINDSCALE, ENGLAND

THE ACCIDENT

On October 10, 1957, a fire at the Windscale No. 1 plutonium production reactor in England resulted in the largest known releases of radioactive gases from a nuclear reactor accident into the environment. (35) For example, it was calculated that about 20,000 curies of iodine 131 were released from the plant's stack, well over a thousand times the amount estimated for TMI. (36)

The reactor was located at Sellafield, Cumberland, some 50 miles from Carlisle and Blackpool, cities with populations of about 71,000 and 153,000 respectively. Intensive sampling was conducted in the area throughout the period of the releases; several European countries cooperated in the meteorological surveys. It was estimated that the total dose of gamma radiation to persons in the region of heaviest deposits was 30–50 milliroentgens, or one-tenth the maximum permissible exposure of 500 milliroentgens per year for the general public.[4] (37) Onsite, the average level of air contamination during the accident was about twice the daily standard established by the International Commission on Radiological Protection. (38)

A six-week ban was placed on consumption of milk to avoid contamination from iodine 131. (39) Other foodstuffs—eggs, meats, vegetables and water—were screened for strontium isotopes. (40)

CLEANUP

The No. 2 production reactor at Windscale, which was unaffected by the fire at No. 1, was shut down while inquiries into the accident and its causes were undertaken and cleanup was begun. (41)

A report of the U.K. Atomic Energy Authority's Committee of Inquiry into the accident concluded that it would be prohibitively expensive to make design changes to the No. 2 reactor to prevent a similar type of fire. (42) All of the natural uranium fuel from the No. 2 reactor and the remaining undamaged fuel from the No. 1 reactor were removed. (43) Eventually both Windscale reactors were sealed with concrete. (44) There is no available information on recovery costs or on the occupational hazards to workers involved in the Windscale cleanup. (45)

Despite the unprecedented releases of radioactivity, the report of the British Medical Research Council, which conducted an analysis of the radiation hazards, stated that:

> After examining the various possibilities, we are satisfied that it is in the highest degree unlikely that any harm has been done to the health of anybody, whether a worker in the Windscale plant or a member of the general public. (46)

In contrast to TMI, good public relations apparently were maintained, and public confidence in the U.K. Atomic Energy Authority was preserved. (47) The milk ban was publicized to indicate government concern that there be no possibility of contamination from radiation. According to a report on the accident:

> [The British government is] particularly anxious that the Windscale accident

[4] This exposure limit has remained basically unchanged and is an internationally used value.

brought to the surface the latent public anxiety about the hazards of atomic energy work. Now that the nation is committed to a large nuclear program, we consider of the utmost importance that the hazard of atomic energy shall neither be exaggerated nor minimized in the public mind. (48)

ENRICO FERMI, ILLINOIS

In 1955, the AEC established a Cooperative Power Reactor Demonstration Program, offering government financing to utilities prepared to join the AEC in building nuclear-powered generating stations.

The Enrico Fermi—a "fast," 200-megawatt breeder reactor[5] whose sodium-cooled core was about 3 feet in diameter and 3 feet high—was one of the AEC-backed demonstration facilities. (49) The reactor, located at Newport, Michigan, 30 miles south of Detroit (population 1.5 million), began operations on August 23, 1963. (50)

THE ACCIDENT

On October 5, 1966, during a controlled increase in power, several subassemblies began registering abnormally high outlet temperatures. After the radiation alarms sounded, the reactor was shut down. Subsequent analyses revealed that the circulation of liquid sodium coolant over four out of about 100 adjacent fuel subassemblies had been blocked. Two subassemblies had melted, while the remaining two had overheated. (51)

Although the accident resulted in a partial meltdown of the core, assessments made of the measured levels of radiation showed no hazard offsite. (52) Radiation exposure to the public was not large in comparison with the normal radiation levels surrounding the plant. (53)

CLEANUP

Recovery of the Enrico Fermi facility began December 1966, when fuel unloading was started. By March 1967, an area of the core around the pair of fused subassemblies was opened for viewing. In July they were separated, removed and shipped to the Battelle Memorial Institute for dismantling and study. (54) The damaged core was later returned to the Federal Government for eventual reprocessing at the Savannah River plant. Most of the radioactive debris was shipped to a disposal site in Maxey Flats, Kentucky. (55) As of June 1980, the primary sodium coolant (about 70,000 gallons) was still being stored in drums at the Enrico Fermi plant. (56) At that time, the radioactivity of the sodium storage area was quite low (about 3 millirem per hour), due to the radioactive decay that had occurred since removal of the sodium from the reactor.

The Department of Energy (DOE) purchased the primary sodium in anticipation of the Clinch River Breeder Reactor Project. DOE will take possession of the sodium at some point, regardless of the outcome of the Clinch River project.

Cleanup was largely completed in December 1968, two years after the accident. (57) On July 18, 1970, the Fermi plant resumed operations. In 1972, after it had used up the fuel in its second core, it was shut down and decommissioned; the reason was largely financial.[6]

SRE, CALIFORNIA

In the 1950s, another "fast" reactor, a 20-megawatt Sodium Reactor Experiment (SRE), was built at Santa Susana, California, about five miles from Canoga Park (within the greater Los Angeles area). The project was to further the development of a sodium-cooled graphite-moderated reactor for commercial use. (59)

THE ACCIDENT

On July 24, 1959, leakage of an organic material (Tetralin auxiliary coolant) from a pump into the sodium coolant caused a blockage to form in the coolant channels. Twelve of 43 fuel elements melted. (60)

[5] A "fast" reactor is so named because the neutron velocity is high, in contrast to a water reactor. Fast reactors are often cooled with liquid sodium, instead of water. They produce more fuel than they consume—thus, the term "breeder."

[6] In November 1970, the owners of Fermi, the Power Reactor Development Company (PRDC), who had leased two cores, proposed a program to redesign and fabricate an improved oxide core for the reactor. However, by the end of 1971, when the fuel in the second core was used up, there were insufficient funds to begin the program. The fuel melting incident and cleanup had required substantial resources in terms of time, costs and financial support within the industry. Consequently, PRDC decided not to refabricate the second core or to negotiate obtaining a reload core, leaving decommissioning as the only alternative. (58)

Iodine released from the fuel elements was effectively retained in the sodium coolant. No radioactivity except noble gases[7] was detected in the reactor vessel. (61) Hence, as with the Enrico Fermi incident, virtually all of the radioactivity was contained and did not create a public hazard.

CLEANUP

Following the partial melt, a cleanup effort was launched. The reactor was repaired and brought into operation, though intermittently (for low power testing, etc.), in September 1961. This type of operation continued through February 1963. The reactor was then run at full power for one year. (62)

In February 1964, the reactor was permanently shut down because the AEC concluded that it had served its purpose as a demonstration facility. (63)

Recently, the Department of Energy issued a blanket request that contaminated, unused facilities be decontaminated and decommissioned. (64) A decision was made to dismantle the SRE facility. This task was ongoing in May 1980. (65)

BROWNS FERRY, ALABAMA

On March 22, 1975, there was an accident involving two units at the Tennessee Valley Authority's Browns Ferry Nuclear Plant in Limestone County, Alabama. The plant is about 40 miles from Huntsville (population approximately 150,000). (66) At the time, the Browns Ferry facility consisted of two operating units, generating 2,200 megawatts, with a third unit under construction.

THE ACCIDENT

A fire originated in the electrical cable system beneath the common control room for Units 1 and 2. All of Unit 1's Emergency Core Cooling System was rendered inoperable, and portions of Unit 2's system were likewise affected because the fire destroyed some of the cables for the control and backup systems of each. Nevertheless, sufficient equipment remained operational throughout the accident that both reactors eventually could be shut down and their cores maintained in a safe condition.

The Browns Ferry fire resulted in no adverse radiological effects to the public, plant personnel or the environment. (67) Some minor injuries were sustained by personnel in firefighting.

THE NRC'S ANALYSIS

Because electrical cables for redundant safety systems were routed through a single cable tray, the fire knocked out the backup as well as the main systems. Had anything else serious gone wrong at the reactor, reactor protection would not have functioned. (68)

As a result of Browns Ferry, the NRC issued a report recommending generic steps that should be taken at nuclear power plants, including

—improved fire protection
—improved fire control and containment
—separation and isolation of redundant function (shutdown systems). (69)

These recommendations have been incorporated in revised guidelines for fire protection, and a proposed rule on 10 CFR 50.48 was published in the *Federal Register* on May 29, 1980.

The NRC also received recommendations from a consultant for improving information flow and emergency response during an accident, based on an analysis of problems experienced during the Browns Ferry fire. (70) The NRC did not effectively follow-up on these recommendations and experienced similar problems during the TMI accident.[8]

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[7] See "Technical Glossary," p. 372.
[8] See "Prior to the Accident," pp. 82–83, and "The Accident at Three Mile Island: The First Day," pp. 130ff.

Appendix B

Nuclear Regulatory Commission Organization

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Nuclear Regulatory Commission Organization

The Energy Reorganization Act of 1974, (1) effective January 19, 1975, (2) created the Nuclear Regulatory Commission (NRC) and (3) transferred to it the licensing and related regulatory functions of the Atomic Energy Commission, which was abolished.

The Act specified three new program offices for the NRC. They were Nuclear Material Safety and Safeguards, Nuclear Reactor Regulation and Nuclear Regulatory Research. Two other offices—Standards Development and Inspection and Enforcement—were subsequently set forth in the Code of Federal Regulations. (4)

NUCLEAR REACTOR REGULATION

The Reorganization Act charged the Office of Nuclear Reactor Regulation (NRR) with licensing functions associated with the construction and operation of those reactor facilities that must be licensed, according to the Atomic Energy Act of 1954, as amended. This Office licenses the receipt, possession, ownership and use of special nuclear and byproduct materials used at reactor facilities.[1] In addition, NRR evaluates the health, safety and environmental aspects of nuclear facilities and sites; develops and administers regulations; licenses reactor operators; analyzes reactor design concepts; evaluates methods of transporting nuclear materials and radioactive wastes on reactor sites; monitors and tests operating reactors; and recommends upgrading of facilities or modification of regulations. NRR also provides assistance in matters involving reactors or critical facilities exempt from licensing.

DIVISIONS WITHIN NRR

At the time of the accident there were four major Divisions within the Office of Nuclear Reactor Regulation: Operating Reactor (DOR), Project Management (DPM), Site Safety and Environmental Analysis (DSE), and Systems Safety (DSS).

The Division of Operating Reactors (DOR) reviewed changes in the design and operation of operating reactors. It analyzed operating experience (e.g. incidents), some of which, such as increased testing or surveillance, have to be accounted for in new licensing actions.

The Division of Project Management (DPM) administered the reviews of reactor safety through the Operating License stage, and was responsible for coordinating and scheduling the review by the technical review staff. This Division was also responsible for the examination and licensing of reactor operators and senior reactor operators.

The Division of Site Safety and Environmental Analysis evaluated all reactor sites for potential health, safety and environmental impacts.

The Division of Systems Safety (DSS) evaluated the safety issues associated with the design of the facility in both Construction Permit and Operating License applications.

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[1] Special nuclear material refers to plutonium, uranium 233, uranium enriched by the isotopes 233 or 235, and any other material which the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, as well as any material artificially enriched by any of the foregoing.

Special nuclear materials do not include source materials. These are uranium or thorium, or any combination of them, in any physical or chemical form, and ores which contain by weight 0.05% or more of uranium, thorium or any combination of them.

Byproduct material means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation during the process of producing or utilizing special nuclear material.

NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

The Office of Nuclear Material Safety and Safeguards (NMSS) is chartered under the Reorganization Act with responsibility for licensing and regulating all facilities and materials licensed under the Atomic Energy Act of 1954, as amended, associated with the processing, transport and handling of nuclear materials. Among its duties are to review and assess the licensee's safeguards against potential threats, thefts and sabotage of those materials.

NUCLEAR REGULATORY RESEARCH

Finally, the Energy Reorganization Act charged the Office of Nuclear Regulatory Research (RES) with planning, recommending and implementing those nuclear research programs related to the NRC's licensing and regulatory functions. There are two formal research divisions within RES: the Division of Reactor Safety Research (RSR) and the Division of Safeguards, Fuel Cycle and Environmental Research.

The Division of Reactor Safety Research plans and oversees programs relating to the safety of civilian power and advanced reactors and to the behavior of reactor components and systems under accident conditions.

The other Division of RES—Safeguards, Fuel Cycle and Environmental Research—plans and oversees programs relating to safeguards, fuel cycle and environmental research.

STANDARDS DEVELOPMENT

The Office of Standards Development, as defined in the Code of Federal Regulations, focuses on NRC rules, regulations, standards and guides governing the licensing of nuclear facilities and the commercial use of nuclear materials.

Its Division of Engineering Standards (DES) directs the development of standards and regulations for safe design, construction, other production and utilization facilities and facilities for the storage, processing and use of nuclear materials. Similarly, it develops regulations and standards for the production, use and transportation of radioactive materials. This Division also is responsible for providing technical assistance on generic issues related to nuclear wastes and fuel cycle facilities. It works with the American National Standards Institute (ANSI) as well as other Federal and international agencies.

Also within the Office of Standards Development is the Division of Siting, Health and Safeguards (DSHS). Its focus is on radiological protection, environmental impacts and safeguards for nuclear facilities.

INSPECTION AND ENFORCEMENT

The Office of Inspection and Enforcement (I&E) consists of a headquarters group and five regional offices. I&E's purpose is to ascertain compliance with the NRC's licensing regulations, orders and conditions through the development of policies and programs for the inspection of licensees, applicants and their contractors and suppliers. I&E further ensures safety by identifying conditions that may adversely affect public health and safety, the environment or the safeguarding of nuclear materials and facilities. This Office also makes recommendations on the issuance of authorizations, permits or licenses and determines the adequacy of the licensee's quality assurance programs. Finally, I&E develops enforcement policies and recommends or takes appropriate action regarding incidents or accidents.

In additional to these five major offices, there are interoffice Research Review Groups whose purpose is to monitor and direct research programs in specific areas. One such group is the Human Engineering Research Review Group, which was formed in 1976. (5) Its members include designated representatives from the Office of Inspection and Enforcement, the Division of Operating Reactors, NRR, the Office of Standards Development, the Office of Management and Program Analysis and the Probabilistic Analysis Staff, RES. The Review Group uses the services of industry consultants. It focuses on human factors engineering and other safety-related aspects of plant operations, and outlines and recommends additional research projects to be undertaken by the NRC.

Appendix C

Nuclear Regulatory Commission Reactor Licensing Process

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Appendix C

Nuclear Regulatory Commission Reactor Licensing Process

NRC REQUIREMENTS

Before a utility can build and operate a powerplant at a particular site, it first must obtain a Construction Permit and then an Operating License from the NRC.

Applicants for a Construction Permit must file a Preliminary Safety Analysis Report (PSAR) with the Office of Nuclear Reactor Regulation (NRR). This document presents design criteria and other preliminary design information on the proposed reactor, as well as comprehensive data on the proposed site. Hypothetical accident situations and safety features related to them are discussed. The PSAR must also include information on safety design, site characteristics, personnel qualifications, management and administration, emergency response plans, quality assurance, control of radiation effluents and wastes, and financial capability. In addition, the utility must submit an Environmental Report, which provides a basis for the evaluation of the environmental impact of the proposed plant.

If these documents meet the NRC's criteria for content of an application, the NRC formally dockets for review the application for a Construction Permit. It then issues a press release.

Once docketed, the NRC sends copies of the application to Federal, State and local officials. A notice of receipt of the application is also published in the *Federal Register*. All material related to the application is made available to the public.

THE REVIEW PROCESS

The licensing review is conducted within the Office of Nuclear Reactor Regulation in accordance with a Standard Review Plan and criteria contained in NRC regulations and Regulatory Guides, as well as industry standards developed in conjunction with the NRC.

NRR staff evaluates the applicant's quality assurance program for the design and construction of the facility. Components, systems and structures important to safety are reviewed to ensure that their design, fabrication, construction and testing meet quality standards, commensurate with the importance of their safety functions.

Staff examines design methods and procedures for calculations for accuracy and for scope. Further, it determines whether the design of the reactor and its equipment is adequate to protect public health and safety. If any proposal in the application is found to be inadequate, the NRR staff requires that the applicant correct it.

SAFETY EVALUATION REPORT

When the NRR staff concludes that acceptable criteria and preliminary design information, as well as financial information, are fully documented, it prepares a Safety Evaluation Report (SER) on the application. The SER is a summary of the staff's evaluation of the anticipated effect the proposed facility will have on public health and safety.

ENVIRONMENTAL CONSIDERATIONS

The NRC also evaluates the potential environmental impact and provides comparisons between the benefits and the possible risks to the environment of the proposed plant and of other reasonable alternatives.

The Commission issues its conclusions from this review in a Draft Environmental Statement

(DES). It circulates the DES to appropriate Federal, State and local agencies, as well as to individuals and organizations representing the public, for their consideration. After receipt of all comments and resolutions of any outstanding issues, the NRC prepares and makes public a Final Environmental Statement (FES).

ACRS RECOMMENDATIONS

The Advisory Committee on Reactor Safeguards (ACRS), an independent statutory committee established to advise the NRC on reactor safety, reviews each application for a Construction Permit, and subsequently each application for an Operating License. Its members serve four-year terms and are experienced individuals selected from applicable technical disciplines. Consultants may be called in for specialized analyses.

Each Construction Permit or Operating License application is assigned to an ACRS project subcommittee. During the Committee's evaluation, the NRR staff advises the Committee of requests for additional information, meetings and developments warranting a change in the plant. Where the plant is of "standard design" and the site appears generally acceptable, the ACRS Subcommittee review does not begin until the NRC staff has nearly completed its review of the safety-related features. Otherwise, the ACRS Subcommittee may begin its formal review earlier.

The NRC staff's Safety Evaluation Report and the ACRS Subcommittee evaluation of the application form the basis for the review by the full Advisory Committee. The ACRS pays particular attention to safety issues and any new or advanced features proposed by the applicant. It meets at least once with both the NRC staff and the applicant to discuss the application; these meetings are open to the public.

When the Advisory Committee completes its review, it submits a report to the Chairman of the NRC that is also made public.

The NRR staff then prepares a supplemental Safety Evaluation Report to address those safety issues the ACRS have raised. The Supplement includes any additional information made available since issuance of the original Safety Evaluation Report.

PUBLIC HEARINGS

The Atomic Energy Act requires that the NRC hold a public hearing(s) before a Construction Permit is issued. As soon as an application is docketed, the NRC issues a notice of the hearings, although the hearings are not held until the safety and environmental reviews have been completed. These hearings, advertised in newspapers in the vicinity of the proposed facility and in a public announcement, afford the public the opportunity to participate in the licensing process.

A three-member Atomic Safety and Licensing Board, appointed from the NRC's Atomic Safety and Licensing Board Panel, conducts the public hearings. A lawyer, who acts as chairman, and two other technically qualified persons constitute the Board. The NRC offers as evidence the Safety Evaluation Report, its supplements and the Final Environmental Statement.

The Board considers all the evidence, together with findings of fact and conclusions of law filed by the parties. If the Board issues a favorable initial decision regarding environmental, health and safety matters, the NRC will issue a Construction Permit. However, the decision is subject to review by the Atomic Safety and Licensing Appeal Board, either at its instigation or in response to appeals by affected parties. The initial decision may also be reviewed by the Commissioners.

LIMITED WORK AUTHORIZATIONS

If, while the hearings are in progress, the Board determines that the proposed facility has met the requirements of the National Environmental Policy Act and NRC's implementing regulations and that the proposed site is suitable for the plant, a Limited Work Authorization (LWA) may be granted for construction of features not subject to quality assurance requirements. These include site preparation work, excavation, installation of temporary construction support facilities, and construction of service facilities. If, in addition, there are no safety issues outstanding regarding the work to be authorized, the LWA may also permit the installation of structural foundations.

FINAL APPLICATION

After a Construction Permit is issued and work on the facility has progressed to the point at which most of the final information on design and operations is complete, the applicant submits a Final Safety Analysis Report (FSAR). It details the final design of the facility, including the containment, the nuclear core and waste handling system.

The NRC's review of the Operating License application is similar to its evaluation of the Construction Permit application. The staff prepares a second Safety Evaluation Report, which the ACRS then reviews. The ACRS returns its final evaluation of the safety issues to the Commission. The NRR staff may prepare a Supplement to the Safety Evaluation Report. As during the Construction Permit review, the Safety Evaluation Report and any Supplements and other documents are made available to the public. ACRS meetings may be attended by the public. A public hearing prior to issuance of an Operating License is not mandatory, although it may be requested.

THE OPERATING LICENSE

Upon satisfactory completion of these reviews, the NRC issues an Operating License.

Each license for operation of a nuclear reactor contains Technical Specifications that set forth the particular safety and environmental protective measures to be imposed upon the facility and the conditions of operation that are to be met in order to assure protection of the health and safety of the public and of the surrounding environment.

The Office of Inspection and Enforcement monitors onsite all construction and actual operations of the plant. It enforces the utility's compliance with Commission regulations and the operation and maintenance of the plant according to the Technical Specifications.

IN THE EVENT OF INCIDENTS

The Technical Specifications require that the licensee inform the Commission of Reportable Occurrences. The licensee documents these events in Licensee Event Reports (LERs), submitted to the NRC. Reportable occurrences include violations of the Technical Specifications; degraded conditions of systems designed to contain radioactivity; failures or malfunctions of components, personnel errors or procedural inadequacies which could prevent a system from performing its required safety function; and certain errors discovered in the analysis of transients.

The Licensee Event Report (LER) is a standardized form. It calls for, among other things, a description of the event, its causes and probable consequences and the actions taken to correct the problem and prevent its recurrence. The information is fed into a computer-based data file to facilitate evaluation. The Office of Management and Program Analysis is responsible for maintaining this file.

NRC ANALYSIS OF EVENT REPORTS

The regional Inspection and Enforcement Offices receive the LERs from the licensees. I&E reviews the reports and determines if the licensee's corrective actions are acceptable. Copies of the LERs are also sent to the NRR and are distributed to staff. However, there were no formalized procedures for reviewing these reports, and neither NRR nor I&E had a formal system for identifying trends in equipment failure or new generic safety concerns, at the time of the accident.[1]

[1] Since the accident, procedures have been implemented for the systematic evaluation of LERs.

Appendix D

Chronology of First-Day Responses to the Accident

CHRONOLOGY OF FIRST DAY RESPONSES TO THE ACCIDENT

TIME	EVENT	REFERENCES
4:00 am	Turbine Trip/Reactor Trip at TMI-2	
4:01 am	(Bill Zewe) (Unit 2 Shift Supervisor)----(Dale Pilsitz) (Unit 1 Shift Foreman)----(Gary Miller TMI Station Manager) (Bill Zewe) Unit 2 Shift Supervisor)----(Scott Wilkerson) (Plant Nuclear Engineer)----(George Kunder) (Supt. Technical Support, Unit 2) At the request of Bill Zewe, Unit 2 Shift Supervisor, Dale Pilsitz, Unit 1 Shift Foreman, called Gary Miller, the station manager. Apparently, this was as a matter of policy and not as a result of any suspicion about the nature of the "trip". George Kunder, the Supt. of Technical Support of Unit 2, the on-call Duty Officer, was also called at about this time, and arrived 40 minutes later.	NUREG-0600, p. I-A-13, Item 67
4:02 am	Fred Scheimann, Unit 2 shift foreman enters control room and obtains the emergency procedures for turbine trip, reactor trip, and safeguards actuation, to confirm that all appropriate actions occurred.	NUREG-0600, p. I-A-14, Item 77
4:08 am	Ken Bryan, Unit 1 shift supervisor, who was on-site because of start-up in progress on Unit 1, arrives in Unit 2 control room to assist as necessary. Note: The availability of a second shift supervisor is not required by Technical Specifications, but he was available due to the pending start-up of Unit 1.	NUREG-0600, p. I-A-18, Items 100 and 101
4:10 am	Scott Wilkerson, plant nuclear engineer, arrives from Unit 1 and commences post-trip review. He also calls Joe Logan, the Unit 2 Superintendent, to notify him of the trip. This notification was also apparently as a routine action with no mention of anomalous conditions.	NUREG-0600, pp. I-A-20, 21, Item 114 I&E Interview, Tape No. 183, Logan, p. 3, and Met Ed Tape of 4/14/79, M-C Transcript, p. 12
4:35 am	Dale Pilsitz, Unit 1 Shift Foreman, called Mike Ross, Unit 1 Operations Supervisor to inform him of the "trip" in Unit 2.	NUREG-0600, p. I-A-26, Item 150

TIME	EVENT	REFERENCE
4:50 am	George Kunder, Superintendent of Technical Support, the on-call Duty Officer, reports to the site. He had been called soon after the turbine trip and left home for the site approximately 30 minutes later. Kunder arrived in Unit 2 and directed Wilkerson to call Walter "Bubba" Marshall, Dick Dubiel, and a number of other individuals.	NUREG-0600, p. I-A-27 Item 157 Met Ed Tape of 4/14/79, M-G transcript, p. 11
5:00 am	Walter "Bubba" Marshall, On-call Operating Engineer, called to come to site. He arrived at site approximately 45 minutes later.	NUREG-0600, p. I-A-29 Item 166
5:00 am	(George Kunder, TMI-2 Superintendent, Technical Support) -------------------- (Dick Dubiel, Supervisor, Rad Protection) Dubiel was phoned at home by Kunder, and told to report to the site.	NUREG-0600, p. II-A-3 Item 11
5:15 am to 5:40 am	(Gary Miller, TMI Station Manager) ------------------ (George Kunder, TMI-2 Supt., Technical Support) Mr. Miller calls TMI-2 to ascertain plant status, not having heard further since original notification. When informed of status, Miller directs Kunder, Duty Officer, to establish conference call with Jack Herbein, Met Ed V.P. Generation and Leland Rogers, B&W site rep.	NUREG-0600, p. I-A-33 Item 183 Met Ed Tape of 4/14/79 M-G transcript, p. 6
5:30 am	Michael Ross arrives in Unit 1 control room.	Met Ed Tape of 4/14/79, M-G transcript, p. 12
5:45 am	Joseph Logan, Dick Dubiel, and "Bubba" Marshall arrive in Unit 2.	Met Ed Tape of 4/14/79, M-G transcript, p. 12 I&E Interview, Tape No. 182, p. 3 NUREG-0600, p. II-A-4, Item 16
5:45 am	Gary Miller calls James Seelinger, Unit 1 Superintendent, and Daniel Shovlin, Superintendent of Maintenance, and requests that they report to site.	Met Ed Tape of 4/14/79, M-G transcript, p. 10, and I&E Tape No. 169, Seelinger, p. 4
6:00 am	George Kunder asks Scott Wilkerson to call Ivan Porter, Lead Instrumentation and Control Engineer, and Michael Benson, Lead Nuclear Engineer, and ask them to report to Unit 2.	Met Ed Tape of 4/14/79, M-G transcript, p. 11

TIME	EVENT	REFERENCE
6:00 am	Bill Zewe calls Michael Ross in Unit 1 and asks him to come over to Unit 2. Brian Mehler, another Unit 2 shift supervisor, arrives in Unit 2 and replaces Kenneth Bryan, who returns to Unit 1.	Met Ed tape of 4/14/79, M-G transcript, p. 12
6:00 am to 6:30 am	(George Kunder, TMI)--------------------(Gary Miller, Jack Herbein, Leland Rogers) (TMI, Met Ed, B&W)	NUREG 0600, pp. I-A-38, 39, Item 216
	1. Conference call established between Kunder, TMI-2 Technical Supt.; Miller, Station Manager; Herbein, Vice President of Generation; and, Rogers, B&W site rep. (at their homes). Knew trip was abnormal since RCPs were off and unable to draw pressurizer bubble. Blown rupture disc and water on floor were not surprising since this had happened before. The condition of the EMOV block valve was questioned and reported to be shut. Group decided need existed to restart an RCP and all should report to TMI. (Conference call had been initiated by Miller, Station Supt., following discussion with Kunder, Tech. Supt. (on-call Duty Officer) around 1 hour 15 minutes into event. Kunder had been on site since 50 minutes into the event, following his call to the site shortly following the initial trip.)	
	2. Herbein understood that low pressure suction trip of feedwater pumps which caused a high pressure reactor trip. Miller felt they had taken the plant solid with the HPI, that the code safety valves may have opened creating blown rupture discs on the reactor coolant drain tanks. Following depressurization, operators had secured reactor coolant pumps in the B and then A loops.	Herbein sequence, NRC 7906140462
6:15 am	Daniel Shovlin arrives in Unit 2.	Met Ed Tape of 4/14/79, M-G transcript, p. 11
6:20 am	(Scott Wilkerson, Nuclear Engineer, TMI-2)----------(Michael Benson, Lead Nuclear Engineer, at residence)	Met Ed Tape of 4/14/79, M-G transcript, p. 12 NUREG 0600, p. I-A-38, Item 214

TIME	EVENT	REFERENCE
6:20 am (con't)	Following directive from Kunder, Wilkerson called Benson to Unit 2 to gather information required for standard post trip report. Some question then whether the reactor had experienced a restart based on SRMs.	
6:30 am	Ivan Porter arrives in Unit 2.	I&E Interview Tape No. 237, p. 3
6:50 am	Joseph Logan had Daniel Shovlin call Gary Miller and inform him of indications of fuel failure. Howard Crawford, Unit 2 Nuclear Engineer, arrives for normal shift changeover scheduled for 7:00 a.m.	I&E Interview Tape No. 234, Shevlin, p. 4 Met Ed Tape of 4/14/79, M-G transcript
6:56 am	James Seelinger arrives in Unit 1, while Ronald Warren, Unit 2 Mechanical Engineer, arrives in Unit 2. Both arrive coincident with site emergency declaration.	Met Ed Tape of 4/14/79, M-G transcript, p. 12
6:56 am	Health Physics Technician reports over page that let-down sample lines from TMI-2 was reading 600 R. Auxiliary building evacuated. Joseph B. Logan, Unit 2 Superintendent, and George Kunder, Tech. Supt., then declared a site emergency. Declaration based on radiation alarms in more than one area. Notification of offsite authorities begins. North Bridge gates being closed due to guards responding to the establishment of site emergency.	NUREG 0600, p. I-A-45, Items 249-251, and Gary Miller Statement, NRC 7906150423 I&E Taped Interview with Gary P. Miller and Joe Logan on 6/28/79, p. 31

TIME	EVENT	REFERENCE
7:00 am	Michael Benson, Lead Nuclear Engineer, arrives in Unit 2 control room.	Met Ed Tape of 4/14/79, M-G transcript, p. 21
7:00 am	1. Guards at North Gate delay, then allow Rogers, B&W site rep., access to site. Guards were sending others to observation center.	NUREG 0600, p. I-A-46 Item 258
	2. Rogers, B&W site rep. was arriving at site at Miller's, Station Manager, request after earlier conference call which ended approximately at 6:38 a.m. He reached the Control Room about an hour later after contacting B&W in Lynchburg.	
7:02 am	(Bill Zewe, TMI) --------------------- (Clarence R. Deller, Jr., PEMA)	1. PEMA Log 3/27-28, p. 1, entry 8
	1. Call from Bill Zewe, Shift Supervisor, stating they had an emergency in TMI-2 which has been shut down. There is a high level of rad. in containment building but no off-site release. Zewe requested that the Bureau of Radiation Protection be notified and return the call.	
	2. Zewe phoned Deller, PEMA's Duty Officer, and informed him of the site emergency and requested that the Pennsylvania Bureau of Radiation Protection (BRP) be notified.	2. NUREG 0600, p. II-A-15 Item 54

TIME	EVENT	REFERENCE
7:02 am	(TMI)------------------------------(Kevin Malloy Director, Dauphin Co. Office of Emergency Preparedness) Notification of site emergency.	Gary Miller Statement, NRC 7906150423, and Note: NUREG 0600, p. II-A-17, Item 62, places this at 7:09 a.m.
7:04 am	(Clarence R. Deller, Jr.,---/-----(PA BRP) Duty Officer, PEMA) Called Bureau of Radiation Protection but no answer since no one was yet in the BRP office.	PEMA Log, 3/27-28, p. 1 entry 9
7:04 am	(Duty Officer--------------------(PA BRP) Dauphin Co. Office of Emergency Preparedness) Civil Defense called PA BRP.	Gary Miller Statement, NRC 7906150423
7:05 am	Gary Miller, Station Manager, arrives at site and proceeds to Control Room to assume duties as Emergency Director.	NUREG 0600, p. I-A-47, Item 261, and Met Ed Tape of 4/14/79, M-G transcript
7:05 am	(Clarence R. Deller, Jr.,----------(Bill Dornsife, Duty Officer, PEMA) at home, PA BRP) 1. Notified Dornsife, Duty Officer-BRP, of TMI reported incident. 2. Note: 7:10 entry in NUREG 0600, p. II-A-18, Item 64: "A PA BRP nuclear engineer was called by PEMA and notified that TMI had declared a site emergency. The engineer was instructed to call the site to obtain details."	PEMA Log 3/27-28, p. 1, entry 10

TIME	EVENT	REFERENCE
7:08 am	(Clarence R. Deller, Jr.-----------(Dauphin Co. Office PEMA) of Emergency Preparedness)	PEMA Log 3/27-28, p. 2 entry 11
	Notified Dauphin County Office of Emergency Preparedness of TMI incident. Dispatcher at DCCD indicated that they had been notified by TMI.	
7:09 am	(TMI)----------------------------(DOE:RAP:BNL)	NUREG-0600, p. II-A-17, Item 60, and Gary Miller Statement
	The site phoned the Department of Energy Radiological Assistance Plan Office at Brookhaven National Laboratory and informed them of the Site Emergency.	
7:10 am	The first offsite dose calculations were completed by Howard Crawford, an engineer. The initial calculations indicated a total body exposure rate of 40 R/hr * in Goldsboro (1.3 miles west of the plant). The calculations were verified shortly thereafter by Richard Dubiel, Supervisor, Radiation Protection and Chemistry but, together with the engineer, he concluded that the calculations were overly conservative because the reactor building pressure was only about 2 psig, and hence the leak rate was much lower than assumed in the source term estimates (approximately 50 psig) used in the offsite dose calculation procedure (1670.4). Following these calculations, the licensee dispatched survey teams in the downwind direction to the west side of the island (where the initial survey was made at (0748) and to Goldsboro (where the initial survey was made at 9832).	NUREG-0600, pp. II-A-17, 18, Item 63
	*NOTE: Dubiel's cursory check was also based on misreading the dome monitor, and he concluded Crawford had made no error, although he recalled the calculated exposure rate to be 10 R/hr. This latter estimate was reported to BRP at 7:25 a.m.	NUREG-0600, p. II-3-77

TIME	EVENT	REFERENCE
7:10 am	(Richard Bensel)----------------(NRC Region I) (Answering Service) (TMI) (NRC Region I) 1. Message: Site emergency, please call (717) 944-6017 or (717) 944-4041, reported 7:45 a.m. 2. NRC Region I notified, no one there but secretary to beep duty officer.	1. Arista Telephone Message (3/28)(7906140264) 2. Gary Miller Statement NRC 7906150423
7:10 am	(Clarence R. Deller, Jr.)-------(dispatcher) (PEMA) (York Co. Emergency Op. Ctr.) PEMA duty officer attempted to call York Co. EMA No answer.	PEMA Log 3/27-28, p. 2, entry 12
7:12 am	(Clarence R. Deller, Jr.)-------(dispatcher) (PEMA) (Lanc. Co. Emerg. Mgmt. Agency) Notified Lanc. Co. EMA of TMI report. Requested Lanc. dispatcher to inform York Co. dispatcher.	PEMA Log 3/27-28, p. 2, entry 13
7:12 am	(Bill Dornsife)-------/---------(U-2 Control Room) (PA BRP) (TMI) Bill Dornsife, the Pennsylvania Bureau of Radiological Protection nuclear engineer attempted to call the site but was not able to get through the switchboard to the control room. He left his phone number with the switchboard operator and asked to have the control room call him.	NUREG-0600, p. II-A-18, Item 66

TIME	EVENT	REFERENCE
7:13 am	(TMI)------------------------------(Rad. Mgmt. Corp.) An individual at the site phoned Radiation Management Corporation, the licensee's health physics consultant firm. The phone was answered by the Philadelphia Electric Company load dispatcher.	NUREG-0600, p. II-A-19, Item 67
7:14 am	(Ronald Warren)--------------------(Desk Officer) (Lead Mechanical Eng.) (TMI) (Pa. State Police) Desk Officer - Troop "H" Harrisburg Station received a call from Ronald Warren, Lead Mechanical Engineer at Three Mile Island (TMI), stating that, due to a mechanical difficulty a state of emergency has been declared. Note: NUREG-0600 places this at 7:18 a.m. Gary Miller statement places this at around 7:30 a.m.	Pa. State Police Chronology
7:15 am	(Bill Zewe)------------------------(Bill Dornsife) (TMI) (PA BRP) 1. Bill Zewe, Shift Supervisor, returned the call to the Pennsylvania Bureau of Radiological Protection nuclear engineer and informed him that a transient had occurred, the plant was shutdown, safeguards were operational, and there was a slight pressure increase in reactor building but no offsite releases. 2. Dornsife asked a few questions and was satisfied that conditions were stable. He heard a background announcement over the plant's public address system to evacuate the fuel handling and auxiliary buildings.	1. NUREG-0600, p. II-A-19, Item 70 2. Gerusky-Reilly-Dornsife, I&E Interview of 5/3/79
7:15 am	Leland Rogers, B&W On-site Manager, arrives in Unit 2 control room.	I&E Interview Tape No. 234, Rogers, p. 6

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TIME	EVENT	REFERENCE
7:15 am	Control and service building evacuated with exception of control room. Building reported to be clear by operator who has just returned.	NUREG 0600, P. I-A-48 Item 270
7:15 am	(Clarence R. Deller, Jr., PEMA)--------(Dick Lamison, Operations Officer, PEMA) Lamison is enroute to PEMA office	PEMA Log 3/27-28, p. 3 entry 14
7:15 am	(Jack Herbein, V.P., Met Ed)-----------(B. F. Fabian, Manager, Communications Services, Met Ed) Herbein phoned Fabian to advise him that there had been an event at TMI-2 about 4:00 a.m. Herbein advised that the unit was off-line because a feedwater pump failed in the secondary loop causing the turbine to trip which, in turn, caused a trip in the reactor.	Herbein sequence, NRC 7906140462
7:20 am	One state police corporal and two troopers dispatched to control traffic at the North and South Gates of TMI.	Pa. State Police Chronology
7:20 am	The site phoned American Nuclear Insurers. There was no answer to the phone call.	NUREG 0600, p. II-A-22 Item 80
7:24 am	A general emergency was declared by Gary Miller, Station Manager, based on the greater than 8 R/hr reading on the reactor containment dome monitor (HP-R-214). This reading corresponded to 800 R/hr when corrected for shielding around the detector.	NUREG, p. II-A-23, Item 85 and Gary Miller Statement, NRC 7906150423

TIME	EVENT	REFERENCE
7:25 am	(TMI)------------------------------(Tom Gerusky & Margaret Reilly, PA BRP)	Gary Miller Statement NRC 7906150423 and
	Notification via direct phone line from TMI-2 control room. This line was then held open between PA BRP and TMI-2 control room.	Gerusky-Reilly-Dornsife, I&E Interview of 5/3/79
7:30 am	(Dick Dubiel, Supervisor, Rad. Prot. & Chem.)----------(Kevin Malloy, Director, Dauphin Co. Ofc. of Emergency Preparedness)	NUREG 0600, p. II-A-25 Item 91
	Dubiel recalled Molloy to inform him of the general emergency.	
7:35 am	(TMI)______________________________(DOE:RAP)	NUREG 0600, p. II-A-27 Item 98
	The site called the Department of Energy Radiological Assistance Plan Office to inform them of a general emergency. The Department of Energy was subsequently requested by the Commonwealth of Pennsylvania after 11:00 a.m. to provide assistance.	

TIME	EVENT	REFERENCE
7:35 am	(Bill Zewe, Met Ed)------------------------------(Dick Lamison, PEMA) Change of alert status to general alert situation. Reactor has tripped because it "failed to fuel". [(sic) erroneous notation for "fuel failure" in PEMA Log.] Small offsite release reported in direction of 30 degrees.	NUREG 0600, p. II-A-27 Item 100, Gary Miller Statement, NRC 7906150423, and PEMA Logs 3/28, p. 1, entry 23
7:35 am	Thomas L. Mulleavy, the Radiation Protection Supervisor, arrived on site and assumed control of the Emergency Control Station.	NUREG 0600, p. II-A-27 Item 101
7:35 am	(Troop H, Pa. State Police)------------------------(Ronald Warren, Met Ed) Patrol Unit Supervisor - Troop "H" Harrisburg Station called Ronald Warren who confirmed that a general emergency existed.	Pa. State Police Chronology
7:36 am or 7:37 am	(Dick Dubiel, Met Ed)------------------------(Kevin Molloy, Dauphin Co. EMA) 1. The Dauphin County Civil Defense was contacted by Dubiel, Supervisor, Radiation Protection and Chemistry. He verified that Molloy, the Director, Dauphin County Civil Defense, had been notified. 2. Dubiel--"...we are in for real...we've got the core covered right now. I don't think we've got a real big problem but we've got some bad radiation readings that could, in fact, be erroneous, but we can't rely on that, okay.... I need to get Maggie Reilly, the foreman, back in touch with us." (TMI tape #210)	1. NUREG 0600, p. II-A-28, Item 102 2. Dauphin Co. Incident Log NRC 7906150166

TIME	EVENT	REFERENCE
7:37 am	(Troffer, Met Ed)------(NRC:Region I answering service) 1. Please call immediately (717) 921-6566. 2. Reported to office at 7:45 a.m.	Arista Telephone Messages 3/28
7:38 am	(Dick Lamison, PEMA)------(M. Reilly, PA BRP) Notified Reilly of TMI General Alert and requested instructions on recommended action. Reilly will call back with information.	PEMA Logs 3/28, p. 2, entry 25
7:40 am	(PA BRP)------(George Kunder, TMI) A representative of the Pennsylvania Bureau of Radiological Protection called the control room on a direct outside line using a phone number which had been previously given to the Commonwealth for such events. Kunder, TMI-2 Superintendent, Technical Support, briefed Pennsylvania Bureau of Radiological Protection on the situation. The phone line was left open.	NUREG 0600, p. II-A-29 Item 107
7:41 am	(Richard Bensel------(NRC:Region I) Bensel phoned NRC:Region I, to inform them that a general emergency had been declared. The answering service informed the caller that they had been unable to contact designated NRC:Region I individuals, but the regional office would open the switchboard at 0745 to receive any messages.	NUREG 0600, p. II-A-29 Item 108

TIME	EVENT	REFERENCE
7:41 am Cont.	(Richard Bensel-----------------------(NRC Region I) TMI) Mr. Bensel left a message that TMI-2 had declared a general emergency at 7:20 and that they have a primary to secondary leak in the B Steam generator and there has been an offsite release.	Arista Telephone Messages 3/28, NRC 7906140264
7:45 am	Gary Miller calls James Seelinger over to Unit 2 control room from Unit 1.	Met Ed Tape of 4/14/79, M-G transcript, p. 52, and I&E Interview Tape No. 164, Seelinger, p.23
7:45 am	(Oran K. Henderson, -------------------(Gov. Thornburgh, at mansion) Director, PEMA) Called Governor at mansion and related incident. Directed to work through Scranton, Lt. Gov.	PEMA Log 3/28, p. 2, entry 28
7:45 am	(M. Reilly,-----------------------------(Dick Lamison, PEMA) PA BRP) Call from Reilly stating that there was a 10 mR/hr offsite release in direction of Brunner Island and Goldsboro. High levels of radiation in plant. Further, it was advisable to make preparation for possible evacuation from Brunner Island and Goldsboro, but not to execute evacuation. Note: error in transmission. Actually it was 10 ′R/hr, which was a projected release, not an actual one.	PEMA Log, 3/28, p. 2, entry 28
7:45 am	(Bensel, Troffer,-----------------------(NRC:Region I) Met Ed) 1. Upon opening the NRC:Region I switchboard, messages of 7:10, 7:37, and 7:41 a.m. from Met Ed were received.	1. Conver Chronology

TIME	EVENT	REFERENCE
7:45 am (con't)	2. Region I telephone operator takes over from answering service. NRC: Region I operator is informed of general emergency and she notifies Eldon J. Brunner, Reactor Operations and Nuclear Support Branch Chief. Boyce Grier, NRC: Region I Director, informed of general emergency. Brunner and Hilbert W. Crocker, Fuel Facility and Materials Safety (FF&MS) Branch Chief, call site (informed that site emergency was declared at 6:45 a.m. and general emergency at 7:45 a.m.)	2. NUREG 0600, p. I-A-53, Items 302 & 303
7:45 am	(James Floyd, Met Ed---------------(Kenneth Bryan, employee in Lynchburg, VA at B&W HQ) Shift Supervisor, TMI-2 Control Room) Floyd heard, via hearsay, that the main steam safety valve on TMI-2 had been opened for two hours from about 4:00 a.m. until about 6:00 a.m. He called to find out the basic plant status and specifically about radiation monitors in the reactor building. These numbers told him that something was drastically wrong, and he started to do calculations to determine the extent of cladding damage. He was working for several hours on the simulator without key bits of information which would have made his job easier.	Hart Subcommittee staff interview with James Floyd, August 23, 1979, pp. 1 thru 4.
7:45 am	(Leland Rogers, B&W Site-----------(W.H. Spangler, Operations Manager) et al., B&W:HQ, Lynchburg) This was the first report of the TMI-2 incident to B&W, Lynchburg, VA. Rogers relayed the sequence as follows: Around 4:00 a.m., plant was at 98 percent power, when malfunction of condensate Polisher Isolation Valve caused loss of feedwater transient. High Pressure Injection (HPI) initiated, turbine tripped, reactor tripped on high pressure, the pressurizer (PZR) went	B&W Power Generation Group memo, G.K. Wandling, 3/29/79

TIME	EVENT	REFERENCE
7:45 am (Con't)	solid, Reactor Coolant System (RCS) pressure went to around 2500 psig, the reactor coolant drain tank (RCDT) rupture disc blew, there are indications of fuel failure, readings of 800 R/hr in dome of containment building, operators lost RCS flow indication, tripped RCP's and there are indications of primary to secondary leaks.	
	At time of call, RCS: T=300^{o}F, P=1500 psig. Site declared state of emergency conditions. Only Leland Rogers and Gary Miller (Unit 2 Station Manager and Emergency Director) were allowed onto site this morning. Rogers will call back as soon as more detailed information is available. NOTE: No subsequent direct communication between B&W representatives in control room and Lynchburg until 6:35 p.m.	
7:50 am	(Don Haverkamp)--------------------(TMI) (NRC Region I)	1. Conver Chronology
	1. Telephone link-up with Unit 2 control room. Open line established between U-2 control room and NRC Region I. Notified them of general emergency. They will send a team to site.	
	2. The NRC had a direct line in TMI control room to Don Haverkamp of the Region I office.	2. Gary Miller Statement NRC 7906150423
7:50 am	State Police Troop "H" Officer of the Day contacted at home by Troop "H" York Station personnel and advised of a spillage of radioactive material into the Susquehanna River. Request was made to close Rt. 30 in the vicinity of river; denied, pending determination of severity of the situation.	Pa. State Police Chronology

TIME	EVENT	REFERENCE
7:50 am	(Dick Lamison)--------------------(Pa. State Police) (PEMA)	1. PEMA Log 3/28, p. 3 entry 31
	1. According to PEMA Log, the operations officer notified the State Police of the TMI updated situation at 7:55 a.m.	2. Pa. State Police Chronology
	2. Commanding Officer (CO) Troop "H" arrived at Harrisburg Station and was advised of the situation at TMI.	
7:52 am	(Jim Lothrop)-------------------- (County Director) (PEMA) (PEMA-York Co.)	PEMA Log 3/28, p. 2, entry 29
	Notified York Co. Director of need to make preparations for possible evacuation of Brunner Island.	
7:53 am	(Dick Lamison)-------------------- (Kevin J. Molloy) (PEMA) (Dauphin Co. Office of Emergency Preparedness)	PEMA Log 3/28, p. 3, entry 30
	Lamison contacts Molloy, Dauphin County Director of Emergency Preparedness.	
7:55 am	1. Miller, Station Supt. directed that outside agencies be contacted to report incident.	NUREG-0600, pp. I-A-53, 54, Item 305
	2. Established open line to NRC:Region I.	
7:55 am	(Dick Lamison)-------------------- (Pa. Dept. of Transportation) (PEMA)	PEMA Log 3/28, p. 3, entry 32
	(Substance of conversation was not noted in PEMA Log.)	

TIME	EVENT	REFERENCE
7:55 am	"Region I classifies event as a Level I severity incident in accordance with Region I incident response plan."	Conver Chronology
7:58 am	(Dick Lamison)---------------------(Pa. Military Affairs) (PEMA)	PEMA Logs 3/28, p. 3, entry 33
8:00 am	(Dick Lamison)---------------------(J.R. Stimmel) (PEMA: Central Region) (PEMA)	PEMA Log, 3/28, p. 3, entry 34
	(Substance of conversation was not noted in PEMA Log)	
8:00 am	(Region I Public Affairs)----------(Joseph J. Fouchard) (NRC, Office of Public Affairs)	Conver Chronology
	Fouchard notified by Region I.	

TIME	EVENT	REFERENCE
8:00 am	(Joseph J. Fouchard)---------------(John G. Davis) (Director, NRC Office of Public Affairs) (Acting Director) (NRC Office of Inspection and Enforcement) (Substance of conversation was not noted in Conver Chronology)	Conver Chronology
8:00 am	(Boyce Grier)---------------------(John G. Davis) (Director, Region I) (Acting Director) (NRC Office of Inspection and Enforcement) 1. Notification to headquarters. 2. Region I activates its Incident Response Center.	1. NUREG-0600, p. I-A-55, Item 314 2. Conver Chronology
8:00 am	(TMI)-----------------------------(Region I) Detector shielded with 2" of lead located in containment dome reading 200 R/hr. (Monitor HP-H-214)	NUREG-0600, p. I-A-54, Item 310 and p. II-3-74
8:00 am	(Dick Lamison)-------------------(Pa. Dept. of Health) (PEMA) (Substance of conversation was not noted in PEMA Log)	PEMA Log, 3/28, p. 3, entry 36

TIME	EVENT	REFERENCE
8:00 am	One Pa. State trooper dispatched to control and ensure the free flow of traffic on Pa. Rt. 441.	Pa. State Police Chronology
8:05 am	NRC:HQ Incident Response Center was activated upon orders from John Davis, OIE	Conver Chronology and NUREG-0600, p. II-A-31, Item 122
8:05 am	(Jim Lothrop, PEMA) (Anderson, Lancaster Co. EMA) (Substance of conversation was not noted in PEMA Log)	PEMA Log, 3/28, p. 3, entry 36
8:05 am	(Troop H Commanding Officer, Pa. State Police)----------------(Greg Hitz, Met Ed) C.O. Troop "H" called Greg Hitz at TMI and was advised that Unit 2 had an on-site emergency and he requested three to four troopers for traffic control and the helicopter.	Pa. State Police Chronology
8:07 am	(Dick Lamison, PEMA)---------------(Pa. Dept. of Public Welfare) (Substance of conversation was not noted in PEMA Log)	PEMA Log 3/28, p. 3, entry 37
8:10 am	NRC:Region I Incident Response Center fully manned and activated. Communications established between NRC:Region I, I&E:HQ and licensee.	NUREG-0600, p. I-A-56, Item 321 and p. II-A-32, Item 124
8:10 am	(Dick Lamison, PEMA)---------------(Pa. Dept. of Agriculture) (Substance of conversation was not noted in PEMA Log)	PEMA Log 3/28, p. 3, entry 38

TIME	EVENT	REFERENCE
8:10 am	(Duane Mundorf, Pa. DOT Emer.Serv.)----------------(Dick Lamison, PEMA) Mundorf requested information re: notifications made by PEMA office.	PEMA Log, 3/28, p. 3, entry 39
8:10 am	(Governor Dick Thornburgh, Pennsylvania)---------(Paul Critchlow, Govr's Press Secy.) Governor reported that he had received a call from Col. Henderson about an emergency having been declared at TMI-2, the exact details were not known, but that Mr. Critchlow should begin checking it out.	Transcript, Paul Critchlow, 10/19/79, p. 5
8:10 am	Pa. State Police commanding officer of Troop "H" called Deputy Commissioner to inform him of the situation and his conversation with Greg Hitz.	Pa. State Police Chronology
8:12 am	(Ed Kulpa, Pa. Dept. of Health)---------------(Dick Lamison, PEMA) Requested clarification of previous info. to his office.	PEMA Log 3/28, p. 3, entry 40
8:15 am	(M. Reilly, PA BRP)----------------(Blaisdell, PEMA) Reilly stated that problem was isolated in No. 2 steam generator, which was leaking. All releases have been contained. No outside implications. Advised to release imposed alerts for possible evacuation.	PEMA Log 3/28, p. 4, entry 42
8:15 am to 8:30 am	Gary Miller, Station Manager, assembles emergency management advisory team, consisting of Miller, Ross, Seelinger, Logan, Kunder, Zewe, Rogers, and Dubiel. First meeting of this team at this time.	Hart Subcommittee Interview with Gary Miller, 9/28/79, p. 17

TIME	EVENT	REFERENCE
8:15 am	(Commanding Officer, Pa. State Police)---------------(George Kunder, TMI-2	Pa. State Police Chronology
	Pa. State Police commanding officer of Troop "H" called George Kunder, Supt. Technical Support, who advised that a general emergency exists at Unit 2, no outside release had occurred and the problem was contained within Unit 2. He requested traffic control on Pa. Rt. 441, and a trooper at the North Gate, South Gate and the observation center. He requested the helicopter to fly a monitoring team to down-river area.	
8:18 am	(J.R. Stimmel, PEMA: Central Area)---------------(Dick Lamison, PEMA)	PEMA Log 3/28, p. 4, entry 45
	1. Call from Stimmel to report that Molloy of DCCD has notified Lower Swatara, Middletown and Londonderry Twps EMA coordinators of possible critical situation.	
	2. Henderson advised Stimmel he would retain alert status for an additional 30 minutes.	
8:20 am	(Ron Warren, TMI-2)---------------(NRC:Region I)	NUREG-0600, p. I-A-57 Item 329
	Containment dome monitor reads 600 R/hr.	
8:20 am	1. "Independent Measurement Van" dispatched to TMI site from Millstone, Connecticut.	1. Conver Chronology
	2. Phil Stohr, Envir. S.C. and Jim Kottan, FFMS specialist were among four dispatched to the TMI site.	2. Memo Bob Martin to Bob Marsh (4/20) NRC 7905230088

TIME	EVENT	REFERENCE
8:20 am	(Captain Hurley, Pa. State Police)-----------------(Dick Lamison, PEMA) Hurley reported that Kunder, TMI-2 Supervisor, has confirmed that the general emergency situation was contained inside plant premises. Police have established traffic controls at North Bridge, South Bridge, and observation site. No outside release of information made. Police helicopter sent to north end of island to pick up two-man monitoring team. Destination unknown. Reported that facility information officer was Brian Fabian at Reading office.	PEMA Log 3/28, p. 5, entry 45
8:23 am	(Norm Moseley, Bernie Weiss, IRACT, Bethesda) ------------(Boyce Grier, NRC:Region I) 1. Open line from IRACT to NRC:Region I established. 2. Phone call from Weiss and Moseley to Grier. 3. Operator has indications of failed fuel. 4. Primary pressure = 1500 psi Temperature (ave.) - 571^{o}, although not identified on tapes as the "average" temperature.	1. Conver Chronology (1 and 2) 2. IRACT tapes, 01-017-02 thru 06 (3 and 4)
8:23 am	(Joseph J. Fouchard, Director, NRC Ofc. of Public Affairs)----------------(Lee Gossick, Exec. Dir. for Ops, Ofc. of EDO) (Substance of Conversation was not noted in Conver Chronology.)	Conver Chronology

TIME	EVENT	REFERENCE
8:23 am	(John Davis, Ofc. of Insp. & Enforcement)---------------(Lee Gossick, Ofc. of the Exec. Dir. for Operations) (Substance of conversation was not noted in Conver Chronology.)	Conver Chronology
8:25 am	(Furrer, Pa. Dept. of Agriculture)---------------(Dick Lamison, PEMA) Call from Mr. Furrer that the key contact for Dept. of Agriculture is Mr. Luther Syndor.	PEMA Log 3/28, p. 5, entry 48
8:25 am	(Lee Gossick, Ofc. of EDO)-------------------(John Davis, IRACT) (Substance of conversation was not noted in Conver Chronology.)	Conver Chronology
8:25 am	(Bernie Weiss, IRACT)------------(Comm's Gilinsky NRC Commissioner) Weiss tries to call Gilinsky who is not yet in his office.	Commissioner Gilinsky's Office Log NRC 7905110206
8:30 am	(NRC:Region I)------------------(Pa. State Police) State Police had highway closed, notification that "NRC emergency vehicle would be enroute."	Conver Chronology
8:31 am	(Norm Moseley, IE Div. Dir. IRACT oper.)---------(Victor Stello, NRReg, Dir. Div. of Op. Reactors & Darrell Eisenhut, NRReg, Dep. Dir. of Op. Reactors)	1. Conver Chronology 2. IRACT tape 01-066-1 thru 3.

TIME	EVENT	REFERENCE
8:31 am (con't)	(IRACT)--------------------------(NRReg, Division of Operating Reactors) 1. Pulled a bubble into the reactor vessel. 2. Reactor is okay, but they have a release. 3. Moseley requests someone at IRACT with radiological expertise.	
8:32 am	(Mike Wilbur, IRACT, Bethesda)---------------------(Boyce Grier, Dir. Region I) Mike Wilbur calls Boyce Grier, to obtain technical information.	1. Conver Chronology 2. IRACT tapes 01-018-02 thru 10
8:32 am	(John Davis, Act. Dir. I&E at IRACT)-----------(Lee Gossick, Exec. Dir. Ops.) "Decision made to convene Emergency Management Team." (EMT)	Conver Chronology
8:33 am	(John Davis, IRACT East West Hwy. Bldg.)---------------(Lee Gossick, Maryland Nat. Bank Bldg.) (John Davis): "There was a loss of pressurizer level and apparently a BUBBLE pulled in the vessel (phonetic). There's about a one pound pressure in the containment. Now what this lead people to believe that there has been some LOSS OF COOLANT. We do not know whether the situation was an OFF-SITE RELEASE, and we do not know whether the situation has been terminated." (Lee Gossick): "Okay, I'll be right over."	IRACT tapes, 210-1 (Day 1, Ch. 6)

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TIME	EVENT	REFERENCE
8:34 am	(John Davis, Act. Dir. I&E, IRACT, E/W) ------------------ (Edson Case, Dep. Dir. NRR, Office of Nuclear Reactor Regulation-Phillips Bldg.)	Conver Chronology and IRACT tapes, 210-3 (Day 1, Ch. 6)
	(John Davis, called Denton's office but spoke with Case): "We got a call from Region I....Apparently there was a rapid cool down of the primary coolant system safety injection where they lost pressurizer level and pulled a bubble into the vessel.....It looks like there's some loss of coolant."	
8:35 am	(M. Reilly, PA BRP) ------------------------ (Blaisdell, PEMA)	PEMA Log, 3/28, p. 5, entry 50
	National Weather Service meteorologists are tracing and forecasting winds. Situation currently normal. Venting of system anticipated later in day which would be under stringent control.	
8:35 am	(Commanding Officer, Pa. State Police, Troop "H") --------------- (Dep. Com. Pa. State Police)	Pa. State Police Chronology
	Pa. State Police commanding Troop "H" called Deputy Commissioner regarding TMI situation.	
8:35 am	Pa. State Police helicopter landed at site north of the parking lot.	NUREG 0600, p. II-A-35 Item 138
8:36 am	(John Davis, IRACT (Bill Dorie, AA to Chmn. Hendrie, Ofc. of NRC Chairman)	Conver Chronology
	Davis calls Hendrie's office, speaks to Bill Dorie.	

TIME	EVENT	REFERENCE
8:39 am	Note: At this time, a telephone line between IRACT and the Region I Incident Response Center was opened and remained open throughout the incident. Region I had already opened one or more telephone lines to the TMI site to receive information, and Region I relayed that information and questions between IRACT and the site. Later in the day, between 8½ to 9 hours after the start of the accident, these lines were tied together putting IRACT, Region I and the site on a common conference line.	NUREG 0600, p. I-A-59 Item 341
8:40 am	Gossick and Case arrive at IRACT.	Conver Chronology
8:40 am	(R. C. Arnold, GPU)--------------(Jack Herbein, Met Ed) Arnold notified Herbein that Creitz will call him.	Herbein sequence - NRC 7906140462
8:40 am	State Police helicopter went into service.	Pa. State Police Chronology
8:45 am	1. Five inspectors with radiation monitoring equipment leave for site.	Conver Chronology
	2. Jim Higgins, OPS, Chick Gallina, SG Invest., Don Neely, FFMS, Ron Nimitz, FFMS, Karl Plumlee, FFMS.	Memo Bob Martin to Bob March NRC 7905230088
	3. Team left King of Prussia for TMI at 8:47 a.m. per NUREG 0600	NUREG 0600, p. II-A-35 Item 142
8:45 am	(Dick Lamison, PEMA)--------------(Frederickson, Def. Civil Preparedness Agency, Region II) Notified DCPA:II of current TMI situation to include update info. that it appeared no serious outside problem would develop.	PEMA Log 3/28, p. 5 entry 50

TIME	EVENT	REFERENCE
8:45 am to 9:15 am	(Greg Yuhas, NRC: Region I)---------------------(Mike Wilber, IRACT, Bethesda) 1. Radiation Monitors a) Outer monitors (305' elevation) reading 100 mr/hr b) Containment dome monitors went from 200 to 1000 R 2. Core is not being cooled, no flow, they're having trouble cooling the core because they think that the primary system is vapor bound. 3. Containment pressure is now at one pound, down from a maximum of two pounds. (Later in conversation, containment pressure is now four psi, but that number was questioned.)	IRACT Tapes 01-018-10 thru 019-17
8:46 am	(John Davis, IRACT)------------------(Bill Dorie, Ofc. of Commissioners) Davis calls for Hendrie, asks for Comm. Gilinsky in Chairman's absence; Gilinsky not in yet.	Conver Chronology and Gilinsky's office log NRC 7905110206
8:47 am	(NRC:Region I)---------------------(IRACT, Bethesda) Region I relays 1000 R/hr dose rate to IRACT. This entry made to indicate that at this time, certain aspects of key information being relayed were current. In general, however, responses to questions asked about plant conditions were not responded to promptly because of the activities in the control room and the need to relay information, both between IRACT and Region I and the site, as well as the relaying required within the control room.	NUREG 0600, pp. I-A-60 and 61, Item 348

TIME	EVENT	REFERENCE
8:48 am	(Dudley Thompson, IRACT)----------(Tom Carter, Ofc. of Nuclear Material Safety & Safeguards)	Conver Chronology
	Notified Carter of accident at TMI and said it involved an off-site release. No NMSS action required.	
8:49 am	(William Ward, IRACT)----------(John J. Davidson, NMSS, Div. of Safeguards)	
	1. Ward notifies J. Davidson, NMSS, to make IAT (Information Assessment Team) notification.	Conver Chronology
	2. Gave Davidson summary of events as known so far, concluding with, "...there's been a release of radiation of unknown consequences...."	IRACT Tapes 01-066-3 thru 6
8:50 am	(TMI)--------------------------------(NRC:Region I)	Conver Chronology
	Licensee calls Region I with current status report.	
8:50 am	(Thomas Elsasser, NRC:Region I, State Liaison)-----(Thomas Gerusky, PA BRP)	Conver Chronology
	1. Region I notified that "the State" is in constant contact with Met Ed.	
	2. Met Ed is "responding to news media but only to say that something has happened and is not providing specific details."	
	3. State questions for Region I: a) Q: What is NRC doing? A: NRC dispatched a team of 5 people to the site who would arrive in 1½ to 2 hours. b) Q: Does NRC plan a press release? A: NRC does not plan one in immediate future and will only issue one when more information is available.	

TIME	EVENT	REFERENCE
8:50 am (con't)	c) Q: Is it NRC's info. that there is no off-site release? A: That is NRC's info.	
8:50 am	(Dick Lamison, PEMA)----------------------(Cumberland Co. EMA) (Substance of telephone conversation was not noted in PEMA Log.)	PEMA Log 2/28, p. 6, entry 51
8:50 am	(Blaisdell, PEMA)------------------(Lebanon EMA) (Substance of telephone conversation was not noted in PEMA Log.)	PEMA Log 3/28, p. 6, entry 51
8:52 am	(John Davis, IRACT)----------------(Comm. Kennedy, NRC: OCM, "H" Street) Notification of accident. Kennedy is the first Commissioner that Davis was able to contact. The following information is all Davis knows at the present time: --Rapid cooldown of primary cooling system, HPI occurred, loss of pressurizer level, and a bubble pulled into the vessel. --One psi inside containment, leading to a resulting loss of coolant but the primary coolant system is intact.	IRACT Tapes, 01-258-5 and Conver Chronology
8:56 am	(Lee Gossick, IRACT)---------------(John Austin, Commissioners, NRC:OCM 1. Gossick attempted to reach Gilinsky through Bill Dorie, requested that Dorie reach the Chairman. Gossick then talked to Austin. Told Austin of apparent release within containment, urged Austin to have Dorie contact Hendrie; Gossick doesn't know if things are under control.	Conver Chronology and IRACT Tapes, 01-210-1

TIME	EVENT	REFERENCE
8:56 am (con't)	2. Davis also tried to call Gilinsky who had not yet arrived at his office.	Comm. Gilinsky office log, NRC 7905110206
8:57 am	(John Davis, IRACT)-------------(Comm. Ahearne) Notification of accident included: --Rapid cooldown of primary cooling system, HPI occurred, loss of pressurizer level, and a bubble pulled into the vessel. --One psi inside containment building. --High radiation detected at top of the dome. (Dome Monitor HP-R-214)	IRACT Tapes, 01-258-7 and 8, and Conver Chronology
8:59 am	(TMI)---------------------------------(Region I) Information relayed to NRC, Region I office is that HPI flow is 250 gpm/leg and RCS pressure 1400 psig.	NUREG 0600, p. I-A-61, Item 349
8:59 am	(Bernie Weiss, IRACT)--------------(Secretary, DOE Emer. Ops. Center) Reference to "pulling a bubble" into the reactor vessel from the pressurizer.	Conver Chronology IRACT Tapes 01-498-01
9:00 am	(TMI)--------------------------------(Region I) Containment dome monitor reaches 6000 R/hr. (Dome Monitor HP-R-214)	NUREG 0600, p. I-A-61 Item 351
9:00 am	(Dick Lamison, PEMA)----------------(All state agencies) Emergency situation is under control and it was emphasized that there were no outside implications. Agencies were further informed of the possibility that when the generator was repaired there may be	PEMA Log, 3/28, p. 6, entry 52

TIME	EVENT	REFERENCE
9:00 am (con't)	some release of gases, but that as far as can be determined, there would not be outside implications.	
9:00 am	(Rhoades, Pa. Bur. of Corrections)----------------(Dick Lamison, PEMA) Rhoades offered assistance of Bureau of Corrections if needed.	PEMA Log, 3/28, p. 6, entry 53
9:00 am	(TMI)----------------------------------(NRC:Region I) Licensee reported to Region I at 0900 that the auxiliary building was isolated at 0800. Reported that "B" steam generator leak was noted at 0800 by vacuum pump monitor. Unit 2 control room placed on recirculation air.	NUREG 0600, p. I-A-61, Item 352
9:00 am	Second vehicle leaves Region for site: Ray Smith, Invest., Walt Baunack, OPS, a two-man backup team was dispatched from Region I. This is the second vehicle leaving the Region for TMI site.	NUREG 0600, p. II-A-36, Item 144 Conver Chronology and Memo from Bob Martin to Bob Marsh, NRC 7905230088
9:00 am	B&W attempts, without success, to fax list of information which they must have to make recommendations.	NUREG 0600, p. I-A-62, Item 352A
9:00 am	(Randy Pine, Ofc. Cong. Aff., NRC)------------------(Bill Ward, IRACT) 1. Randy Pine indicates that she will inform local Congressmen. 2. Carlton Kammerer, Director of the NRC Office of Congressional Affairs had received information of	Conver Chronology Kammerer Memo, NRC 7905160041

TIME	EVENT	REFERENCE
9:00 am (con't)	problem at TMI. Kammerer advised Randy Pine before 9:00 a.m. to contact Incident Response Center. Randy called IRACT and was informed by Bill Ward that reactor had shut down after a turbine trip.	
9:00 am	(NRC:Region I, OSP)--------------------(Bob Ryan, Ofc. of State Programs)	Conver Chronology
	(Substance of telephone conversation was not noted in Conver Chronology)	
9:00 am	(R. Bores, NRC: Region I) ----------------------(Schweller, RAP)	Conver Chronology
	1. NRC:Region I contacts RAP, who had already been notified by TMI and PA BRP. RAP has two teams organized and standing by.	
	2. U.S. Coast Guard to furnish transportation, if necessary.	R. Bores, NRC 7906130483
9:01 am	(Comm. Ahearne, NRC: OCM, "H" St.)---------------(Edson Case, (IRACT)	IRACT Tapes, 01-259-3
	1. Ahearne called to have the "bubble" explained to him.	
	2. Case explained that it seems that they lost enough primary coolant, apparently causing an uncovery of part of the core, and the increased levels of radioactivity are probably due to popping of some fuel elements.	

TIME	EVENT	REFERENCE
9:02 am	(Bernie Weiss, IRACT)---------------(Floyd Galpin, EPA) Weiss notifies EPA. Reported that although there were high radiation levels in containment, readings at the site boundary were less than 1 mR/hr.	Conver Chronology IRACT Tapes, 01-499-3
9:06 am	(Bill Ward, IRACT)----------------(John G. Jones, NRC, Ofc. of Admin, Dir. of Facilites & Ops., Telecommunications Branch) Ward warns the communications branch to expect traffic.	Conver Chronology & Tape summary
9:08 am	(Lee Gossick, IRACT)------------(John Austin, NRC:OCM, "H" St.) Initial reading of 200 R at top of containment, possibly resulted from saturated monitor, and should be disregarded. Gossick did not know if this was Unit 1 or Unit 2.	IRACT Tapes 01-211-1
9:08 am	(Joseph Fouchard, IRACT)--------(Karl Abraham, NRC: Region I, Pub. Aff.) Abraham has no indication of off-site releases but has unconfirmed reports of very high radiation readings inside the containment dome.	IRACT Tapes 01-211-4, and Conver Chronology

TIME	EVENT	REFERENCE
9:10 am	(Boyce Grier, NRC: Region I)------------------(Norm Moseley, IRACT) Grier calls Moseley to explain "technical aspects of incident."	Conver Chronology
9:10 am	Emergency Control Station (ECS) moved to Unit 2 control room.	NUREG 0600, p. I-A-62, Item 355
9:10 am	(Lee Gossick, IRACT)--------------(Randy Pine, NRC, Ofc. Cong. Aff.) Randy Pine informs Gossick that OCA had received several inquiries from local Congressmen.	Conver Chronology
9:10 am to 9:30 am	(Randy Pine, Steve Kent, NRC, Ofc. Cong. Aff)----------------(U.S. House and Senate) 1. Notification of declaration of site emergency. 2. Completed calls to Henry Myers, Bob Terrell, Carol Hackes and Bailey Guard. Messages left for Mike Ward, Steve Bienstock and Jim Asselstine.	Conver Chronology

TIME	EVENT		REFERENCE
9:11 am	(Comm. Gilinsky, NRC: OCM: "H" St.)	(Gossick, Davis, Fouchard, Comm. Ahearne; Exec. Dir. Ops, IE Acting Dir., Dir. OPA, and NRC Commissioner)	Comm. Gilinsky office log, NRC 7905110206, and Conver Chronology
	(Substance of telephone conversation was not noted in Commissioner Gilinsky's office log or Conver Chronology.)		
9:15 am	(TMI)	(Don Caphton, NRC: Region I)	Reg. I Tape No. 1, pp. 1-2 NUREG 0600, p. I-A-63 Item 356.
	1. MSL safety valves said to be shut. 2. S/G A level reported at 44%. 3. S/G B level reported at 66%. 4. S/Gs are reported isolated. 5. RB Spray had not actuated yet.		
9:15 am	(IRACT)	(White House Situation Room)	Conver Chronology
	(Substance of telephone conversation was not noted in Conver Chronology.)		
9:15 am	(W. J. Gillen, WI Pub. Ser. Com.)	(NCR:OSP)	H. Collins Log, NRC 7905300274
	Call in from W. J. Gillen, Adm. of WI P.S.C.		

TIME	EVENT	REFERENCE
9:15 am	(Mike Wilber, IRACT, Bethesda)------------------(Rick Keimig, NRC:Region I)	NUREG 0600, p. I-A-63 Item 358
	1. First instance of a request from IRACT thru Region I to site for specific information on steam generator levels and meteorological data.	
	2. Incident Response Center is informed that the reactor coolant pumps are not operating.	IRACT Tapes 01-019-5
9:15 am to 10:45 am	(media)--------------------------------(Dick Lamison, PEMA)	PEMA Logs 3/28, p. 6 entry 54
	Received calls re TMI incident from TV stations in Portland, Or., UPI, Sherry Denton, IO, DCA, <u>Nucleonics Weekly</u> and Pittsburgh office of the <u>Washington Post</u>.	
9:16 am	(Joseph Fouchard, IRACT)--------------(Bob Dulin, Dept. of Energy)	Conver Chronology
	Fouchard notifies DOE Public Affairs office (Bob Dulin).	
9:17 am	The Emergency Control Station was established at the Unit 2 control room.	NUREG 0600, p. II-A-38 Item 151
9:17 am	(Thad Baxter, Defense Civil Preparedness Agency Op. Center, DCPA)----------------(Joe Hegner, IRACT)	
	1. Baxter received unofficial word of TMI accident.	Memcon, Dave Bucher with John McConnell on 8/2/79 (see also 9:27 am entry)

TIME	EVENT	REFERENCE
9:17 am (con't)	2. Baxter first called DCPA:II at Olney but they reportedly knew nothing. (Presumably DCPA:II knew of the incident but had not received enough information from PEMA to satisfy DCPA:HQ, See PEMA entry of 8:45 a.m. notifying DCPA:II.)	Conver Chronology
9:20 am	(Comm. Gilinsky, NRC:OCM: "H" St., NRC Commissioner)------------------(Jessica Tuchman Matthews, White House, NSC staff)	Comm. Gilinsky's office log, NRC 7905110206
	Gilinsky informed Matthews of a general emergency resulting from a radiation release which had occurred at TMI-2.	
9:27 am	(Joe Hegner, IRACT)-------------(Sam Wilson, DCPA)	
	1. Response to Baxter's call of 9:17 a.m. General alert information.	Memcon Dave Bucher with John McConnell on 8/2/79
	2. IRACT Tapes reveal the following info. given to Wilson by Hegner. a. Evidently pulled a "bubble" into the reactor. b. Containment pressure of 1 psi above atmospheric. c. Initial indications of high radiation in the containment, but they don't know if there has been a significant off-site release.	IRACT Tapes 01-211-6 and 7, (see 9:17 a.m. entry)
9:30 am	RCS pressure ~ 1500 psi.	NUREG 0600, p. I-A-65, Item 365
9:30 am	(NRC:Region I)------------------(IRACT)	NUREG 0600, p. I-A-65 Item 366
	During the IRACT-Region I information exchanges, some period of time (15 minutes) is spent clarifying information. This appears to some extent to be due to the quality of communications and to clarification of terminology and plant layout and configuration.	

TIME	EVENT	REFERENCE
9:30 am	(Laverne Copeland, MO Energy Program) -------(NRC:OSP) Call-in from Copeland of MO Energy Program.	Doc Collins Log of SP NRC 7905300274
9:30 am	(Mark Knouse, Exec. Assist., Lt. Gov's Ofc.)----------------------(Oran Henderson, Director, PEMA) Knouse of Lt. Gov'r office directed that Henderson come over for a meeting.	PEMA Logs 3/28, p. 6, entry 55
9:30 am	(W. M. Creitz, Met Ed)------------(Jack Herbein, Met Ed) Herbein is requested by Creitz to leave Phila. and report to TMI.	Herbein sequence, NRC 7906140462
9:30 am	American Nuclear Insurers returned the licensee's phone call, i.e., 7:20 a.m. attempt.	NUREG 0600, p. II-A-39 Item 154
9:30 am to 10:00 am	(James Floyd, Met Ed employee in Lunchburg, Va at B&W HQ)--------------(Kenneth Bryan Shift Supervisor, TMI-2 Control Room) Basic information of 7:45 a.m. telephone conversation of Leland Rogers and W. H. Spangler confirmed, with the following additions or corrections: --Primary to secondary leak in "B" OTSG --60,000 R/hr in dome of reactor building (doubtful) --10^4 counts on radiation monitor (#748)-200 is background --100 mR/hr at personnel hatch outside of reactor building --Iodine high off-scale	NUREG 0600, p. I-A-70 Item 393A

TIME	EVENT	REFERENCE
9:30 am to 10:00 am (con't)	--plant is in natural circulation cooldown --In-core temperature 450°F. (Computer output) --T_c = 250°F. --On and off-site area radiation negligible --Water in the control air lines of condensate polisher isolation valves had caused loss of feedwater transient. --ESFAS actuation- MU pumps stopped, let-down established (during high pressure RCS condition) --RC-V2 shut after quench tank rupture disc blew --Aux feedwater initiated but no flow to OTSG's until about 12 minutes after trip --OTSG's did not go dry --RCS pressure went as low as 1200 psig, saturation conditions possibly reached --RCS flow decreased by about 1/3--RCP's were tripped	
9:31 am	(Jim Sniezek, IRACT)-----------(George Smith, NRC: Region I) 1. Dome monitor reading of 60 R/hr., monitor has four ([sic] two) inches of lead, so 6,000 R/hr at the top. 2. Discussion about the significance or reliability of the reading.	IRACT Tapes, 01-068-3 thru 7
9:33 am	(Bernie Weiss, IRACT)-------------(Thomas Engelhardt, NRC Dep. Exec. Legal Dir.) In the course of notification, Weiss states that there is coolant over the core and the core is covered, but there are high levels of radiation in the containment building.	IRACT Tapes 01-500-1 and 2

TIME	EVENT	REFERENCE
9:35 am	George Kunder, TMI)---------------(Don Haverkamp, NRC:Region I)	Reg. 1 Tape No. 1, pp. 6-11
	1. Licensee reports to Region I that OTSG pressure transient probably lifted OTSG safety reliefs.	NUREG 0600, p. I-A-65, 66 Item 370
	2. No one evacuated from site yet.	
9:39 am	(John Davis, Joe Fouchard,--------(Boyce Grier, Karl IRACT, Bethesda) Abraham, NRC:Region I)	IRACT Tapes, 01-212-2, 10, 11
	1. Reading and discussing latest draft of press release to be issued from Bethesda. 2. Includes sentence stating: "There has been a release of radioactivity inside the reactor containment. Measurements are still being made to determine if there has been any radioactivity detected off-site." 3. "They apparently have a vapor lock in the primary system so that they're not able to circulate coolant and get as cool as they would like to..."	
9:40 am	(Comm. Gilinsky,--------------------(Herb Brown) NRC Commissioner) (Substance of telephone conversation was not noted in Gilinsky Log.)	Comm. Gilinsky office log NRC 7905110206
9:45 am	The IRACT tapes at this point show that a second line was opened to Region I in addition to the primary line from the IRACT. This resulted in a different set of questions being asked to be relayed to the site (radiological matters) in addition to those being transmitted from the IRACT (operational matters). This produced some conflict in establishing priorities for the two requests, but appears to have been resolved fairly promptly.	NUREG 0600, p. I-A-66 Item 376

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TIME	EVENT	REFERENCE
9:45 am	(George Kunder, TMI)------------------(Greg Yuhas, NRC: Region I) Yuhas inquired if any consideration had been given to off-site evacuation. Kunder responded that such considerations had not taken place. Kunder added that Met Ed monitoring teams had found nothing in Goldsboro. Met Ed has seen no radiation levels which would generate a plume to give them off-site concerns. Kunder reports that the Pa. Dept. of Environmental Resources BRP is hanging on an open line.	Reg. I tape No. 1, pp. 12, 13
9:45 am	(Dick Lamison, PEMA)------------------(M. Reilly, PA BRP) Notified BRP of need for situation report.	PEMA Log 3/28, p. 7, entry 57
9:50 am	(Comm. Gilinsky, NRC:-----------------(Don Martin) OCM: "H" St., NRC Commissioner) (Substance of telephone conversation was not noted in Gilinsky office log.)	Comm. Gilinsky office log, NRC 7905110206
9:50 am	(Tom Hardy, FPA:III)--------------(Jim Thomas, FPA:HQ) Thomas was notified by Hardy of Region III that an incident had just occurred at the TMI-2 plant near Harrisburg. His information indicates a relatively serious release within the facility, but that it had apparently been contained within the power plant. Hardy also reported that some people had been evacuated, although it was not clear at that point whether the evacuation involved anyone other than the power plant employees.	Jim Thomas memorandum to Arnold Lewis of 3/28/79

TIME	EVENT	REFERENCE
9:53 am	(Edwin Flack, I&E, E-W Bldg., Bethesda)---------------(George Smith, NRC:Region I)	IRACT Tapes 01-068-8 thru 9
	1. Smith reported only "a little bit of iodine downwind."	
	2. There has been "no consideration of evacuation off-site."	
10:00 am	("Doc" Collins, NRC:OSP)----------(James Thomas, FPA:HQ)	Jim Thomas memorandum to Arnold Lewis of 3/28/79
	Notification that incident had occurred at 3 or 4:00 a.m. as a result of low water level in the coolant chambers. NRC has activated its incident management center and all appropriate people/offices have been notified. According to Collins, the temperature around the core of the power reactor is now coming down, which indicates the problem may be under control.	
10:00 am	("Doc" Collins, NRC:OSP)--------(Floyd Galpin, EPA, Ofc. of Rad. Pgm)	
	1. "Doc" Collins reported a notification of J. Logsdon, who had already been notified.	SP Logs 7906060150
	2. Mr. Logsdon said he did not talk with Collins until Thursday. Probably spoke with his boss Galpin, who was notified earlier by Bernie Weiss (see 9:02 a.m.)	MemCon, Dave Bucher with J. Logsdon on 8/8/79

TIME	EVENT	REFERENCE
10:00 am	(W.J. Gillen, WI P.S.C.)-----------(NRC:OSP) Call in from W.J. Gillen, Adm. WI P.S.C.	H. Collins Log of OSP, NRC 7905300274
10:00 am	(H.L. Robidoux, Met Ed)------------(J.G. Herbein, Met Ed) Robidoux calls Herbein and informs him that a helicopter has been secured for transporting him to TMI from Philadelphia.	Herbein Sequence NRC 7906140462
10:05 am	(Victor Gilinsky, Acting Chairman, NRC, OCM at "H" St.) (Joseph Hendrie, Chairman, NRC, OCM at hospital) Gilinsky informed Hendrie of TMI-2 accident.	Oct. 30, 1979 letter from Hendrie to Paul Leventhal, with attached notes of Hendrie's legal assistant
10:05 am to 10:10 am	1. First five members of Region I response team arrive on site: Jim Higgins, Don Neely, Charles Gallina, Karl Plumley and Ron Nimitz.	Conver Chronology and TMI North Gate Visitor Registration Log, NRC 7906130470
	2. They were immediately taken to Unit 1 control room where briefed by J. Seelinger, Unit 1 superintendent, on the status of Unit 2, both operationally and radiologically.	Nimitz - Report of Activities NRC 7906210219
10:05 am	(Rick Keimig, NRC:Region I)---------------------(Mike Wilber, IRACT) Plant has no natural circulation, and without circulation through the core, the temperatures are not correct.	IRACT Tapes 01-021-3 and 4
10:05 am	(R. Bores, NRC:Region I)-----------------------(R. Augustine's ofc., Otis Underhill, Sec., EPA HQ, EPA III, Dr. Dave Langford, 10:00 a.m.) 1. Region I contacts EPA HQ (also attempts to contact EPA Reg. III. 2. Bores asked Underhill to contact Dr. Langford in EPA Region III.	Conver Chronology and R. Bores, NRC 7906130483

TIME	EVENT	REFERENCE
10:05 am to 10:10 am	(Bob Friess, DOE:RAP:BNL)--------(R. Bores, NRC: Region I) RAP: "Does NRC want an AMS Aircraft survey?" NRC: "Not at this time; no indication of any off-site release. AMS was put on stand-by. Inquiry as to ETA in event of order to fly.	Conver Chronology and R. Bores NRC 7906130483
10:10 am	Airborne levels in Unit 2 control room require evacuation of all but essential personnel.	NUREG 0600, p. I-A-68 Item 381
10:10 am	(Sen. John Heinz, U.S. Senator, Pa.------------(NRC:OSP) Call in from Sen. John Heinz from Philadelphia.	SP log, NRC 7906060150
10:12 am	ESC moved from Unit 2 control room to Unit 1 control room.	NUREG 0600, p. I-A-68 Item 382
10:14 am	(Richard Dubiel, TMI-2 control room)-----------(Greg Yuhas, NRC:Region I) 1. Radiation readings - 100 mr/hr at the air lock, 6000 R/hr at the containment dome, and 140 MCi/cc in primary coolant.	IRACT Tapes, 01-021-15
	2. Licensee reports to Region I: a. 140 uc/cc gross (beta-gamma) activity in RCS b. Concerned "B" OTSG primary to secondary leak may lead to burp of activity from safety reliefs. Water level high.	NUREG 0600, p. I-A-68 Item 385

TIME	EVENT	REFERENCE
10:15 am	(George Kunder, TMI-2) ----------- (Don Haverkamp, NRC:Region I) "Still injecting" and BWST level dropping, based on report from licensee to Region I. Note: Interim Sequence incorrectly attributed this to a Region I inspector.	Region I tape #2, p. 5, and NUREG-0600, p. I-A-68, Item 386
10:15 am	(NRC:Region I)----------(IRACT) IRACT notified by Region I that evacuation of TMI-2 control room has been accomplished. Key events continue to be reported promptly but responses to information requests still require longer periods. At about this time, IRACT was told that the operators had "secured" HPI within 5 minutes after it was initiated following the turbine trip. Shortly thereafter, IRACT is informed by NRC:Region I that site communications will be interrupted while they change telephones to Unit 1 control room due to evacuation of TMI-2 control room.	NUREG-0600, p. I-A-69, Item 387
10:15 am	(NRC:Region I onsite team) ------------(Margaret Reilly, PA BRP) Onsite team informed PA BRP that they are available for questioning.	Conver Chronology

TIME	EVENT	REFERENCES
10:15 am	("Doc" Collins, NRC:OSP) ------------ (Jim Thomas, FPA:HQ) Collins called Thomas. Reported that incident occurred at 3 or 4:00 a.m. as a result of low water level in the coolant chambers. NRC has activated its incident management center and all appropriate offices/people have been notified. According to Collins, the temperature around the core of the reactor is coming down, which indicates the problem may be under control. Jim Thomas had just received notification from Thomas Hardy of FPA, Region III, who had in turn been notified by Snyder of the DOE regional office.	Memorandum for Arnold Lewis from Jim Thomas, 3/28/79; State Program Logs, NRC 7906060150 and NRC 7905300274; and, MemCon, Dave Bucher with Thomas Hardy on 8/3/79.
10:16 am	(John Davis, Edson Case, IRACT) -------------- (Gilinsky, Kennedy and Bradford, OCM) 1. Lee Gossick originates call to the Commissioners and then turns briefing over to the other members of the Executive Management Team (EMT). 2. Briefing included: a) Davis: "...directly on top of the core, or taken about 80 feet above the core, there's a reading of 3000 to 4000 rem per hour, which is very high. There's still a fairly low pressure level within containment, about four pounds per square inch (4 psi)." b) Davis: "...probably some of the fuel pins popped because of the pressure transient or low level, we're not sure which...In other words, popped the cladding and released the activity in the gap."	IRACT Tapes, 01-213-4 thru 8

TIME	EVENT	REFERENCES
10:17 am	(George Kunder, ------------ (Greg Yuhas, Don Haverkamp, TMI-2) NRC:Region I) 1. TMI-2 people having to don respirators. 2. Using A OTSG for cooling. Staff believed natural circulation working.	NUREG-0600, p. I-A-69, Item 388
10:20 am	(Rep. Walker, ------------------(NRC:OSP) Lancaster Congressman) Call-in from Congressman Walker to the Office of State Programs at the IRACT Center.	"Doc" Collins log of NRC:OSP NRC-7905300274
10:20 am	(NRC:OSP)------------(Tom Gerusky, PA BRP) Call from State Programs Office to PA BRP to discuss status of air sampling and radiation monitoring. Gerusky was not available. This call was returned at 10:45 a.m.	Conver Chronologv and "Doc" Collins NRC-7905300274
10:22 am	(TMI-1)-------------------(Don Haverkamp, NRC:Region I) An open phone line between the Unit 1 control room and the NRC Region I was established.	NUREG-0600 p. II-A-41, Item 165
10:25 am	(Com. Gilinsky, ------- (Glen Schleede) NRC:OCM) (Substance of telephone conversation was not noted in Gilinsky Log.)	Com. Gilinsky Log, NRC-7905110206
10:25 am	(Com. Gilinsky, ------- (Don Fortier) NRC:OCM) (Substance of telephone conversation was not noted in Gilinsky Log.)	Com. Gilinsky Log, NRC-7905110206

TIME	EVENT	REFERENCES
10:27 am	("Bubba" Marshall, TMI-2) --------- (Don Haverkamp, NRC:Region I) 1. Everyone moved to Unit 1 control room except essential personnel. 2. I&E notes that "not many left control room as result of evacuation order" and TMI-2 control room door without automatic recloser. People failed to close on their own possibly compromising recirculation venting system.	NUREG-0600, p. I-A-69, Item 391
10:30 am	(Jim Martin, NRC:HQ) ----------- (R. Bores, NRC:Region I) Call from Jim Martin with quick means of assessing I-131 and gross iodine depositions on surrounding pastures.	R. Bores, NRC-7906130483
10:30 am	(NRC)---------(Public) Press release based on Preliminary Notification 79-67.	Conver Chronology (4-9)
10:30 am	(NRC:Region I)-------(IRACT) IRACT informed of evacuation of non-essential personnel from site. IRACT also informed that first NRC team from Region I has arrived on site. Within next few minutes, questions from IRACT are being brought into TMI-2 control room from the Unit 1 control room by NRC inspectors. However, this process is delayed because of the airborne radioactivity in the TMI-2 area. Shortly thereafter, IRACT decides to contact telephone operator to attempt to establish 3-way conference call between IRACT, NRC:Region I and the site.	NUREG-0600, p. I-A-70, Item 393

TIME	EVENT	REFERENCES
10:30 am	(James Floyd, MetEd, Lynchburg) ------------ (J.D. Phinney, B&W, Lynchburg) Floyd informs Phinney about the 9:30-10:30 a.m. information from Kenneth Bryan.	B&W Power Generation Group, G.K. Wandling, 3/29/79
10:30 am	("Doc" Collins, NRC:OSP) --------- (M. Stangler, G. Meyers, DCPA) Simply notified of TMI incident, but note that DCPA had already received notification at 9:27 a.m.	NRC:OSP Log, NRC-7906060150; CR 9:17 and 9:27 entries
10:30 am	(Elsasser, NRC:Region I) ---------- (State of Delaware, Rep. for Gov. DuPont) (Substance of conversation was not noted in Conver or Collins Logs.)	Conver Chronology and SLO Log NRC-7906130483, and "Doc" Collins' Log of NRC:OSP NRC-7905300274
10:30 am	State Police helicopter flew monitoring team taking test samples of air in vicinity of TMI site.	Pa. State Police chronology
10:30-11:30 am	(NRC:OCA)---------(U.S. House and Senate) NRC:OCA calls principal oversight committees (including Appropriations) and Pa. Representatives to advise of release of radioactive materials. (<u>See</u> list of persons contacted on 9:00 a.m. entry.)	Conver Chronology
10:32 am	(Brian Grimes, IRACT) -------- (Harold Denton, NRC) 1. Core in fairly normal status. 2. Controlling 2000 psi, only abnormal thing is high radiation reading in containment, suspects gap activity release, but questions high dome monitor reading given 10 R/hr reading on operating deck.	IRACT Tapes, 01-070-1 thru 3.

TIME	EVENT	REFERENCES
10:38 am	(Bernie Weiss, John Davis, IRACT)---------(Tom Gerusky, PA BRP)	IRACT Tapes, 01-070-3 thru 9
	1. Gerusky reports that radioactive iodine detected across the river in the plume.	
	2. BRP contact moving to Unit 1 given activity levels in TMI-2 .	
	3. Problems seem to be created by gap activity rather than melted fuel based on the oxygen activity in the coolant.	
	4. Pa. has detected very low levels of radioactivity in one off-site sample.	
10:39 am	(Joe Fouchard, IRACT)--------------------(Karl Abrahams, NRC:Region I)	IRACT Tapes, 01-214-5
	Press release being read to Region I contains statement: "...There is no indication of releases off the site at this time."	
10:40 am	(NRC:OSP)--------------------------(Jim Lothrop, PEMA)	"Doc" Collins Log of NRC:OSP NRC-7905300274
	Call to Lothrop of PEMA. PEMA is on "standby status." PEMA had apparently been told by Met Ed that there is no off-site problem.	
10:40 am	("Doc" Collins, NRC:OSP)-------------------(D. Carbone, HUD)	NRC:OSP Log, NRC-7906060150
	Notified D. Carbone of Federal Disaster Assistance Administration	

TIME	EVENT	REFERENCES
10:40 am	(Sheldon A. Schwartz, NRC:OSP) --------------- (Bernie Schlein, FDA-BRH, HEW) Notified Schlein in Rockville, Md.	NRC:OSP Log 7906060150
10:40 am	(NRC:Region I) --------------------- (Joe Capita, Pa. Governor's "Action Center") (Substance of conversation was not noted in Conver Chronology.)	Conver Chronology
10:45 am	(Don Goddard, State of Oregon) --------------------- (Sheldon A. Schwartz, NRC:OSP) (Substance of conversation was not noted in OSP Log.)	NRC:OSP Log, NRC-7906060150
10:45 am	(Tom Gerusky, PA BRP) --------------------- (IRACT) PA BRP returns 10:20 call and establishes first liaison with Headquarters. Subsequent calls every hour or two starting at 5:45 p.m.	Conver Chronology
10:45 am	(Dick Lamison, PEMA) --------------------- (Tom Gerusky, PA BRP) Notified PA BRP of need for situation report. Informed Gerusky that this office would call every hour for a report on TMI.	PEMA Log, 3/28, p. 7, entry 62
10:45 am	Raymond H. Smith and Walter F. Baunack arrived at TMI site at 10:45 a.m., having departed Region I at 9:00 a.m. Proceeded to Unit 1 control room where they joined other Region I representatives. At noon, they moved to Observation Center which Met Ed was using as their Emergency Control Center. NOTE: Conver's Chronology places arrival on-site at 11:00 a.m.	NUREG-0600, p. II-A-41, item 167, TMI Northgate Visitor Registration Log, NRC-7906130470, and R.H. Smith Report of Activities, NRC-7906210215

TIME	EVENT	REFERENCES
10:45 am	(R. Bores, NRC:Region I) ------------------------ (Margaret Reilly, PA BRP) 1. Exchange re I-131, with NRC:Region I passing along information relayed by Jim Martin of NRC:HQ. 2. Reilly said B&W reps contended that based on ratios of activity in primary coolant, they believe no fuel melt occurred. 3. Gerusky called in environmental sample data.	R. Bores 7906130483 and 790530274, "Doc" Collins' Log NRC:OSP
10:45 am	(Elsasser, NRC:Region I) ------------------------ (J. Baranski, N.Y. State Energy Office) (Substance of telephone conversation was not noted in Conver Chronology)	Conver Chronology
10:50 am	(Bob Friess, DOE:RAP) ---------------------- (R. Bores, NRC:Region I) 1. Friess gave ETA for AMS aircraft from Andrews AFB after request to fly. 2. Discussion of further contact between DOE:HQ and Region I.	R. Bores NRC-7906130483
10:50 am	(Ben Towsey, PEMA, Central Area) ---------------------- (Dick Lamison, PEMA) Call from Ben Towsey, Central Area, requesting that Commissioner Myers of Cumberland Co. be contacted and informed of TMI situation.	PEMA Log, 3/28, p. 7, entry 58

TIME	EVENT	REFERENCES
10:55 am	At scheduled press conference Lt. Gov. Scranton announced accident and then answered questions, along with Bill Dornsife, BRP; Col. Henderson, PEMA; Pa. State Sen. Jim Ross; Bob Laughlin, Gov's Science Advisor; and, Ray Holst, Energy Officer. Opening statement included 1) TMI accident but everything is under control, 2) no danger to the public, 3) all safety equipment functioned properly, 4) small release of radiation to the environment, but no increase in normal radiation levels have been detected, 5) Civil Defense is on alert, but no need for evacuation, and 6) an NRC investigative team is on the way to the site. Answers to Press Inquiries: 1) Slight design leak rate out of containment but containment pressure is low, 2) BRP does not have mobile monitoring equipment but is depending largely on MetEd, 3) Dornsife is not sure of the origin of "serious situation" to describe the incident, 4) Dornsife reveals radio-iodine detected in the ground.	Pa. Media Center Transcript of 10:55 a.m. Press Conference, Part I
10:55 am	A State Police helicopter transported an air sample (taken in Goldsboro) to Holy Spirit Hospital for pickup by Pennsylvania Bureau of Radiological Protection personnel.	NUREG-0600,P.II-A-41, Item 169.
10:55 am	(NRC:OSP)--------------------(Dick Lamison, PEMA) (Substance of conversation was not noted in Conver Chron.)	Conver Chron. (4-9)
10:55 am	(Greg Hitz, Med. Ed, at TMI), J.C. Higgins, NRC Inspector,----(Don Caphton, Bill Raymond, NRC Region I)	NUREG-0600,P.I-A-71, Items 402 & 403.

TIME	EVENT	REFERENCES
10:55 am (Cont.)	NRC inspector now on site reports trying to cooldown using "A" OTSG and atmospheric dumps. Possible bubble in both RC pump legs; 37 feet left in BWST. Pressurizer level more than 400". Feeding "A" OSTG with emergency feed.	
10:55 am	(M. Markovitz------------(Elsasser Office of Rep. Fish) NRC: Region I) (Substance of conversation was not noted in SLO Log)	SLO Log, NRC-7906130483
10:58 am	(White House)------------------(Bernie Weiss IRACT) (Substance of conversation was not noted in Conver Chron.)	Conver Chron. (4-9)
11:00 am	Unit 2 control room in respirators. Communications in Unit 2 control room are hampered by respirators. Communication problems in Unit 2 control room lead some personnel to remove respirators for short periods.	NUREG-0600, P.I-A-72, Item 408
11:00 am	(Greg Hitz--------------------------(Don Haverkamp TMI-I) NRC: Region I) Still feeding "A" OTSG and using atmospheric steam dumps.	Reg.I Tape 2, P.29, and NUREG-0600, P. I-A-72, Item 409.

TIME	EVENT	REFERENCES
11:00 am	(General Joe Bratton---------(R. Bores, NRC Environmental DOE: HQ Liaison Officer, NRC: Reg. I)	R. Bores contacts, NRC 7906130483
	Request for AMS aircraft at TMI to stand-by at Capitol City Airport.	
	DOE: HQ concurred in this decision and will dispatch AMS and crew.	
	RAP has also been requested to respond by BRP.	
11:00 am	Operators controlling pressure using EMOV Block Valve (RC-V2) at approximatly 2000 psi. Opening valve 3 min. for every 5-8 min. About 7 1/2 hrs, shifted to pressurizer vent valve for fear of RC-V2 failure.	NUREG-0600,P.I-A-72, Item 411.
11:00 am	("Doc" Collins---------------------(J. McCool NRC: OSP) DOE)	OSP LOGS, NRC 7906060150
	Called J. McCool's office. McCool is on way to DOE:EOC. His secretary said McCool knows about TMI incident.	
11:00 am	(Dick Lamison------------------------(PA BRP) PEMA)	PEMA log, 3/28, P.7, entry 59
	Notified BRP of need for situation report. BRP reported "no change."	

TIME	EVENT	REFERENCES
11:00 am	J.G. Herbein leaves Philadelphia by helicopter for TMI.	Herbein Sequence, NRC 7906140462
11:05 am	("Doc" Collins---------------------(Dave Guies, NRC:OSP) Washington State Office of Emergency Services)	NRC:OSP Logs, 7906060150
	Collins called Guies of Washington OES and briefed them on incident.	
11:09 am	(Lee Gossick, John Davis-----------(Comm'r. Kennedy, IRACT) Comm'r. Gilinsky OCM)	IRACT Tapes, 01-215-6 and 11
	Containment pressure levels are back to 2 psi following an earlier report of 4 psi.	
	In response to his inquiries, Gilinsky is informed that if levels of radioactivity off-site increase, recommendations for protective action measures such as evacuation would be the responsibility of the licensee dealing with the State. However, according to measured levels of radioactivity, they are a long way from that.	

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TIME	EVENT	REFERENCES
11:15 am	(Bill Raymond----------------(Mike Wilber NRC Reg. I) IRACT) Region I has still not received any word on hot leg temperatures.	IRACT, 01-023-10.
11:15 am	(Chick Gallina---------------(Greg Yuhas NRC at TMI-I) Region I) 100 ml. RCS sample reads approximately 200 mR/hr. Translates to approximately 72 uc/ml.	NUREG-0600, P.I-A-74, Item 418.
11:15 am	IRACT informed at this point that licensee planned to depressurize to utilize decay heat system. Then the person making this statement indicates he wants to confirm it, and goes off to do so. A specific confirmation or denial is not relayed back to the IRACT. For the next 2 hours, IRACT personnel appear to be under impression that DHR will be used until they learn, at approximately 1:15 pm that licensee is floating CF tanks on the core.	NUREG-0600,P.I-A-74, Item 419.
11:15 am	("Doc" Collins--------------------(Ragnwald Muller NRC:OSP) NRC: Advisory Comm. on Reactor Safeguards) Returned call to Muller to advise him on what OSP knows - ACRS has been receiving calls of inquiry.	OSP Logs, NRC 7906060150
11:20 am	State Police Helicopter returned to TMI.	PEMA State Police Chron.

TIME	EVENT	REFERENCES
11:20 am	(Harold Thornburg--------------(Don Roy IRACT) B&W, Lynchburg)	IRACT Tapes, 01-071-5,6.
	Update on Reactor Status.	
	May have been fuel failure.	
	Looks like reactor is being cooled.	
	Seems as though there was a release of radioactivity causing puff release off-site, but not a lot.	
	Safety release valve probably opened, safety injection system came on then shut off.	
11:30 am	Lt. Frank Lusky, State Police Commander at York Station (Troop "H") arrived at TMI observation center to act as State Police Department liaison.	PEMA State Police Chron.
11:35 am	(Thomas Hardy------------------------(Elsasser Fed. Preparedness Agency, Reg. III) NRC, Reg. I)	Conver Chronology
	(Substance of conversation was not noted in Conver chron.)	
11:40 am	J.G. Herbein arrives at TMI Observation Center and receives telephone briefing from G.P. Miller and other members of plant staff who are on site.	Herbein sequence, NRC-7906140462

TIME	EVENT	REFERENCES
11:40 am	(Ron Nimitz ------------------(Greg Yuhas NRC at TMI-I) NRC:Reg. I)	NUREG-0600,P.I-A-76, Item 432
	"B" OTSG is bottled, but it appears that it may be necessary to relieve its pressure.	
11:40 am	(Ron Nimitz---------------(Greg Yuhas, Don Caphton NRC at TMI) NRC: Reg. I)	NUREG-0600,P.I-A-76, Item 433.
	Region I inspector reports that licensee thinks they have release under control (per superintendent Miller)	
11:45 am	(Harry Kister---------------------(Mike Wilber NRC: Reg. I) IRACT)	
	System Parameters: a.) Pressure = 2000 psi b.) Hot leg temperature = 620° c.) B Steam Generator is isolated at 300 psi d.) Atmospheric dump valves are open e.) RCPs are vapor bound	IRACT Tapes, 01-024-9 Thru 11.
	This is the first operational data relayed to IRACT in more than 1/2 hour. At about this same time there is a discussion in the background concerning injection at maximum rate despite the risk of blowdown. This recommendation, however, is not relayed to the site.	NUREG-0600, P.I-A-77, Item 440

TIME	EVENT	REFERENCES
11:45 am	(F. Greg Schaedel------------------(W.H. Spangler B&W Employee at his B&W, Lynchburg) Harrisburg residence)	B&W Power Generation Group, G. K. Wandling, 3/29/79
	Relayed information just received from Leland Rogers who is the B&W Site Operations Manager at TMI. Updated plant status, and told of plans to depressurize the system.	NURGEG-0600, P.I-A-76 and 77, Item 439
11:45 am	(Thomas Elsasser---------------(Anthony Rizzolo NRC: Reg.I) NJ Dept. of Energy)	
	(Substance of conversation was not noted in Conver Chron.)	Conver Chron. (4-9)
11:45 am	("Doc" Collins------------------(Carl Siebentritt NRC:OSP) DCPA-Pentagon)	
	Returned call to DCPA - Pentagon briefed Siebentritt on what NRC:OSP office knows.	"Doc" Collins Log of OSP, NRC 7905300774
11:50 am	(Herb Hahn----------------------------(R. Bores AMS/RAP) NRC: Region I)	R. Bores Log, NRC-7906130483
	DOE:RAP calls NRC Reg. I from Andrews AFB with estimated ETA Harrisburg at approximately 1500 hrs.	
11:50 am	(A. Pasternak ---------------------(Sheldon A. Schwartz Cal. Energy Comm.) NRC:OSP)	"Doc" Collins Log of OSP, NRC- 7905300274 and OSP Logs NRC-7906060150
	Call from Pasternak, CA Energy Commission	

TIME	EVENT	REFERENCES
11:55 am	(Chick Gallina----------------------------(Don Caphton NRC at TMI-I) NRC:Reg. I)	NUREG 0600, p. I-A-77, Item 444, Region I Tape No. 4, p. 12
	Using atmospheric dumps on the "A" OTSG Unit I reported to be in Hot Standby.	
Before Noon	Kevin Molloy, Dauphin County Civil Defense (DCCD) called C.O. Troop "H" and advised that he received a report of high rediation readings and wanted Pa. Rt. 441 closed. Subject could not verify source of information nor provide readings and decision was made to keep Pa. Rt. 441 open until verification could be made. Verification never made, road never closed.	PA. State Police Chron.
Prior to 12:00 pm	(Wm. Scranton III-------------------------(Walter Creitz, Office of Lt. Governor) Pres. MetEd)	I&E Interview, Tape #193, p. 16
	(Conversation requesting knowledgeable utility representative at capitol complex).	
Prior to 12:00 pm	(Walter Creitz----------------------------(V.P. Jack MetEd) Herbein MetEd)	I&E Interview, Tape #193, p. 16
	(Conversation relaying Acranton's request for knowledgeable representative at capitol complex).	
12:00 pm	(Jack Herbein-----------------------------(Gary Miller MetEd at Observation Center) MetEd at TMI-2)	NUREG 0600, p. I-A-78, Item 446
	Station Manager, Gary Miller, was directed purportedly over his objection, by Herbein to be prepared to meet with the Lt. Gov. in Harrisburg. The Station Manager directed George Kunder the Superintendent-Technical Support to collect thechnical materials prior to the meeting.	

TIME	EVENT	REFERENCES
12:00 pm	(NRC:REGION I)--------------------------(IRACT) NOTE: IRACT is notified of arrival of second Region I team at the site.	NUREG-0600,P.I-A-78, Item 448
12:00 pm	(Schweller--------------------------(R. Bores DOE:RAP) NRC: Region I) Two DOE:RAP teams being dispatched. BRP wants DOE:RAP to assist in monitoring airborne activity. Estimated time of arrival is about 2:00 p.m.	
12:00 pm	(Michael J. Slobodien----------------(John R. White Rad. Specialist) Rad. Specialist) Slobodien called White at his residence and informed him of events at TMI and read PN to White. Slobodien was manning Health Physics desk at NRC:REG.I Incident Response Center. He provided technical support in selection and procurement of equipment.	White-Report of Activities 7906200477
12:00 pm	(Schwartz-----------------------("Sandy" NRC:OSP) Comm'r Gilinsky's office) Sandy, Q: Who does NRC:OSP office talk to in PA A: Region contacts Gerusky. All other communications with IRACT.	OSP Log, NRC-7906060150
12:04 pm	(Thomas Elsasser---------------(George Bochanski NRC:Reg.I) EPA Region III) (Substance of conversation was not noted in Conver Chron.)	Conver Chron. (4-9)

TIME	EVENT	REFERENCES
12:05 pm	(Bonnie Schlein,FDA-BRH-------(Sheldon A. Schwartz HEW) NRC:OSP) Schlein asked Schwartz who directs FDA to take samples	OSP Logs, NRC 7906060150
12:10 pm	(Karl Abraham -----------------(James M. Brown, Jr.) NRC, Region I) DOE, Valley Forge) Brown, Chief of Emergency Electrical Response Systems, spoke with Mr. Abraham, although he had earlier called Jerry Feffer, DOE Assistant Administrator for Utility Systems, for details of the incident.	Conver Chron. and MemCon, Dave Bucher with James Brown on 8/1/79.
12:15 pm	(IRACT)-----------------------------(NRC:Region I) IRACT requests that licensee be asked if they considered blowing down the primary system, and if they considered bumping the RCP's. It appears that this is the first instance of HQs asking questions of a planning nature rather than a status nature. NRC: Region I agreed to relay request to Inspector at site.	NUREG-0600,P.I-A-79, Item 453.
12:15 pm	Brian Grimes and Stello Discussion within IRACT, re: fuel failure calculations. Grimes states that if the operating deck monitor with the lower readings is correct, the percentage of fuel failure or core damage is much less than if the dome monitor is correct.	IRACT Tape, 01-025-11 and Hart Subcommittee Interview of Dr. Grimes, P.32.

TIME	EVENT	REFERENCES
12:20 pm	(Walter Baunack)------(Don Caphton NRC at TMI-I) NRC:Reg. I)	NUREG-0600, P.I-A-79, Item 455. Region I Tape No. 4, p. 15
	Pressurizer level is still off scale high	
	Inspector believes bubble exists in OTSGs "candy canes"	
12:20 pm	IRACT informed of hot leg temperature of 620°F. (No comment is made that this is the limit of display for detector) IRACT requests information be provided on fuel assembly outlet thermo-couples. There appears to be a discussion in the background of why the licensee throttled back on HPI flow (as understood by IRACT) but no question is relayed to site.	NUREG-0600, P. I-A-79 and 80, Item 456.
12:20 pm	(J. Barry ------------------------(Elsasser Rep. Fish's office, NY) NRC:Reg.I, SLO)	"Doc" Collins, NRC-7905300274
12:23 pm	(Comm'r Gilinsky--------(Ed Case, Lee Gossick, John Davis NRC Comm'r) Exec. Dir. Ops, IRACT)	
	Call from Commissioner Gilinsky inquiring about radiation levels in containment. Short conversation in which Gilinsky inquiries if deck monitor reading on magnitude of 10 to 50 R/hr is consistent with readings from normal leakers, to which Mr. Case responded affirmatively.	IRACT Tapes 01-217-2 and 3
	Gilinsky also inquired about pressurizer levels. Case responded that the operator "apparently" just keeps pumping the water in as fast as he can.	Comm'r Gilinsky's Calls 7905110206
	(NRC:OCA)---------------(Gilinsky, NRC and OCM staff)	Kammerer Memo 7905160041

TIME	EVENT	REFERENCES
	Telephone briefing for Commissioner Gilinsky and OCM staff as to the status of TMI. This occurred between 10:30 a.m. and 12:30 p.m., but is not recorded on Gilinsky's log.	
12:30 pm	(NRC:OCA)--------------(US SENATE & HOUSE)	Conver Chronology (4-9)
	NRC:OCA calls principal oversight committees & Pa. reps. regarding latest information.	
	Henry Myers requests briefing on technical infomation.	
	NRC:OCA arranges briefing by Stello.	
12:30 pm	Lt. Frank Lusky, State Police Department liaison officer at TMI directed helicopter to clear boats from the river in the immediate vicinity of the plant.	PA State Police Chronology
12:35 pm	(Donald Caphton------------(Mike Wilber NRC: REG. I) IRACT)	
	Caphton reported to IRACT that "B&W (Babcock and Wilcox) representative says please don't start the reactor coolant pumps. We don't know what the status is and we may end up blowing the seal."	IRACT Tapes, 01-026-3 thru 8
	IRACT also informed HPI flow to core is 400 gpm. minutes later, a direct connection between IRACT, NRC: REG.I, and Raymond Smith in the TMI-1 control Room is established.	NUREG-0600,P.I-A-80, Item 459
	NOTE: NUREG 0600, contains a typo, i.e., "please <u>do</u> (sic) start RCPS"	

TIME	EVENT	REFERENCE
12:41 pm	RCS pressure reaches 600 psig, which is equivalent to the nominal gas pressure maintained in the core flood tank (CFT) nitrogen cover gas.	NUREG 0600, P. I-A-80, Item 462
12:43 pm	(Walter Baunack---------------------(Don Caphton NRC at TMI-1) NRC:Region I) 32' BWST, RCS press=576 psig	NUREG 0600, p. I-A-81, Item 464
12:50 pm	State Police helicopter returned to site at TMI.	Pa. State Police Chronology
1:00 pm	(NRC:Region I)---------------------(NRC:HQ IRACT) Operators were feeding "A" OTSG with condensate pumps and still steaming out atmospheric dump valves. State had made several calls requesting releases be secured, each time more militant. Note: All persons in the Lt. Governor and Governor's offices interviewed to date by the Subcommittee denied knowledge of any such requests made from their offices.	NUREG 0600, p. I-A-81 Item 468
1:00 pm	(NRC:Region I)---------------(Gary Miller, Met Ed at TMI-2) Inspector pointed out to Gary Miller that source of water (steamed out atmospheric reliefs) was probably contaminated. Miller, Station Manager, may have been unaware that OTSG feed had been shifted from the condensate storage tanks to the main condenser.	NUREG 0600, p. I-A-79 and 80, Item 468

TIME	EVENT	REFERENCES
1:00 pm	NRC inspector reports from site that: TMI I control room going on masks. Excess personnel moved to Observation Center.	NUREG-0600,P. I-A-82, Item 471
1:00 pm	(Karl Abrahams---------------------(Joe Fouchard NRC: Region I) IRACT) Discussion of public relations stance regarding inquiries related to levels of radioactivity at TMI.	IRACT Tapes, 01-267-1 Through 4.
1:00 pm	(R.Shaw -------------------------------(R. Bores DOE:HQ, Emergency Operations Center) NRC: Region I) NRC does not want to establish an open line with DOE: HQ/Emergency Operations. AMS crafts do not have air sampling instrumentation, only gamma measuring instruments.	
1:00 pm	Bill Raymond, in third vehicle, departs for site.	Conver Chronology Bob Martin Memo to Bob Marsch NRC-790523088.
1:00 pm	(Robert Corcoran -----------------------(Thomas Elsasser MD Health Department) NRC: Region I) (Substance of conversation was not noted in Conver Chron. or Collins Log.)	Conver Chronology and "Doc" Collins, NRC-7905300274

TIME	EVENT	REFERENCES
1:00 pm—1:45 pm	Henderson (PEMA) accompanied Lt. Gov. to Gov's office. Bill Dornsife (PA-BRP) explained situation and events to Governor. Henderson assured Governor that PEMA could evaluate a 5 mile radius around TMI-2.	PEMA Log, 3/28,P.F. entry 60
1:00 pm	(NRC: Reg. II Atlanta, Ga.) ------------------------ ("Doc" Collins NRC:OSP) Received call from NRC:II erroneously reporting that three counties in VA. evacuated and that MD and WV were starting air monitoring.	"Doc" Collins OSP Log, NRC-7906060150
1:01 pm	(Victor Stello IRACT) ---------------------------- (Henry Myers House Subcommittee) Stello explains the confusion over radiation levels in the containment. Stello conveys others' doubts about the validity of the 6000 R/hr reading of the dome monitor. There seems to be little airborne radiation, and one would not need 6000 R/hr in the containment to get the 3mR/hr reading at the Observation Center.	IRACT 01-219-2 thru 4.
1:05 pm	(R.G. Ryan NRC:OSP) ------------------ ("Doc" Collins NRC: OSP) Ryan reports that PA highway 441 was closed by State Police 15 mi. N& S of plant. DOE's RAP team from BNL arriving at 2:00 p.m. AMS aircraft arriving at 3:00 p.m. from Andrews. NRC:Reg.I. I&E Rad van arriving in two or three hours. Radiation reading 1/3 mi. from site is 7 mR/hr and is thought to be containment "shine".	NRC:OSP Logs, NRC 7906060150

TIME	EVENT	REFERENCES
1:09 pm	(Edward Fay, NRC:OCA)---------------------(IRACT) Fay questions his contact at IRACT about pumps (presumably accident sequence as reported in AP wire story). No one at the Response Center is prepared to be definitive about the accident sequence. But everything is reportedly "just great".	IRACT Tapes 01-219-7
1:10 pm	(C. George, DOE:RAP)---------------------(NRC:OSP) (Substance of conversation was not noted in Collins Log).	"Doc" Collins Log NRC-7905300274
1:10 pm	(W. Riley, Phila. Air Pollution Div.)----------------------------------(Elsasser, NRC:Reg. I) (Substance of conversation was not noted in Collins Log).	"Doc" Collins Log NRC-7905300274
1:12 pm	("Doc" Collins, NRC:OSP)----------------------------(George Jones, VA Civil Defense) Collins, who was working in the state programs office, which is right off of the IRACT center, called the Office of Emergency and Energy Services within the Va Civil Defense organization. He told Mr. Jones about the Va evacuation rumor which IRACT had heard from their Region II. Jones had no knowledge of the rumor.	IRACT Tapes, 01-171-6 to 8, Conver's Chronology, and NRC:OSP Log, NRC-7906060150

TIME	EVENT	REFERENCES
1:13 pm	(A. Pasternak-------------------(Sheldon A. Schwartz CA Energy Comm.) NRC:OSP) (Substance of conversation was not noted in Collins Log.).	"Doc" Collins-NRC:OSP Log NRC-7905300274 NRC-7906060150
1:15 pm	(Chick Gallina-(Don Haverkamp, George Smith,-(Mike Wilber, NRC at TMI-1) Don Caphton, NRC:Region I) IRACT) Region I is informed that: 1. Condenser is isolated. (Thus not available as a heat sink). 2. Reported Harrisburg TP Exit at 25 mR/hr using uncalibrated instrument. 3. Core flood tanks have partially injected. 4. BWST now at 31 feet. 600 psig in RCS. 5. Hoping core flood injection will drop temperature allowing use of decay heat removal (DHR) system. 6. General plant announcement heard, "SHUTTING DOWN ATMOSPHERIC DUMPS".	Region I Tape #5, p. 9 through #6, p. 3 NUREG 0600, p. I-A-84, Item 478
1:15 pm	(1) J.G. Herbein met with members of the press at the TMI Observation Center. Herbein informs the press that he is not totally knowledgeable of the situation, but stated that (a) there was a problem with the secondary side to the plant-#2 lost two main feed pumps and the reactor tripped on high pressure, (b) no one was injured and Met Ed does not intend to expose anyone in the plant clean-up effort (c) radiation levels at the site boundary are being monitored and the levels are a tenth of the general emergency level, (d) plant reps did not see any indications of a high level of radiation in the reactor building until approximately 6:50 am, at which time a site emergency was declared.	Herbein Sequence, NRC-7906140462

TIME	EVENT	REFERENCES
1:15 pm	(D. Lavine,--------------------(NRC:OSP) Conn.)	H. Collins-NRC:OSP Log NRC-7905300274
	(Substance of conversation was not noted in Collins Log).	
1:15 pm	(Sheldon A. Schwartz-----------(J. Dunkleburger, New York NRC:OSP) State Energy Office)	H. Collins-NRC:OSP 7905300274 OSP Log - 7906060150
	Called Dunkleburger and briefed him. Called for Ted DeBorn, but spoke with Dunkleburger and updated him on TMI status.	
1:15 pm	(Hufham,-----------------------("Doc" Collins, NRC:II) NRC:OSP)	NRC:OSP Logs 7906060150
	Hufham called and said evacuation rumors involved Pa. counties, but still bad data/false information.	
1:15 pm	(Dave Langford,-----------------(R. Bores, EPA:III) NRC:Region I)	R. Bores contacts, NRC-7906130483
	Update for EPA Region III upon request of Dr. Langford.	
1:15 pm	(N. Penzario,------------------(R. Bores, Yankee Atomic Elec. Power Plant)NRC:Region I)	R. Bores contacts, NRC-7906130483
	Inquiry as to incident/status at TMI.	
1:15, 1:18 pm	(Chick Gallina,--(Don Caphton,-(Jerry Klingler, NRC at TMI-I) NRC:Region I) NRC:IRACT)	Region I tape #6, p. 3-5 NUREG 0600, pg. I-A-85, Items 482 and 483
	1. NRC inspector, Gallina reports steam dumps closed. NRC expresses concern that leaving core flood tank isolation valves open may lead to injecting nitrogen into vessel. 2. This concern was reiterated at approximately 1:30 pm. In both cases, the response indicated the licensee's conclusion that nitrogen injection was not possible, based on system design and plant conditions.	

TIME	EVENT	REFERENCES
1:20 pm	(NRC:OSP)----------------------(George Jones, Va. Civil Defense)	NRC:OSP Log 7906060150
	State Programs called office of Mr. Jones and told him (through secretary) that rumors were false.	
1:20 pm	(NRC:OSP)----------------------(Tom Gerusky, PA BRP)	NRC:OSP Log 7906060150
	OSP called BRP to ask about ariborne and direct radiation in Harrisburg. OSP informed of transitory status of release. OSP also informed that state has no capability to check for Iodine (airborne).	
1:20 pm	("Doc" Collins, NRC:OSP)----------------(S. Davies, L. Czech, NY State Rad. Health)	"Doc" Collins Log, NRC-7905300274 NRC:OSP Log, NRC-7906060150
	Called NY Rad. Health. Gave them known accident details. Advised them to contact PA BRP (Reilly) about any potential milk problems in N.Y.	
1:25 pm	(David Lavin, Conn.)------------------(Sheldon A. Schwartz, NRC:OSP)	OSP Log, NRC-7906060150
	Call from D. Lavine, Conn. to be filled in on latest details of incident.	
1:25 pm	(W. Gillen, WI P.S.C.)--------------------(NRC:OSP)	"Doc" Collins Log, NRC-7905300274
	(Substance of conversation was not noted in Collins Log.).	
1:30 pm	(F. Greg Schaedel, B&W Employee at his Harris-burg residence)--------------(B. Karrasch & Task Force, B&W, Lynchburg)	B&W Power Generation Group, G.K. Wandling, 3/29/79
	Relayed information just received from Leland Rogers who is the B&W Site Operations Manager at TMI.	
	Rogers will let Schaedel know of any further personnel needs by 3:00 pm.	

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TIME	EVENT	REFERENCES
1:30 pm (cont.)	B&W, Lychburg recommended to Schaedel/Rogers: 1. Obtain cooldown data. 2. Ensure accurate RCS temperature before going onto DHR. 3. Confirm core outlet temperature by pressurizer temp. since that is now the flow path.	
1:30 pm	(R. Bores, NRC:Region I)------------------------(Margaret Reilly, PA BRP) 1. Results of Goldsboro sampling of 11:30 am taken by TMI. 2. Discussed dosage rates reported on news (on Rt 441) as possible direct radiation from containment. 3. BRP will collect milk samples this pm to analyze for Iodine. 4. Pa. Dept. of Agriculture alerted re milk pathway. No action considered at this time.	R. Bores contacts, NRC-7906130483 Conver Chronology
1:30 pm	DOE advance party establishes command post at Capital City Airport.	Reg. I tape #6, p. 6-7 NUREG 0600, pg. I-A-86, Item 488
1:30 pm	(Chick Gallina, NRC at TMI-I)---(Don Caphton, NRC:Region I)----(Jerry Klingler, IRACT) 1. Gallina, Region I inspector, reports from site to Region I that State of Pa. was concerned about steam dump. 2. At this time atmospheric steam dump had been secured for approximately 15 minutes. This message appears to be for the purpose of explaining a wide spread notion about the impetus for securing the atmospheric dump valve.	
1:30 pm	(J. Abbott, Mo. Energy Program)------------------------(NRC:OSP) (Substance of conversation was not noted in Collins Log.).	"Doc" Collins Log NRC-7905300274

TIME	EVENT	REFERENCES
1:30 pm	John R. White reported to Region I office and stationed himself at the incident center.	White - Report of Activities NRC-7906200477
1:33 pm	(Bill Runch,-----------------------(NRC:Region I) SC State Legislature)	SLO Contacts NRC-7906130483
	(Substance of conversation was not noted in SLO Contacts.).	
1:33 pm	(Mike Pawlowski,-------------------(NRC:Region I) DCPA:II)	SLO Contacts NRC-7906130483
	(Substance of conversation was not noted in SLO Contacts.).	
1:33 pm	(Col. Wm. Brown,-------------------(NRC:Region I) Public Service Environmental Protection, DE)	SLO Contacts NRC-7906130483
	(Substance of conversation was not noted in SLO Contacts.).	
1:35 pm	(Chick Gallina,---(Don Caphton,----(Jerry Klingler, NRC at TMI-I) NRC:Region I) IRACT)	Reg.1 tape #6, p. 8 NUREG 0600, pg. I-A-86, Item 490
	Gallina, Region I inspector, in response to question states to Region that pressurizer relief valve is closed.	
1:35 pm	(Bernie Schleien,------------------(NRC:OSP) FDA-BRH, HEW)	"Doc" Collins Log NRC-7905300274
	1. Schleien passed on air sample data which he received from R. Corcoran (MD BRH) who apparently got it from Gerusky (PA BRP).	

TIME	EVENT	REFERENCES
1:42 pm	(Commissioner Gilinsky, Bill Dorie, NRC:OCM, "H" Street)------------(Edson Case, Lee Gossick, EMT at IRACT) 1. Radiation monitors inside the containment building show 6000 R/hr at the dome and 10 R/hr at the operating deck, with a reading of 500 mR/hr outside the base of the containment. 2. EMT reports that the situation seems to be stabilizing, i.e. there is no indication that the contamination level inside the containment building is rising. 3. Hot leg temperature incorrectly given as 250°.	IRACT Tapes 01-220-5 and 15, and Comm. Gilinsky's calls, NRC-7905110206
1:45 pm	(J.C. Higgins, NRC:Region I at TMI-2)------(Don Haverkamp, Greg Yuhas, Don Caphton, NRC:Region I)-(Jerry Klingler, IRACT) Region I inspector reports to Regional Office that: 1. DHR will be initiated when RCS pressure gets to about 350 psig. 2. Rx Press ~500 psig. 3. Temperature ~ 250°F. 4. Pressurizer being vented to vent header. 5. Normal letdown in operation 6. Pumping bleed tank to core flood tanks to complete water cycle. 7. The path described here by Higgins was not confirmed by any interviews conducted. It appears to be a misunderstanding on the part of Higgins.	Reg. I tape #6, pp. 10 through 13, NUREG 0600, pg. I-A-86 and I-A-87, Items 492 and 493

TIME	EVENT	REFERENCES
1:50 pm	Hydrogen combustion and pressure spike 1. Oxygen analysis days later indicate combustion has occurred. The Station Manager recalls hearing a "thump", but attributed it to a change in ventilation damper position. Recognition that hydrogen combustion has occured, will not come until the next day as data is analyzed. 2. Review of IRACT and Region I IRC tapes shows that this event was not brought to the attention of NRC Management. 3. NRC inspector in control room was alleged to have been aware of spike.	NUREG 0600, pg. pg. I-A-88, Items 499 and 500 Subcommittee interview with Brian Mehler
1:55 pm	(Chick Gallina, NRC at TMI-1)------(Don Caphton, Greg Yuhas, NRC:Region I)--(Jerry Klingler, IRACT) Unit 1 control room still in respirators.	Region I Tape #7, pg. 1 NUREG 0600, pg. I-A-89, Item 504
1:55 pm	J.G. Herbein, G.P. Miller, and G.A. Kunder depart TMI Observation Center for meeting with Lt. Gov. Scranton.	Herbein Sequence NRC-7906140462
2:00 pm	IRACT expresses their concern that continued injection will prevent discharge of the core flood tanks, with the result that the system will remain above the DHR interlock for a long period. IRACT asks how licensee is going to get the pressure down so that DHR can be put into use.	NUREG 0600, pg. I-A-91, Item 511
2:00 pm	(Jack McCool, DOE:HQ, Emergency Operations Center)----------------------(R. Bores, NRC:Region I) 1. RAP from BNL being sent in two helicopters. Will be touching down momentarily in Harrisburg. 2. Andrews RAP personnel craft landing now. ETA of instruments 1/2 to 3/4 hour.	R. Bores Contacts, NRC-7906130483
2:00 pm	(J. Logsdon, EPA-ORP)--------------(NRC:OSP) Mr. Joe Logsdon, called for update on TMI.	

TIME	EVENT	REFERENCES
2:00 pm	(Bernie Schleien, FDA-BRH, HEW)------------------(NRC:OSP) FDA-BRH is ready to help (Information transmitted via Ryan).	OSP Log, NRC-7906060150
2:00 pm	(Conn. Pub. Utilities Control Authority)--------------(NRC:OSP) (Substance of conversation was not noted in Collins Log.).	"Doc" Collins NRC-7905300274
2:00 pm	(Bob Arnold, GPU, V.P.-------------(Leland Rogers, Gary Miller, et.al B&W Site Representative, Station Manager, at TMI-2 Although those in the Unit 2 control room reportedly tried to reassure Arnold that the core was covered, he was not reassured. Recognizing that he did not have detailed information about the plant, Arnold felt that the temperatures he was being given indicated the core had not been continuously covered and may not be adequately cooled as the afternoon was wearing on. He felt the safest thing to do under the circumstances was to put as much water into the reactor cooling system as was necessary to ensure flow through the core, including, if necessary, pumping with the make-up system or HPI system directly through the safety valves. His objective was to get the system solid so that a reactor coolant pump could be started and to provide forced circulation.	Hart Subcommittee Interview with Bob Arnold, Aug. 23, 1979, pp. 5-6
2:10 pm	(Commissioner Gilinsky, NRC:OCM "H" Street)------------(Congressman Robert A. Walker, U.S. Representative) (Substance of conversation was not noted in Gilinsky's Log.).	Commissioner Gilinsky's Office Log, NRC-7905110206
2:10 pm	(Bernie Weiss, IRACT)-------------(R. Bores, NRC:Region I) AMS crew was to fly. Commissioners have been told that crew will be flying.	
2:15 pm	The Department of Energy Aerial Monitoring System helicopter arrived and began tracking the plume.	Conver Chronology and NUREG 0600, pg. II-A-45 Item 188

TIME	EVENT	REFERENCES
2:15 pm	(F. Adair, WA State)---------------(NRC:OSP) (Substance of conversation was not noted in Collins Log.).	"Doc" Collins Log, NRC-7905300274
2:15 pm	(Chick Gallina, NRC at TMI-1)------(Don Caphton, Greg Yuhas, NRC:Region I)-(Mike Wilber, Jerry Klingler, Norm Moseley, IRACT) 1. RCS pressure 500 psig. (T_h 600°F) T_c 230°F. 2. Suspect bubble in loops. 3. Reported to be venting pressurizer.	Reg. I Tape #7, p. 12 through 16, NUREG 0600, pg. I-A-92, Item 516
2:15 pm	(D. Goddard, Oregon State)---------(NRC:OSP) (Substance of conversation was not noted in Collins Log.).	"Doc" Collins Log, NRC-7905300274
2:20 pm	(R. Bores, NRC:Region I)------------------------(Sherwood, DOE:HQ Emergency Operations Center) 1. NRC informs DOE:HQ of decision to fly. DOE already knew of decision. 2. Jim Stone of NRC is at DOE:HQLEOC.	R. Bores Contacts, NRC-7906130483
2:25 pm	(Sheldon A. Schwartz, NRC:OSP)--------------(M. Reilly, PA BRP) OSP contacted Reilly. Asked for environmental sampling information.	"Doc" Collins Log, NRC-7905300274

TIME	EVENT	REFERENCES
2:26 pm	(Chick Gallina, NRC at TMI)-----(Greg Yuhas, Don Caphton, NRC: Region I)---(Mike Wilber, IRACT)	Reg. I Tape #8, pp. 2 through 8
	1. Licensee reported to believe release coming from Auxiliary Buildings, floor drains. Reading 1-2 R/hr in area of Rad. Waste Control Panels.	NUREG 0600, p. I-A-92, Item 518
	2. All TMI-2 water tanks are full.	
	3. Going to dump TMI-2 Neutralizing Waste Tank to TMI-1 Miscellaneous Waste Tank, then dump that water to floor of TMI-1 Bleed Tank Room (apparently this technique of shifting water had been used year before), then pump TMI-2 Aux. Bldg. sumps to various TMI-1 and 2 tanks.	
	4. Some places in Aux. Bldg. water was 6-8" deep, usually in areas of floor drains.	
2:27 pm	(Comm. Gilinsky, NRC Commissioner)-----------------(Joseph Fouchard, OPA of NRC)	Gilinsky Log, NRC-7905110206
	(Substance of conversation was not noted in Gilinsky Log.).	
2:27 pm	(Comm. Gilinsky, NRC Commissioner)-----------------(Hanfling)	Gilinsky Log, NRC-7905110206
	(Substance of conversation was not noted in Gilinsky Log.).	
2:27 pm	(Comm. Gilinksy, NRC Commissioner)-----------------(Henry Myers, Science Advisor, House Subcommittee on Energy and the Environment)	Gilinsky Log, NRC-7905110206
	(Substance of conversation was not noted in Gilinsky Log.).	

TITLE	EVENT	REFERENCES
2:28 pm	Rapid drop in RCS "A" loop outlet temperature noted and operators believe bubble has moved. Operators believe bubble collapse resulted from their actions of injecting heavily thru MU-V16C, only	NUREG-0600,P I-A-92, Item 519
2:30 pm	(J.G. Herbein)----(Lt. Gov. Scranton G. Miller PA Lt. Gov.) G. Kunder Met. Ed)	NUREG-0600,P.II-A-45, Item 505.
	Herbein briefed Scranton of plant status as of 1:00 p.m. Herbein explained the plans for natural flow cooling and belief of an orderly cool-down duringthe day. He apologized for venting steam that was possibly radioactive. Herbein reviewed the emergency notification procedures, referring to 6:50 and 7:30 a.m. communications.	Herbein sequence, NRC 7906140462 and NUREG 0600, p. II-A-45, Item 189, p. I-A-89 Item 505
	Herbein, Metropolitan Edison Vice President, Generation; Miller, the Station Manager (Emergency Director) and Kunder, TMI-2 Technical Support Superintendent,met with the Lt. Governor	
	Gary Miller, Station Manager, went with as much information as he could about the incident. Miller was fitted with a beeper to permit him to be contacted in the event of a change in conditions. Upon arrival at the Lt. Gov.'s office, Kunder called the plant and remained on the phone approximately 15 minutes after the meeting started. Miller was on the phone during the last 20 minutes of the meeting.	
	Joe Logan, Emergency Director Designee (Unit 2 Superintendent) was directed to maintain status of plant without change, during absence of Herbein, Miller and Kunder.	

TIME	EVENT	REFERENCE
2:30 pm	(Don Caphton, NRC:Region I) ------------------ (Mike Wilber, NRC:HQ IRACT) Note: During conversations between IRACT and Reg. I, IRACT is informed of contaminated water being on the floor of the auxiliary building. This is the first reference to this condition found in the telephone tapes.	NUREG 0600, p. I-A-93 Item 523
2:30 pm	BNL RAP arrives Capitol City Airport, and sampling begins.	Conver Chronology
2:30 pm	(P. Smith, Conn. Power Facility Evaluation Council) -------------------- (NRC:OSP) (Substance of telephone conversation was not noted in Collins Log.)	H. Collins Log NRC 7905300274
2:30 pm	(Elsasser, NRC: Region I) -------------------- (NRC:OSP) Reg. I SLO called. Pa. State had made an announcement at press briefing that radiation readings on west bank of Susquehanna was 10^{-8} uCi/cc	H. Collins Log NRC 7905300274

TIME	EVENT	REFERENCES
2:31 pm	(Edson Case, IRACT)--------------------(Comm. Gilinsky, NRC:OCM at "H" Street) Correction on hot leg temperatures given at 11:09 am and 1:42 pm. Now reportedly up around 600°F, so they still have that bind in the system. Case explains this as steam bubbles.	IRACT Tapes 01-222-2 and 3
2:35 pm	(F. Brenneman, Conn.)------------------(Sheldon A. Schwartz, NRC:OSP) (Substance of conversation was not noted in Collins Log.).	"Doc" Collins Log, NRC-7905300274
2:41 pm	(Chick Gallina, NRC; Greg Hitz, TMI-2--------(Don Caphton, NRC:Region I) 1. All the Auxiliary Building sumps are full. 2. Greg Hitz, Unit 1 shift supervisor, indicated his tour of auxiliary building identified no visible leaks, just water on the floor around the drains.	Region I Tapes #8, pp. 9-12 and NUREG 0600, p. I-A-94, Item 528
2:45 pm	(Mike Wilbur, IRACT)-------------------(Don Caphton, NRC:Region I) IRACT repeats its request to site for status of licensee's plans to reduce pressure and use DHR system.	NUREG 0600, p. I-A-94, Item 530
2:45 pm	(Thomas Elsasser, NRC:Region I) (Kathleen Merton, Conn. Gov's Office) (Substance of telephone conversation was not noted in Conver or Collins Log.).	Conver Chronology and "Doc" Collins Log, NRC-7905300274
2:45 pm	(Peckham, Rep. Goodling's Off.)--(NRC:OSP) Call from Mr. Peckham in Rep. Goodling's office.	"Doc" Collins Log, NRC-7905300274

TIME	EVENT	REFERENCES
2:53 pm	(Edson Case, IRACT) --------------- (Harold Denton, NRC) 1. It is fair speculation that the core was uncovered. 2. Continuing problem is large delta temperatures: T_h=600, T_c=250. 3. Steam bubble or binding is evidently preventing free circulation. 4. B&W has advised the operator not to run the pumps for fear of blowing out the seals. 5. Case speculates that bubble may have been caused by the operator improperly shutting off the ECCS.	IRACT Tapes, 01-222-9 and 10
2:55 pm	(Bernie Shleien, FDA-BRH) ----------- (Sheldon A. Schwartz, (NRC:OSP) Call from Shleien informing NRC:OSP that FDA had talked to PA BRP (Reilly). PA BRP will take milk samples this evening.	"Doc" Collins Log, NRC-7905300274

TIME	EVENT	REFERENCES
2:57 pm	(Greg Hitz, TMI-2)---------------(Don Caphton, NRC: Region I) 1. Greg Hitz reports current status to be: $T_h = 550^oF$ and $T_c = 200^oF$, with RCS pressure at 450 psig NOTE: I&E Final Reports shows this at 530^oF, 236^oF, and 418 psig respectively. 2. Plan to go to DHR via BWST. Use flow path BWST-DHR-Core.	Region I Tape #9, pp.1 and 2, NUREG 0600, pp. I-A-94 and 95, Items 531 and 532 and Interim Sequence of Events, May 8, 1979
3:00 pm	(Joe Fouchard, IRACT)------------(Comms. Bradford, Kennedy, & Gilinsky, NRC:OCM "H" St.) Discussion of press release: --Rad readings of 1 milliroentgen per hour at one mile from plant. --ECCS cooling reactor. --Discussion of whether this is an "accident"? Will fax proposed press release down to Commissioners for their work on it.	IRACT Tapes, 01-271-1 through 5
3:00 pm	(Greg Hitz, Met Ed.,---(Don Caphton,---(Mike Wilber, and Chick Gallina, NRC) NRC:Region I) IRACT) 1. Licensee plan reported by Greg Hitz, Unit 1 Supervisor to Region I is to initiate low pressure injection followed by normal hot let cooldown using DHR. 2. NRC:HQ requests clarification of 16-18 hour estimate to get on DHR. Told (1) cooling down at 3^oF/hr; (2) that there is an interlock on DHR valves at 430 psig; (3) that plant currently at 450 psig; and (4) that to be conservative they had assumed they would wait to shift over to DHR until they arrived at 400 psig. Thus 18 hr. estimate. NOTE: Actual DHR interlock was 320 psig until 4:30 pm. when it was reset to 385 psig.	Region I Tape #9, pp. 4,5,10, 14-16 and NUREG 0600, p. I-A-95, Items 533, 535, and 536

TIME	EVENT	REFERENCES
3:00 pm	NRC inspector notes that pressurizer level being established and venting of pressurizer has been stopped.	NUREG-0600, p. I-A-95, Item 534
3:00 pm	(IRACT)---------(PA BRP) A proposed NRC press release is cleared with the PA Bureau of Radiation Protection.	Conver Chronology

TIME	EVENT	REFERENCES
3:00 pm	(L. Northam)------------------------------(NRC:OSP) (Pa. State Senate Republican Research Staff) (Substance of conversation was not noted in Collins Log.)	H. Collins Log, NRC-7905300274
3:10 pm	(Chick Gallina)---------------------(Don Caphton) (NRC in TMI-1) (NRC: Region I) Operators authorized to remove respirators in control room - Unit 2. Personnel in Unit 2 control room had to use respirators for approximately 5 hours.	NUREG 0600, p. I-A-96, Item 539
3:10 pm	(Dick Lamison)---------------------------(PA:BRP) (PEMA) Called PA:BRP for sitrep. No change.	PEMA Log, 3/28, p. 7, entry 63
3:12 pm	(Greg Hitz)----------(Don Caphton)--------(Mike Wilber) (TMI-1) (NRC:Region I) (IRACT) Greg Hitz, Unit 1 Shift Supervisor, reports to Region I and Headquarters that: 1. Feed coming from condensate storage. 2. Steaming out of atmospheric reliefs. 3. Reported no radioactivity at these reliefs. 4. Using atmospheric reliefs since have no condenser vacuum. Lost turbine seals after no longer able to get steam from Unit 1. Note: Actually Items 2 and 4 are not correct in this report. The licensee is not now cooling down OTSGs. They have stopped because contamination. (Note: In fact, use of the atmospheric dumps had been terminated for almost two hours at the time of this report.) RCS pressure begins upward trend from about 415 psig. "A" OTSG pressure begins to decay due to vapor lock compression.	NUREG 0600, pp. I-A-96, Items 541 through 543

TIME	EVENT	REFERENCES
3:15 pm	(Bernie Weiss, IRACT)-------------------(R. Bores, NRC:Region I)	R. Bores Contacts, NRC-7906130483
	Weiss requesting information re what radiation people are asking AMS to do? Answer: Perform quick, preliminary survey to see if offsite radiation/plume is seen.	
	NRC:Region I does not want AMS data van at this time. Van can be brought up if survey results warrant it.	
3:15 pm	(Greg Hitz, TMI-1)----(Don Caphton, NRC:Region I)-----(Mike Wilber, IRACT)	NUREG 0600, p. I-A-97, Item 545
	Suction from BWST, 5A and B, now open, MUP running, supplying water to RCS via 16 valves which are used to throttle flow when the pumps are running in the HPI mode.	
3:20 pm	(J. Bunchuck, Environmental Policy Center)--------------------(NRC:OSP)	H. Collins Log, NRC-7905300274
	(Substance of conversation was not noted in H. Collins Log.).	

TIME	EVENT	REFERENCES
3:25 pm	(A. Pasternak----------------------(Sheldon A. Schwartz NRC:OCA) NRC:OSP) (Substance of conversation was not noted in Collins Log.)	"Doc" Collins Log, NRC-7905300274
3:28 pm	(Greg Hitz----(Don Caphton---------(Mike Wilber TMI) NRC:REGION I) IRACT) Only one 16 valve open. Pressurizer level 175". Periodically bumping electromatic. Worried continued bumping of relief valve might cause it to fail. Failure mode uncertain. Not using OTSG cooling at all at this point.	NUREG 0600, p. I-A-98, Item 550 and Region I Tape #10, pp. 2-5
3:30 pm	(R. Bores-------------------------(Margaret Reilly NRC:REGION I) PA BRP) Reilly is becoming less convinced of any off-site airborne problem. Discussed updates in previous information.	R. Bores Contacts, NRC-7906130483
3:30 pm	(J. Cox-----------------------------(NRC:OSP) Conn. Pub. Utilities Control Auth.) (Substance of conversation was not noted in Collins Log)	"Doc" Collins Log, NRC-7905300274

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TIME	EVENT	REFERENCES
3:32 pm	(TMI)-----------------------------(NRC:REGION I) Region I Incident Messageform states pressurizer level 166" and periodically cycling EMOV. Information coming from TMI-I Control Room with potential significant time delay.	NUREG-0600,P.I-A-98, Item 554
3:34 pm	(Chick Gallina-------(Don Caphton-----(Mike Wilber NRC at TMI-I) NRC:REGION I) IRACT) North Gate 30mR/hr. When asked for confirmation, Gallina came back with a reading of 70 mR/hr.	I&E, Interim Sequence of Events 5/8 Region I tape #10,pp.8,9,11.
3:35 pm	(Chairman Hendrie---------(Comm'r Gilinsky NRC Chairman) NRC Comm'r) Chairman Hendrie calls for Gilinsky who is out of his office.	Gilinsky Log, NRC 7905110206
3:43 pm	(Don Caphton-----------------(Mike Wilber NRC: REGION I) NRC HQ IRACT) Reported readings from TMI-2: RBP = zero psig. Pzr Level 170". Pzr Temp. 460°F. Pzr Pressure 450 psig. NOTE: Pressurizer readings reported here vary from Utility typerwriter.	NUREG-0600,P.I-A-99, Items 559,560. Region I tape #10,pp.13,14.
3:45 pm	PN 79-67 First formal preliminary notification report distributed by NRC.	Conver Chron (4-9)

TIME	EVENT	REFERENCES
3:45 pm	(Alice Dolezal--------------------(NRC:OSP) MN BRH)	"Doc" Collins Log, NRC 7905300274
	(Substance of conversation was not noted in Collins Log.)	
3:50 pm	(Gene Fischer---------------------(Elsasser, SLO NJ BRH) NRC:Region I)	SLO contacts, NRC 7906130483
	(Substance of conversation was not noted in SLO contacts)	
3:52 pm	(Dick Lamison---------------------(PA BRP) PEMA)	PEMA Log 3/28, p. 8, entry 64
	Call from PEMA to BRP for sitrep. No change	
3:59 pm	(Greg Hitz----(Don Caphton)--------(Victor Stello, Met Ed at (NRC:Region I) Mike Wilbur TMI-1) (NRC HQ IRACT)	NUREG-0600, p. I-A-99, Item 563
	NRC senior manager, Victor Stello, asks Greg Hitz in TMI-1 to communicate NRC concern that pressurizer level indication does not preclude bubble in core, that temperature readings indicating superheat may be real and implying core is uncovered. Would then need to put water into core and get core level back up. Question is asked if licensee has talked to B&W, because B&W had been trying to get in touch with the licensee and had the same concern.	

TIME	EVENT	REFERENCES
4:00 pm	(NRC:REG I)------------------------(IRACT) HPI alignments still heavily biased to "C" injection leg. Operators believed natural circulation did exist at this time. Rate of BWST level loss had been reduced, but still concerned would eventually run out of clean water.	NUREG-0600, p. I-A-100, Item 564
4:00 pm	(J.C. Deddens B&W, Lynchburg)----------------------(Klingaman Met Ed/GPU) Deddens of B&W asked Klingaman if the licensee would establish a communications link between the site and Mr. Spangler of B&W Lynchburg.	Subcommittee Staff interview with James Floyd, August 23, 1979, pp. 16, 17.
	(Leland Rogers B&W Employee at TMI-2 site)----(F. Greg Schaedel B&W Employee at Harrisburg res.)--(B. Karrasch & Task Force B&W, Lynchburg)	B&W Power Generation Group, G.K. Wandling, 3/29/79.
	(TMI-2)----(Richard Hutchinson TMI-I)---(James Floyd Met Ed Employee at B&W, Lynchburg) A. Womack of B&W,Lynchburg suggested 500 gpm (at least 400 gpm) HPI flow be established immediately. These recommendations were passed through Floyd and through Schaedel. Rogers relayed further plant parameters to B&W and various further recommendations were relayed back to site management. B&W was trying to identify considerations for running RCP in the "B" loop (DH drop line side.)	NUREG-0600, p. I-A-100, Items 565A and 566

TIME	EVENT	REFERENCES
4:00 pm	Craig Williamson and Oran Henderson reported to Lt. Gov's office for NRC briefing. Meeting had been underway for some time when Williamson and Henderson arrived. Rep. Bill DeWeese also in attendance.	PEMA log, 3/28,P 8, entry 65
4:00 pm	(R.Bores ------------------(DOE:HQ/EOC) NRC:REG.I) Trying to locate AMS crew. Got new number for contacting Hahn at Capital City Airport.	R.Bores contacts, NRC7906130483
4:00 pm	(P.Paul-------------------(Elsasser,SLO VT) NRC:REG.I) (Substance of conversation was not noted in SLO contact)	SLO contact, NRC 7906130483
	PA State Police Dept. liaison at TMI directed York Station to dispatch patrol units into the Goldsboro area for general protection, psychological reassurance of the general public, to provide a communications link and to take radiation readings in the area. Readings, using a C.D.V. 700 survey meter, ranged from .01 to .03 mR/HR during this day. The patrol vehicle's PA System was utilized to dispel evacuation rumors alleged to be circulating in that area.	PA State Police Chron.

TIME	EVENT	REFERENCES
4:05 pm	(R. Bores, NRC:REG I) ---------- (Herb Hahn, AMS)	R. Bores Contacts, NRC-7906130483
	AMS helicopter up for 35-40 minutes.	
	Flight started at the perimeter of island, across the river and progressing North.	
	Data Van will be moved up per DOE management decision. Will be at TMI 3/29 a.m.	
	RAP air samples taken at airport showed only noble gas concentrations.	
	Some newspaper interest was shown in AMS aircraft.	
4:05 pm	(Bill Dornsife, PA BRP) ---------- (J. Fouchard, OSP)	SP Logs, NRC 79060150
	PA BRP called about NRC Press Release. J. Fouchard (OSP) of NRC talked to BRP.	
4:10 pm	(Greg Hitz, Met Ed at TMI-2) --- (Rick Keiming, NRC:REG I) --- (Mike Wilbur, IRACT)	NUREG-0600, p. I-A-101, Items 568 Region I tape #11, pp. 6-9
	Reported in-core temperatures unavailable. Supervisor Hitz, reports to NRC they are all printing question marks which means either the computer point or the sensor is malfunctioning. The supervisor did not indicate that the same result occurs when the temperature exceeds the range of the software calibration for those points. This is the first thermocouple data or comments to the NRC. First request had been made at approximately 12:20 p.m. States core flood tanks floating on core, on $T_h = 590^{o}F$, other "pegged" and that staff is convinced there is no boiling in the core.	

TIME	EVENT	REFERENCES
4:10 pm	(Greg Hitz-----(Rick Keimig-----(Sam Bryan Met Ed at NRC:REG I) IRACT) TMI-I) Hitz reports that licensee is NOT planning to use electromatic to blowdown because could fail open with resulting rapid cooldown that could overstress RCS. Bryan reiterates IRACT concern about covering the core.	NUREG-0600, p. I-A-101, Items 569 Region I tape #11, p. 13
4:13 pm	(Nat. Goldhaber, Adm. Asst.--------(Comm'r Gilinsky Lt. Gov. Scranton's Office) NRC Comm'r) (Substance of conversation was not noted in Gilinsky Office Log)	Gilinsky Office Log, NRC 7905110206
4:14 pm	(Victor Stello--------------------(Darrell Eisenhut IRACT) NRR, Phillips Bdg.) Stello--"I want somebody to get on the phone with B&W and do the best they can in understanding that anamolous temperature." Eisenhut-"They are...B&W just said they don't have enough info. to straighten it out either... They've hunted all over to find B&W's hot shot heat transfer guy." Need to think of all the possible ways to get the steam bubble out of the core.	IRACT Tapes, 01-225-12
4:15 pm	(R. Bores-------------------------(Bob Shipman NRC:REG.I) AMS Scientist) Technical Rad information and meteorological data as well as geographical information.	R. Bores contact, NRC-7906130483

TIME	EVENT	REFERENCES
4:15 pm	NRC:HQ asks if licensee has considered blowing the system down, and Hitz responds that it had been discussed and rejected. NRC:HQ requests it be considered again, stressing this was a request to consider it, not an order to do so. Approximately 5 minutes later Hitz returned stating the licensee thought it was a good idea and decided to do it. NRC:HQ then relayed their concern about valving out the CFT's before the blowdown to prevent nitrogen from getting into the vessel.	NUREG-0600, p. I-A-102, Item 572
4:25 pm	(F. Brenneman---------------------(Elsasser Conn. Energy Office) NRC:REGION I) (Substance of conversation was not noted in SLO Contacts.)	SLO Contact, NRC 7906130483
4:25 pm	(Chairman Hendrie------------------(Comm'r Gilinsky NRC Chairman) NRC Comm'r) (Substance of conversation was not noted in Gilinsky Office Log.)	Gilinsky Office Log, NRC-7905110206
4:30 pm	Gary Miller Station Manager and George Kunder Superintendent-Technical Support return from Lt. Governor's Office. NOTE: Review of IRACT tapes and NRC:REG. I tapes shows that NRC was not aware that the Station Manager and the Superintendent-Technical Support had been away from the site for the last 2½ hours.	NUREG-0600, p. I-A-103, Item 577

TIME	EVENT	REFERENCES
4:30 pm	J.G. Herbein returns to TMI Observation Center to obtain an update of the plant status. Herbein remains at the TMI Observation Center until approximately 2:00 3/29/79 to organize on Operation's Watch which will monitor and record all communications and record all significant plant conditions. During these hours, he meets with several people including Richard Vollmer (NRC).	Herbein sequence, NRC-7906140462
4:30 pm	(Chick Gallina--(Rick Keimig--(Sam Bryan TMI-I) NRC:REG.I) IRACT) NRC inspector reported TMI-I control room is back in masks.	NUREG-0600,P.I-A-102,Item 575 Region I tape #12,p.4.
4:30 pm	(Comm'r Gilinsky-----------(Rep. Morris Udall NRC Comm'r) Arizona Congressman) (Substance of conversation was not noted in Gilinsky Log.)	Gilinsky Office Log. NRC-7905110206.
4:30 pm—5:30 pm	Lt. Governor's Press Conference: Press release: "This situation is more complex than the company first led us to believe. We are taking tests. And at this point, we believe there is still no danger to public health. "Metropolitan Edison has given you and us conflicting information. We just concluded a meeting with company officials and hope this briefing will clear up your questions.	PA Media Center Transcript of 4:30 pm Press Conf. Part II.

TIME	EVENT	REFERENCES
4:30 pm Cont.	"There has been a release of radioactivity into the environment, the magnitude of the release is still being determined, but there is no evidence yet that it has resulted in the presence of dangerous levels"	
	"The company has informed us that from about 11 am until about 1:30 pm, Three Mile Island discharged into the air, steam that contained detectable amounts of radiation. The discharge was a part of the normal reactor emergency cooling process. It was done to relieve potentially dangerous pressure in the reactor chamber.	
	" Because of an apparent leak in the primary cooling system, radioactive material was discharged into the air along with the steam.	
	" The PA Department of Environmental Resources (DER) was not notified of the release until about the time that it was halted.	
	" The Company has said that further discharges may be necessary and has promised to notify us in that event.... "	
	Press Questions: Press was briefed on contamination of employees, wind directions and off-site contamination, the amounts and types of radiation releases, the Lt. Gov. said there was no need to evacuate people but that he was "disappointed" with Met. Ed. Dornsife explained failed fuel as a breakdown of the zirconium cladding around the fuel and said the plant would be shut down for a matter of weeks at least, depending upon the amount of damage.	

TIME	EVENT	REFERENCES
4:30 pm	(J.C. Higgins----(Rick Keimig------(Mike Wilber TMI-2) NRC:REG. I) IRACT)	NUREG-0600, p. I-A-103 and 104, Item 580 and 581
	NRC inspector on line in TMI-2 Control Room reports:	Region I tape #12, pp. 5-7

1. Originally had bubble in both loops
2. Have collapsed bubble in "A" loop
3. Had bubble in pressurizer but lost it
4. Floating Flood Tanks on core and got some injection
5. Normal letdown at 120 gpm
6. Makeup pumps feeding from BWST
7. B&W calculations indicate 120 gpm insufficient to remove core decay heat
8. Operating electromatic relief and (Pressurizer Vent Valves) periodically to remove additional heat
9. Plan is to establish vacuum in condensor, steam A OTSG and remove core heat through natural circulation

NOTE: Inspector reported to NRC:Region I licensee believes "A" loop is solid since: original T_h (A&B loops) approximately 700° with T_c approximately 225°; directed MU into "A" loop to collapse steam bubble, and its T_h dropped quite rapidly to approximately 575°F. At the same time PZR level dropped considerably and came back on scale.

TIME	EVENT	REFERENCES
4:31 pm	(Victor Stello--------------------(Darrell Eisenhut IRACT) NRR, in Phillips Bdg.)	IRACT Tapes, 01-226-3 and 4

Eisenhut reports that they are talking to Don Roy of B&W and the B&W people doing their set of calculations have come up with different numbers so that they don't see any super heated steam.

Stello reports that the pressure in the primary system is 450 psi, with the hot leg temperature now at 550°F, pegged at one time all the way up to 620°F. Stello argues there is no way one can get those numbers without having super heat.

TIME	EVENT	REFERENCES
4:32 pm	(H. Otto, MD State) ---------- (Elsasser, NRC:REG. I) (Substance of conversation was not noted in SLO Contact.)	SLO Contact, NRC-7906130483
4:35 pm	(Victor Stello, Lee Gossick, John Davis IRACT) ---------- (Comm'r Gilinsky OCM, "H" Street) Watching T_h all day and it is higher than it should be. They've got to get rid of bubbles, or whatever they've got. If superheated, need to get more water into the core. Core is uncovered when steam bubble is at the top of the core. Licensee is now planning to open pressurizer valve and blow down system. But this is most critical and difficult part of the entire operation. e.g. accumulators have nitrogen in them and since they have no LOCA, cannot work as designed.	IRACT Tapes, 01-226-6 thru 8
4:35 pm	(James Boranski, NY State) ---------- (SLO NRC:REG. I) (Substance of conversation was not noted in SLO Contact.)	SLO Contacts, NRC-7906130483
4:40 pm	(TMI-2)---(F. Greg Schaedel, B&W Employee at Harrisburg residence)---(B. Karrasch & Task Force, B&W, Lynchburg)	NUREG-0600, p. I-A-104, Item 583-A
	B&W informed by site of plant status, recognized now to represent superheat conditions by B&W. $T_h = 550^{o}F$ and 450 psig.	B&W Power Generation Group, G.W. Wandling, 3/29/79

TIME	EVENT	REFERENCES
4:42 pm	(Bernie Weiss-------(Clark W. Heath IRACT) Center for Disease Control)	IRACT Tapes, 01-514-3.
	Weiss told Heath that a loss of coolant water, exposure of the core, and keeping the core covered was never a problem at TMI-2.	
4:43 pm	(Don Harmeson------------(NRC:REG.I) DE Health Dept.)	SLO Contacts, NRC-7906130483.
	(Substance of conversation was not noted in SLO Contacts.)	
4:45 pm	(Lee Gossick--------(Comm'r Victor Gilinsky John Davis IRACT) OCM,"H" Steet)	IRACT Tapes, 01-226-14 and 15.
	The Executive Management Team (EMT) made it very clear to Commissioner what their posture was vis-a-vis the licensee.	
	Namely, that the licensee is in charge, and all the NRC can do is ask questions and offer suggestions. The licensee is on top of the situation, and the EMT of NRC is only on the other end of a telephone line.	
4:45 pm	(J.C.Higgins-----(Rick Keimig----(Mike Wilber TMI-2) NRC:REG.I) IRACT)	Region I tape #12,pp7-9 I&E Interim Sequence of Events, May 8, 1979.
	A loop T_h reported approximately 580°F. (IRACT) Reg:I inspector reports conditions are: pressure 450-500 psg continuing normal letdown (120 gpm), and EMOV opening intermittenly. Lowest pressure reached 450 psig during blowdown and it just "hung" at 450 psig. Nothing tried so far could drive it lower.	
	Utility typer and Plant Strip Chart indicates RCS pressure is actually 620 psig at this time.	
	NOTE: Report of pressure hanging up at 450 psig may be a transcription error of 415 psig, the actual level at which pressure stabilized during depressurization.	

TIME	EVENT	REFERENCES
4:45 pm	(F.Greg Schaedel-----(B.Karrasch & Task Force B&W employee at B&W, Lynchburg) Harrisburg residence) Schaedel passes along the latest information from the site by way of Leland Rogers. The task force recommended to Schaedel that the HPI be increased immediately, stop the let down, and go to sub cooled conditions in RCS.	NUREG-0600,P.I-A.104,Item 583-A. B&W Power Generation Goup, G.K. Wandling, 3/29/79
4:45 pm	(Edson Case-------------(Walter G. Martin IRACT Bethesda) NRC:REGION I) Case reports that it is unclear whether part of the core is getting water with consequent overheating and popped cladding, with resulting fission products in the primary system.	IRACT Tapes, 01-034-18.
4:50 pm	(J.C.Higgins---(Rick Keimig-----(Mike Wilber,Norm Moseley NRC AT TMI-2) NRC:REGION I) IRACT) Reported natural circulation cooldown being conducted using "A" OTSG. Working on getting main condenser vacuum. Until can get temperature and pressure reduced further, can't go on decay heat removal.	NUREG-0600,P.I-A-105,Item 586. Region I tape #12,pp 14,15
4:55 pm	(D. Lavine-------(NRC:OSP) Conn) (Substance of conversation was not noted in Collings Log.)	"Doc" Collin Log, NRC-7905300274
4:56 pm	(J.C. Higgins--(Rick Keimig--(Norman Moseley NRC at TMI-2) NRC:REGION I) IRACT) NRC inspector reports the following: (1) licensee concerned that current cooldown process is too slow and believe will be faster steaming OTSG. (2) licensee	NUREG-0600,P.I-A-105 and 106, Items 587. Region I Tape #12,pp.15-21

TIME	EVENT	REFERENCES
4:56 pm Cont.	working to get rid of bubbles in loops, establish bubble in pressurizer and go on natural circulation (3) licensee concerned for futher use of electromatic since water dumps to floor, and with sources of clean water being exhausted, would be forced to use dirty sump water for recirculation. (4) licensee concluded core was covered. Discussed and rejected further blowdown since would ultimately entail recirculation of sump water, greatly increasing magnitude of cleanup. Discussed and rejected repressurization to collapse all bubbles. Latter discussion included input from B&W. (5) Have regained some pressurizer heaters. (6) Plan to draw condenser vacuum using TMI-2 Mechanical Vacuum Pumps and TMI-I steam for Turbine Gland Seal. Having problems because of high radiation and contamination levels, restricting free movement through plant.	
	Final report notes that #4 rejection of repressurization, "appears to be contrary to recommendations of B&W, of which the licensee is aware."	
	Higgins said that Miller, Arnold, et.al. are fairly confident that the core was covered, although they could not give assurance of 100%. NOTE: Higgins statement, insofar as it relates to Mr. Arnold, is in conflict with statements made by Mr. Arnold to Subcommittee staff.	
5:00 pm	Press Release PR-79-65	
5:05 pm	(J.C. Higgins--(Rick Keimig--(Mike Wilber NRC at TMI-2) NRC: REG.I) IRACT)	NUREG-0600,P.I-A-107, Item 593.
	Operators starting to draw vacuum. Staff remains confident no bubble in "A" loop. RCS pressure 650 psig and PZR level 400" decreasing. Continuing normal letdown and makeup. T_{ha} approximately 530°F and dropping T_{hb} approximately 700°F.	Region I tape #12,pp25-27

TIME	EVENT	REFERENCES
5:15 pm	NRC mobile lab arrives at site, includes Phil Stohr, Envir. S.C. Jim Kottan, FFMS Specialist	Conver Chron (4-9) and Memo Bob Martin to Bob Marsh (4-20) (7905230088)
5:15 pm	(Edson Case, John Davis---(Sen. Gary Hart IRACT) U.S. SENATOR, D-CO. Chariman, Sub-Comm. on Nuclear Regulation) EMT gave Sen. Hart brief run-down on status of the reactor, brief scenario of events, and current radiation readings.	IRACT Tapes, 01-227-8 thru 17.
5:23 pm	(Jim Higgins--(Rick Keimig--(Kermit Whitt TMI-2) NRC:REG.I) IRACT) Reported by Region I inspector: (1) 15" vacuum in condenser (2) just starting to steam now (3) RCS approximately 650 psig T_{hb} 650-700°F T_{ha} 570-580°F $T_{cb\&a}$ 225°F (4) Electromatic Relief indicates closed although they are still periodically cycling it.	IRACT Tapes 01-083-10 thru 12 Region I tape #13,P.4
5:25 pm	("Doc" Collins--------------(Tom Gerusky NRC:OSP) PA BRP) Called for Gerusky. He was not in but OSP left word for Gerusky to return call.	OSP Log, NRC 7906060150
5:30 pm	(R. Bores----(Commander Strommen NRC: REG.I) DOE:HQ/EOC) Filled DOE:HQ in on technical rad and weather information.	R.Bores Contact, NRC 7906130483

TIME	EVENT	REFERENCES
5:30 pm	(Comm'r Gilinsky--------(Robert Kleiman) NRC Comm'r) (Substance of conversation was not noted in Gilinsky Office Log.)	Gilinsky Office Log, NRC 7905110206
5:40 pm	(Jim Higgins--(Don Caphton-(Kermit Whitt TMI-2) NRC:REG.I) IRACT) A OTSG valve not opening - not steaming. Bleed valve for generator to condenser. Start investigating. Indicator must be in error. A OTSG pressure had dropped 30psi from 144 psig, but now is slowly rising.	IRACT Tapes 01-084-4 Region I tape #13,p.11
5:40 pm	(Bernie Weiss----(White House Situation Room) IRACT Bethesda) During the course of the briefing of the White House Situation Room, Mr. Weiss stated that "....there was never a problem with regard to keeping the core covered..."	IRACT Tapes,01-036-8.
5:45 pm	(Ray Smith--(Don Haverkamp---(Kermit Whitt NRC at TMI-2) NRC:REG.I) IRACT) Reactor building pressure is -0.2 psig.	NUREG-0600-P.I-A-110, Item 608 Region I tape #13,p.15
5:45 pm	(Herb Hahn-----(R. Bores DOE AMS) NRC:REG.I) Hahn inquiry- (a) Was steam being dumped from TMI? (b) Will rate of release be increased? Bores response- Don't know. Hahn inquiry- Will NRC be requesting full survey of TMI tomorrow (3-29)? Bores response- Has not heard anthing. Probably not. May do more plume work.	R.Bores Contacts, NRC 7906130483

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TIME	EVENT	REFERENCE
5:45 pm Cont.	Hahn and crew at Mechanicsburg Cross Gate Inn.	
5:50 pm	(J.C. Higgins---(Don Haverkamp-----(Kermit Whitt NRC at TMI-2) NRC:REG. I) NRC HQ IRACT)	NUREG-0600, p. I-A-110, Items 610 and 611
	A OTSG started steaming using turbine bypass valves to condenser. Indication of level change in steam generator and indication of feedwater flow. Not now wearing respirators in TMI-2 Control Room.	Region I tape #13, pp. 4,5
5:52 pm	(Comm'r Gilinsky-------------------(Paul Leventhal NRC Comm'r) Subcommittee on Nuclear Regulation)	Gilinsky Office Log NRC-7905110206
	(Substance of conversation was not noted in Gilinsky Log)	
5:55 pm	(Edson Case------------------------(Stan Benjamin IRACT, Bethesda) Associated Press)	IRACT Tapes, 01-036-13 thru 14
	Met Ed may have had some cladding damage but no idea how extensive it may have been.	
6:00 pm	Rick Keimig, OPS S.C. Fourth NRC:REG. I vehicle leaving for site.	Conver Chron (4-9) Memo Bob Martin to Bob March (4-20) NRC-7905230088
6:00 to 7:00 pm	(R. Bores--------------------------(Herb Hahn NRC:REG. I) DOE AMS)	R. Bores Contact NRC-7906130483
	Tried unsuccessfully to recontact AMS group at airport and hotel to request another flight this evening.	

TIME	EVENT	REFERENCES
6:00 pm	(Jim Higgins--(Don Haverkamp--(Kermit Whitt TMI-2) NRC:REG.I) IRACT) NRC Region I inspector, Higgins, reports BWST 23' NRC Region I inspector reports his understanding that: 1. Either licensee staff or senior management have concern whether core covered or not. (NRC notes show VP-Generation has directed repressurization of RCS). 2. The plan has changed now. Licensee plans to continue cooldown by steaming. "A" OTSG; T_h now 548°F, T_c now 446°F. They increased makeup to 480 gpm with letdown at 40 gpm, letting pressure increase and plan to take plant solid at approximately 2000 psig to collapse all bubbles. No longer concerned with remaining volume of clean water since going solid. NOTE: This information appears to lag actual decision about 1/2 hour.	IRACT Tapes, 01-085-2. Region I tape #14,pp 7-10, and NUREG-0600,p.I-A-111, Items 615 and 616.
6:00 pm	(PEMA)---------------------------(PA BRP) Called BRP for sitrep no change	PEMA Log 3/28,P.8, entry 67
6:03 pm	(Lee V. Gossick, John Davis,----------------(Comm'r Harold Denton, & Edson Case) NRC:OCM) IRACT) Since the operator has decided to restore natural circulation, they are beginning to see a smaller delta temperature across the core. Therefore, reported temperatures are coming together: T_h=548°F. and T_c=446°F.	IRACT Tapes, 01-229-7 thru 9.
6:10 pm	(Bob Arnold------------------(B&W, Lynchburg) GPU V.P.) Arnold informed B&W that since 4:25 pm, the HPI had been maintained at 400 gpm.	B&W Power Generation Group, G.K. Wandling, 3/29/79.

TIME	EVENT	REFERENCES
6:10 pm	(Jim Higgins----------(Kermit Whitt TMI-2) NRC HQ IRACT) Higgins reports to Whitt that "B" OTSG hot leg still appears to have bubble with temperatures in the range of 650°F to 700°F. States that B&W people are taking thermocouple readings on the back panel and they have obtained 700°F to 750°F readings.	NUREG-0600 , p I-A-112, Item 620 Region I tape#14,p.17
6:15 pm	("Doc" Collins-----------(Tom Gerusky NRC:OSP) PA BRP) Called PA BRP about AMS data. Gov. is being kept informed.	SP Logs, NRC 7906060150
6:17 pm	(Jim Higgins--(Don Havekkamp--(Kermit Whitt NRC at TMI-2) NRC:REG.I) IRACT) Higgins reports: (A) Continuing cooldown of "A" OTSG. The (delta) T for A loop is increasing. T_{ha} = 555 T_{hb} 650-700 T_{ca} 300° T_{cb} 200°. (I&E notes that the T_{hb} is old data "from last time B&W manually read back panel Thermocouple or RTD parameters.) (B) Makeup at 450 gpm. Pressure 1100 psig increasing, Pressurizer full but pressure increase indicates bubble still exists somewhere in system. (C) Using condensate pumps, not emergency feed, for OTSG level control. I&E notes: appears time lag in information flows to NRC is much shorter for data than it is for change in management plans. "A lot of people" at IRACT reportedly thought that at 1100 psi, 555°F is saturation temperature. Therefore, these people think there cannot be natural circulation through the primary system.	IRACT Tapes 01-085-7 thru 9 Region I tape #15,pp 17-19, and I&E Intervim Sequence of Events May 8, 1979.

TIME	EVENT	REFERENCES
6:20 pm	(R. Bores---------(Tom Gerusky NRC:REG.I) PA BRP) Gerusky just returned from Gov's press conf: has been out of office for 3 hours. RAP teams are under direction of Gerusky/Reilly Bores mentioned that Stohr could assist Gerusky with RAP direction if needed. Stohr and Van will be at TMI shortly.	R. Bores Contacts, NRC-790613048
6:29 pm	(Jim Higgins--(Don Haverkamp--(Kermit Whitt NRC at TMI-2) NRC: REG.I) IRACT) Higgins reports: (1) OTSG level approximately 90% (2) 27" vacuum in condenser (3) Main steam bypass valve indicates 30% open.	IRACT Tapes 01-085-10 Region I tape #15, pp. 1,2 and I&E Interim Sequence of Events. May 8, 1979.
6:34 pm	(Leland Rogers--------(B. Karrasch B&W TMI) B&W Lynchburg) Leland Rogers, B&W site operations manager, contacts B&W at Lynchburg who indicate that they had also come to conclusion that licensee should repressurize and start a RCP. Task force recommended to Rogers that the IA RCP be given a 5 second "bump" then stop and let RCS parameters stabilize.	NUREG-0600, p. I-A-114, Item 628. B&W Power Generation Group G.K. Wandling, 3/29/29.
6:34 pm	(Jim Higgins---(Don Haverkamp---(Kermit Whitt NRC at TMI 2) NRC:REG.I) IRACT) Higgins, NRC Region I inspector, reports : (1) still steaming "A" OTSG but indications not getting much natural circulation ("A" OTSG pressure essentially zero now.) (2) T_{ha} approximately 570°F, T_{ca} approximately 220°F; one incore T/C reads 570°, indicating T_h may be accurate; other T/Cs can not be read. (This	NUREG-0600, p.I-A-114, Item 627 IRACT Tapes 01-086-2 thru 5. Region I tape #15, p.4

TIME	EVENT	REFERENCES
6:34 pm Cont.	apparently refers to the "?" output for the T/C's indicating they are outside the range of the computer software.)	
6:35 pm	(J.C. Higgins--(Don Haverkamp--(Whitt NRC at TMI-2) NRC:REG.I) IRACT) Higgins NRC Region I inspector reports: (1) RCS pressure 1800 psig increasing (2) indication some bubbles may be collapsing since have seen some temperature changes. (3) T_{ha}=570°, T_{ca}=220°	NUREG-0600, P. I-A-114, Item 629. Region I tape #15,p.5
6:35 pm	TMI-2 control room to B&W open line established. (Will be maintained through rest of sequence.)	NUREG-0600, P. I-A-114, Item 629A
6:45 pm	(J.C. Higgins--(Don Haverkamp--(Kermit Whitt NRC at TMI-2) NRC:REG.I) IRACT) Higgins, NRC Region I inspector, reports: (1) Pressure approximately 2300 psig (2) Appears still have bubble in B loop (3) Makeup and letdown at 150 gpm (4) T_{ha} 560°, T_{ca} 320 (5) steaming approximately 100,000 #/hr based on constant OTSG level and rate of feeding (6) level in "A" OTSG at approximately 93%. (7) A steam generator ~50psi.	NUREG-0600,P.I-A-116 and 117, Items 638,642. Region I tape #15, pp 10-13
6:50 pm	(R. Bores-----------(Todd Jackson) NRC:REG.I) Stohr wants to meet Jackson at Visitor's Center tomorrow.	R. Bores Contacts, NRC 7906130483
6:55 pm	(Mike Pawlowski--------(Elsasser, SLO DCPA:II) NRC:REG.I) (Substance of conversation was not noted in SLO Contacts)	SLO Contacts, NRC 7906130483

TIME	EVENT	REFERENCES
6:56 pm	(PEMA)------------------------------(PA BRP) Called BRP for sitrep: no change	PEMA Log 3/28, p. 8, entry 68
6:55 pm	(Jim Higgins-----(Don Caphton-----(Kermit Whitt NRC at TMI-2) NRC:REG. I) IRACT) Caphton asks Higgins if licensee has considered running an RCP.Higgins states that those preparations are underway but they are having trouble with the oil lift pumps. Whitt asks if they considered that they might have a gas bubble rather than a steam bubble in the "B" loop. Concerned it could be nitrogen, xenon, or hydrogen. Higgins agrees to pass concern along. This concern apparently developed from evidence that only the "A" leg bubble quenched while the "B" loop remained superheated. Shortly thereafter, Higgins reported back that there was nothing licensee could do about it. There was no way to vent that leg, and the only way to sweep it out, whether it be steam or gas, would be to use the pumps. NOTE: NUREG places this at 6:45 p.m.	NUREG-0600, p. I-A-115, Item 633 Region I tape #15, pp. 14 thru tape #16, p. 4 IRACT tapes 01-086-11 thru 01-087-5
7:00 pm	(J.C. Higgins----(Don Caphton----(Kermit Whitt NRC at TMI-2) NRC:REG. I) IRACT) 1. Higgins reports: T_h dropping slowly, T_c rising slowly. Licensee believes getting some natural circulation flow but still very little. 2. Licensee has considered starting RCP but unable to do so since has lost power to RCP oil pumps. Having problems restoring power to oil pump bus because of high radiation and contamination levels. B&W in Lynchburg has been contacted and is doing calculations for TMI. Proceeding to attempt start of a RCP. Inspector reports $T_{ha} = 560^o$, $T_{ca} = 360$, $T_{bn} = 220$, T_{hb} off scale high, 2300 psig.	NUREG-0600, p. I-A-117, Item 643 and 645 Region I tape #15, p. 16 thru tape #16, p. 4

TIME	EVENT	REFERENCES
7:04 pm	(J.C. Higgins----(Don Caphton----(Kermit Whitt NRC at TMI-2) NRC:REG.I) IRACT)	NUREG-0600
	HQ NRC were of opinion might have to bump RCP to clear candy canes of voids to allow full natural circulation, since trend of parameters strongly suggest little or no natural circulation is occurring.	I&E Interim Sequence of Events, May 8, 1979
7:05 pm	(Helen Haars-----------------------(Elsasser, SLO State of WA BRH) NRC:REG.I)	SLO Contacts, NRC-7906130483
	(Substance of conversation was not noted in SLO Contact.)	
7:05 pm	("Doc" Collins---------------------(Tom Gerusky NRC:OSP) PA BRP)	OSP Log, NRC-790060150
	Collins called Gerusky who is getting all data from RAP--Milk measurements will come later after evening milking--ground observations and AMS estimations- 50 mR/hr upstream and between one and 10 mR/hr in Middletown.	
7:05 pm	(PEMA)-----------------------------(Kevin Molloy Dauphin Co. EMA)	PEMA Log 3/28, p. 8 entry 69
	Notified Molloy--explained cooling process at TMI. Molloy stated he would be available in EOC.	
7:10 pm	(R. Bores--------------------------(Herb Hahn NRC:REG. I) DOE AMS)	R. Bores Contacts NRC-7906130483
	Can AMS fly at night? Answer -- Yes, per Jack Watson, pilot.	
	Request for night flight to redefine the plume.	

TIME	EVENT	REFERENCES
7:10 pm	(Walt Baunack----(Don Caphton----(Jim Gagliardo NRC at TMI-2) NRC:REG.I) IRACT)	NUREG-0600, p. I-A-118, Item 648
	Baunack, NRC:REG.I inspector, reports T_{ha} 557°, T_{ca} 380°, T_{cb} 240°, 2300 psig. OTSG "B" 180 psig. OTSG "A" 20 psig. Baunack had arrived in Unit 2 control room around 3:00 p.m. However, his first temperature and pressure entries were recorded at 7:00 p.m.	Region I tape #16, pp. 10, 11 I&E Interview, Tape No. 146, pp. 5,6
7:14 pm	(Dennis Hamsher--------------------(Blaisdell Goldsboro E.M. Coordinator) PEMA)	PEMA Log 3/28, p. 8, entry 70
	Call from Hamsher requesting latest TMI status.	
7:15 pm	(Walt Baunack----(Don Caphton----(Jim Gagliardo NRC at TMI-2 NRC:REG.I) IRACT)	NUREG-0600, p. I-A-119, Item 650
	1. Baunack report: Heaters now on in an attempt to draw a bubble, but currently pressurizer level is off-scale high.	Region I tape #16, p. 11
	2. Since no power to A.C. RCP oil pump, trying to start D.C. RCP oil pumps.	
7:15 pm	(Craig Williamson------------------(Dr. Washington, PEMA) Dep. Sec., PA. BRP)	PEMA Log 3/28, p. 8, entry 71
	Deputy Dir. (PEMA) called Dr. Washington and requested that he and PA BRP evaluate situation and furnish release so as to enable both organizations to inform public of radiation impact on pregnancies.	
7:17 pm	(PEMA)--------------------------- (Cumberland Co. EMA)	PEMA Log 3/28, p. 8, entry 72
	Provided sitrep to Cumberland Co. coordinator.	

TIME	EVENT	REFERENCES
7:20 pm	(Ray Smith, J.C.-----(Don Caphton-----(Jim Gagliardo Higgins NRC:REG. I) IRACT NRC at TMI-2)	NUREG-0600, p. I-A-119 and 120, Items 652, 654, 655.
	Higgins reports that BWST 22'. Still steaming; "A" loop delta T decreased, RCS pressure 2300 psi. Increasing Temp. with heaters. Trying to steam down "B" OTSG level and have secured feeding it. T_h 560° T_{ca} 395° T_{cb} 220° makeup and letdown approximately 60 gpm. Reactor Building Pressure - 0.2 psig. Pressurizer Temp. increasing with heaters on. Smith reported that at 1600 hours the gross beta was less than minimum detectable at condensate pump discharge MDA=$10x10^{-5}$uC/ml. Reported that have been unable to get a primary sample since approximately 0900 hours this morning.	Region I tape #16, pp. 15 thru 20
7:20 pm	(J.C. Higgins----(Don Caphton----(Jim Gagliardo NRC at TMI-2) NRC:REG. I) IRACT)	Region I tape #16, p. 17
	Higgins reported that he and Neely will soon be leaving to go to a meeting at the Governor's office. In their absence, Walt Baunack will be relaying information back to NRC:REG. I and IRACT.	I&E Interim Sequence of Events, May 8, 1979
7:21 pm	(PEMA)----------------------------(Lancaster Co. EMA)	PEMA Log, p. 8, entry 73
	Provided sitrep to Lancaster County coordinator	

TIME	EVENT	REFERENCE
7:22 pm	(Ray Smith, NRC at TMI-2)---(Don Caphton, NRC:REG. I)---(Jim Gagliardo, IRACT)	Reg. 1 tape No. 16, pp. 23, 24
	Smith reported to NRC that early morning sample of SGs were checked with frisker. "B" sample pegged meter. "A" SG sample did nothing to meter. Based on results, isolated "B" SG.	NUREG-0600, p. I-A-120 Item 657
7:20 pm	(PEMA)----------------------------(Central Area Director, PEMA)	PEMA Log, 3/28, p. 9, entry 74
	Provided Control Area Director with sitrep.	
7:31 pm	(PEMA)----------------------------(York Co. EMA)	PEMA Log 3/28, p. 9, entry 75
	Provided York Co. Coordinator with sitrep.	
7:33 pm	Operator starts RCP 1A, runs it for 10 seconds and then trips it. RCS pressure begins to drop and operator attempts unsuccessful start of makeup pump IC. Pressure drop actuates ES and starts decay heat pumps 1A and 1B. Operator bypasses ES and starts makeup pump 1C within 6 seconds. Pressure turns at a minimum of 1409 psig and climbs to 2200 psig over next 17 minutes.	NUREG-0600, p. I-A-120 Item 659
7:35 pm	(Walt Baunack, NRC at TMI-2)---(Don Caphton, NRC:REG. I)---(Jim Gagliardo, IRACT)	Reg. 1 tape, No. 16, p. 26
	Baunack reported: T_{ha} below 520°, the lowest meter can read. T_{ca} did not go up much. Believe got some flow. Must wait 15 minutes due to RCP motor start limitations until can bump RCP again.	NUREG-0600, p. I-A-121, Item 660
7:35 pm	(Gary Miller, TMI-2)---------------------(John Flint B&W TMI)	NUREG-0600, p. I-A-121, Item 661
	Miller, Station Superintendent, consulted with Flint, B&W representative, on appropriate delay before pump restart.	Interview with John Flint Senate Subcommittee on Nuclear Regulation, p. 40

TIME	EVENT	REFERENCES
7:38 pm	(Walt Baunack, NRC at TMI-2)----(Don Caphton, NRC:REG.I)----(Jim Gagliardo IRACT)	Reg. I tape #17, p. 1
	Baunack reports that he believes current plans are to run that RCP and conduct normal cooldown. When Baunack reports that they bumped RCP, SG pressure jumped from 20 psig to 200 psig, indicating did get heat transfer, (Still steaming SG to condenser)	NUREG-0600, p. I-A-121 Item 664
7:39 pm	(Comm. Gilinsky NRC Commissioner)--------------------(John Davis, Lee V. Gossick, Edson Case IRACT)	
	1. The operator just bumped the recirculation pump for 10 seconds and the pressure is back up to 1800 psi.	IRACT Tapes 01-232-3 thru 5
	2. Natural circulation is not working as well as it should, likely due to the presence of something peculiar like a steam bubble.	Gilinsky Log, NRC-7905110206
7:45 pm	(Ray Smith, NRC at TMI-2)----(Don Caphton, NRC:REG. I)----(Jim Gagliardo, IRACT)	Reg. I tapes, #17, p. 3
	Operators are setting up to start and run a RCP in "A" loop. Miller, Station Superintendent, waited appropriate delay time on RCP restart and then directed operators to start RCP.	NUREG-0600, p. I-A-121 & 122 Items 667 & 668
7:50 pm	(Walt Baunack, NRC at TMI-2)----(Don Caphton, NRC:REG. I)----(Jim Gagliardo, IRACT)	NUREG-0600, p. I-A-122 Items 670 & 671
	Started RCP 1A and let it run. Flow and amps look good. Bypassed ES prior to its actuation on train "A", but train "B" actuates and then clears due to contact race. Reactor coolant pressure drops to 1123 psig. "B" OTSG indicated level drops below 79% and recovers to above 85% within 8 second span. "A" OTSG indicated level drops below 81% and recovers to above 82% within a 9 second span, 40 seconds after "B" OTSG transient.	

TIME	EVENT	REFERENCE
7:50 pm (Con't)	1. Loop Temperatures: "A" Loop Cold Leg: 340°F "B" Loop Cold Leg: 338°F 2. Steam Generator Pressures: "A" Generator increases from 0 to approximately 40 psig (94 psig). "B" Generator decreases from 140 psig to approximately 50 psig. (T_{sat} approximately 330°F). 3. Pressurizer level reportedly still off scale high.	
7:55 pm	Dr. Washington (Pa. Dept. of Health) and Gerusky (PA BRP) advise PEMA that no one outside plant exposed to over 100 mR, which is nothing more than the human body absorbs within a year. If situation worsens, everyone will be advised.	PEMA Logs, 3/28, p. 9, entry 76
7:55 pm	("Doc" Collins,--------------------(M. Reilly, PA BRP) NRC:OSP)	
	1. AMS data shows count is up, status of BNL monitoring activities.	Conver Chronology
	2. a) Not good communication between BRP & BNL due to terrain. b) Teams cruising Rt. 283 called in: Not seeing much of anything. c) Periodic updates from utility teams: Activity on order of 1 mR/hr close-in and 2 mR/hr at airport at 7:23 p.m. d) Bob Friess--BNL team has some air samplers coming in soon and will analyze on state equipment. Another team is leaving BNL in 20 minutes with other equipment and air samplers: ETA is 7 hours: Will have a portable MCA to analyze data. Collins asked Friess and Reilly to call any results into OSP.	OSP Log, NRC-7906060150

TIME	EVENT	REFERENCE
8:00 pm	(Walt Baunack, NRC at TMI-2)----(Don Caphton, NRC:REG. I)----(Jim Gagliardo IRACT)	NUREG-0600, p. I-A-123 Item 676
	RCP 1A is running with both RCS loop cold legs temperatures at about 290°F. Pressurizer level is still full scale with RCS pressure at about 1350 psig. "B" OTSG is isolated at about 97% level and 99 psig, while "A" OTSG is steaming to the main condenser at about 93% level and 76 psig. Makeup pump 1B is operating, supplying RCP seals and normal makeup, the latter at 95 gpm. Makeup pumps 1A & 1C are secured, as are the decay heat removal pumps 1A & 1B. Pressurizer temperature is about 105°F and operators are letting down in attempt to draw a bubble. The core flood tank isolation valves are open with breakers racked out. Operators are utilizing normal cooldown procedures.	
8:15 pm	PA BRP acknowledge receipt of AMS data and say they are keeping Governor informed.	Conver Chronology
8:17 pm	(Ray Smith, NRC at TMI-2)----(Don Haverkamp, NRC:REG. I)----(Jim Gagliardo IRACT)	Reg. 1 tape No. 17A, pp. 2-41
	Site and Region I notified of decision to send NRR team to site; arrival expected next a.m.	Conver Chronology
8:25 pm	(Comm. Gilinsky, NRC Commissioner)------------------(Lee V. Gossick, Exec. Dir. OPS, IRACT)	Gilinsky Log, NRC-7905110206
	(Substance of telephone conversation was not noted in Gilinsky Log.)	
8:30 pm	Rick Keimig, in fourth vehicle from Region I arrives on site.	Conver Chronology

TIME	EVENT	REFERENCE
8:30 pm to 9:45 pm	NRC reps, BRP, and RAP team members brief Lt. Gov. Scanton.	Conver Chronology
8:35 pm	(Tom Gerusky, PA BRP)----------------------(PEMA)	PEMA Log, 3/28, p. 9 entry 80
	Gerusky said reactor is coming under control. The pumps were working and the pressure was rising. Further advised that the situation should be normal in a few hours.	
9:00 pm	("Doc" Collins, NRC:SP)------------------(M. Reilly, PA BRP)	
	1. SP verifies that FAA has not been notified. Collins suggested PEMA call FAA.	Conver Chronology
	2. BNL had a Distenfeld sampler and a hi-volume sampler. They will run analysis at County HQ.	SP Logs, NRC 7906060150
	3. Reilly took readings outside her Harrisburg office with 2 varieties of G.M.s and saw nothing.	SP Logs, NRC 7906060150
9:00 am	Region I notified that Salem providing equipment.	Conver Chronology
9:00 am	Pa. State Police Dept. liaison departed TMI because there was no need for state police services at the site. Traffic was normal and the situation appeared stabilized from a police operation standpoint.	
9:09 pm	(John Davis, Acting Dir. IE)----------------(John Austin, Gilinsky's ofc.)	Gilinsky Log, NRC 7905110206
	(Substance of telephone conversation was not noted in Gilinsky Log.)	

TIME	EVENT	REFERENCE
9:23 pm	(PEMA)----------------------------(Kevin Molloy, Dauphin Co. EMA)	PEMA Log, 3/28, p. 9 entry 81
	Furnished latest sitrep to Molloy per his request.	
9:30 pm	("Doc" Collins, NRC:OSP)------------------(PA BRP)	SP Log, NRC 7906060150
	Requested BRP to call George Smith at NRC:Region I.	
9:32 pm	(Bill Dornsife, PA BRP)------------------("Doc" Collins,	SP Log, NRC 7906060150
	Dornsife called in results of gross sample: Beryllium - natural, essentially nothing. Sample taken at Middletown around 1:00 pm.	
9:42 pm	("Doc" Collins, NRC:OSP)---------(M. Reilly, PA BRP)	SP Log, NRC 7906060150
	Collins inquiry: Have any water samples been taken at 4 and 15 miles? M. Reilly responded negative. OSP requested they do so. Reilly agreed.	
9:50 pm	Four Health Physicists from Salem Nuclear Station arrived with monitoring equipment to assist in performing off site surveys.	NUREG 0600, p. II-A-49 Item 202
9:58 pm	(M. Reilly, PA BRP)--------------(PEMA)	PEMA Logs 3/28, p. 10, entry 82
	Reilly asking advise at PEMA as to whether airport should be notified of situation. Reply is negative.	

TIME	EVENT	REFERENCE
10:00 pm	Lt. Governor Scranton had just met with Chick Gallina and J.C. Higgins of NRC:Region I and Bob Friess of DOE:BNL. At the meeting's conclusion, Scranton reported to Governor Thornburgh: "That there is currently no radioactive material currently in the auxiliary building, that that is being ventilated and that due to that ventilation, there is some dispersion into the atmosphere." Scranton added that there were no critical levels of radioactivity found in any samples taken, but that there were high levels of radiation on site. Since Gallina and Higgins had been on site since 10:00 that morning, they were able to field press questions about the status of the plant. Gallina and Higgins described several radiation pathways. The major source of radiation was the pathway from the RCS to the atmosphere through venting of the auxiliary building. The other was possible primary to secondary system leaks with lifting of the atmospheric dump valves. They assured the press there was no excessive radiation beyond the site boundaries. They said there was no damage to the plant which cannot be repaired with normal maintenance. No further leaks should occur out of the containment building since the pressure was -0.2 psig. Although there was more failed fuel than before the transient, they had nothing definitive yet about the extent of the damage. However, the reactor was stable and there was no "significant" core damage.	PA Media Center Transcript of 10:00 pm press conference, Part III

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TIME	EVENT	REFERENCE
10:50 pm	(PEMA)---------------------------(DCPA:Region II) Notified Reg. II on update sitrep furnished by Directors, i.e., that reactor coming under control, pressure was up and the reactor cooling should be normal within 24 hours. Air samplings continue to be taken. Continue increased readiness and preparedness to respond in the event of a reversal of the situation.	PEMA Log, 3/28, p. 10 entry 84
11:00 pm	(PEMA)---------------------------(Involved County EMA's) Notified Directors of latest sitrep in following areas: Cumberland Co., Dauphin Co., Lane Co., York Co., and Central Area.	PEMA Log, 3/28, p. 10 entry 85
11:00 pm	(Kevin Molloy, Dauphin Co. EMA)---------------------(PEMA) Molloy reports that there is to be a Met Ed press conf. at 10:00 a.m. tomorrow at Hershey Convention Center which will be open to the public.	PEMA Log, 3/28, p. 10 entry 86
11:01 pm	(White House)---------------------(Comm. Gilinsky, NRC Commissioner) (Substance of conversation was not noted in Gilinsky Log.)	Gilinsky Log, NRC 7905110206
11:03 pm	(Comm. Kennedy, NRC Commissioner)----------/--------(Comm. Gilinsky, NRC Commissioner) Commissioner Kennedy called for Commissioner Gilinsky, who is on the phone with Rep. Walker. IRACT contact informs Kennedy that:	IRACT Tapes, 01-287-1 thru 5 and Gilinsky Log NRC 7905110206

TIME	EVENT	REFERENCE
11:03 pm (con't)	1. It appears there is still a steam binding, 2. Fuel damage is reflected in activity levels of coolant water, 3. Some containment dome monitor reading reportedly as high as 20,000 R/hr. and it has caused a great deal of suspicion.	
11:03 pm	(Comm. Gilinsky, OCM at IRACT)--------------------(Congressman Robert Walker) Gilinsky's update included the following: 1. Plume with radioactive gases is heading up towards Harrisburg, one-third mR/hr, which is way below EPA Protective Action Guidelines (PAGs). e.g. one could work in this atmosphere for 200 hours before reaching occupational doses. 2. Twelve mR/hr at the airport will continue, depending upon what happens to water in the aux. bldg. 3. There is reportedly not enough tankage to hold the aux. bldg. water.	IRACT Tapes, 01-239-3 through 12
11:10 pm	("Doc" Collins, NRC:OSP)--------------------(M. Reilly, PA BRP) OSP called BRP to inquire about evening milk samples taken between 5-7 p.m. about 1 mile from site. Normal samples--3 from Dauphin and 3 from York Co. Analysis is still underway BRP will run cartridges on BNL sampler including the Distenfield sampling device.	SP Log, NRC 7906060150

TIME	EVENT	REFERENCE
11:20 pm	(PEMA)--------------------------------(PA BRP) Confirmed report of Met Ed meeting by checking with PA BRP people.	PEMA Logs 3/28, p. 10 entry 87
11:30 pm to 12:30 am	Lt. Gov. Scranton and office aides, Gallina and Higgins of NRC:Region I brief Thornburgh at the Governor's mansion.	Conver Chronology
11:45 pm	(The Washington Post)----------------(PEMA) Call from unknown reporter of Washington Post who stated NRC told him things were getting out of control at TMI. PEMA advised reporter their info. did not indicate problems of that magnitude.	PEMA Log 3/28, p. 11 entry 88
11:40 pm or 11:47 pm	(Jim Lothrop, PEMA)------------------("Doc" Collins, NRC:SP) OSP received call from PEMA re Washington Post article "NRC feels the situation may be getting a little out of hand."	SP Log, NRC 7906060150 Note: PEMA Log shows this to be at 11:47 pm, entry 89 on 3/28
12:00	("Doc" Collins,----------------------(Bernie Schleien, NRC:OSP) FDA-BRH, HEW) 1. SP relayed contents of 11:20 pm Press Release. 2. FDA-BRH will take samples tomorrow including fish samples and other foods. 3. Call Bernie if any of lower values of I-131 or I-133 reached in analysis of milk according to EPA's, PAG's. 4. Call Bernie Schleien in morning to find results of their various tests.	SP Log, NRC 7906060150

Appendix E

Technical Glossary

Appendix E

Technical Glossary

Abnormal procedure.—Similar to an emergency procedure. Each governs how a licensee is to operate a facility in specified "abnormal" or "emergency" circumstances.

Alarm system ringback feature.—When an alarm in the control room is acknowledged, the alarm window light stops flashing but remains lit. When the cause of the alarm is resolved, a horn sounds and the window begins flashing again, but more dimly than originally. The latter two aspects are the ringback feature.

Alpha particle radiation.—Radiation in which an alpha particle is emitted. The energy of alpha radiation is easily reduced as it passes through matter; most alpha radiation can be stopped by a piece of paper. Alpha radiation is unable to penetrate the outer protective layer of a person's skin and is not an external hazard. It is, however, hazardous if the radioactive material emitting the alpha particles is ingested or if the radiation is breathed; either can damage sensitive tissues inside the body. At TMI, the dominant source of alpha radiation during cleanup is the fuel in the reactor core.

Auxiliary building.—A structure housing the equipment and large tanks used in operating a reactor, including make-up pumps, make-up tank, waste gas decay tanks, and reactor coolant hold-up tanks. Much of the radiation emitted to the atmosphere during the accident came from gases released from the unsealed auxiliary building.

Auxiliary feedwater pumps.—See "emergency feedwater system pumps."

BWR.—See "boiling water reactor."

BWST.—See "Borated Water Storage Tank."

Backfitting.—The modification of a reactor to satisfy a safety need identified subsequent to issuance of its Operating License.

Background radiation. — Radiation arising from naturally radioactive materials always present in the environment; these include solar and cosmic radiation and radioactive elements in the upper atmosphere, the ground, building materials and the human body.

Beta particle radiation.—This form of radiation consists of high-energy electrons that can normally be stopped by the skin or a very thin sheet of metal. A large amount of beta radiation can lead to serious burns. A large quantity of this radiation is present in the TMI–2 containment. The predominant sources are the krypton–85 in the atmosphere and the cesium 137 in the water.

Blow-down.—The release of pressurized water from the primary system as the result of an opening (break, open PORV, etc.) in the piping.

Boiling water reactor.—A nuclear power reactor in which water is allowed to boil in the reactor vessel. The resulting steam is separated from the water and fed directly to a turbine-generator.

Borated Water Storage Tank.—A supply of water containing boron, an element that is used to control or stop the fission reaction in a nuclear reactor. Water from this tank can be injected into the reactor vessel.

Boron.—A chemical that absorbs neutrons and is used to control or stop the fission reaction in a nuclear reactor. See "poisons."

Boron stratification.—The existence of differing boron concentrations at various levels or areas of the coolant in the reactor vessel.

Boroscope.—An instrument that may be used during cleanup to evaluate the damaged core visually.

CP.—See "Construction Permit."

"Candy cane."—A section of the hotleg pipe shaped like a candy cane, with a major reverse curve at the highest point. This design is peculiar to Babcock & Wilcox pressurized water reactors. During this and other accidents, steam and hydrogen have become trapped in the curve, blocking the flow of coolant throughout the primary system.

Cavitation.—Vapor bubbles that form in the coolant when pressure decreases to a point at which the water boils. When this occurred within the primary system coolant at TMI–2, the reactor coolant pumps could not function properly and had to be turned off.

Cesium 137 (Cs–137).—A form of radioactive cesium. Cesium 137 has a half-life of 30 years. The cesium 137 in the water in the containment is the predominant source of gamma radiation.

Chain reaction.—A self-sustaining reaction that occurs in nuclear fission when neutrons released by uranium atoms in the reactor fuel split other uranium atoms to release energy. The chain reaction takes place when the number of neutrons released by split uranium atoms equals or exceeds the number of neutrons that are absorbed by the control rods or boron in the reactor coolant, plus those that escape from the reactor core.

Charcoal adsorption.—A process in which charcoal is used to retain radioactive gas molecules. The contaminated charcoal must later be disposed of safely. This process is one alternative for removing the krypton-85 from the containment.

Cladding.—The metal shell containing uranium fuel pellets in the fuel rods of a nuclear reactor. The cladding prevents the release of fission products and facilitates the transfer of heat to the reactor coolant. See "Zircaloy" and "zirc-water reaction."

Code safety valves.—Valves on top of the pressurizer designed to open when pressure reaches 2,435 pounds per square inch. They are safety-rated components that must meet industry and NRC specifications as to quality.

Coldlegs.—Piping in the primary system through which the reactor coolant travels from the steam generators to the reactor coolant pumps and then into the reactor vessel. They are called coldlegs because the coolant that passes through them has lost some of its heat (and thus cooled down) as a result of passing through the steam generator. Coldleg water is actually about 500°F.

Collective dose.—The sum of the individual doses received by each member of a certain group or population within a specific area. The collective dose is expressed in person-rems. For example, a thousand persons, each exposed to one rem, would have a collective dose of 1,000 person-rems. It is a measure of the risk that radiation exposure poses for a selected population. See "rems."

Condensate polisher.—A device that removes dissolved minerals from the water of the feedwater system on the secondary side. There are seven polishers in the condensate polishing system at TMI-2.

Condensate polishing system.—A system of pipes, valves and polishers that is part of the feedwater system. It demineralizes and cleans the feedwater. A malfunction of the valves in this system initiated the March 28, 1979 accident.

Condensate pumps.—Three pumps in the feedwater system that move water from the condensers to the condensate polishers.

Condensers.—Devices that cool steam after it has passed through the turbine, converting it back into water.

Construction Permit.—An authorization from the NRC to a utility to build a nuclear power plant at a particular site. The permit does not cover plant operations.

Containment building.—The structure housing the nuclear reactor. Also called the containment, primary containment or reactor building. It is designed to seal in an accident so that any radioactive releases from the reactor vessel will be contained. In the March 28, 1979 accident, the pressure point at which the TMI-2 containment automatically sealed was not reached until 4 hours into the accident. In the meantime, slightly radioactive water was pumped into the adjoining auxiliary building.

Containment spray system.—A system that pumps water to spray nozzles at the top of the containment building. At TMI, the sprays are automatically activated if containment pressure goes above 30 pounds per square inch. They release cold water, which causes a reduction in pressure.

Control rod.—A rod containing material that absorbs neutrons. By lowering the control rods between the fuel rods, the chain reaction in a reactor can be controlled or halted.

Core.—The part of a nuclear reactor containing the nuclear fuel that produces heat through fission. The core consists of bundles of fuel rods and control rods, as well as instrumentation that can measure temperature and neutron activity, both indicators of the condition of the core. The instrumentation includes source range neutron monitors and the incore thermocouples.

Core flood tanks.—Tanks of water designed to provide a one-time emergency flooding of the core to assure it is covered with adequate coolant. See "Emergency Core Cooling System."

Core uncovering.—Water level dropping below the top of the core.

Criticality.—A term used to describe the state of a reactor that is sustaining a chain reaction. See "chain reaction" and "fission."

Cross-licensing.—The process of licensing a control room operator to operate more than one power plant. This is usually done only when there are multiple power plants at a site.

Cryogenic processing.—A process for liquefying a gas such as krypton-85. It is one alternative for removing the gas from the TMI-2 containment.

Curie (c, Ci).—A unit of measure of the amount of radioactivity in a material, such as the nuclear fuel of the core. One curie is equal to 37 billion disintegrations per second from the nuclei of atoms.

Deboration.—A reduction in the concentration of boron in the reactor coolant.

Decay heat.—Heat produced by the decay of radioactive material. In a nuclear reactor, this heat results from the continued decay of the radioactive materials in the core even after the reactor is shut down. Decay heat must be removed by coolant after the reactor is shut down to prevent the core from overheating. See "radioactive decay."

Decay heat removal system.—A system that removes decay heat from the core by circulating primary system water through heat exchangers. It can only be used when pressure in the primary system is low, such as after shutdown.

Delta T.—The difference between two temperatures, here the hotleg and the coldleg.

Decommissioning.—The cleanup and retirement of a nuclear plant.

Depressurization.—Lowering of the pressure in the primary system.

Digital volt meter.—A device with a digital display that measures voltage. Voltage readings off the incore thermocouples, located in the core, can be converted to temperature readings. At TMI, some plant personnel used the digital volt meter to determine the temperature of the reactor core.

Dosimetry.—The process or method of measuring a dosage of radiation.

Draft Environmental Statement.—A preliminary document the NRC prepares with respect to a proposed nuclear facility. The document is put together after receipt of the utility's Environmental Report and addresses, in part, the environmental effects of the proposed facility and alternatives for reducing or avoiding adverse environmental effects. It is also to consider environmental, economic, technical and other benefits of the proposed facility. The statement, prepared before issuance of a Construction Permit, is circulated to Federal, State and local agencies and the public for analysis and comment. See "Final Environmental Statement."

ECCS.—See "Emergency Core Cooling System."

ERV.—See "pilot-operated relief valve."

Elastomeric seals.—Seals made out of a material having the elastic properties of natural rubber.

Electromatic relief valve (ERV).—See "pilot-operated relief valve."

Emergency Core Cooling System (ECCS).—An emergency backup cooling system composed of several subsystems designed to supply water to the reactor core in the event of a loss-of-coolant accident. See "loss-of-coolant accident."

Emergency feedwater system pumps.—Backup pumps to those pumps that normally supply water to the secondary side of the steam generators. Also called auxiliary feedwater pumps.

Emergency feedwater valves.—Four valves that control the flow of feedwater to the steam generators during loss of normal feedwater. One pair is designed to open after the feedwater pumps reach full speed; the second pair, the "12-valves," are always supposed to be open except during a specific test. The "12-valves" were shut at the start of the TMI accident.

Emergency plan (for licensee).—The NRC, before it issues an Operating License, requires that the utility provide a plan for coping with emergencies. The emergency plan must include, in part, the emergency response organization to be set up by the licensee, the identification of employees with special qualifications for handling emergencies, means for monitoring radiological releases and procedures for notifying local, State and Federal officials.

Emergency procedures.—See "abnormal procedures."

Emergency safeguard features actuation system (ESFAS).—The electrical sensing equipment and signals that activate the engineered safeguards of a plant, such as the Emergency Core Cooling System.

Energy replacement costs.—A utility's costs for purchasing electricity from other utilities in order to meet the needs of its own customers. These costs have been Met Ed's greatest expense since the accident.

Engineered safeguards (ES).—Automatic or manual safety-related equipment used to control a reactor during an accident, including the Emergency Core Cooling System, containment spray system, and containment isolation system.

Environmental Assessment.—A document intended briefly to provide sufficient evidence and analyses for determining whether to prepare a detailed environmental impact statement concerning a proposed Federal action. Ordinarily, no impact statement is required if the assessment determines that the proposed action will have no significant adverse impact on the quality of the environment. See also "Environmental Impact Statement."

Environmental Impact Statement.—A detailed statement required under the National Environmental Policy Act of 1969 (42 U.S.C. sections 4321 *et seq.*) for "major Federal action significantly affecting the quality of the human environment." The impact statement sets forth alternative approaches to a proposed project and how each alternative might affect the environment.

Environmental Report.—A mandatory part of a licensee's application to the NRC for a Construction Permit. It includes a description of the environment to be affected and the probable impact of the proposed action on the environment. Another such report must be submitted when applying for an Operating License.

EPICOR–I.—A system for the decontamination of low-level radioactive water. The system was used at TMI shortly after the accident.

EPICOR–II.—A water purification system being used at TMI–2 since October 1979 to process the intermediate-level radioactive water (less than 100 microcuries per cubic centimeter) in the TMI auxiliary building. Similar in function to a home water softener system, EPICOR–II contains a series of filters that in succession remove radioactive materials from the water. These materials are absorbed by a resin bed that, when saturated, is removed and stored for disposal.

Failed fuel.—The breaching of the cladding of fuel rods, allowing the escape of radioactive fission products. Such failure includes pinholes, splits or shattering and occurs when the cladding either loses its strength (from excessive heating—1,500°F or more—or oxidation) and/or when the fuel expands, pushing against the cladding until it breaks. Fuel damage can occur without the reactor's fuel melting. It may lead to radiation releases, necessitating declaration of a site or general emergency. See also "Zirc-water reaction."

Feedwater.—The water supply in the secondary system. As the water flows through the steam generators, it absorbs the heat from the primary system coolant and is converted to steam that in turn drives the turbines. Subsequently, the steam passes through condensers that convert it back into water, which then passes through condensate polishers and back to the steam generators.

Feedwater pumps.—Two large pumps capable of supplying the two steam generators at TMI–2 with up to 15,500 gallons of water a minute.

Field Change Request.—A formal means by which Met Ed personnel can request design changes.

Final Environmental Statement.—The final document the NRC develops on the environmental impact of a proposed nuclear facility (see "Draft Environmental Statement"). The final statement is prepared after the NRC staff receives comments from Federal, State and local agencies and the public on its draft statement. The final statement is distributed to these parties for any further comments. In the case of proposed nuclear power plants, the final statement, as well as any comments, is considered during the Commission's Construction Permit and Operating License review processes.

Fission.—The splitting of an atomic nucleus, such as uranium, into two or more parts by a neutron. The splitting releases energy (in the form of heat), as well as neutrons and gamma radiation. The pieces of the split nuclei are called fission products and emit alpha, beta and gamma radiation.

Fission products.—Radioactive elements formed by the fissioning (splitting) of the nuclei of uranium and plutonium atoms. Fission products are normally retained inside the reactor fuel pellets by the Zircaloy cladding of the fuel rods.

Final Safety Analysis Report.—A document a utility must submit to the NRC in connection with its application for a license to operate a plant.

Flux.—The number of neutrons falling each second on a neutron detector to show neutron frequency per square centimeter.

Fuel damage.—See "failed fuel."

Fuel melt.—The melting of uranium oxide fuel as a result of excessive heat (5,000°F). Partial or total fuel melting may lead to radiation releases. See also "meltdown."

Fuel replacement costs.—See "energy replacement costs."

Fuel rod.—A long, slender metal tube with pellets of nuclear fuel inside. The TMI–2 reactor core contains 38,816 fuel rods.

Gamma rays.—A high-energy electromagnetic form of radiation that can penetrate deeply into building materials and body tissues. They are more penetrating than X-rays. Gamma rays are produced by fission and the natural decay of radioactive elements. Virtually all of the radioactive waste at TMI–2 emits gamma radiation.

Gas compression.—A process by which a gas is subjected to high pressure, greatly reducing its volume so that it can be stored in containers. It is an option for removing the krypton–85 from the containment.

General emergency.—In the event of an accident at a nuclear power plant posing a potentially serious threat of radiation releases that can harm the general public, the utility must declare a general emergency. This declaration automatically sets in motion preplanned emergency responses by the utility, the NRC and the State and local jurisdictions.

Grey Book.—"Operating Units Status Report" (NUREG–0200), a monthly publication of the NRC that includes summaries of incidents at nuclear facilities.

HPI.—See "high pressure injection."

Half-life.—The time required for half of a given amount of a specific radioactive material to become non-radioactive. The half-life is a convenient measure of the rate of radioactive decay and is unique for each radioactive material.

Heat exchanger.—A device used to transfer heat from one system to another. A steam generator is such a device.

Health physics.—The science of protecting humans and their environment from the possible hazards of radiation.

High-level radioactive waste.—Concentrated liquid or solid radioactive wastes (as generally defined in 10 CFR Sec. 50, Appendix F) that result from the first round of extracting radioactive matter from nuclear reactor fuels in a reprocessing facility. Reprocessing involves successive rounds of extraction, each producing lower levels of radioactivity in the wastes.

High pressure injection (HPI).—A subsystem of the Emergency Core Cooling System designed to pump about 1,000 gallons a minute into the primary system. It actuates at high pressure to ensure adequate cooling of the core in the event of a break in the primary system.

Hotlegs.—Piping in the primary system through which heated coolant water passes from the reactor vessel to the steam generator, where some of the heat is transferred to the secondary system. See "coldlegs."

HP–R–227.—A radiation monitor that measures particulate and iodine gas radiation in the atmosphere of the containment. It is usually activated by a loss-of-coolant accident and is considered a key indicator of that situation.

Human factors engineering.—The specialty of harmonizing plant design and operations with human needs and capabilities so that the performance of plant operators can be improved.

Hydrogen spike.—See "pressure spike."

IRACT.—See "Incident Response Action Coordination Team."

Incore thermocouples.—Devices used to determine temperature in the core. They are located at various places within the fuel assemblies in the core.

Intermediate range neutron monitors.—Instruments located near the core that measure neutron activity in the core. They provide an indirect indication of core uncovering, on the basis of a change in the number of neutrons that reach the monitor.

Iodine 131.—A radioactive form of iodine with a half-life of 8.1 days. It is absorbed by the human thyroid gland if inhaled or ingested and can cause non-cancerous or cancerous growths.

Ion exchange.—A technique applied to soften water or separate radioactive material from a liquid. As the liquid passes through a container (bed) of resin, the radioactive elements adhere to the resin. When saturated, the resin bed is replaced. The contaminated bed must be disposed of.

Ionizing radiation.—Radiation that is capable of displacing electrons from atoms, thereby producing electrically-charged atoms called ions. Gamma rays, X-rays and alpha and beta particles are forms of ionizing radiation. Not all radiation can create ions.

Ions.—See "ionizing radiation."

Incident Response Plan.—The document containing NRC's procedures governing the Agency's response to incidents or accidents at licensed nuclear facilities.

Isotope.—Atoms of the same element, the nuclei of which have the same number of protons but a different number of neutrons. Since the nucleus of a given element can have varying numbers of neutrons, an element can have many isotopes. There are over 800 radioactive isotopes.

Krypton 85.—A radioactive noble gas with a half-life of 10.7 years. It emits primarily beta radiation and some gamma radiation. It does not remain long in body tissues if ingested and is, therefore, less damaging in small quantities than some other radioactive elements. It is now the predominant radioactive gas in the TMI–2 containment and is a problem because of its large quantity and the size of the potential dose workers would receive if exposed to it during cleanup. See "noble gases."

LOCA.—See "loss-of-coolant accident."

Let-down system.—A system through which water can be removed from the primary system for purification or to reduce pressure in the primary system or to decrease the water level in the pressurizer.

Licensee Event Report (LER).—A report that a licensee must submit to the NRC when an accident or a specified type of incident occurs at its nuclear facility.

Loss-of-coolant accident (LOCA).—An accident involving a broken pipe, stuck-open valve or other leak in the primary system that results in a loss of coolant. If not controlled or counteracted, the core could become uncovered, resulting in damage to or melting of the fuel.

Low-level radioactive waste.—Generally, radioactive wastes that are not covered in the definition of "high-level liquid waste" (as defined in 10 CFR Part 50 Appendix F), such as natural or contaminated materials with low concentrations of radioactivity. See "high-level radioactive waste."

Mrem.—See "millirem."

Make-up system.—The means by which borated water is added to the primary system during normal operations. The system includes the make-up tank and the make-up lines and pumps.

Make-up tank.—A storage tank in the auxiliary building that provides water for the make-up system.

Meggering.—The measurement of the electrical resistance of an electric component, such as a motor, to determine its operability. Two key valves in the containment are now being meggered, because the rising water level could render them inoperable, hampering the cleanup of TMI–2.

Meltdown.—The melting of fuel in a nuclear reactor after a loss of coolant. If the amount of the molten fuel is significant, it could melt through the reactor vessel and release large quantities of radioactive materials into the containment building. In some cases, a meltdown might penetrate the containment, releasing radioactive materials into the soil if the molten fuel were to pass through the foundation or into the atmosphere if a steam explosion were to breach the building.

Millirem (mrem).—One one-thousandth of a rem; see "rem."

Mini Decay Heat Removal System.—Designed specifically for TMI–2 after the accident, this system is similar to the normal decay heat removal system but is smaller to accommodate the low level of decay heat at TMI–2 since the accident.

Multiple failure accident.—An accident in which a combination of two or more equipment failures or operator errors aggravates an initial incident. For example, an initial failure of feedwater, complicated by failure of the auxiliary feedwater to start up and of the PORV to close—as happened at TMI—constitutes a multiple failure accident.

NEPA.—See "National Environmental Policy Act."

Natural circulation.—The circulation of water, without the aid of pumps, resulting from the temperature differential between hotter water in the core and cooler water in the steam generator. The water flows because of the buoyancy of the hot water.

National Environmental Policy Act of 1969 (NEPA).—A Federal statute (42 U.S.C. Sections 4321 *et seq.*) intended to assure protection of the environment. NEPA requires that Federal agencies prepare environmental impact statements regarding major Federal actions that significantly affect the quality of the human environment. See "Environmental Impact Statement."

Neutron.—An uncharged particle found in the nucleus of every atom other than ordinary hydrogen. The neutrons released by the fissioning (splitting) of atoms sustain the chain reaction in nuclear reactors. (See "fission" and "chain reaction.")

Neutron detectors.—Devices located within or above the fuel assemblies in the core to measure neutron activity throughout the core. The source neutron detector ordinarily measures the very low levels of neutron activity present during the startup of a reactor. The intermediate range neutron detector has a higher range and measures neutron activity at intermediate power.

Noble gases.—Gases that do not react chemically and are not absorbed by body tissues, but that can cause damage if they are radioactive. Such gases enter the blood if inhaled into the lungs and are removed from the blood by the normal gas exchange that occurs with breathing. Noble gases include helium and neon, which are not radioactive; krypton and xenon which can be made radioactive; and radon, which is naturally radioactive.

Noncondensible gas.—A gas such as hydrogen that is not easily condensed into a liquid.

Nuclear Steam Supply System.—That portion of a nuclear powerplant associated with the primary system. It includes the reactor vessel, pumps, primary piping and steam generators. It does not include buildings, such as the containment building, or the secondary system, the turbine generator or the cooling towers.

Nuisance alarms.—Alarms improperly activated in the control room during periods of normal operation as a result of faulty wiring or overly sensitive sensors. Also alarms that remain activated after they are no longer needed to indicate the status of some equipment.

NUREG–0200.—See "Gray Book."

OL.—See "Operating License."

OSTG.—See "steam generator."

Off gas radioactivity.—Air and a small amount of radioactive gas are always present in the condenser. The condenser is designed so that this mixture is continuously vented (or "off-gassed") through a discharge line. The release is routed to the auxiliary building and ultimately out of that building's ventilation system to the atmosphere. Off-gas radioactivity, the radioactivity attributable to this process, is ordinarily well below allowable limits for releases.

Once through steam generator (OTSG).—See "steam generator."

Operating License (OL).—The NRC authorization that allows a utility to operate a nuclear power plant.

PAG.—See "Protective Action Guide."

PORV.—See "pilot-operated relief valve."

ppm.—See "parts per million."

psi.—See "pounds per square inch."

psig.—See "pounds per square inch gauge."

PWR.—See "pressurized water reactor."

Parts per million (ppm).—A measurement of concentration reflecting the number of units of a substance in a million units of another substance (e.g. radioactive iodine in the air).

Person-rems.—See "collective dose."

Pilot-operated relief valve (PORV).—A valve on a pressurizer, designed to open when pressure in the primary system reaches a certain point and to close when it drops back to a certain point. The PORV at TMI–2 was designed to open at 2,255 pounds per square inch and to close at 2,205 psi. At TMI–2 the PORV lifted to relieve the pressure but failed to close as designed, leading to the loss-of-coolant accident. Also known as the electromatic relief valve, ERV, RC–R2 and RC–RV2.

Poisons.—Materials that readily absorb neutrons and can be used to control or stop the chain reaction in a nuclear reactor.

Pounds per square inch (psi).—A measurement of pressure. As used in this report, it actually means pounds per square inch gauge (psig) (see next item).

Pounds per square inch gauge (psig).—A measurement of pressure using atmospheric pressure (14.7 pounds per square inch) as a base. This contrasts with "absolute" pressure, which uses the zero pressure of a vacuum as a base. Hence, 0 psig equals 14.7 psi absolute; 1 psig equals 15.7 psi absolute.

Preliminary Safety Analysis Report (PSAR).—A portion of an application to the NRC for a Construction Permit for a nuclear powerplant. It includes a safety assessment of the site and of the design of the facility.

Pressure spike.—A sudden rise and fall in pressure, as recorded on a strip chart of pressure levels. At 1:50 p.m. on March 28, 1979, a rapid hydrogen burn caused a pressure spike to appear on the strip chart recording pressure in the TMI–2 containment.

Pressure vessel.—See "reactor vessel."

Pressurized water reactor (PWR).—A nuclear reactor in which the primary system, containing the coolant water, is kept under high pressure to prevent the coolant from boiling.

Pressurizer.—A tank containing a steam bubble, heaters and water that is used to control pressure in the primary system of a pressurized water reactor. Pressure can be raised or lowered by expanding or contracting the steam bubble, accomplished by heating or cooling the water in the pressurizer. Operators at TMI were trained not to allow the pressurizer to fill with water (to become "solid"). That condition eliminates the bubble and adversely affects the operators' ability to control pressure in the primary system.

Primary system.—A sealed system consisting principally of the reactor vessel, piping, tubing in the steam generators, reactor coolant pumps and a pressurizer. The system contains and circulates the water that cools the core. Also called the primary loop or the reactor coolant system.

Protective Action Guide (PAG).—The projected radiation dose to individuals that warrants taking action to avoid or to reduce exposure of the affected population.

rad.—Acronym for radiation absorbed dose, the basic unit of measurement for amounts of ionizing radiation absorbed by body tissue. See also "rem" and "ionizing radiation."

RCDT.—See "reactor coolant drain tank."

RTD.—See "resistance temperature device."

Radiation.—The emission and propagation of either waves transmitting energy through space (e.g., sound waves, light, gamma rays, etc.), or of a stream of particles (e.g., beta particles and alpha particles).

Radioactive decay.—A progressive decrease in the number of radioactive atoms in a substance, resulting from spontaneous nuclear disintegration.

Radioactivity.—The spontaneous emission of radiation, such as gamma rays, neutrons, and alpha and beta particles.

Radioiodine.—A radioactive form of iodine.

Radiological Assistance Program (RAP).—Administered by the Department of Energy, RAP offers States and nuclear facilities assistance during radiological emergencies. It is administered primarily through the National Laboratories.

Rasmussen Report.—See "WASH–1400."

Ratcheting.—See "backfitting."

Reactivity.—A measure of positive or negative change in the neutron production in a reactor. Once the reactor is critical, power increases with an increase in positive reactivity. Conversely, an increase in negative reactivity (such as insertion of the control rods or the addition of boron) reduces power or shuts the reactor off. See also "chain reaction."

Reactor building.—See "containment building."

Reactor (nuclear).—A device in which a fission chain reaction can be initiated, maintained and controlled.

Reactor coolant drain tank (RCDT).—A storage tank that collects the normally small amounts of coolant released from the primary system through the pilot-operated relief valve (PORV) when the PORV is opened to reduce pressure in the primary system. An overflow of the tank is a strong indicator of a loss-of-coolant accident.

Reactor coolant pump.—A large pump used to circulate water that cools the core. There are four reactor coolant pumps at TMI–2.

Reactor coolant system.—See "primary system."

Reactor vessel.—The steel tank containing the reactor core and some coolant. It is one component of the primary system. Also called the pressure vessel.

Recertification and recommissioning.—NRC requalification of a facility for operation after a prolonged shutdown for repair or design modification.

Refueling outage.—The period during which a nuclear powerplant is shut down for replacement of spent fuel with fresh fuel.

Rem.—A unit of measurement that indicates the damage done to tissue by doses of the various types of radiation. The rem takes into account the fact that the different types of radiation do different amounts of damage to tissue. When low-level radiation is involved, the dose is frequently measured in millirems (mrem). One thousand mrem equal one rem. (See "rad.")

Repressurize.—To raise pressure in the primary system. This action should cause saturated steam in the primary system to be condensed back into water for the purpose of collapsing any steam blockage. This will only work in the absence of a large amount of a noncondensible gas, such as hydrogen.

Reprocessing.—The processing of nuclear fuel, after its use in a reactor, to recover uranium and plutonium for recycling as commercial reactor fuel and to remove fission products for disposal as waste.

Resin beds.—See "ion exchange."

Respirator.—A mask that filters air being breathed as protection against radioactive or other injurious materials.

Resistance temperature device (RTD).—An instrument for measuring temperatures. On March 28, control room personnel used the RTD to obtain accurate readings of hotleg temperatures.

Retrofitting.—See "backfitting."

SAR.—See "Safety Analysis Report."

SER.—See "Safety Evaluation Report."

Safety Analysis Report (SAR).—A document containing information on the safety aspects of a proposed nuclear plant that the utility submits to the NRC. It must be submitted for review before the NRC will issue a license.

Saturation temperature.—The temperature at which water at a given pressure will boil and give off steam. The saturation point of water at atmospheric pressure (sea level) is 212° F.

Saturated steam.—Steam at the same temperature as the boiling water that produced it. The steam in a pot of boiling water is saturated steam.

Scram.—Insertion of the control rods into the reactor core to terminate the chain reaction and shut down the reactor.

Secondary system.—The system containing the water that removes heat from the primary system coolant. It consists of pipes, the shell of the steam generators, the condensers and the feedwater supply and pumps.

Safety Evaluation Report (SER).—The NRC's summary of findings based on its review of a utility's Safety Analysis Report. It is prepared before a license or amendment to a license is issued.

Simulator.—A piece of equipment or model that imitates the operations of a component of a nuclear powerplant. A control room simulator is like an actual control room, though smaller, and is able to reproduce some of the events that can happen within a powerplant control room. It is used to train operators.

Site emergency.—In the event that an incident at a nuclear powerplant threatens to cause an uncontrolled release of radioactivity in the immediate area of the plant, a utility must declare a site emergency. This declaration initiates a preplanned response by the utility, NRC and State and local jurisdictions.

Solid system.—A condition in which the entire primary system, including the pressurizer, is filled with water—an abnormal condition in a pressurized water reactor. See "pressurizer."

Source neutron monitors.—See "neutron detectors."

Standard Review Plan.—The standard procedures NRC staff use to review applications for Construction Permits and Operating Licenses. The plan details criteria for acceptance of an application.

Steam generator.—A large piece of equipment in which heat from the primary system coolant is transferred to the feedwater in the secondary system, causing the feedwater to turn to steam. The heat transfer takes place as feedwater in the secondary system flows past the tubing through which primary system coolant flows. TMI–2 has two once-through steam generators in which the primary coolant enters at one end and passes straight through to the other end and then on to the core. In other steam generators, the coolant makes a loop inside the generator, entering and leaving at the same end.

Steam table.—A chart that can be used to determine the temperature at which water will boil at a given pressure. That information, in turn, will indicate whether there is steam in the system and what its properties are, that is, whether it is saturated or superheated.

Strip chart recorder.—A device that continuously records a signal from a measuring device on a moving strip of paper. An electrocardiogram, for example, uses a strip chart recorder.

Strontium 90.—A form of strontium that emits beta radiation and has a half-life of 28 years. Strontium 90 is present in the contaminated water in the containment and auxiliary buildings at TMI–2.

Subcriticality.—A state in a nuclear reactor in which the rate of neutron production is less than the rate of neutron absorption or loss, and a sustained chain reaction, therefore, is not taking place.

Superheated steam.—Steam that is heated further after becoming steam. At TMI–2, steam became superheated as it passed through or near the uncovered core.

Swipe test.—A means of determining whether a surface is contaminated. The surface is rubbed with a piece of cloth-like material, which is then analyzed for radioactivity.

T_{ave}.—The average temperature of the hotlegs and coldlegs.

T_c.—The temperature of the coldleg. (See coldleg.")

T_h.—The temperature of the hotleg. (See "hotleg.")

Technical Specifications.—The conditions and requirements according to which the NRC permits a plant to be operated.

Thermal cycling.—Fluctuations between hot and cold temperatures. Components of the plant were subjected to this condition during the accident, and it may have affected their mechanical strength.

Transient.—A condition or event resulting in temporary changes in reactor temperature and pressure that a nuclear plant system is expected to experience during normal operations.

Trip.—A sudden shutdown of a piece of machinery in a nuclear powerplant.

Turbine building.—The structure housing the turbine, generator and much of the feedwater system.

Uranium 235 (U–235).—A metallic fissionable element used in reactor fuel.

Vapor lock.—A bubble of steam in the primary system piping that prevents the flow of coolant.

Voiding.—A loss of water from the core as a result of large bubbles in the coolant. In the case of TMI–2, the voiding resulted from boiling in the reactor core.

WASH–1400.—The AEC Reactor Safety Study or Rasmussen Report. Begun by the AEC and completed by the NRC in 1975, it was a major study in which the risks of nuclear power were calculated in terms of the probabilities and consequences of a variety of nuclear accidents. In 1979, the NRC announced that it had withdrawn any past endorsement of the Executive Summary of the study and that it did not regard as reliable the study's numerical estimate of the overall risk of a nuclear accident.

Waste gas decay tank.—A tank in which radioactive gases removed from the reactor coolant are stored. At TMI–2 there are two such tanks, located in the auxiliary building.

Xenon 133.—A radioactive noble gas with a half-life of 5.3 days. Although it is not retained in the body if inhaled or ingested, it emits gamma rays that can penetrate body tissues from inside or outside the body. Xenon 133 was one of the gases released to the atmosphere during the accident.

Zircaloy.—An alloy of zirconium from which fuel rod cladding is made.

Zirc-water reaction.—A chemical reaction between steam and the zirconium alloy in the cladding that takes place in the core at temperatures exceeding 1,500° F and produces hydrogen gas.

Appendix F

Glossary of Organizations

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Appendix F

Glossary[1] of Organizations

AEC.—See "Atomic Energy Commission."

ANSI.—See "American National Standards Institute."

American National Standards Institute (ANSI).—A national organization that provides generally agreed upon standards for manufacturers, consumers and the general public, including standards affecting the nuclear industry.

Atomic Energy Commission (AEC).—An independent agency of the Federal Government that had statutory responsibility for all atomic energy matters from 1946 to 1975. In 1974, it was abolished by Congress and replaced by two new agencies, the Nuclear Regulatory Commission and the Energy Research and Development Administration. The latter was subsequently absorbed by the Department of Energy.

B&W.—See "Babcock & Wilcox Company."

BRP.—See "Bureau of Radiation Protection."

Babcock & Wilcox Company (B&W).—The company ("reactor-vendor") that designed and supplied the TMI–2 nuclear steam supply system, which includes the reactor and the primary system.

Bureau of Radiation Protection (BRP).—A division of the Pennsylvania Department of Environmental Resources. It is the State's lead agency in monitoring radiation releases from nuclear plants and advises the Pennsylvania Emergency Management Agency during radiological emergencies.

Burns and Roe.—The architectural and engineering firm ("architect-engineer") responsible for the overall design of the TMI–2 plant.

CEQ.—See "Council on Environmental Quality."

Council on Environmental Quality.—An office established by law within the Executive Office of the President. It is responsible for reviewing and appraising Federal environmental policies and for establishing uniform Federal procedures for implementing the National Environmental Policy Act of 1969.

DER.—See "Department of Environmental Resources."

DOR.—See "Division of Operating Reactors."

Defense Civilian Preparedness Agency.—Originally, the unit in the Defense Department responsible for developing programs to protect the civilian population during and after nuclear attacks and to encourage State and local governments to develop that capability. It is now part of the Federal Emergency Management Agency.

Department of Energy.—A Cabinet-level department established by law to replace the Energy Research and Development Administration. It is responsible for developing and implementing a comprehensive and balanced Federal energy plan. Its responsibilities include the development of nuclear technology and the nuclear weapons program.

Department of Environmental Resources (DER), State of Pennsylvania.—The agency responsible for protecting the environment and for resource management in Pennsylvania.

Division of Operating Reactors (DOR).—Once a division of the NRC's Office of Nuclear Reactor Regulation. It reviewed design and operational changes at operating reactors licensed by the NRC.

Division of Reactor Operations Inspection (ROI).—A division of the NRC's Office of Inspection and Enforcement. It develops the inspection program, assures the technical adequacy of cases involving enforcement, prepares notifications to appropriate parties, and provides technical management and support for the NRC's response to incidents at operating reactors. It also monitors and appraises program performance by the NRC's regional offices.

EMT.—See "Executive Management Team."

EPA.—See "Environmental Protection Agency."

EPRI.—See "Electric Power Research Institute."

Electric Power Research Institute (EPRI).—A research institute supported by the electric utility industry.

Environmental Protection Agency (EPA).—An independent agency established by law within

[1] This glossary lists the principal organizations whose names or acronyms appear in the report.

the Executive Branch. It is charged with protecting the environment and is responsible for setting standards for radiation emissions beyond the boundaries of nuclear facilities. It also provides guidelines for decisionmaking on evacuation and other protective action in the event of a nuclear accident.

Executive Management Team (EMT).—Senior NRC executive staff designated to make the major decisions concerning the agency's response during accidents at licensed nuclear facilities. This team and the Incident Response Action Coordination Team (IRACT) man the NRC Incident Response Center.

FEMA.—See "Federal Emergency Management Agency."

FERC.—See "Federal Energy Regulatory Commission."

Federal Emergency Management Agency (FEMA).—An independent agency established by law in the Executive Branch. It is responsible for national response to war, natural and manmade disasters and for coordinating, developing and reviewing State and local emergency preparedness plans.

Federal Energy Regulatory Commission (FERC).—An independent regulatory commission established by law in the Department of Energy. It sets rates and charges for wholesale interstate sales of electricity and for interstate transportation and sale of natural gas.

GORB.—See "Generation Operations Review Board."

GPU.—See "General Public Utilities Corporation."

GPU Service Corporation.—See "General Public Utilities Service Corporation."

General Public Utilities Corporation (GPU).—A utility holding company that is the parent corporation of Metropolitan Edison, Pennsylvania Electric and Jersey Central, the three utilities that own Three Mile Island Unit 2.

General Public Utilities Service Corporation (GPU Service Corporation).—A wholly-owned subsidiary of GPU, incorporated in 1971. It was responsible for the design and construction of all new nuclear projects, which were formerly the responsibility of GPU's Nuclear Power Activities Group. It also provides services for the other three subsidiary operating companies of GPU.

Generation Operations Review Board (GORB).—An independent audit group, called for in the Technical Specifications for Unit 1. It is responsible for reviewing the broader issues of nuclear safety at Unit 1 and for the conduct of the Plant Operations Review Committee and all other plant activities. It also addresses matters pertaining to Unit 2.

I&E.—See "Office of Inspection and Enforcement."

ICRP.—See "International Commission on Radiological Protection."

IEEE.—See "Institute of Electrical and Electronic Engineers."

IRACT.—See "Incident Response Action Coordination Team."

Incident Response Action Coordination Team (IRACT).—A group of senior NRC executives who comprise the operations arm of the NRC's emergency response organization. IRACT provides information, options and analyses to the NRC's Executive Management Team, which is located in an adjoining office of the Incident Response Center.

Incident Response Center.—The office for the NRC headquarters emergency response organization in Bethesda, Maryland. The agency's Incident Response Action Coordination Team (IRACT) and Executive Management Team (EMT) work out of adjoining offices in the Center.

Institute of Electrical and Electronic Engineers (IEEE).—A professional engineering association to advance scientific and educational matters related to electrical and electronic engineering.

International Commission on Radiological Protection (ICRP).—An organization that conducts research on and recommends international standards for radiation protection. It also advises such groups as the World Health Organization.

Jersey Central Power and Light Company (Jersey Central).—Owner of 25 percent of Three Mile Island Unit 2. It is a wholly-owned subsidiary of General Public Utilities Corporation.

Met Ed.—See "Metropolitan Edison Company."

Metropolitan Edison Company (Met Ed).—The licensed operator for, and 50 percent owner of, the Three Mile Island Unit 2 nuclear power plant. It is a wholly-owned subsidiary of General Public Utilities Corporation.

NMSS.—See "Office of Nuclear Materials Safety and Safeguards."

NPAG.—See "Nuclear Power Activities Group."

NRC.—See "Nuclear Regulatory Commission."

NRR.—See "Office of Nuclear Reactor Regulation."

NSAC.—See "Nuclear Safety Analysis Center."

Nuclear Power Activities Group (NPAG).—A unit organized by GPU in 1967 to serve as central coordinator for the design and construction of its nuclear projects. It was replaced by the GPU Service Corporation in 1971.

Nuclear Regulatory Commission (NRC).—A Federal independent regulatory commission established by law in 1974 to replace the Atomic Energy Commission. It has statutory responsibility for licensing and inspection of commercial and other non-military nuclear facilities.

Nuclear Regulatory Commission (SIG) Special Inquiry Group.—An inquiry established by the NRC to review and to report to the Commission on the accident at Three Mile Island. The NRC contracted with a law firm to conduct the inquiry. Most of the Special Inquiry staff were NRC staff.

Nuclear Safety Analysis Center (NSAC).—A nuclear safety analysis group managed by the Electric Power Research Institute for the electric utility industry.

Office of Inspection and Enforcement (I&E).—An office within the Nuclear Regulatory Commission charged with assuring compliance with NRC regulations and license requirements. It conducts inspections of licensees, applicants, and their contractors and suppliers, and it is authorized to impose fines for violations.

Office of Nuclear Materials Safety and Safeguards (NMSS).—An office established by statute within the Nuclear Regulatory Commission. It is charged with licensing and regulating all facilities and materials associated with the processing, transport and handling of nuclear materials.

Office of Nuclear Reactor Regulation (NRR).—An office established by statute within the Nuclear Regulatory Commission. It is charged with reviewing applications and issuing licenses for construction and operation of commercial and other non-military nuclear reactors and for nuclear materials in use or stored at reactor facilities.

Office of Nuclear Regulatory Research (RES).—An office established by statute within the Nuclear Regulatory Commission. It is charged with planning and implementing research programs necessary for the performance of the Commission's licensing and regulatory functions.

Onsite Inspection Team.—A Nuclear Regulatory Commission team sent to a nuclear power plant to inspect the licensee's operations during an accident. In the case of TMI, the team was dispatched from I&E's Region I office.

PEMA.—See "Pennsylvania Emergency Management Agency."

PENELEC.—See "Pennsylvania Electric Company."

PUC.—See "Public Utility Commission."

Pennsylvania Electric Company (PENELEC).—Owner of 25 percent of Three Mile Island Unit 2. A wholly-owned subsidiary of General Public Utilities Corporation.

Pennsylvania Emergency Management Agency (PEMA).—The agency responsible for Pennsylvania's response to natural and manmade disasters. The PEMA Director reports to the Pennsylvania Emergency Council, currently chaired by the Lt. Governor of Pennsylvania.

President's Commission on the Accident at Three Mile Island, The.—A 12-member special mission established by President Jimmy Carter to conduct a six-month study of the accident at Three Mile Island.

Public Utility Commission (PUC).—An organization responsible for regulation of a State's utilities. The PUC sets the rates that utilities may charge customers.

RES.—See "Office of Nuclear Regulatory Research."

ROI.—See "Division of Reactor Operations Inspection."

Regional Incident Response Center.—The center of the NRC's regional emergency response at each of the NRC's five regions during a nuclear accident. A Regional Incident Response Action Coordination Team works out of the Center.

SIG.—See "Nuclear Regulatory Commission Special Inquiry Group."

TVA.—See "Tennessee Valley Authority."

Tennessee Valley Authority (TVA).—A corporation owned by the Federal Government. It manages a comprehensive program of resource development for the advancement of economic growth in the region.

Union of Concerned Scientists.—A non-profit tax exempt coalition of scientists, engineers and other professionals who are opposed to nuclear power. The organization has conducted a number of technical studies over the years on a wide range

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In preparing these references, acronyms were used when citing to many of the principal organizations from whom material was obtained. A guide to these acronyms is provided below, along with a list of addresses for those organizations and other sources of documents and related materials used in this report.

The material referenced in this report is on file with the Senate Committee on Environment and Public Works. Published documents of Federal agencies and the U.S. Congress are also available through the U.S. Government Printing Office and the National Technical Information Service (see below).

GUIDE TO ACRONYMS

B&W.—The Babcock & Wilcox Company.
EPA.—Environmental Protection Agency.
GPU.—General Public Utilities Corporation.
GPU Nuclear Corporation.—General Public Utilities Nuclear Corporation.
GPU Service Corporation.—General Public Utilities Service Corporation.
I&E.—Office of Inspection and Enforcement, NRC.
Jersey Central.—Jersey Central Power & Light Company.
Met Ed.—Metropolitan Edison Company.
N.J. Board.—New Jersey Board of Public Utilities.
NRC.—Nuclear Regulatory Commission.
NSAC.—Nuclear Safety Analysis Center.
Pa. PUC.—Pennsylvania Public Utility Commission.
PENELEC.—Pennsylvania Electric Company.
President's Commission.—The President's Commission on the Accident at Three Mile Island.
SIG.—Nuclear Regulatory Commission Special Inquiry Group.
TMI Special Investigation.—Three Mile Island Special Investigation, Senate Subcommittee on Nuclear Regulation, Committee on Environment and Public Works.

ADDRESSES OF PRINCIPAL ORGANIZATIONS

Babock & Wilcox Company,
Nuclear Power Generation Division,
Post Office Box 1260,
Lynchburg, Virginia 24505.

Bureau of Radiological Protection,
Department of Environmental Resources,
Commonwealth of Pennsylvania,
Harrisburg, Pennsylvania 17120.

Burns and Roe, Inc.,
550 Kinderkamack Road,
Oradell, New Jersey 07649.

Committee on Environment and Public Works,
U.S. Senate,
4204 Dirksen Senate Office Building,
Washington, D.C. 20150.

Environmental Protection Agency,
Office of Radiation Programs,
Environmental Analysis Division,
Washington, D.C. 20460.

General Public Utilities Corporation,
100 Interpace Parkway,
Parsippany, New Jersey 07054.

Governor's Office,
Commonwealth of Pennsylvania,
Main Capitol,
Harrisburg, Pennsylvania 17120.

Jersey Central Power and Light Company—*See* General Public Utilities Corporation.

Metropolitan Edison—*See* General Public Utilities Corporation.

National Technical Information Service,
Springfield, Virginia 22161.

New Jersey Board of Public Utilities,
State of New Jersey, Department of Energy,
Board of Utilities,
1110 Raymond Boulevard,
Newark, New Jersey 07102.

Nuclear Regulatory Commission (includes NRC Special Inquiry Group)
Published reports: U.S. Government Printing Office.
All other documents: NRC Public Document Room
1717 H Street NW.,
Washington, D.C. 20555.

Nuclear Safety Analysis Center,
3412 Hillview Avenue,
Post Office Box 10412,
Palo Alto, California 94303.

Pennsylvania Emergency Management Agency,
Post Office Box 3321,
Harrisburg, Pennsylvania 17105.

Pennsylvania Electric Company—*See* General Public Utilities Corporation.

Pennsylvania Public Utility Commission,
Harrisburg, Pennsylvania 17120.

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354. See 40 C.F.R. secs. 1501.4, 1508.9 and 1508.13; 10 C.F.R. secs. 51.5 (b), (c); and 51.7. See also NRC's proposed regulations published in 45 Fed. Reg. 13739 (March 3, 1980).

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357. Op. cit., *City of Lancaster*, Order, filed May 29, 1979.

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359. *Susquehanna Valley Alliance*, *et al.* v. *Three Mile Island Nuclear Reactor*, *et al.*, Civil Action No. 79–658 (M.D. Pa., filed May 24, 1980).

360. Ibid., Plaintiffs' Complaint, paras. 10–20.

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364. NRC, "Environmental Assessment—Use of EPICOR–II at Three Mile Island Unit 2," Staff Report, NUREG–0591, August 14, 1979 (hereafter EPICOR–II Environmental Assessment, 8/79).

365. Ibid., p. 25; see also 10 C.F.R. secs. 51.5(b), (c) and 51.7; 40 C.F.R. secs. 1501.4, 1508.9 and 1508.13, indicating that an agency finding of "no significant impact" means that no environmental impact statement will be prepared. See also NRC's proposed regulations published in 45 Fed. Reg. 13739 (March 3, 1980).

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377. See 42 U.S.C. secs. 4342–4345; Executive Order No. 11514, reprinted in 35 Fed. Reg. 4247 (March 6, 1970), as amended by Executive Order 11991, reprinted in 42 Fed. Reg. 26967 (May 25, 1977). The regulations prepared by the Council on Environmental Quality are found at 40 C.F.R. Part 1500.

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391. See *Susquehanna Valley Alliance, et al.* v. *Three Mile Island Nuclear Reactor, et al.*, CA Docket No. 79–2446 (3d Cir.), Brief of Appellants, dated October 29, 1979, p. 3.

392. Memorandum to Recovery Files from William G. Ballaine, TMI Special Investigation Staff, Re: "Telephone Conversation with Stephen F. Eilperin, NRC," June 6, 1980.

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412. Letter from Robert C. Arnold, Met Ed, to Richard H. Vollmer, Office of Nuclear Reactor Regulation, NRC, November 13, 1979, p. 1.

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472. See, e.g., op. cit., *Fantasky*, Consolidated Class Action Complaint, para. 15(h); op. cit., Pennsylvania Governor's Commission Report, pp. 47, 51-52.

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APPENDIX A: THREE MILE ISLAND IN PERSPECTIVE: OTHER NUCLEAR ACCIDENTS

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APPENDIX B: "NUCLEAR REGULATORY COMMISSION ORGANIZATION"

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