A PEDAGOGICAL REVIEW OF REACTOR OPERATOR TRAINING

AT

THREE MILE ISLAND NUCLEAR PLANT

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A Post TMI-2 Accident Analysis

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Nuclear Engineering Department

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The Pennsylvania State University

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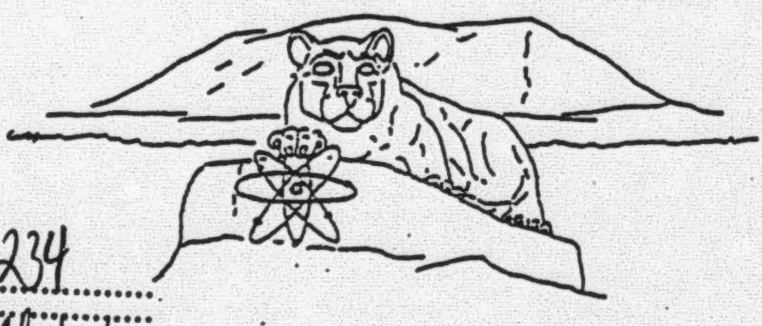

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Warren F. Witzig
Editor

I. Introduction

During the summer of 1979, General Public Utilities (GPU) requested that a few members of the Nuclear Engineering Department Faculty conduct a pedagogical review of GPU's nuclear reactor operator training. This review was conducted under a contract with GPU, the scope of which evolved with the increasing understanding of the TMI-2 accident and related events in nuclear power production and regulation. The review was focused upon two primary subjects:

A. The training program before the TMI-2 accident.

B. The training program after the TMI-2 accident.

These subjects are examined in detail in this report, Sections III and IV. Principal findings of this report are in Section II and detailed comments supporting the findings are contained in Sections III and IV. A partial list of resources are listed in Section V.

The review was conducted by the following Nuclear Engineering Department Faculty members who are the authors of this report:

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Edward S. Kenney, Professor
John L. Penkala, Research Assistant
Gordon E. Robinson, Associate Professor
Warren F. Witzig, Professor and Department Head

The authors drew upon their personal reactor operations knowledge, their educational experience, the knowledge of fellow faculty members and their reactor design experience to carry out the review. The GPU training materials were examined, instructors interviewed, trainees interviewed, and classrooms as well as the simulator were observed during this review.

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Each phase of a reactor operator training program typically has a set of objectives for the operator to achieve. These objectives include such performance related items as basic technical knowledge, reactor and plant systems design knowledge, systems operational procedures, emergency plans, regulatory requirements and communicative skills. The reviewers reduced these objectives to the primary ones of:

1. Oral and written preselection procedures of operator candidates, with follow up on training and on-the-job performance evaluations,
2. An educational and training program to improve the operator's mental ability so he(she) can detect, understand and properly respond to expected and routine plant conditions,
3. An educational and training program to enable the operator to distinguish between routine or normal plant conditions and unexpected or new plant conditions, evaluate new or abnormal conditions and thus properly respond to these conditions.

These objectives lead to the priority items of (a) public safety, (b) operator safety, and (c) equipment preservation in the production of electrical energy. Under the general guidance of these objectives and priorities, the authors conducted the pedagogical review of the pre TMI-2 accident reactor operator training programs as preparation for the post TMI-2 accident training program review.[1,2,3]

II. Findings and Recommendations

This section of the report is divided into three parts, the first deals with the pre-accident training program, the second deals with the operator accelerated retraining program (OARP), post-accident training program and the third deals with a composite of parts one and two and the national reactor training picture at this time.

A. Training Program, Pre-Accident

A1. Substantial parts of the training program are descriptive in nature. That is, modest attention is given to problem solving, analysis of operations as to design limitations or the basic behavior of systems. Only the reactor theory and health physics sections included problem solving with increasing complexity going from elementary to involved problems.

Recommendation - A well developed problem set should be used to lead the candidate from beginning understanding to a level commensurate with the objectives.

A2. The mathematical skills of the candidates are not developed beyond that expected of a technically oriented high school graduate. This handicaps the candidate in the problem solving portion of the learning process.

Recommendation - The mathematical level of the candidates should be raised to that of college algebra for reactor operators (RO's), college calculus for the senior reactor operator (SRO), and differential equations for shift technical advisor (STA). This will take a significant period of time to accomplish, about 18 months.

A3. Recognizing that the ability to reason, analyze, and act decisively does not reside equally in every candidate, it cannot be expected that every candidate would capably respond to expected or unexpected plant conditions. Further, the complexity of a nuclear power plant control room is such that few unexpected plant conditions could be handled by one operator. Thus a training program selection process for candidates must assure that those candidates who are selected for training hold good promise of quality performance and thus provide backup for each other.

Recommendation - A rigorous set of screening tests, written and oral, should be employed for all control room personnel. Consideration should be given to tests such as OTIS, Engineering and Physical Sciences, Abstract Reasoning and Nuclear Concepts.[4]

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A4. Other findings and recommendations were in development during this part of the review process. These were modified as the post-accident training review was conducted and the training methods of other nuclear utilities underwent review. Also the developing criteria and qualifications for reactor operators of the Nuclear Regulatory Commission (NRC) and the Institute of Nuclear Power Operations (INPO) helped to shape these additional findings. They are reported in part three of this section, entitled "Longer Range and Composite Views."

B. Operator Accelerated Retraining Program, Post-Accident

B1. Detailed aspects of the material used to make the principal findings and recommendations in this section are located in Section IV. The OARP is a definite improvement over the pre-accident training program at TMI and should be considered as a large step in a series of steps needed to continue the upgrading of reactor operating training over a period of several years. As a result, some progress has been made in increasing the homework (i.e., problem solving) discussed under Part A of this section.

<u>Recommendation</u> - This finding in Part A, while still applicable to the OARP, has been partially remedied by steps taken in the OARP. The other findings in Part A on mathematical skills and on pre-training selection have not been dealt with in OARP and thus are directly applicable to OARP.

B2. To the reviewers, as experienced teachers, the amount of material to be covered in the OARP with a good understanding on the part of the candidate requires greater instruction time, inclusion of basic principles, and upgrading of the candidates educational level and the use of instructors who are well qualified as teachers, as they appear to be experienced in nuclear plants. Hence the OARP, while achieving many of its objectives, does not achieve them all.

Recommendation - The OARP objectives, topical outlines, rationale, instructional procedure, evaluation procedure and format should continue to be improved and fully implemented over the next several years. The improvements should come from application of current as well as older Licensee Event Reports (LER), from examples such as the detailed comments in Section IV, and from the criteria and qualifications for reactor operators developed by NRC and INPO as they unfold.

B3. Many of the OARP classes contained SRO's, RO's and Auxiliary Operators (Aux Op's) whose experience, training and educational levels varies substantially. This lack of homogeniety results in difficulty in the transfer of knowledge. Should the instructor challenge the most capable in the class, and thus make it very difficult, if not impossible, for the less capable to achieve except through sheer memorization? Or should the instructional level be directed so the less capable have clarity and high achievers are bored?

Recommendation - Up to and perhaps through the RO level trainees can share the same educational program. Above this level of RO, the SRO's should receive additional training, greater analysis and perception or detection experiences and more comprehensive homework, examinations and special assignments.

C. Longer Range and Composite Views

C1. It is a finding of the reviewers that the pedagogical methods used in the OARP are a very important step in the direction of improving reactor operator training. The GPU organizational changes, the acquisition of educational professionals to augment the training staff that is experienced in plant operations and systems, the development of training objectives and the follow through to accomplish these objectives as well as the evaluation of accomplishments, are examples of improvement that are an exemplary effort. The objectives that were set for OARP were tailored to build upon the existing skills of the operators and add the increase in skill thought to be required as the result of the Davis Besse, TMI-2 and the Crystal River experiences. By and large these objectives were substantially met, but not completely as details in Section IV indicate.

Recommendation - The training organization of GPU should continue to improve the entire spectrum of operator training to broaden the objectives and training methodology to encompass the findings and recommendations of parts of this report. Nor should these improvements be limited to the modest scope of this effort, e.g., see the references in Section V.

C2. The reviewers also wish to reflect their general findings crystallized by this study, but which have been in formulation for over a decade. Societal value judgements, engineering complexity and prudent thinking have led to the generally accepted belief that the operation of important modern technology calls for increasing skill and education on the part of the operators. The following recommendations on the general training levels needed for nuclear power plant operators could be regarded by many as extra stringent; even self serving to educators, such as the reviewers. These recommendations are the result of over 130 man years of collective experience of the reviewers in manufacture, design, construction, naval propulsion, operation, and education in the nuclear field. The reviewers helped initiate a graduate program 21 years ago, a baccalaureate program 11 years ago, and an associate degree program 8 years ago, all in nuclear engineering. The reviewers have observed first hand the benefits of quality education.

Accredited universities have painstakingly built a reputation over a period of years of producing a broad-based, well-rounded engineer, well-grounded in fundamentals with the proven ability to apply basic principles to practical problems. The B.S. degree in engineering is generally held in high repute, not only by those who hire engineers, but also by the general public. Public confidence in the abilities of those who operate reactors is an absolute necessity if the nuclear industry is to survive. The recommendations listed below are considered vital to obtaining and keeping that public confidence. It should be understood that a well organized utility training program, staffed with professional teachers and utilizing highly motivated and intelligent trainees could produce an operating staff with the same abilities and knowledge of those who have a college degree. However, public confidence in their abilities would be difficult if not impossible to achieve.

The following recommendations are strong medicine to correct and improve reactor operator training. Such corrections are necessary for greater overall general plant performance in nuclear utilities, and to improve public perception of nuclear power as well as retaining nuclear energy as a viable energy option. To carry out these recommendations is a tough job. This is especially true considering shift work hours, availability of candidates and career futures. Location of accredited programs and their nearness to power plants, quality of faculty with nuclear plant experience and a cooperative university-nuclear utility liaison are the bigger problem areas. These problems represent a genuine challenge to educators as well as nuclear utilities to be innovative and flexible.

Recommendations - That more formal accredited academic preparation be instituted over a period of several years (≈ 5 years) as a part of the upgrading of reactor

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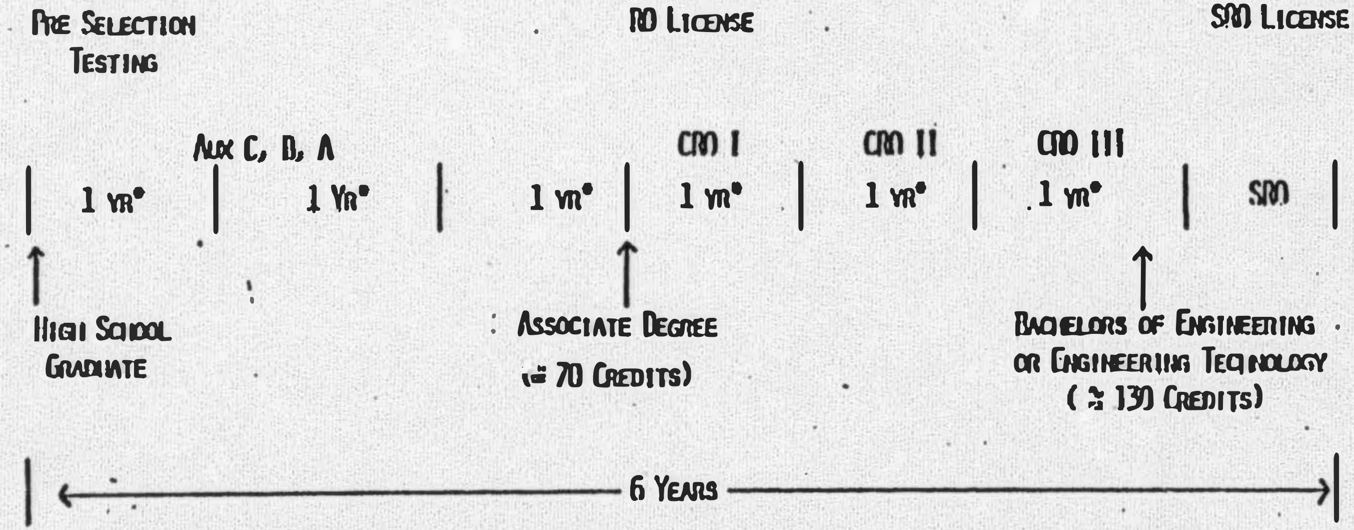
operator qualifications. This calls for a close-utility-university liaison. Specifically, it is recommended:

a) That a candidate for the RO license have completed an associate degree from an accredited program in nuclear, mechanical, or electrical technology, and the improved specialized operator training program. These can occur simultaneously as shown in Figure 1, Proposed Training Sequence for RO and SRO. This is similar to cooperative programs that some universities and utilities now use.

b) That a candidate for the SRO license has completed a baccalaureate in technology or in engineering from an accredited program in the nuclear field or in mechanical or electrical with a nuclear minor and the improved operator program. Again, these can occur simultaneously; see Figure 1.

c) That the shift technical advisor possess a B.S. in nuclear engineering or an appropriate engineering discipline with a nuclear minor from an accredited program, receive a condensed RO/SRO training, pass a mock SRO exam and serve in the plant for a year while receiving specialized courses in system dynamics, heat transfer, thermodynamics, fluid flow, health physics, and instrumentation. Candidate testing can be used to determine which of the above courses are individually appropriate. See Figure 2, Proposed STA Education and Training.

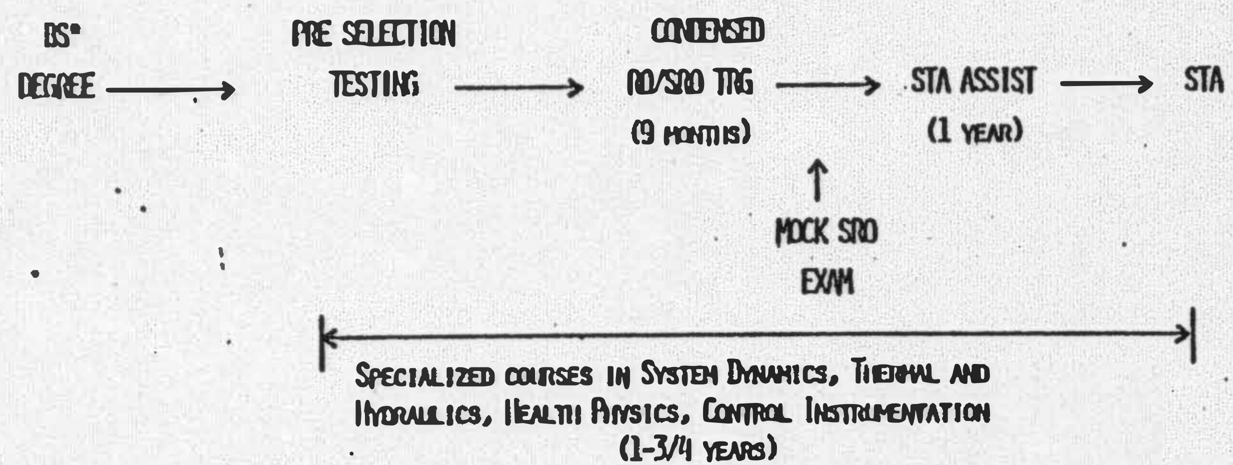
d) That the shift supervisor possess a B.S. in nuclear engineering or an appropriate engineering B.S. with a nuclear minor from an accredited program, receive an Aux Op, RO Training Program, pass the RO License exam, receive a modified SRO training program, pass the SRO license exam, acquire six to twelve months experience as an SRO, and with satisfactory performance be eligible for shift supervisor responsibilities. See Figure 3, Proposed Shift Supervisors Training. A summary of these recommendations are shown in Figure 4.



*YEARLY TRAINING AND EDUCATION PROGRAM CONSISTING OF PLANT SPECIFIC TRAINING AND ACADEMIC CREDIT AT THE RATE OF APPROXIMATELY 22 CREDITS/YEAR. (6 CREDITS FOR ON THE JOB TRAINING, 3-6 VIA CORRESPONDENCE, 13 VIA 3 MONTH RESIDENCE STUDY).

FIGURE 1.

PROPOSED TRAINING SEQUENCE FOR RO AND SRO



*BS IN NucE OR APPROPRIATE ENGINEERING, BS WITH 21-26 NucE CREDITS.

FIGURE 2.

PROPOSED SHIFT TECHNICAL ADVISOR EDUCATION AND TRAINING

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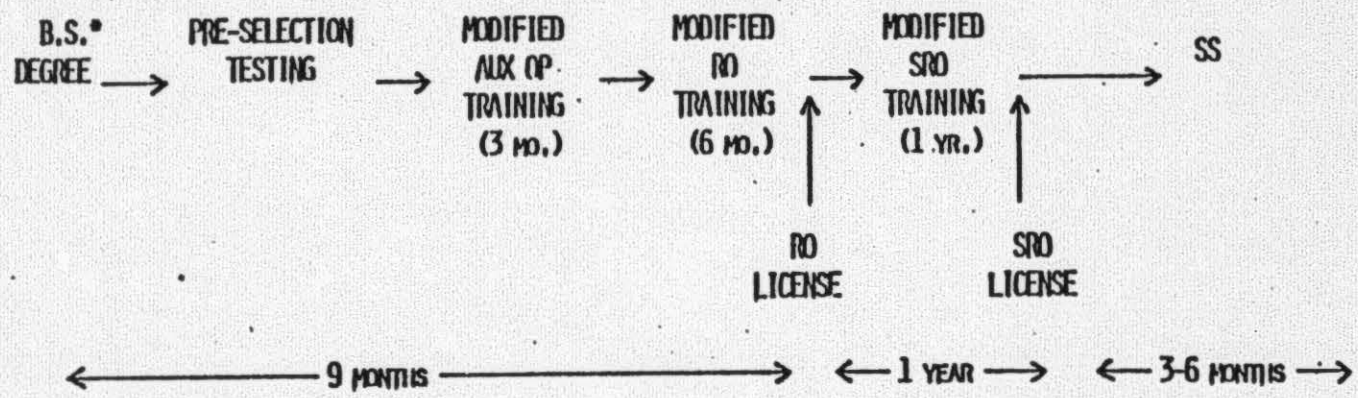

*B.S. IN NucE, OR APPROPRIATE ENGINEERING
B.S. AND NucE CREDITS 18-21

FIGURE 3.

PROPOSED SHIFT SUPERVISOR TRAINING

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SHIFT SUPERVISOR (SS) - B.S. - LICENSED SRO - TRAINING AND EXPERIENCE

SHIFT TECHNICAL ADVISOR (STA) - B.S. - NO LICENSE - EXPERIENCE AND CONDENSED TRAINING

SENIOR REACTOR OPERATOR (SRO) - LICENSED SRO - BACHELOR OF TECHNOLOGY - TRAINING AND EXPERIENCE

REACTOR OPERATOR (RO) - LICENSED RO - ASSOCIATE DEGREE - TRAINING AND AUX OP EXPERIENCE - CANDIDATE SCREENING

FIGURE 4.

SUMMARY OF PROPOSED REQUIREMENTS

e) That in cooperation with career and motivation counselors and accredited local universities, a career development program be established for nuclear power plant operators. Morale, motivation, and retention all improve as a competent operator becomes aware of the excellent professional opportunities that exist for the operator on into the future. This will assist personnel transitions at the SRO-SS level and the SS-STA level. Likewise, attention must be given to further career channels up through management to the corporate officer level.

C3. The last finding and recommendation concerns the question, "How well have the pre- and post-accident training programs measured up to the objectives that the authors established at the start of the review in Section I, 1, 2, and 3?" The answer is, taken as a whole, the on-going reactor operator training programs (pre and post) are a large and important step to meet those objectives. <u>Recommendation</u> - The first step, a more rigorous selection testing needs to be implemented with the next training group. While capable of improvement, the overall training program meets the objective 2, concerning expected and routine plant conditions and evolutions. The program must continue to be improved along the lines of the findings in part B of this section to meet objective 3, New or Abnormal Plant Conditions or Evolutions.

III. Pedagogical Review of the Training Program, Pre-Accident

The GPU (Met. Ed.) training program consisted of those phases shown in Figure 3. The Auxiliary Operator (Aux Op), C, B, and A training consisted of approximately 600 hours of classroom training and an additional period of shift work involving on-the-job training. Under this program, it took approximately 2 years to progress from

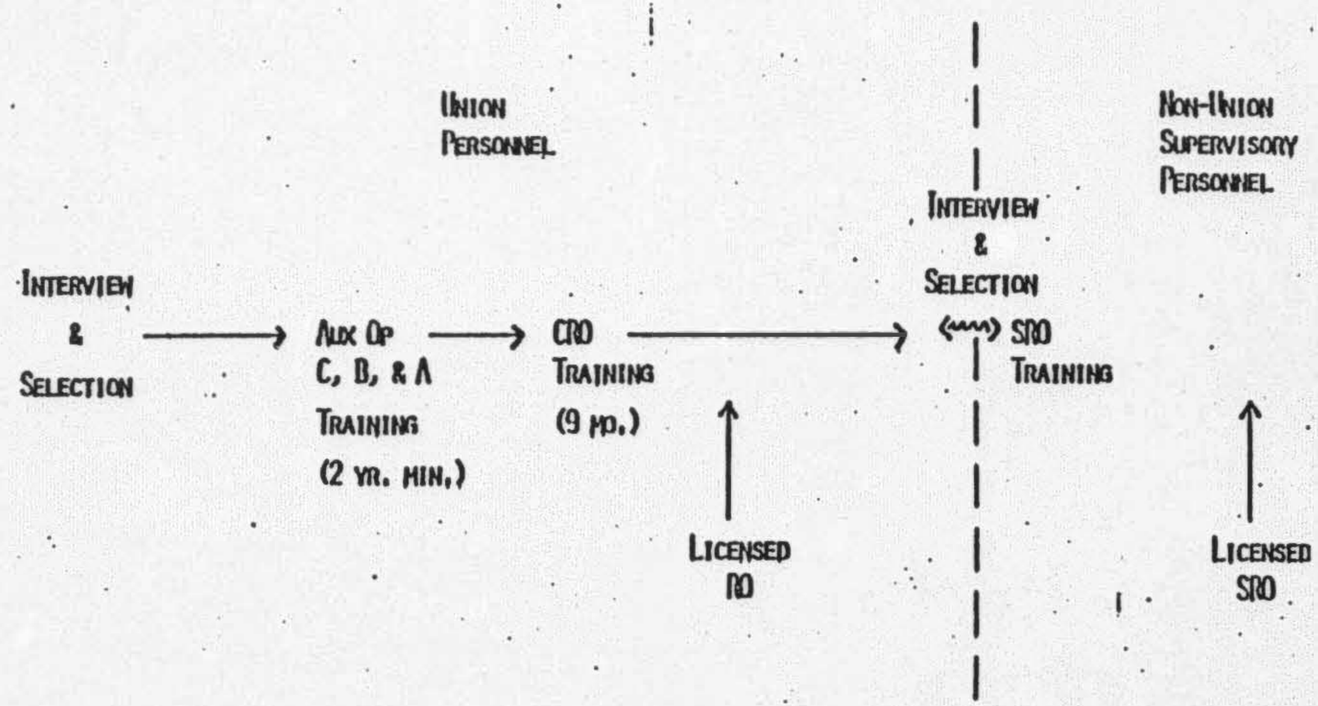

Figure 5.
Pre TMI-2 Accident Phases of Reactor Operator Training

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Aux Op C to A. The classroom and on-the-job training covered primarily:

a) Primary systems
b) Secondary systems
c) Electrical systems
d) Instrumentation
e) Reactor protection systems
f) Health Physics
g) Operating and casualty procedures

In addition, Aux Op's were required to take high school or equivalent courses in algebra, trigonometry, and nuclear or atomic physics.

Once qualified as an Aux Op A, an operator was eligible to "bid" for training and for advancement to Control Room Operator (CRO). Upon selection as a CRO candidate, he(she) entered the Cat. IV CRO training program where the individual received a 9-month training program. This included a 90-day probationary period plus 550 hours of training and instruction. This program was predominantly self-study, on-the-job training. The instruction covered:

a) Reactor theory
b) Integrated control systems
c) Reactor protective systems
d) Engineered safeguards
e) Radiation measurement

Both written and oral exams were given throughout the program along with a comprehensive written exam at the end. Upon completion, a Cat IV CRO was advanced to Cat II and subsequently could take the NRC license exam.

A licensed CRO advanced to Senior Reactor Operator (SRO), should a position which required an SRO license become vacant. The training program for an SRO consisted of a formal interview, a pre SRO training mock written exam, an orientation program, a tailored training program, on-the-job training, and a post training mock Nuclear Regulatory Commission (NRC) exam. Typically a series of lectures covering the integrated control system, reactor theory, engineered safeguard systems, the reactor protection system, radiological waste systems, radiological monitoring systems, technical specifications, and safety analysis were also provided. Upon completion of this program, a candidate was eligible to sit for the NRC exam.

In addition to the above training both CRO's and SRO's were given simulator training by Babcock & Wilcox (B&W). The simulator

Aux Op C to A. The classroom and on-the-job training covered primarily:

a) Primary systems
b) Secondary systems
c) Electrical systems
d) Instrumentation
e) Reactor protection systems
f) Health physics
g) Operating and casualty procedures

In addition, Aux Op's were required to take high school or equivalent courses in algebra, trigonometry, and nuclear or atomic physics.

Once qualified as an Aux Op A, an operator was eligible to "bid" for training and for advancement to Control Room Operator (CRO). Upon selection as a CRO candidate, he(she) enter the Cat. IV CRO training program where the individual received a 9-month training program. This included a 90-day probationary period plus 550 hours of training and instruction. This program was predominantly self-study, on-the-job training. The instruction covered:

a) Reactor theory
b) Integrated control systems
c) Reactor protective systems
d) Engineered safeguards
e) Radiation measurement

Both written and oral exams were given throughout the program along with a comprehensive written exam at the end. Upon completion, a Cat IV CRO was advanced to Cat II and subsequently could take the NRC license exam.

A licensed CRO advanced to Senior Reactor Operator (SRO), should a postion which required an SRO license become vacant. The training program for an SRO consisted of a formal interview, pre SRO training mock written exam, orientation program, tailored training program, on-the-job training, and a post training mock Nuclear Regulatory Commission (NRC) exam. Typically a series of lectures covering the integrated control system, reactor theory, engineered safeguard system, reactor protection system, radiological waste system, radiological monitoring system, technical specifications, and safety analysis were also provided. Upon completion of this program, a candidate was eligible to sit for the NRC exam.

In addition to the above training both CRO's and SRO's were given simulator training by Babcock & Wilcox (B&W). The simulator training was intended to provide a certain realism to the operators training. The operation of the simulator gave the operators first-hand experience with plant transients they could have expected to see during normal and most abnormal operations.

The training information provided by Met-Ed did not address training provided to the Shift Technical Advisor (STA) since this position did not exist prior to March 1979. It is assumed that individuals assigned to the STA position after March 1979 would have as minimum the requirements outlined in reference 5.

The information provided by Met-Ed did not address what training other operating personnel such as the Shift Supervisor (SS) might receive. To provide some basis for judgment, it was assumed by the reviewers that the SS is an experienced licensed SRO with training comparable to an SRO. The resulting education and training requirements are depicted in Figure 6, Present Requirements for TMI Control Room Operators.

During the conduct of the review, observations, comments and suggestions were developed by the reviewers. These developments provide an explanation and the logic which is condensed into the findings and recommendations in Section II of this report. All of these observations, comments and suggestions were shared with GPU representatives orally and are presented in the following brief manner.[6-14]

a) To assure technically correct material of adequate scope and depth, a GPU engineering department review of all training should be conducted. Likewise, for training materials in radiological protection, a review by Radiological Controls is appropriate. In addition, any changes to the training program should receive review by the cognizant department prior to implementation.

b) A review of the topics covered in the pre TMI-2 accident training programs did not identify lesson material on heat transfer and fluid flow or on elementary system dynamics. To understand the technical basis for the design and operation of a reactor plant, one must be familiar with

SHIFT SUPERVISOR (SS) - LICENSED SRO - HIGH SCHOOL EDUCATION* - TRAINING

SHIFT TECHNICAL ADVISOR (STA) - B.S. - NO LICENSE - EXPERIENCE & TRAINING

SHIFT FOREMAN - LICENSED SRO - HIGH SCHOOL EDUCATION* - TRAINING

CONTROL ROOM OPERATOR (CRO) - LICENSED RO - HIGH SCHOOL EDUCATION * - TRAINING

CONTROL ROOM OPERATOR (CAT. II) - COMPLETED CRO TRAINING - HIGH SCHOOL EDUCATION*
-TRAINING

CONTROL ROOM OPERATOR (CAT. IV) - CRO TRAINING - HIGH SCHOOL EDUCATION*
- TRAINING AS AUX OP.

* OR EQUIVALENT, GED

FIGURE 6.

PRESENT REQUIREMENTS FOR TMI-2 CONTROL ROOM OPERATORS not only reactor theory but also heat transfer and fluid flow. In addition, it is essential that one be familiar with system dynamics in order to understand the expected response of a reactor plant under transient conditions. Accordingly, sections covering this material should be added to the CRO and SRO training programs. Appropriate topics to be added include, fluid properties in depth, fluid statics and dynamics, heat conduction, convection, radiation, two phase heat transfer, flow instability and thermal and material limits.

c) A large portion of the training is accomplished through the use of on-the-job training and self-study. For example, most of the present CRO training program (500 hours compared to the total of 550 hours) involves self-study on the job. Such a technique is satisfactory for subjects such as piping layout, procedures, system design descriptions, and system schematics. It is not adequate to teach reactor theory, health physics, two phase heat transfer, flow instability, and other complex technical subjects. Because of this, GPU should revise their training program so include more teacher-led instruction in these areas.

d) With regards to on-the-job training (OJT) conducted by the operations department, we note no audits of this effort by the training department are evident. To provide for a check on the satisfactory progress of an individual, periodic testing of trainees during the OJT portion of the training program must be conducted and the results audited. An improved teaching structure is needed to integrate the OJT with performance standards, classroom instruction, simulator instruction, and self-study.

e) At various points in the discussion of the training program, it is noted that each evolution performed by a trainee is assigned a point value and the accumulation of points is a measure of progress. Nowhere is it clear how many points must be accumulated as a function of time to ensure adequate

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progress. The point progression should be clearly identified. In addition, a monitoring method should be devised to ensure satisfactory progress.

f) Classroom instruction is included at various levels in an individual's training. Yet no provisions for monitoring the adequacy of that instruction is identified in the material provided. To ensure high quality, comprehensive, in-depth instruction, frequent audits of classroom instruction must be provided for. The method used by The Engineering Council on Professional Development (ECPD), now Accreditation of Bachelors of Engineering and Technology (ABET), are suggested[15]. These include classroom visits, student and faculty interviews, analysis of teaching material, textbooks, problem sets, grading, etc.

g) Based on the organization chart provided, the Training Department Head reports to the Quality Assurance (QA) Manager. Since training is a function of the operating division, this arrangement seems inappropriate. In addition, such a reporting structure does not allow QA to perform independent audits of training performance. The present organization should be changed to place training directly under the corporate office responsible for operation. Since this observation, the training group reporting has been changed to the Vice President level, and a well-qualified teaching professional has been selected to head training.

h) Nowhere in the program is it evident that homework is assigned. The use of homework, particularly problems, provides for a certain contemplative experience not attainable in the classroom. It is recommended that frequent problem solving-type homework be assigned, particularly at the SRO level. Whether time be permitted during working hours for homework completion is a corporate policy matter.

i) As discussed in TMI-Training Memo #5, change #2 dated October 8, 1976, a CRO could get as little as one day's classroom instruction in reactor theory. The decision is based on an individual's previous experience. Specific guidelines should be developed and testing performed to determine if a reduction in classroom instruction is warranted. The reviewers are dubious of this practice.

j) It is understood that instruction is provided by video-taped lectures. Recent experience by the reviewers in lectures and laboratories in nuclear curriculum (courses at Penn State such as NucE 200 and NucE 440) indicates such an approach is deficient because of the lack of student-teacher contact. Because of this, video-taped lectures should be avoided unless there is a qualified teacher present to amplify the instruction, ask questions, monitor class comprehension, and reinforce material as required. A video only approach should be used only when no other method is available.

k) Under present procedures, it appears that a person can enter the training program after a training sequence is well underway. Late entry is inconsistent with an ordered program and should be strongly discouraged.

l) It appears that the same material is used for Aux Op's and CRO's. Such an approach is questionable since the level of experience, knowledge and maturity is quite different. A revised program should provide a logical progression in both depth and breadth of material covered.

m) Examinations are important - oral as well as written. Sample written Aux Op's exams were not available for review by the authors.

n) As indicated in the description of the training program, a union representative may be present during discussion of a trainee's performance by the instructor. Assurance is needed that the union representative is technically competent to understand the performance review, even if the representative is there for contractual purposes only.

o) A high school diploma is thought to provide marginal preparation for training to ensure an acceptable level of performance in training on the job. Prospective trainees for the

CRO position should have an associate degree (2 years of technical education beyond the high school degree) in Technology from an ABET accredited program, or acquire one while an Aux. Op.

p) A comparative review of the GPU training program to a selected small utility was also performed. Because of the sketchy information provided by the small utility, little if any conclusions could be drawn. One aspect worth noting, however, was that records of Aux Op training and record entries are computerized. Such a system allows quick and easy evaluation of an individual's performance.

q) To ensure adequate progress, frequent benchmarks must be set. These benchmarks can be in the form of points or number of lessons completed. Regardless of the form, a minimum acceptable level of performance versus time should be established and monitored. If an individual falls behind, then clearly defined corrective action should be identified and implemented.

r) It appears from discussions with various training personnel at GPU that some decline in the overall quality of the training program may have occurred prior to the TMI-2 accident. To avoid this in the future, the Quality Assurance Division should be required to develop a QA plan for periodically measuring the quality of the program. As a minimum this QA plan should require yearly audits of the training program. In addition, periodic independent audits by an objective outsider should be conducted on a scheduled basis.

s) In any evolving field, it is necessary to provide some means of education to keep up to date with the changing requirements. The present operator training program provides for this through periodic retraining programs on an annual basis. This frequency does not appear to be adequate so as to ensure that individuals are aware soon enough of operating problems at the plant and at other plants.

Accordingly, a formal program should be established as a part of the six-week training cycle to provide all operating personnel with updates on changes in procedures and operating philosophy, and on problems. Such a program might consist of seminar-type briefings on Licensee Event Reports (LER's), plant modifications and procedure changes and employ quizzes.

t) It appears that the two weeks of simulator training concentrates on "this-is-what-occurs," with little information on "why-this-occurs." It is recommended that the lectures at the simulator include details relating basic concepts to the actual occurrence with in-depth explanations of "why" as well as cause and effect. Integration with classroom, on-the-job, and self-study portions of the program is appropriate. This change may necessitate extension of the simulator training program.

u) The Certification Examination for the simulator is given after the first week of training at the simulator and includes only normal operation. No examination or evaluation appears to be given on abnormal operation and unannounced casualties (the second week of the simulator program). While not required by current NRC regulations, it is recommended that the certification examination be given at the end of the simulator training program and include all material covered. As in the comment above, this addition may lengthen the simulator program.

v) It appears that the simulator instructors do not have detailed familiarity with TMI plant specifics and practices. It is recommended that a TMI instructor who has a TMI SRO license be lead instructor or co-instructor at the simulator, coordinating all simulator activities. The SRO would utilize simulator instructors in running the program but would hold overall responsibility for the simulator program. It is recognized that this recommendation requires consent by B & W. It is expected that this action will lead to better integration of the simulator training into the overall program.

w) It is not apparent that significant differences, if any, in the response of the TMI plant and that shown by the simulator are discussed as part of the simulator training. A "differences" notebook exists but is not in the lesson plan. It is recommended that this information be incorporated into the simulator training program. Such differences are particularly important under abnormal conditions. It is clear that more time must be allotted to simulator training. As part of the expanded program, the following experiences should be considered to provide realistic situations that may be encountered by the trainee during accidents:

1) multiple equipment failures or malfunctions,
2) equipment malfunctions with important associated equipment previously tagged out,
3) both 1 and 2 over a suitable period of time, i.e., small break plus other failures over several hours duration.

x) The present program does not appear to provide SRO's with any additional simulator training beyond that of the CRO. The SRO's need additional simulator training especially in areas of recognizing transients, coordinating RO efforts in effectively controlling transients, and applying basic knowledge to cause-effect relationship as well as interpreting and integrating data from plant instrumentation. Accordingly, additional training, stressing these areas should be provided SRO trainees.

IV. Pedagogical Review of the Operator Accelerated Retraining Program (OARP), Post-Accident

As a part of the preparations to have the Three Mile Island Nuclear Station Unit I move from the cold shutdown status, a retraining program for the reactor operators and senior reactor operators was conducted in the fall of 1979 and in the spring of 1980. While the OARP is a review of essentially all aspects of reactor operator training it was conducted in greater technical depth, rigor and organization than the pre-accident training program. The OARP covered topics which can be divided into four functional areas:

a) TMI Plant Operational Review c) Radioactive Materials Control
b) TMI Plant System Review d) TMI Plant Transient Analysis

These functional areas were taught in some sixty separate lessons in the classroom, in the TMI control room "walk through" and in a simulator control room.

Seven modules were developed to teach the functional areas and these modules were tailored to fit a six week cycle TMI training shift or to be taught as a full-time program. A brief outline of the modules' content follows:

A. Simulator Training Module (4½ days)
   1. Power Distribution and Rod Withdrawal Limits (4 hrs lecture)
   2. Heat Transfer and Fluid Flow (4 hrs lecture)
   3. Small Break Analysis (4 hrs lecture)
   4. Safety Analysis (4 hrs lecture)
   5. TMI-2 Accident Analysis (4 hrs lecture)
   6. Unannounced Casualties (16 hrs simulator)

B. TMI Module One (4 days)
   Fundamentals integrated with specific operational characteristics.
   1. Heat Transfer and Fluid Dynamics (16 hrs)
   2. Reactor Theory (16 hrs)

C. TMI Module Two (3½ days)
   1. TMI-2 Transient (4 hrs)
   2. Reactor Coolant System (5 hrs)
   3. Make-up and Purification System (4 hrs)
   4. In-Core Instrumentation (1 hr)
   5. Control Rod Drive System (4 hrs)
   6. Nuclear Instrumentation (2 hrs)
   7. Integrated Control System (4 hrs)
   8. Radiation Emergency Plans (4 hrs)

D. TMI Module Three (4½ Days)
Twenty-two individual lecture topics to provide detailed coverage of selected TMI-1 primary and secondary plant systems essential to normal and emergency cooling of the reactor core.

E. TMI Module Four (4½ days)
Some twelve individual lecture topics giving detailed coverage of selected TMI-1 systems and plant procedures with an emphasis on: radiation safety, radiation monitoring, radioactive materials control and changes made after the TMI-2 accident.

F. TMI Module Five (5 days)
Fourteen lecture topics giving a detailed coverage of selected TMI-1 systems, and operational characteristics for normal and abnormal events using the TMI-1 control room. Expected plant response to operational situations and actual control instrumentation locations are emphasized.

G. TMI Module Six (5 days)
This module taught plant modifications and a rather detailed safety analysis workshop. Emphasis was on computer modifications, TMI-1 long range design modifications and about three-quarters of the emphasis was on the safety analysis workshop for normal and abnormal events.

Very good pedagogical procedures were set up for the OARP. These procedures included program objectives, topical outlines, rationale for the material to be taught, instructional procedures and evaluation procedures. With diligence in following the procedures, with quality instructors, with motivated students and a suitable learning environment a most satisfactory program would be expected. While the reviewers conclude that the OARP was a very great improvement over the pre-accident program, a continuation of improvement in training is required. Section IX of this report contains the principal findings and recommendations of the OARP review; and the following observations, comments and suggestions provide a background for the principle findings.

A. One of the lectures listed under simulator training (TMI-2 accident analysis) was given at TMI by a GPU employee with a B & W employee as backup instructor. A large class of 40-50 SRO's, RO's and Aux Op's with a variety of educational backgrounds and experience had difficulty in assimilating the materials taught. This resulted in inattention, classroom disruptions and a difficult learning-teaching atmosphere. Smaller classes of more uniformly prepared students is recommended.

B. At the B & W Nuclear Training Center a small group, 5 or 6 people, who would be on shift together constituted each class. This is a good arrangement and allows for evaluation as a team, which is particularly important for abnormal, unexpected or casualty drills. However, evaluation of individuals should also be conducted. This would allow weaker members of the team to be assisted and stronger members to be considered for advancement.

C. Evaluation of team performance was predicated primarily on the criterion of controlling a transient such that no core damage occurred. This criterion should be upgraded to a higher level to provide a small but adequate margin before core damage would occur. This is analogous to a DNBR larger than 1.0, such as 1.3, which is a design criteria.

D. Those teams which did not meet the new upgraded criteria in the OARP should receive additional simulator training and be retested. Also a stronger and tighter liaison between the TMI training group and the B & W simulator personnel is encouraged and a TMI training member should monitor the simulator training and performance evaluations.

E. The simulator training is better scheduled at the end of the OARP to reinforce the whole educational experience rather than have it given at the beginning of the OARP. The simulator training is better understood when all the educational building blocks are in place before that training. It is recommended that each shift team, as a part of maintaining its skills, be scheduled for casualty training on the simulator using upgraded criteria of item C before power operation of TMI-1 and regular intervals thereafter. Such action would obviate the first part of the recommendation in item D.

F. It is difficult to comment on the lecture series included with the simulator training. It was not designed to directly dovetail with the casualties done on the simulator. The content of the lectures is such that it is doubtful that an in-depth understanding of the material covered was obtained by a majority of the team members. Both the amount of material covered, and the team's educational background at the time these lectures were given, are justification for the previous statement. It should be noted that almost all, if not all, of the material covered in these lectures was repeated in later modules of the program. See item E.

G. For future lectures given simultaneously with simulator training, lectures more directly related to the casualties seen on the simulator are recommended, somewhat along the lines of Part 1 of the Safety Workshop. Why certain actions are taken should be stressed. Relating the result of action or inaction to basic principles (i.e., reactivity coefficients, heat transfer, fluid flow) is also recommended. In addition, these lectures should emphasize any differences between what is seen and done at the simulator, and what would be seen or done in the actual control room.[16]

H. As a general comment too much material is attempted to be taught in all of the modules in the time allotted. Lectures should be extended over a larger period of time and be limited to 4 hours per day. Supervised practicums can be interspersed with lectures for reinforcement as well as modest laboratory sessions involving basic principles of the subject area being taught; likewise OJT training or study periods can be interspersed.

I. Homework problems ranging from simple illustration to complex relationships should be assigned to illustrate basic principles and reinforce learning. Due dates for completion is necessary and individual effort encouraged rather than group solutions of a problem.

J. Frequently examinations were given as "take home" exams, often without a due date, due to lack of class time and several weeks expired before they were returned. This is not a preferred method for learning or testing as there is a lack of supervision. Also the length of time given to complete the exam is too long. As a general rule, examinations should be given and completed in class time, even if this extends class time.

K. Physical classroom quality is very important to provide a climate conducive to learning. Improved and upgraded construction offices are often of insufficient quality. Proper room size, desk or chair spacing, blackboards, lighting, noise levels and ventilation are very critical items to the learning environment. Food consumption and smoking are not conducive to good class decorum. Instructor authority to maintain decorum by removal of a disruptive trainee or other measures is highly desirable. A professional education and training atmosphere is important! Such facilities are best provided off the plant site to reduce classroom interruption by operational problems. These comments apply to all parts of this review.

L. Both SRO's and RO's were given the same educational material which is inconsistent with the different requirements associated with their positions. While the matter is difficult to handle, the SRO's should receive additional training beyond that received by the RO's at least in homework and practicums and hopefully in some lecture material.

M. By means of review of the written material and tests, and a review of the schedule and discussions with several participants of the heat transfer portion of OAHP, it has become obvious that the course objective of obtaining a clear understanding of the basic principles has not been met. In order to rectify this problem, it is recommended that a review of the material presented in the four lesson plans be held. This review could take many forms; but the recommendations, given under the above comments H, I, J, K, L, should be heeded. A possible form this review could take would be the following; have the class read a given portion of the material, then hold informal discussions on the material, work examples on the board, and then hold a supervised practicum session. This method would work best with small classes (i.e., no more than 10 to 12 people). It is felt that the recommended review could be part of an on-going requalification program, and as such, be completed within a year.

N. In several areas, such as reactor theory and heat transfer, the basic concepts stressed in an early lecture are not fully used in subsequent lectures to explain a phenomenon under study. For example, in discussing radial fuel pin temperature profiles, inclusion of the application of conduction and convection would be helpful. This could help the trainee understand the relative thermal resistances and how changes in these values affect heat transfer and temperature. Another example exists in the reactor theory section where the six factor equation components are not clearly explained before the coefficients of reactivity are developed. Basic principles are then difficult to involve in parameter variation such as thermal utilization and resonance escape probability. Thus, it is not possible to substitute phenomenological changes for partial differentials.

O. In some areas such as the safety analysis workshop, nuclear instrumentation and the integrated control system, a large amount of material is covered. Thus, it is very difficult, if not impossible, for the instructor to go into depth examination of parameters and then to explain why events happen. Basic principles cannot be applied to explain the results of parameter variation. Revised lesson objectives and more detailed lesson plans are one possible solution. These comments also apply to other sections such as the engineered safeguard actuation system, computer modifications, and the reactor building emergency cooling system.

P. In the systems lectures some improvement is possible by keeping the lesson plans closer to the objectives, with operations as a primary focus; for example: discussion of weld efficiencies in the reactor coolant system lecture could be omitted, design aspects of the reactor coolant pump as they influence operation is not included, details of the strainer design in the reactor building emergency cooling system could be omitted, the inclusion of event tree or fault tree analysis would help the casualty drill area, parameters of all modes of operation of the nuclear services closed cooling water system probably should be included, the system parameters available in the control room for the feed system and the main steam system are not adequately described and lastly the operational parameters for the emergency diesel generator are not emphasized.

Q. Teaching emphasis should be increased on the detection by the operator of unexpected events in all safety related systems including in-core detectors, rod drive system, engineered safeguards actuation system, rad-waste system, reactor coolant system, decay heat systems, etc.

R. The training review on procedures and their use should encourage the use on all procedures of the what, why, when approach which is used in some of the procedures. Clarity on what items to be logged, why and when would be helpful to the trainee. A clear statement is needed on the availability of procedures, on the need to have current procedures, on the consultation of procedures if a question exists, on the need of timing of sign-offs (i.e., during fuel transfer) and that editorial changes to procedures are not to be made unless the procedure is undergoing change for other reasons.

S. The radiation emergency plan description can be improved by including a check list of specifics, i.e., when is the Pennsylvania Department of Environmental Resources (DER), and the Governor called, who calls, to whom do I report, what is my responsibility as a function of the event. Accident "drills" should be used to test the plan and systems, locate weaknesses and repair them.

T. The radiation control and safety section and the operational chemistry section are examples of some of the better lesson objective outlines and instructional material.

U. Trainee reviews of instructors which show unsatisfactory ratings initiate a remedy of having the instructor repeat the lecture. Thus there is a motivation to satisfactorily grade instruction to avoid another potentially unsatisfactory lecture. A preferred remedy is to correct the instruction by counseling the instructor and monitoring the result or using another instructor. A discussion session on the deficient lecture topic may be included as a remedy.

V. References

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2. GPU - Letter from R. W. Zechman - dated December 17, 1979.
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5. Technical Staff Analysis Report of Selection, Training, Qualification, and Licensing of Three Mile Island Reactor Operating Personnel to the President's Commission on the Accident at Three Mile Island, dated October 31, 1979.
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7. ANSI/ANS 3.1-1978, "Selection and Training of Nuclear Power Plant Personnel."
8. Title 10, Code of Federal Regulations, Part 55, "Operators Licenses."

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9. TMI-2 - Lessons Learned Task Force Status Report and Short-Term Recommendations NUREG-0578 - July 1979.

10. Investigation into the March 28, 1979, Three Mile Island Accident by Office of Inspection and Enforcement NUREG-0600 - August 1979.

11. GAO Report of TMI Accident to Congressman Schweiker - dated May 5, 1979.

12. Presidential Fact Sheet of December 7, 1979 - The President's Response to the Recommendation of the President's Commission on the Accident at Three Mile Island.

13. The Report of the President's Commission on the Accident at Three Mile Island (Kemeny Commission) - dated October 31, 1979.

14. TMI-2 Lessons Learned Task Force Final Report NUREG-0585 - October 1979.

15. "Criteria for Accrediting Programs in Engineering in the United States," Engineers' Council for Professional Development 47th Annual Report, dated 1979.

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