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The 35th Anniversary of the Three Mile Island Nuclear Power Plant Accident of 1979:

Working at TMI During and Following the Accident

March 25, 2014 Presentation to the NRC by

Gordon R. Skillman
Member, NRC Advisory Committee on Reactor Safeguard

A Special Video Event in Volume 1 of NUREG/KM-0001,
Three Mile Island Accident of 1979
Knowledge Management Digest

The Presenter

Gordon R. Skillman
Member, Advisory Committee on Reactor Safeguard

Mr. Skillman is an independent consultant in nuclear power plant design and operation with over 47 years of commercial nuclear power experience. He has served on nuclear safety oversight boards and engineering councils for many years and has been directly involved in design, consultation or oversight actions at 27 of the 104 live-core nuclear plants in the United States. Mr. Skillman earned his Reactor Operator's License and Senior Reactor Operator's license from the US Atomic Energy Commission in 1967 and 1969 respectively and served on the nuclear merchant ship NS Savannah as a Reactor Operator, Steam Plant Operator, Health Physicist and Water Chemist. On completion of his sailing obligation he joined the Babcock and Wilcox Company where he contributed as an engineer and manager for B&W's Nuclear Power Generation Division in Lynchburg, Va. and in Mannheim, Germany. He was an immediate-responder to the TMI-2 accident and served for 7 years on the stabilization and clean-up of TMI-2 both as a B&W and, later, as a General Public Utilities Nuclear Corporation employee. At TMI-2 Mr. Skillman was Manager of Recovery Support Engineering and later was Manager of Defueling. Mr. Skillman then served GPUNC as a Director in multiple leadership positions at TMI-1. Following the sale of TMI-1 to AmerGen Mr. Skillman established Skillman Technical Resources Inc. (STR) serving as its President and Principal Officer providing consultation and oversight services to the nuclear industry.

Presentation Video and Narrative

For the 35th anniversary of the TMI-2 accident, the NRC a hosted a special seminar event titled, “The 35th Anniversary of the Three Mile Island Nuclear Power Plant Accident of 1979: Working at TMI During and Following the Accident.” The seminar featured a presentation by Mr. Gordon Skillman, a current member of NRC’s Advisory Committee on Reactor Safeguards who was an immediate-responder to the TMI-2 accident. As an employee of Babcock and Wilcox during and following the accident, he served for seven years on the stabilization and cleanup of TMI-2 as Manager of Recovery Support Engineering and later as Manager of Defueling.

The presentation covered Mr. Skillman’s first-hand experiences while working on technical issues involving plant and reactor core stabilization, accident water cleanup, and defueling the damaged core. Mr. Skillman shares his personal experiences while living in a nearby community and working closely people from the utility, many contractors, the NRC, the DOE, national laboratories, and Pennsylvania’s and Maryland’s environmental agencies.

The DVD in Volume 1 to the NUREG/KM-0001 provides a multimedia presentation of this event (see DVD-1 folder NRC 30th Anniversary Seminar).

This document, authored by Mr. Skillman, provides the narrative and slides of the presentation. The narrative pages and slides are numbered separately. An abridged version of this narrative was used for the script of the presentation.

Frequently Used Acronyms

B&W	Babcock & Wilcox
CFR	Code of Federal Regulations
cm	centimeter
GPUSC	General Public Utilities Service Corporation
GPUNC	General Public Utilities Nuclear Corporation
mm	millimeter
NRC	Nuclear Regulatory Commission
PORV	Pilot-Operated Relief Valve
ppm	parts per million
psig	pounds per square inch gage
Rad Con	Radiation Control
R/hr	roentgen per hour
RCS	Reactor Control System
SDS	Submerged Demineralizer System

The 35th Anniversary of the Three Mile Island Nuclear Power Plant Accident of 1979:
Working at TMI During and Following the Accident

The Narrative to the Presentation to the NRC by
Gordon R. Skillman

Slide 1 - Three Mile Island

How I got to TMI-2

Through B&W. Babcock & Wilcox's (B&W's) entire NPGD office in Lynchburg, Virginia, was promptly mobilized within hours following the accident on Wednesday, March 28, 1979. The first call came in at about 0630. Part of the Lynchburg Engineering Management team promptly traveled to Middletown and attempted to gain access to the Island. They were not successful in getting on the Island and either remained in local worker's homes, or in motels, awaiting opportunity to participate. I remained in Lynchburg for the first several days following the accident – participating in B&W's Engineering Department's response for a little over a week. On Monday, April 9, 1979 I flew to Harrisburg on a charter aircraft from Lynchburg for what was supposed to be a two week emergency assignment. That assignment lasted over 22 years.

My purpose for traveling to the Island was to try to determine what happened to TMI-2's core.   My instructions were to try to understand the core's behavior based on the sparse data available to us. Our work required us to be either in the TMI-2 control room or in construction trailers on the island. Our concerns surrounded gaining assurance of subcriticality and assurance of provision of core cooling. The TMI-2 operators conducted their business using their original and newly written procedures. My team and I were trying to interpret the core's behavior based on what they did. We were involved in decisions regarding poisoning the Reactor Coolant System (RCS) with Boron, RCS pressure control, decay heat removal, and initiation of natural circulation by directing the stopping the last (final) Reactor Coolant Pump on April 27, 1979. Once we were confident that we knew that the core was subcritical and cooled, I became involved in multiple additional areas of the stabilization and clean up, first as Manager of Recovery Support Engineering for General Public

Utilities (GPU), then Manager of Disassembly and Defueling Planning (for GPU), and then Manager, Defueling (for GPU).

Acknowledgement of Participants

I would like to communicate at the outset of this presentation that the response to the events that unfolded at TMI-2 in the days, weeks and months, then years after the March 28, 1979 accident, and the challenges and successes achieved by the participants, was an industry-wide effort that included hundreds of dedicated and highly skilled people. These include the Metropolitan Edison (or “Met Ed”) personnel, the GPU personnel, the original architect engineers of both TMI-1 and TMI-2, personnel from B&W, the U.S. Nuclear Regulatory Commission (NRC), U.S. Department of Energy (DOE), from numerous national labs whose often real-time response and counsel was so valuable, from Pennsylvania’s environmental agencies, and from numerous large and small contractors. It took all of these working together, sometimes harmoniously, sometimes at odds, to achieve TMI-2’s stabilization and clean up. I was one of those people.

Multiple well documented studies that focused on the technology associated with the TMI-2 accident and its impact on the US Nuclear Industry have been authored, critiqued and filed away in dusty file cabinets. The distillate, the distilled wisdom, from these have become in some form part of our present regulations, have become an additional element in our understanding of light water reactor accident behavior and in our accountability for emergency preparedness. As exciting as these topics are, they are not the objective of this presentation.

The objective of this presentation is to be ‘How it’s Made’ presentation to describe what happened AFTER the accident’s initial sequence of events, particularly from the site perspective, and specifically from the perspective of the sometimes frantic actions in the days and weeks following the accident to regain control of the plant, and in the months and years later to establish normalcy to TMI. My intention is to communicate my personal involvement that spans 7 years of recovery support – from March 28, 1979 to June 1986. I will be using original material from ‘transparencies’ that I used in presentations that I made 35 years ago – before there were PCs (personal computers), before there was a Microsoft, and before Power Point. These images are primitive by today's standards – but they are also historical documents hence have not been altered. Don Marksberry, from the Office of Nuclear Regulatory Research staff, has been gracious in taking my ancient material and creating from it many of the slides that you will be viewing. I acknowledge Don's efforts and I thank him. Importantly, Don was also at TMI-2 in the early 80's, and we worked together back then.

ACRS Connection

I am in my third year as a Member of the Advisory Committee on Reactor Safeguards (ACRS), a Committee that deliberates nuclear safety issues most often with the luxury of time; my colleagues and I can discuss or debate these issues in a large meeting room with comfortable seating and ample lighting, and we can take breaks when we want to. The environment at TMI-2, for the first several years, had none of this luxury. The actions associated with maintaining basic nuclear safety while taking effective actions to shut down, cool down, and stabilize TMI-2, were accompanied by a sense of urgency that was palpable – one could sense it. Each day brought new information, new challenges, and renewed pressure for success. Concurrently, nearly all of our actions were under the scrutiny of the NRC, the media, our Industry peers, and, very often, a hostile public. My hunch is that our Fukushima colleagues are experiencing this same environment today.

Concurrently, we were well aware of the fear that prevailed in the local communities. That the Accident occurred while the movie "China Syndrome" was still in the local theaters has always seemed to me to be part of the TMI-2 story. The time of the Accident combined with the chilling images from that very popular movie had the impact of magnifying the public's fear of the technology and polarizing their early contempt for the TMI-2 workers.

The sequence of actions that the combined organizations undertook were pursued with uncompromised respect for nuclear technology – and were executed while addressing basic and fundamental nuclear safety issues contemporaneously – in real time while they were occurring – and while accounting for uncertainties in containment integrity, in uncertainties in RCS integrity, in uncertainties in core condition and criticality, uncertainties in decay heat removal and in RCS pressure control, and uncertainties regarding isotopic behavior and fuel fines behavior.

The Beginning

Slides 2 and 3 – Three Mile Island

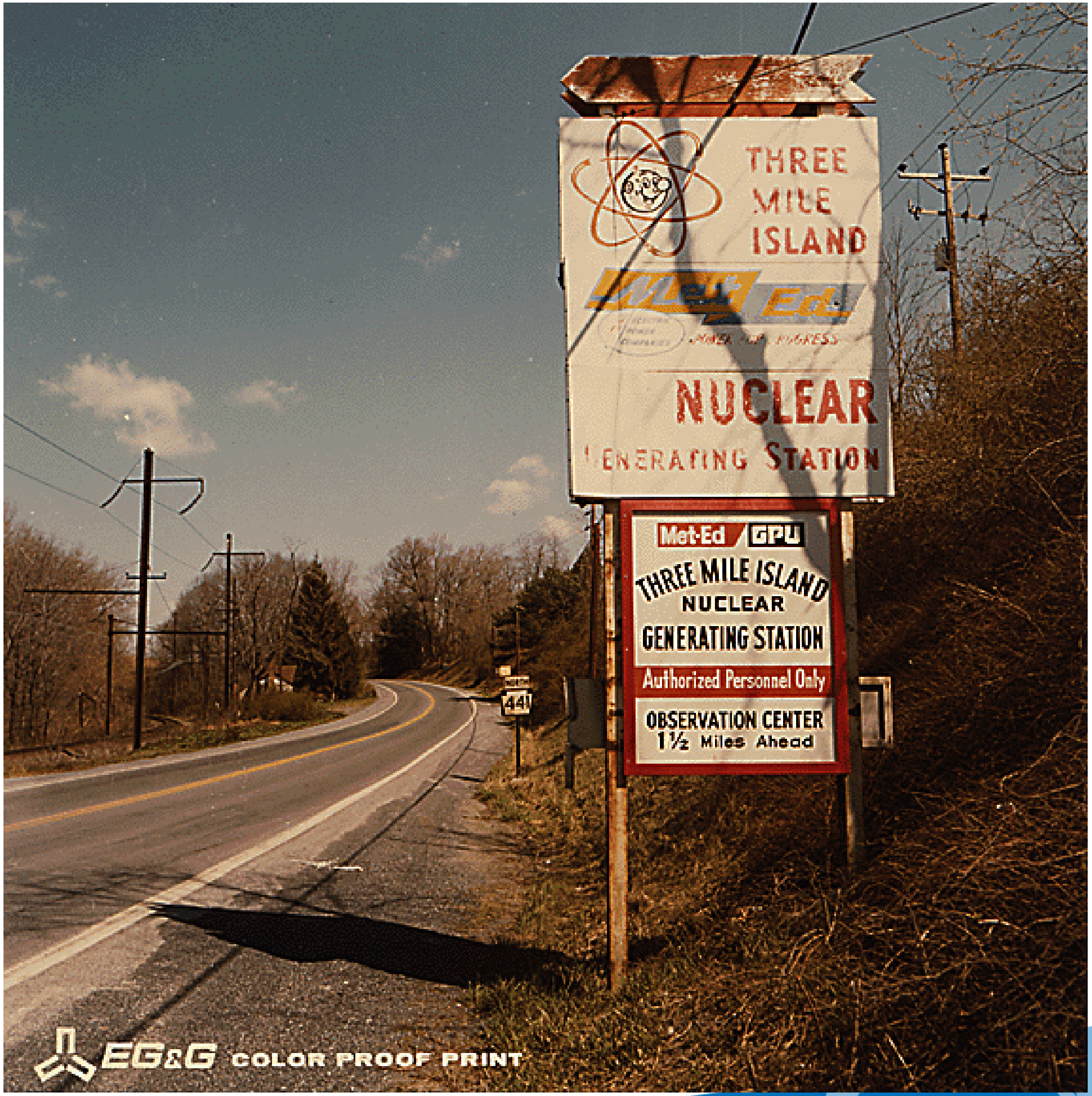
TMI-1 and TMI-2 share a common plot of land on an island in the Susquehanna River about 10 miles south of Harrisburg, Pennsylvania's state capital. Entrance to the Island is by two bridges off of Pennsylvania Route 441 about ~3 miles south of Middletown, Pennsylvania. TMI is surrounded by the Susquehanna River and effectively sits in a 'moat'. The bridges access TMI from the east side of the Susquehanna River

Immediate Focus

Our immediate focus at TMI-2 was on assurance of core subcriticality, provision of dependable decay heat removal, retention of Reactor Coolant System pressure to assure sub-cooling for both the unknown core condition and for net positive suction head for the operating reactor coolant pump, and preservation of the RCS pressure boundary. We succeeded in accomplishing these things in spite of questionable or failed instrumentation, hastily written procedures, in the presence of unprecedented media scrutiny and under enormous political pressure.

Prevailing over all of our activities at both TMI-1 and TMI-2 was an unyielding sense of accountability for safety at all levels including nuclear, radiological, personnel and industrial, tempered by recognition of, and acceptance of, the risks that were and would be associated with performing the work required to complete the stabilization and clean up.

In parallel with those actions was the urgency associated with removal of the highly radioactively contaminated water in the Reactor Building sump amounting to thousands of gallons, with the intent to assure the sump water remained securely in place



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TMI Sign at South Bridge Turnoff

(Pennsylvania Highway 441 on April 6, 1979)

Aerial View of Three Mile Island through Unit 2 Cooling Towers

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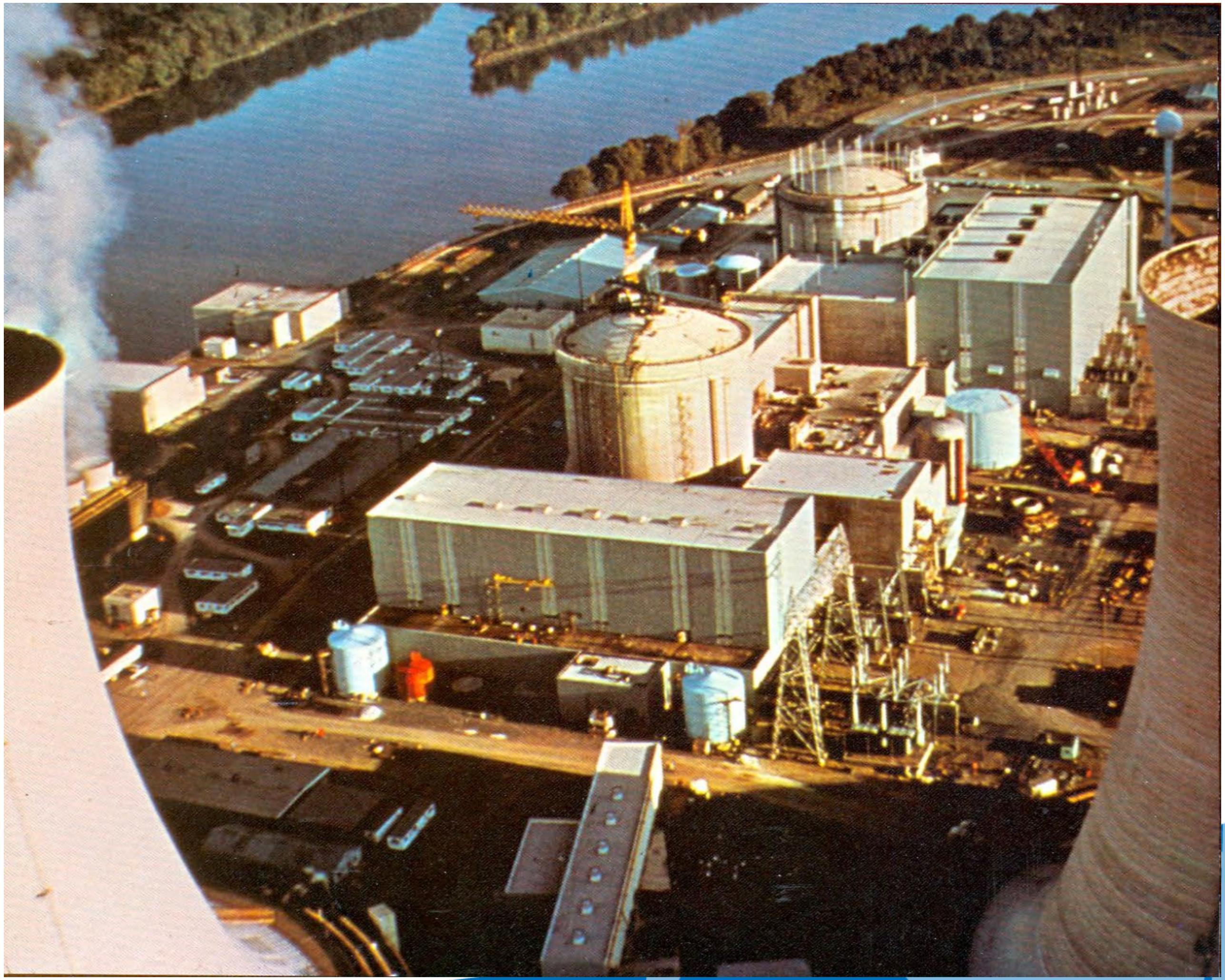

until such time as we could safely remove it. That same urgency accompanied the actions for the disassembly of the Reactor Vessel by repair of the polar crane, removal of the Reactor Vessel Head, removal of the Plenum, movement of both to safe storage away from workers, and actions to initiate Defueling.

Generally not recognized is that there was a fully functional, refueled, and ready to operate TMI-1 next door. At the time of the TMI-2 accident TMI-1 had just completed its refueling outage and was in the process of restarting. TMI-1 was prevented from restart for approximately 5 ½ years based on concerns regarding the reactor design (B&W-177) and the owner's/operator's capability.

1979 – March 28 – 0400 – The Accident

Slide 4 - TMI-2 Control Room during Accident Operations

The accident at TMI-2 occurred at ~0400 hours (4:00 a.m.) on Wednesday morning, March 28, 1979, approximately 100 days into TMI-2's commercial life. TMI-2 had entered commercial operation on New Year's Day 1979 after an approximate one year startup and test program. The cause of the accident was failure of a valve to open – in the Condensate Polisher Demineralizer System - causing a loss-of-feedwater. The combination of the loss of feedwater, the low secondary side mass inside the B&W Once Through Steam Generator and the huge surface area presented by the Once Through Steam Generator tubes, caused T/H imbalance when the Primary Temperature increased, expanded the contained reactor coolant, raised the Pressurizer Level and primary pressure, resulting in the intended opening of the spray valve and in the intended actuation (opening) of the Pilot-Operated Relief Valve (PORV). All of these actions were normal, anticipated, and analyzed.

Slides 5, 6, and 7 - TMI Elevations, RCS Isometric

Slide 8 - PORV Inside Primary Shield

However, the PORV did not reseat, and the operators did not recognize that occurrence. If they had, they would have isolated the PORV by closing the PORV block valve. The indication for the

TMI-2 Control Room During the Accident

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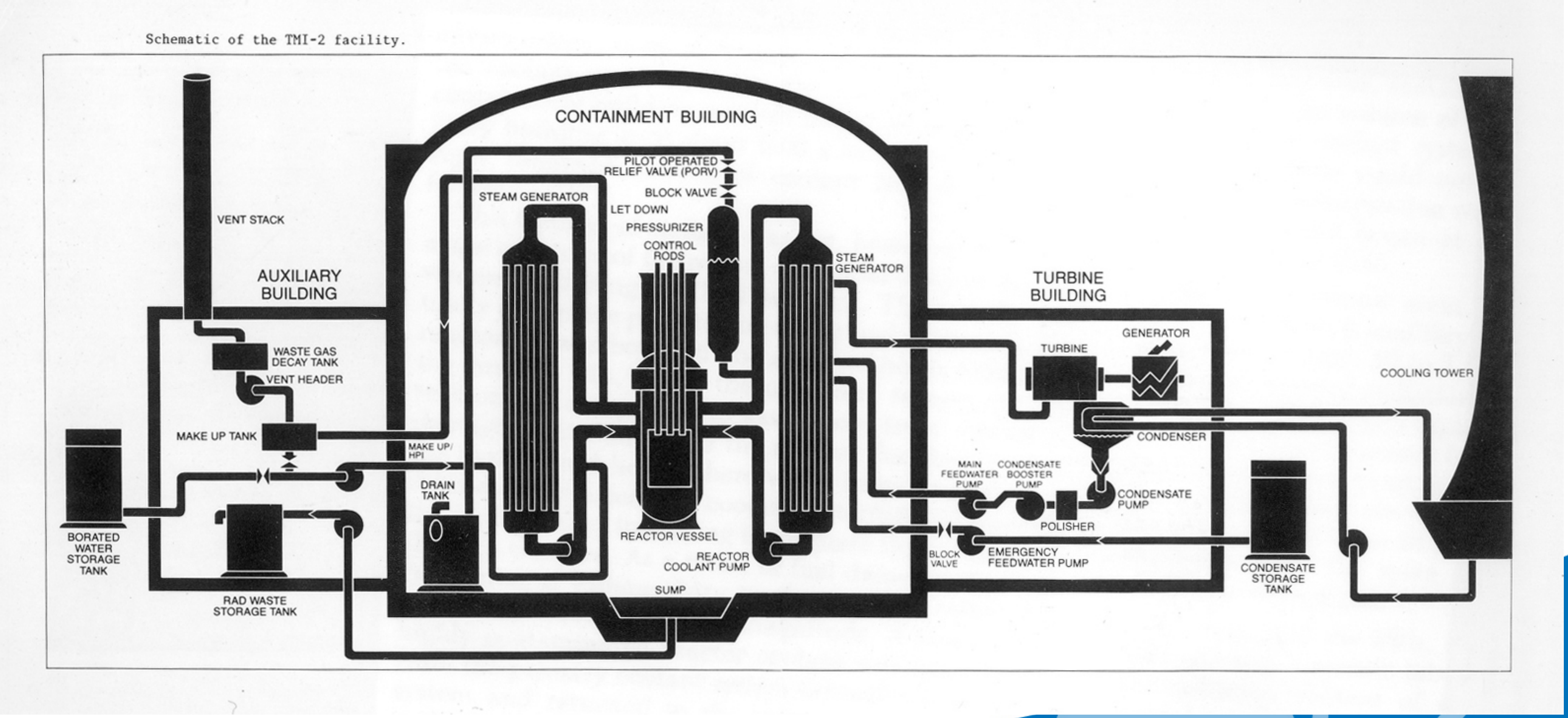
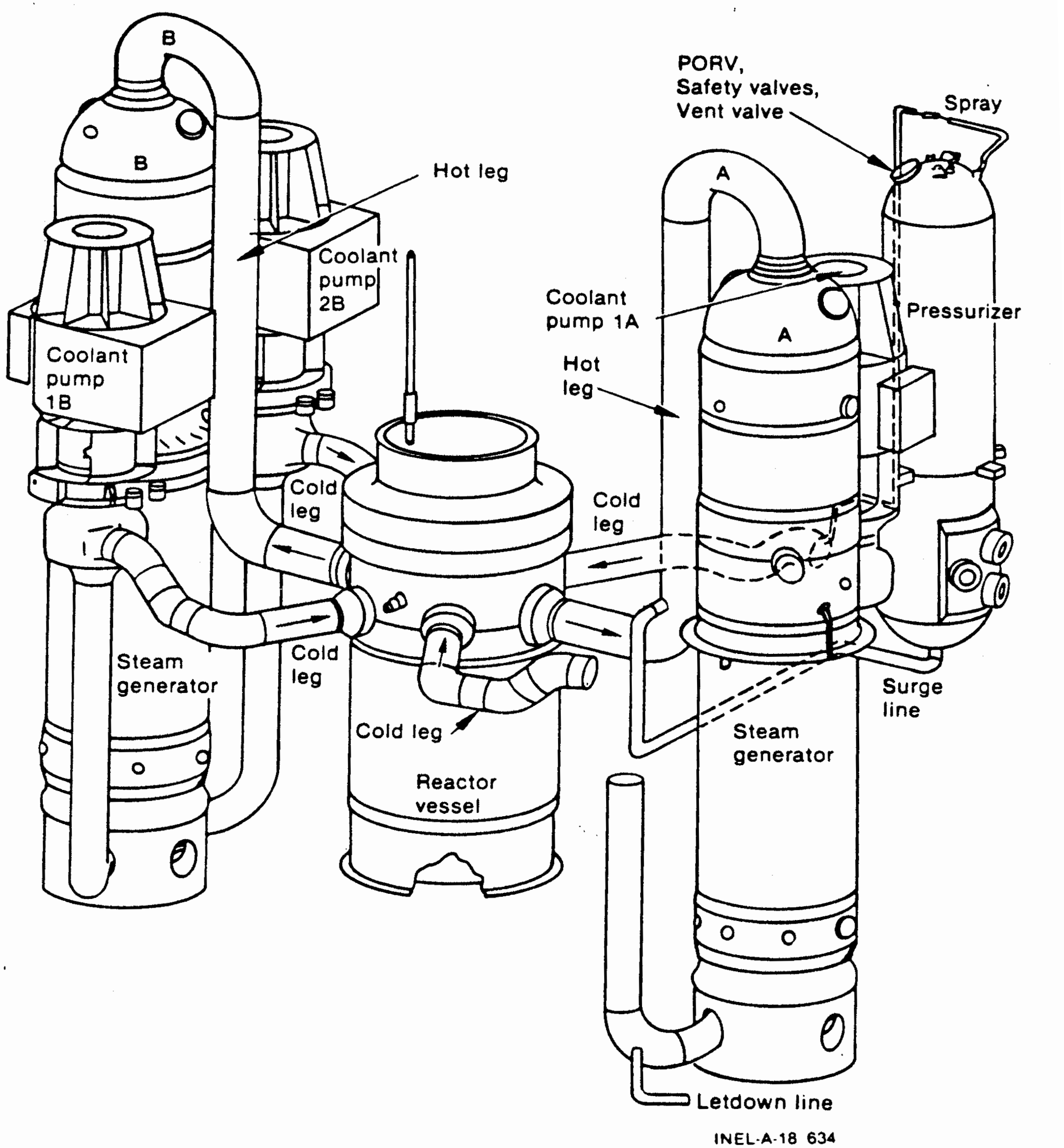
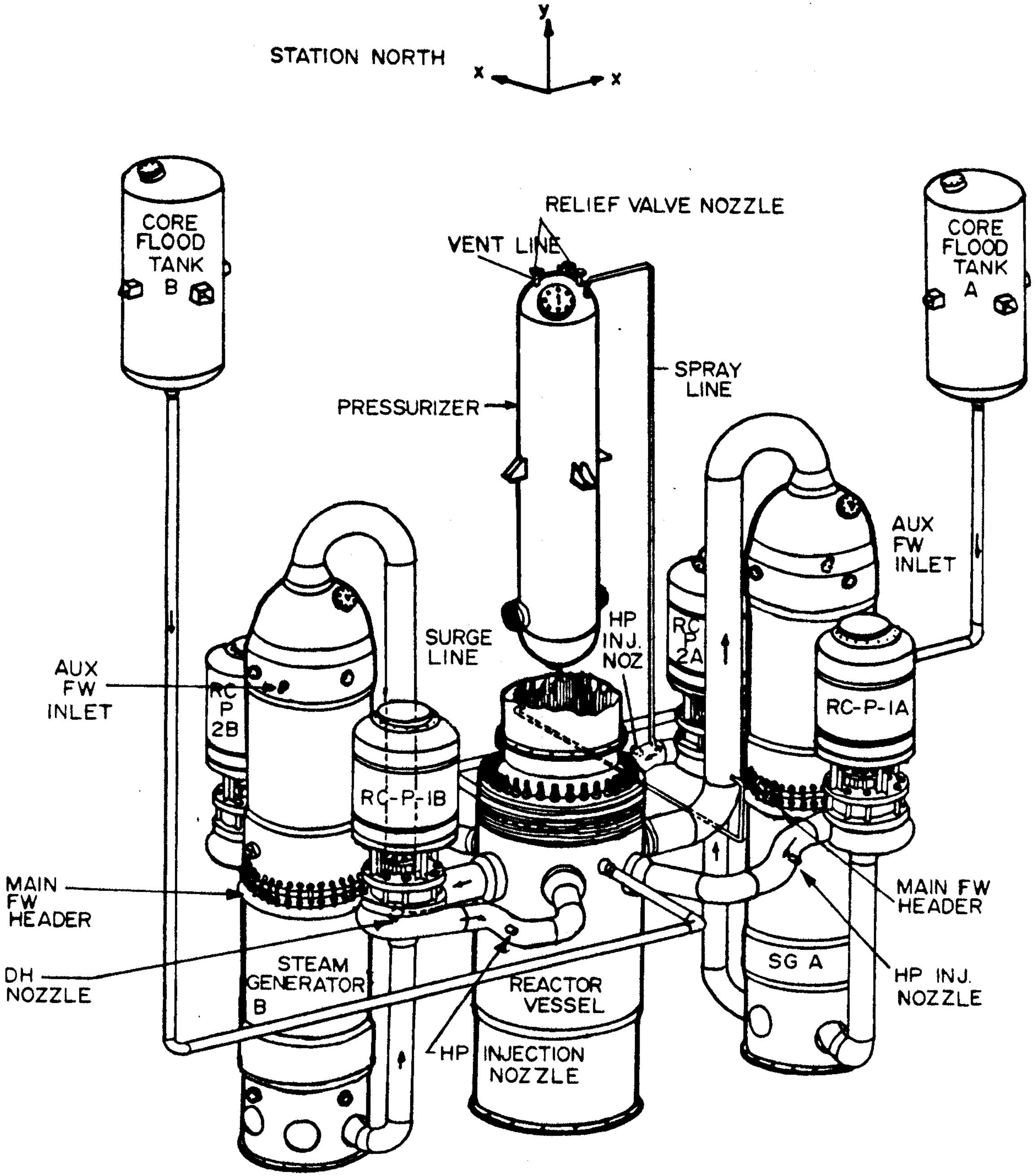
Schematic of TMI-2





TMI-2 Reactor Coolant System

(Isometric Diagram Showing Primary Loops)



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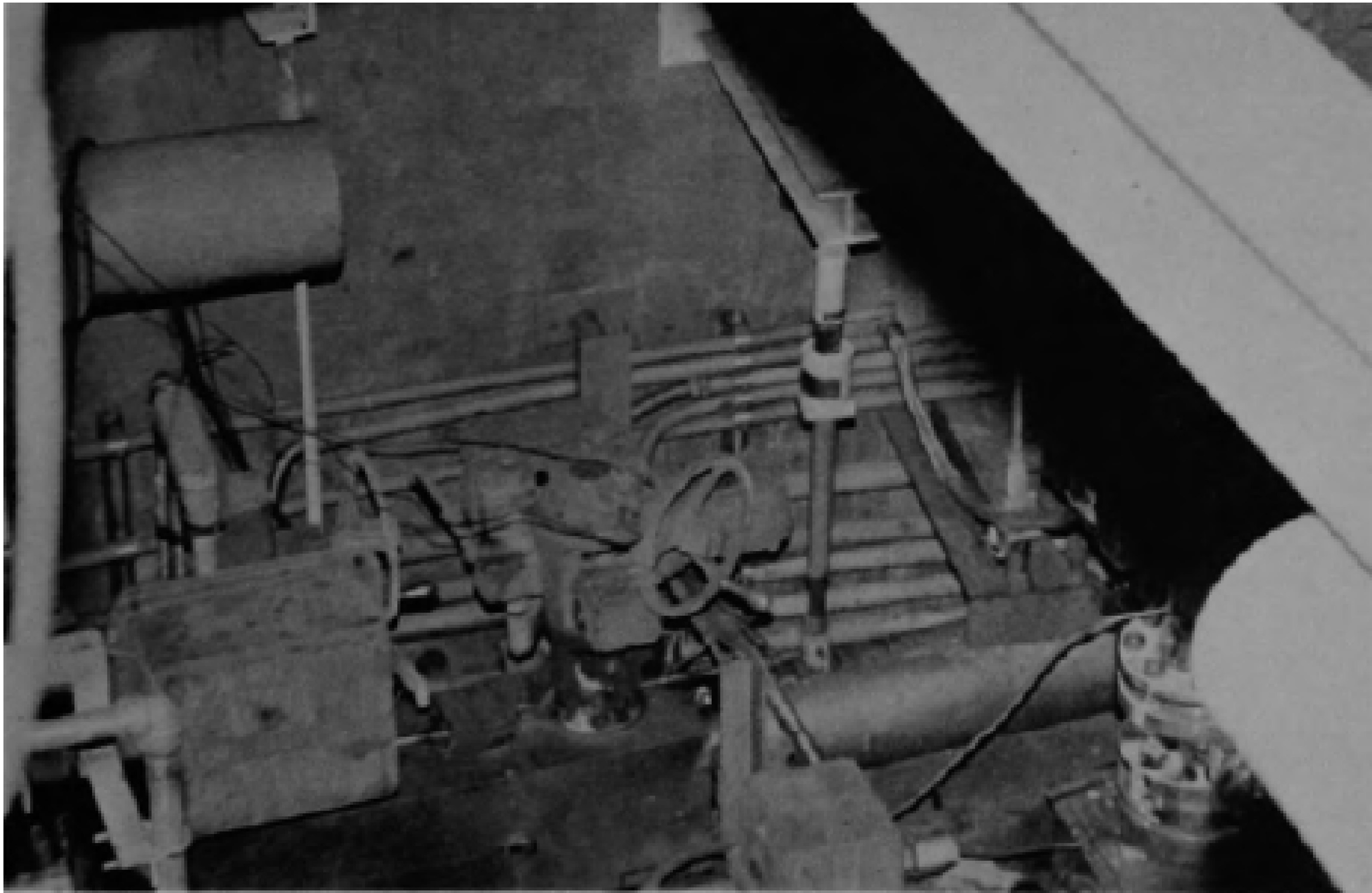
TMI-2 Reactor Coolant System

(Isometric Diagram Showing Core Flood Tanks)

TMI-2 Pressurizer Pilot-Operated Relief Valve (PORV)



PORV Block valve was on the main control room panel immediately in front of the operators; the indication for the Reactor Coolant Drain Tank, into which the PORV blow-down discharged, was on the back-side of the control room cabinets, on a waste disposal panel, not visible from the control room operators facing the main horse-shoe panels.

Slide 9 - RCS Pressure in Minutes

As the consequence, the open PORV 'flowed' from ~0400 hours to ~0620 hours, approximately 140 minutes, from the Pressurizer to the Reactor Coolant Drain Tank. In time the Reactor Coolant Drain Tank overpressured and the pressure blew out the rupture disk on the Reactor Coolant Drain Tank and flowed ~220,000 gallons of primary coolant to the Reactor Building basement floor. While the transient presented itself as a RCS leak, or a Small-Break Loss-of-Coolant Accident, the RCS and Emergency Core Cooling System responded exactly as designed, analyzed and anticipated.

In those ~140 minutes the core developed a steam bubble, or void, at the top of the Reactor Vessel that displaced primary coolant into the pressurizer. This transfer of fluid provided indication that the RCS inventory was 'normal' because the Pressurizer Level was 'normal', when in reality the RCS inventory was catastrophically not normal. The steam void that had formed at the top of the core in the Reactor Vessel caused core uncovery, allowed significant zirconium water reaction, produced a destructive flame burn inside the Reactor Vessel on top of the core, and caused widespread core damage and subsequent failure, to the extent that tons of molten 'corium' flowed out of the lower portions of the core into the reactor vessel's lower internals and lower head. When RCS flow was restored, the upper portion of the core, now severely overheated, and metal/ceramic, shattered. Because of fuel pin spacing, the small fines could 'sift' their way into the underlying undamaged fuel assemblies, and the cavern created by the 'melt' immediately below enabled fuel from upper portions of the core to relocate to lower portions of the core leaving the 5 ½ foot void in the top of the core.

Slides 10, 11, and 12 - Reactor Vessel and Core Pre Accident

TMI-2 Primary Pressure vs. Time

(Minutes After Reactor Trip)

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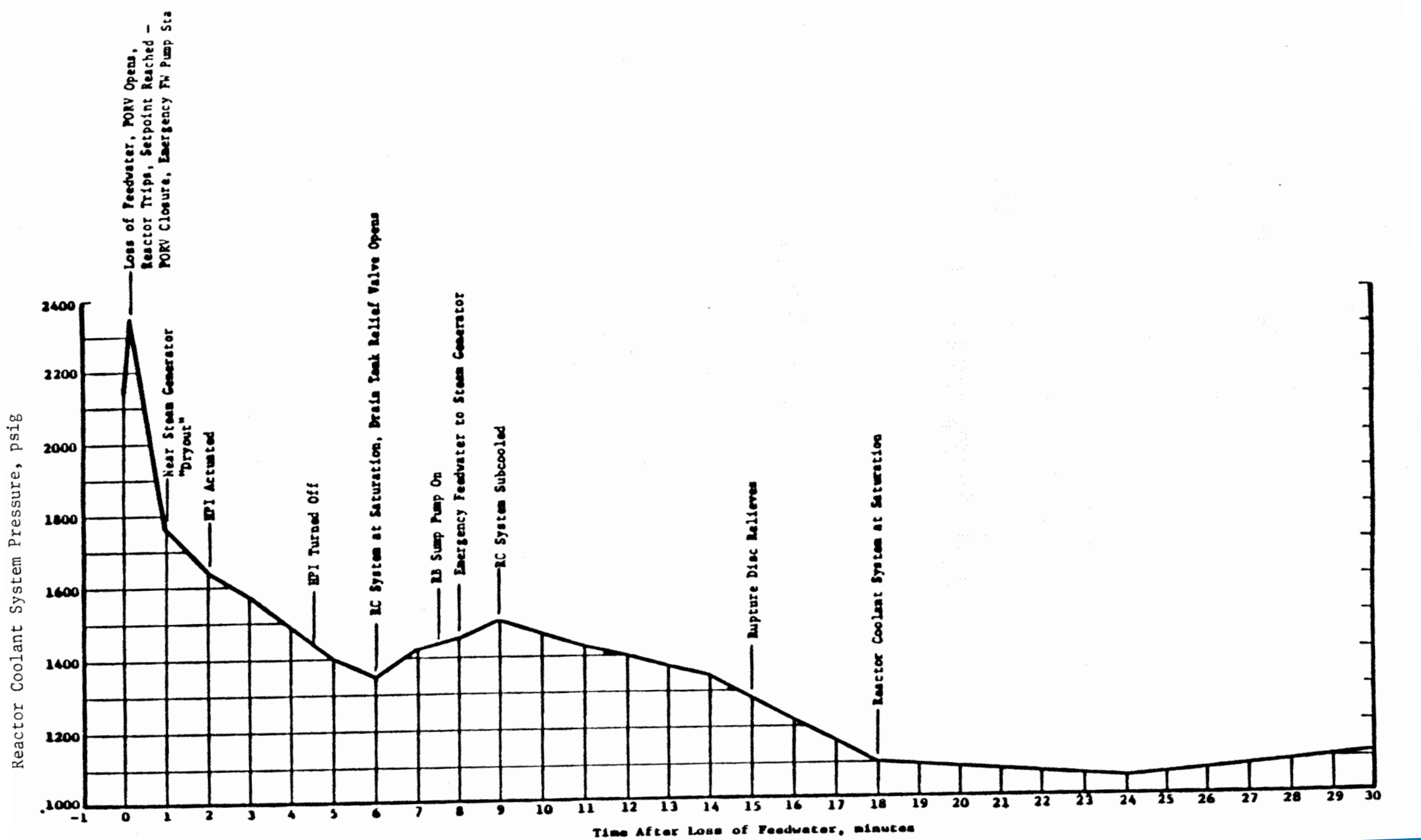
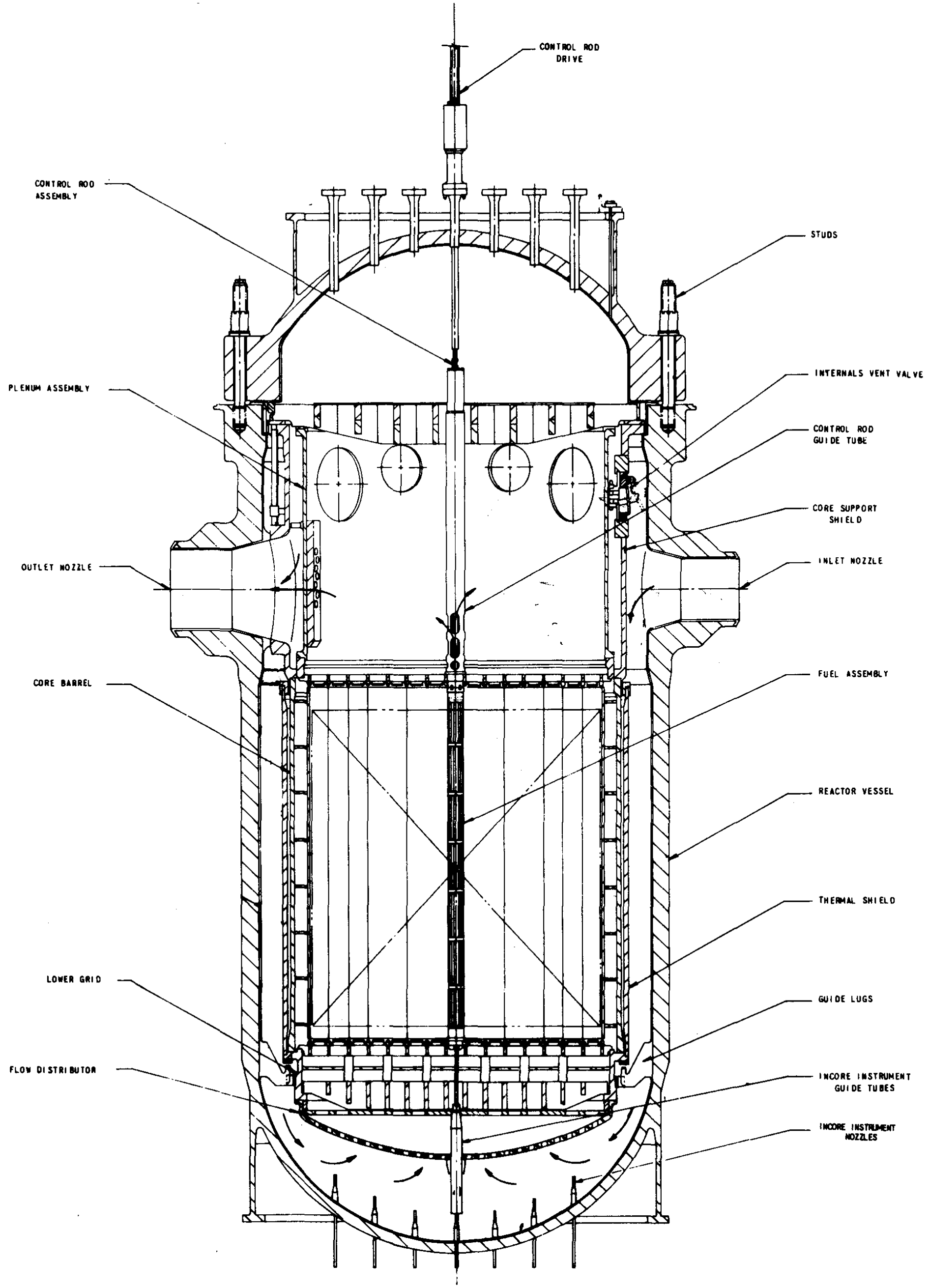
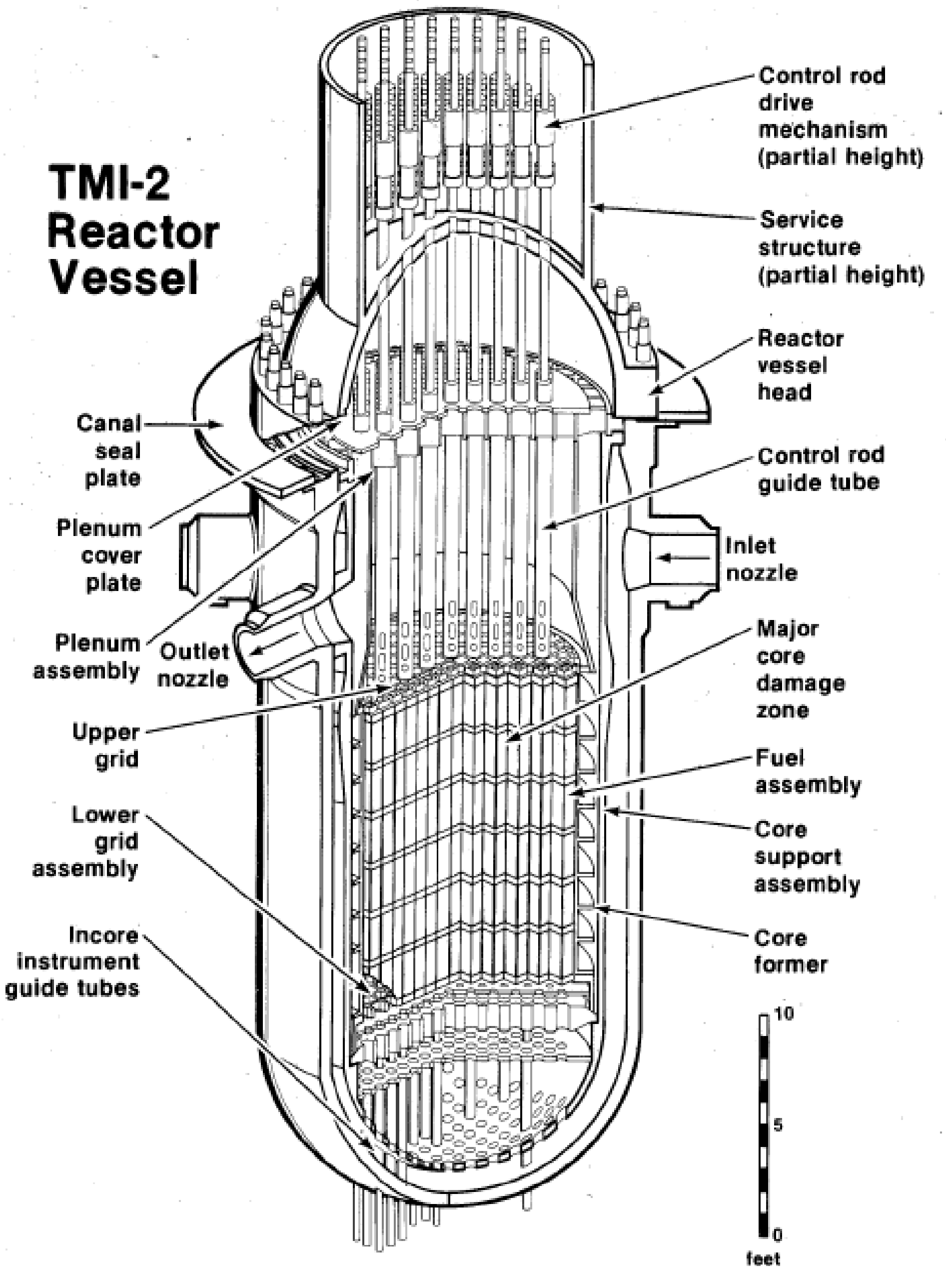


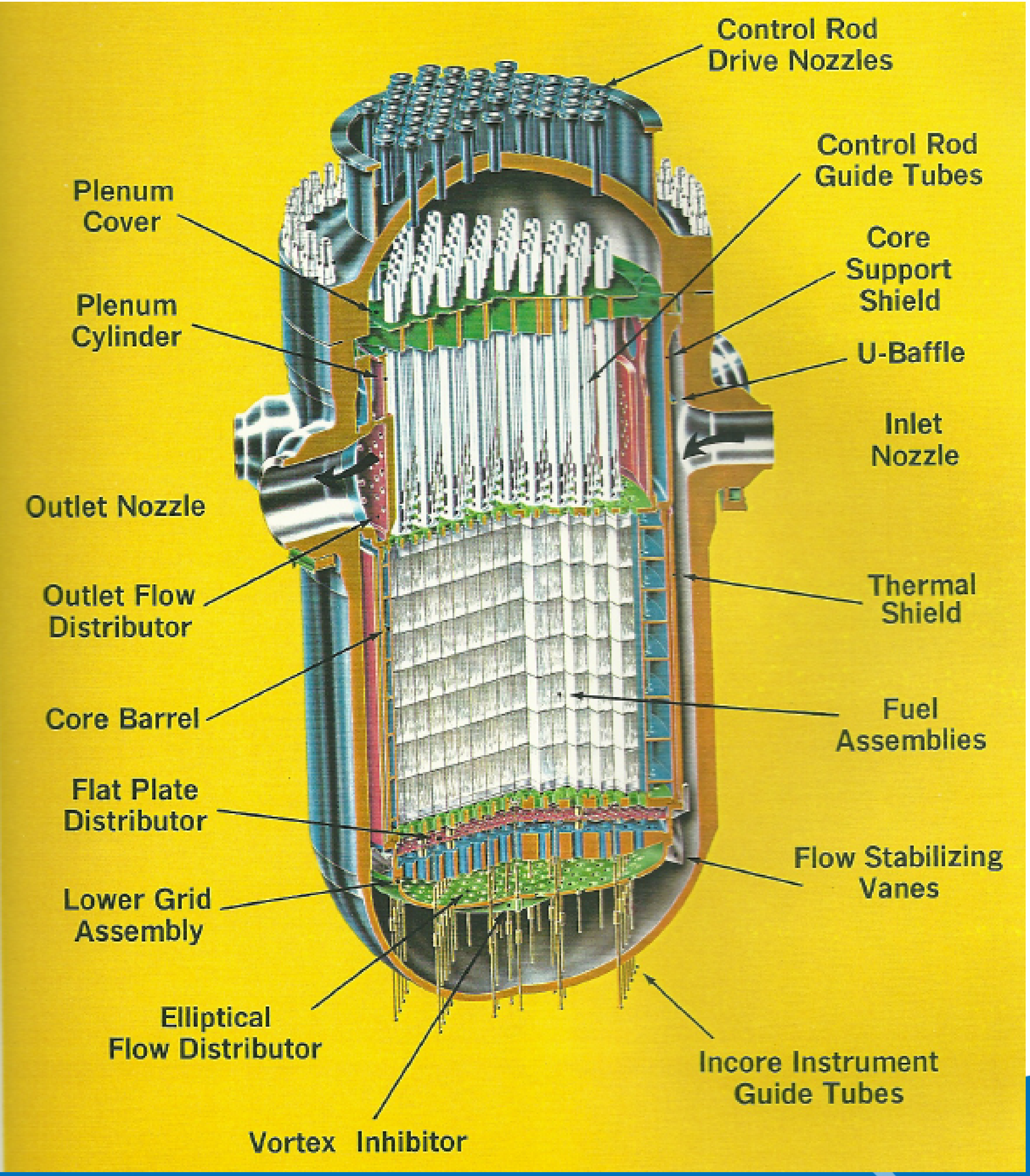


TMI-2 Reactor Vessel

(Sectional View Showing Internals)

TMI-2 Reactor Vessel
(Pre-accident Cutaway View)





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TMI-2 Reactor Vessel

(Pre-accident Cutaway View)

The events as described above began to halt at 0620 hours when the PORV Block valve was commanded to close thus allowing the Reactor Vessel to begin to refill. By that time the core and major portions of the internals, particularly the upper grid plate that forms the lower structure of the 55 ton Plenum, were thoroughly destroyed. Later we would conclude that as long as the fuel remained wet, even to a degraded amount, the fuel would be partially protected, and where the fuel remained immersed, fuel damage did not occur. We also concluded that as long as the inside surface of the reactor vessel remained wet, vessel failure would be avoided. To that point, TMI-2's Reactor Vessel retained its integrity.

Slide 13 - RCS Pressure in Hours

Early actions beginning later in the day on March 28 show that the operators were to attempting to regain control of RCS pressure and pressurizer level and to provide heat removal. The Control Room logbook provides insight into their actions and clearly communicates the challenges the operators faced.

The ORIGEN computer code runs conducted for the TMI-2 core at the time of the accident indicate that the core contained about 15 billion curies of isotopic inventory.

Slide 14 - Isotopic Inventory

Slide 15 - Isotopic Inventory and Isotopic Decay

Millions of curies were released to the Reactor Building. There was no consequential release from the Reactor Building and the public was not harmed. Years of study following the accident showed that the isotopes behaved differently that had been originally understood, particularly the behavior of the Iodine species and Iodine's proclivity to combine with nearly anything near it. Actions in the following years would give us confidence in use of what is now known as the 'Alternate Source Term.'

Logbook review shows repeated instances of the operators in the control room wearing respirators, shows persisting action by the operators to remove the gas bubble from the. Their goal was to retain forced cooling using Reactor Coolant Pump operation (net

Primary Pressure vs. Time

(hours after reactor trip)

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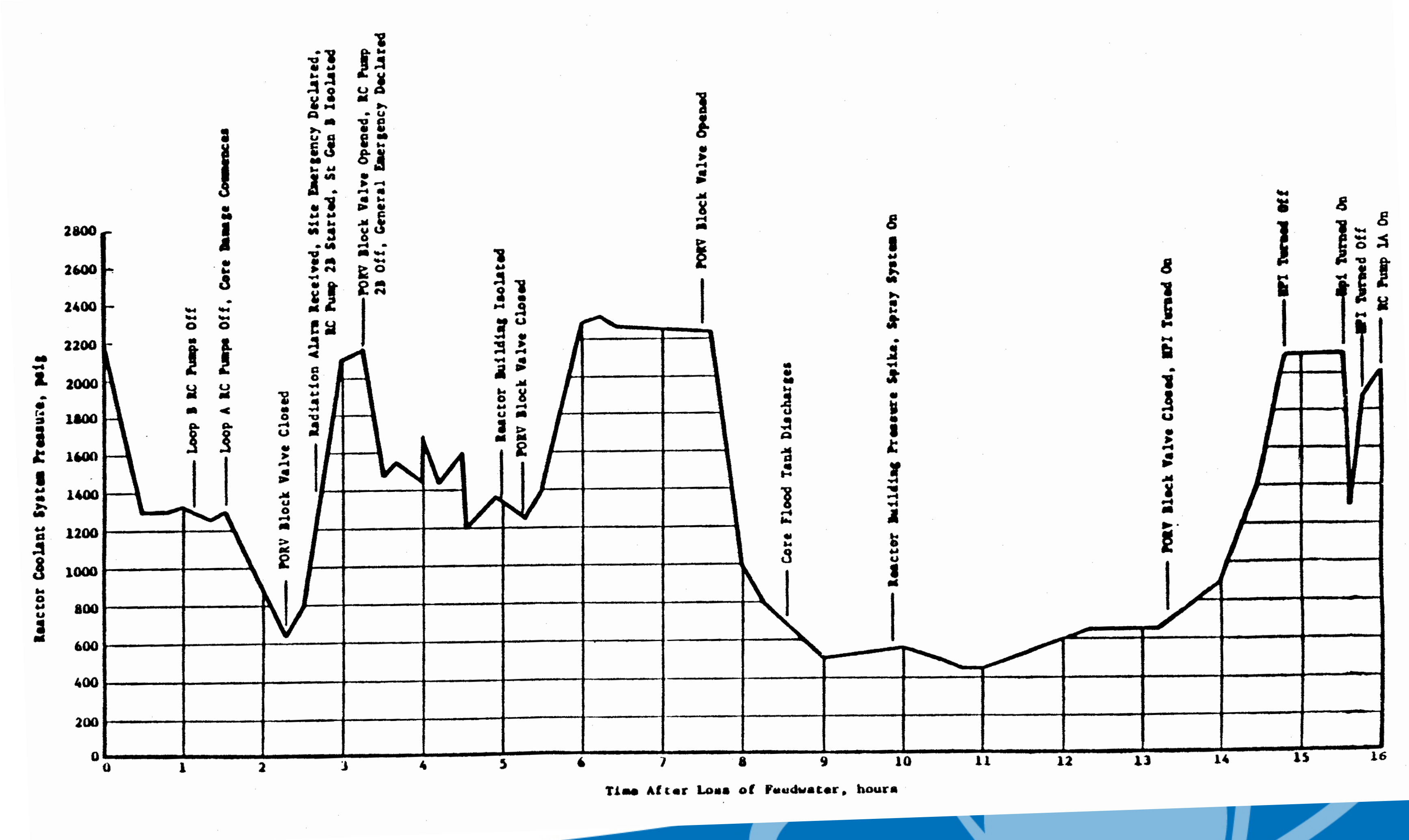

Radionuclide Activities for TMI-2

(Partial Listing Calculated at Shutdown and After Decay, GEND-INF-19)

Radionuclide	Half-Life[b] (yr)	Radionuclide Activity (Ci)[a] At Shutdown ($t_d = 0$)	After Decay (t_d = 63 months)
^{3}H [c]	12.33	4.1×10^{3}	3.1×10^{3}
^{85}Kr	10.7	9.7×10^{4}	6.9×10^{4}
^{90}Sr-Y	28.8	7.5×10^{5}	6.6×10^{5}
^{106}Ru-Rh	1.01	3.3×10^{6}	9.0×10^{4}
^{125}Sb	2.7	1.2×10^{5}	3.3×10^{4}
^{134}Cs	2.062	1.6×10^{5}	2.7×10^{4}
^{137}Cs	30.17	8.4×10^{5}	7.5×10^{5}
^{144}Ce-Pr	0.778	2.5×10^{7}	2.3×10^{5}
^{147}Pm	2.6234	2.6×10^{6}	8.1×10^{5}
^{151}Sm	90	1.1×10^{4}	1.1×10^{4}
^{155}Eu	4.9	3.2×10^{4}	1.5×10^{4}
^{238}U	4.468×10^{9}	2.7×10^{1}	2.7×10^{1}
^{238}Pu	87.74	7.3×10^{2}	7.6×10^{2}
^{239}Pu	2.41×10^{4}	8.6×10^{3}	9.0×10^{3}
^{240}Pu	6.57×10^{3}	2.4×10^{3}	2.4×10^{3}
^{241}Pu	14.4	2.0×10^{5}	1.6×10^{5}
^{241}Am	433	2.1×10^{1}	1.9×10^{3}

a. The quantity of t_d is the decay time.

b. Half-lives were taken from and are given with the same number of significant figures as in Reference 3.

c. An additional 200 Ci is estimated to have been produced by neutron activation reactions in the coolant during power operation.

TMI-2 Core Activities As Function of Time (in Curies)

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(Source: ORNL...ORIGEN)
Power : 2.1863E + 03 MW
Burnup: 2.558E + 05 MWD
FWX : 2.47E + 14 M/cm^2 sec

	ACCIDENT	1 Day	33 Days	94 Days	1 Year	2 Years	4 Years	8 Years
ACTIVATION PRODUCTS	3.54E + 07	1.54E + 07	5.49E + 06	3.01E + 06	4.23E + 05	1.90E + 05	1.16E + 05	5.9E + 04
ACTINIDES + DAUGHTERS	2.9E + 09	1.11E + 09	8.03E + 05	1.72E + 05	1.66E + 05	1.58E + 04	1.45E + 05	1.23E + 05
FISSION PRODUCTS	1.25E + 10	2.01E + 09	4.52E + 08	1.99E + 08	3.42E + 07	1.45E + 07	5.76E + 06	3.07E + 06
GRAND TOTAL	1.55E + 10	3.14E + 09	4.58E + 08	2.03E + 08	3.48E + 07	1.488E + 07	6.03E + 06	3.25E + 06

positive suction head) while removing gas, soon recognized to be hydrogen.

The consequence of the hydrogen release into the Reactor Building was a detonation and deflagration at about 1400 on March 28. The resulting pressure pulse was approximately ~29 pound per square inch gauge (psig).

Slides 16 and 17 - Rotary Telephone

Slides 19 - Crushed Barrels

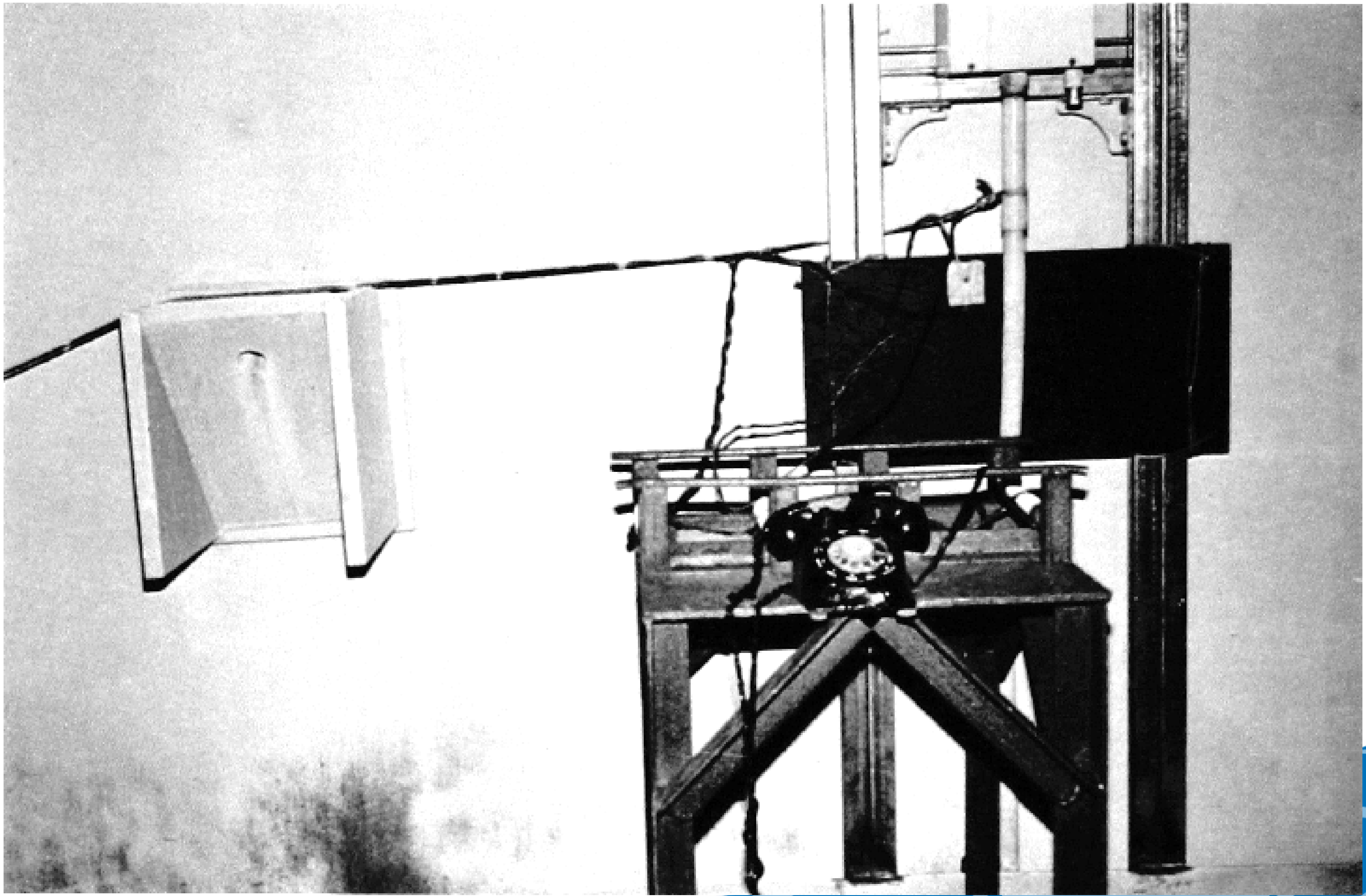
That pressure wave resulted in compressed barrels; the heat that resulted in burned components inside the Reactor Building. In spite of this, the Reactor Building held.

The control room logbook indicates that contact radiation readings on the Reactor Building Equipment Hatch were 40 roentgen per hour (R/hr) contact and that the Waste Gas Decay Tanks were 60 R/hr contact. (TMI-2 Logbook at 0205 hours on March 30, 1979)

Hydrogen Scare

During this time the concerns for hydrogen accumulation and a greater and catastrophic explosion were growing. The hydrogen gas scare is the story of legend in the Harrisburg area. As stated earlier, the accident occurred on Wednesday morning, March 28. Thursday and Friday, March 29 and 30, were days of community confusion and fear. As the weekend approached the community was being warned that the 'Hydrogen Bubble' could explode. Thousands of local residents evacuated. Pennsylvania's Governor Thornburgh urged pregnant women to find shelter at the Hershey Arena that is located approximately 10 miles north and east of TMI. It should be recognized that there was no clear consensus as to the likelihood of hydrogen explosion until sometime Saturday, March 31. President Carter had declared his intention to visit TMI with his wife and entourage, believing that their presence would bring calm to Central Pennsylvania. Dr. Harold Denton called on his staff to provide assurance that the president would be safe if the President entered the plant, specifically from the potential of hydrogen explosion. That assurance was provided and the president arrived for the visit.

Telephone Bench, Inside Reactor Building
(Due South Against Liner, GEND-006)



Telephone Bench (Continued)

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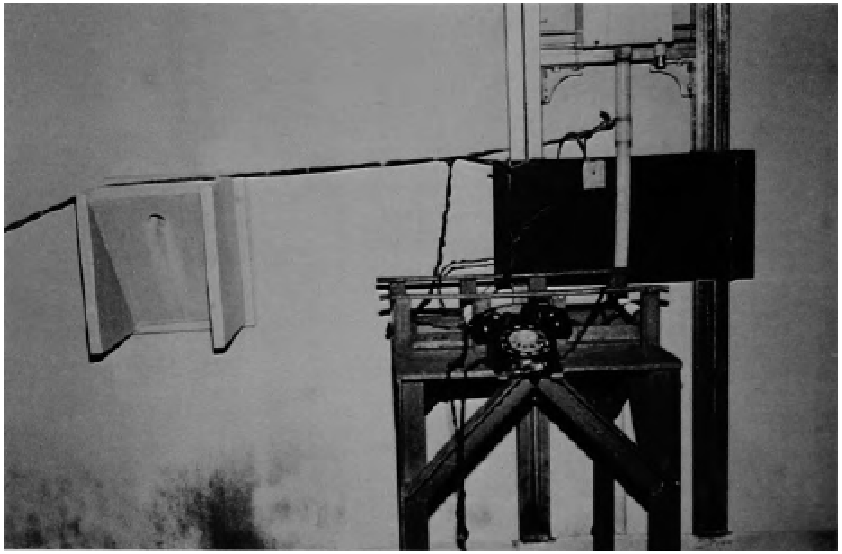
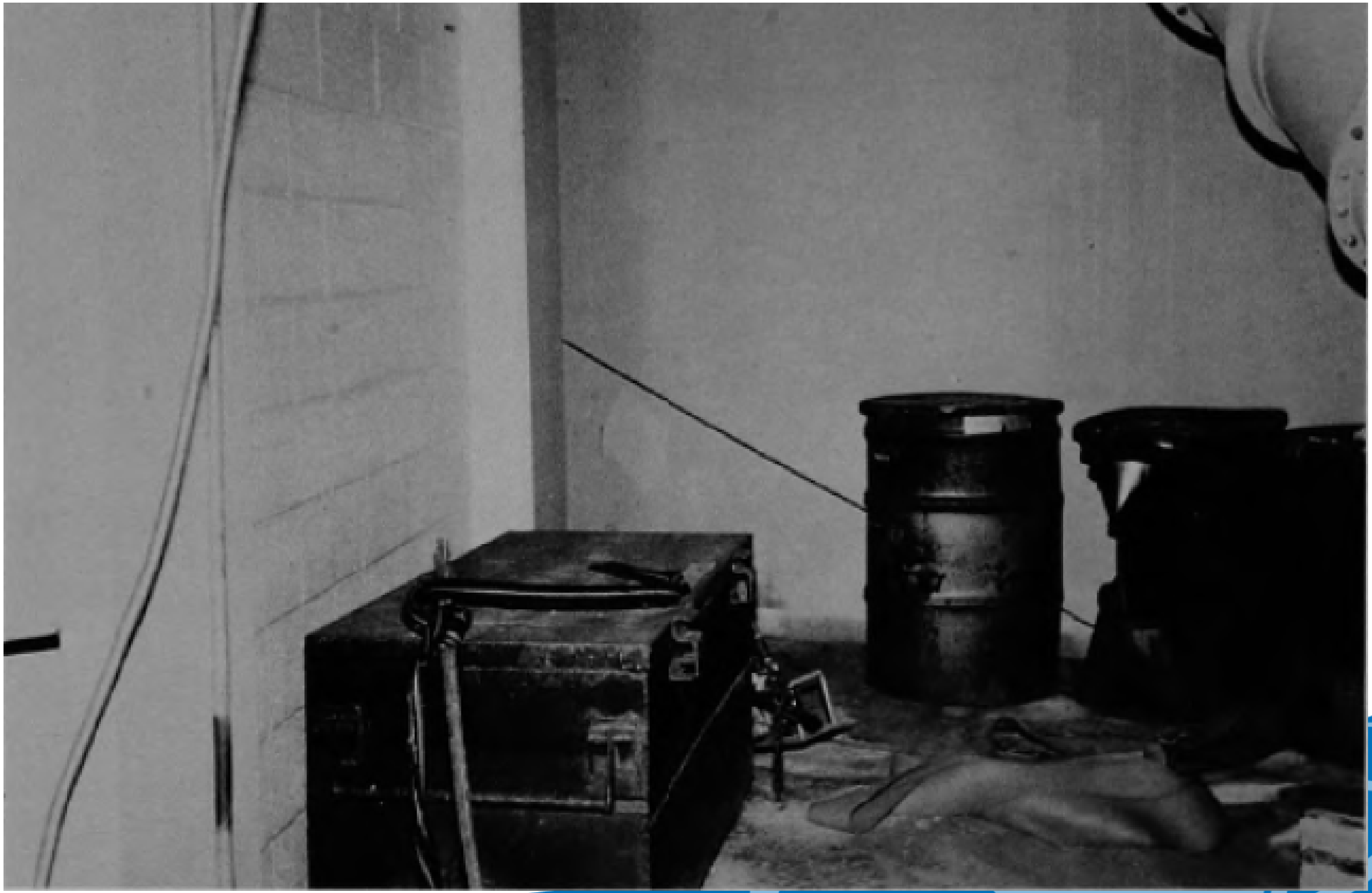



55 Gallon Drum, Inside Reactor Building

(Northeast Elevator Wall Right, Containment Liner Background, GEND-006)

Area Inside Reactor Building
(Between South Wall of Enclosed Stairway and Air Duct, GEND-006)



Slide 20 - President Carter in TMI-2 Control Room

On Sunday, April 1, 1979, President Carter and members of his entourage entered the TMI-2 control room. The hydrogen, and the Reactor Building, didn't explode.

Slide 21 - Dr. Kemeny and Entourage in TMI-2 Control Room

Later, as the various examination boards dug into the event, they also visited the control room. Dr. Kemeny, Chairman of the President's Commission on the TMI-2 Accident, made that visit.

The Reactor Building physical conditions I just described to you were unknown to the operators and responders until over a year later.

Slide 22 - Pristine Core and Core Contents.

We knew what the original core design was, and what the core was supposed to look like. The actual core conditions that existed after the accident, and during the events described above, were not known until over 3 years later. These images are from camera examinations made in 1982 and 1983.

Slide 23 - Damaged Core Graphic

Slides 24, 25, 26, 27, 28, and 29 - Actual Damaged Core Images

1979 – March – April - Access to the Site

Slide 30 - Press Truck

Access to the Island was rigidly controlled by Site Security by controlling access to the bridges. Getting on and off the Island immediately after the accident was difficult. To accommodate the growing number of volunteers and workers, GPU began to set up 'Trailer City' at the company owned Visitor's Center on the east shore of the Susquehanna, just across the 'East Dyke' from the plant. It was from there that most early visitors to the site were met and dispatched. From there were the early Press Conferences. Early press images are from the Visitors Center

President Carter and Governor Thornburgh Entering TMI-2 Control Room

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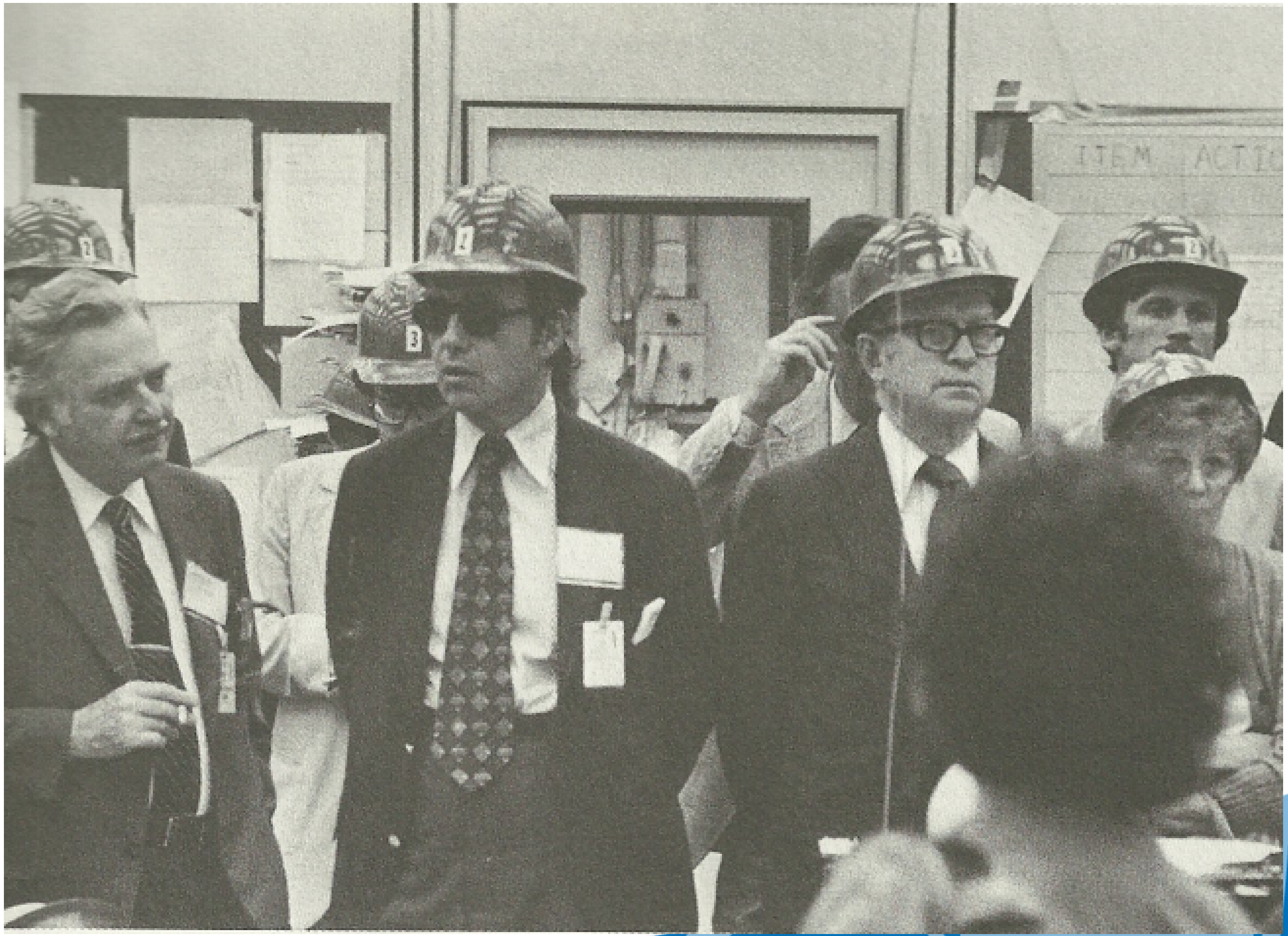
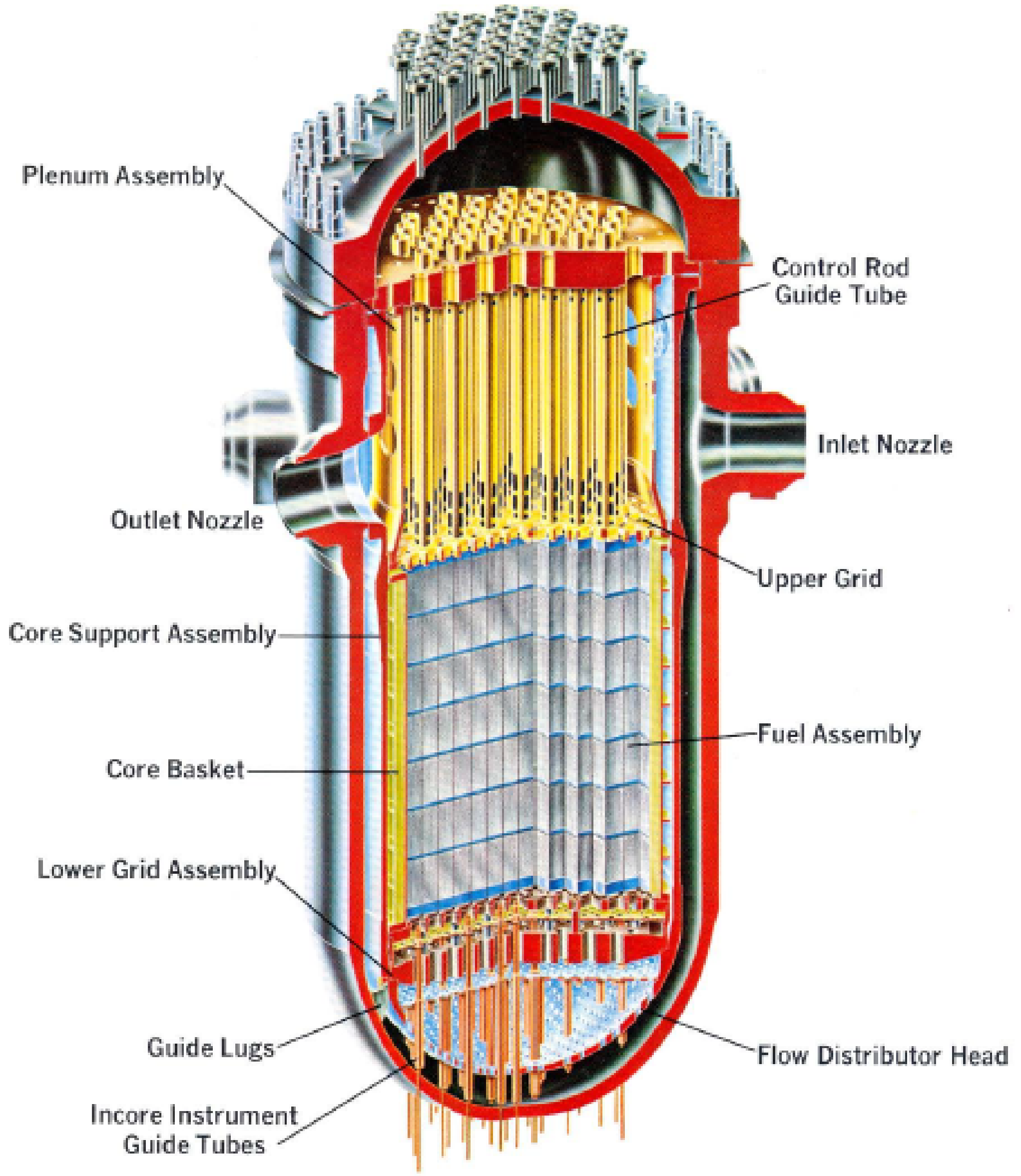
Members of the President's Commission Tour TMI-2

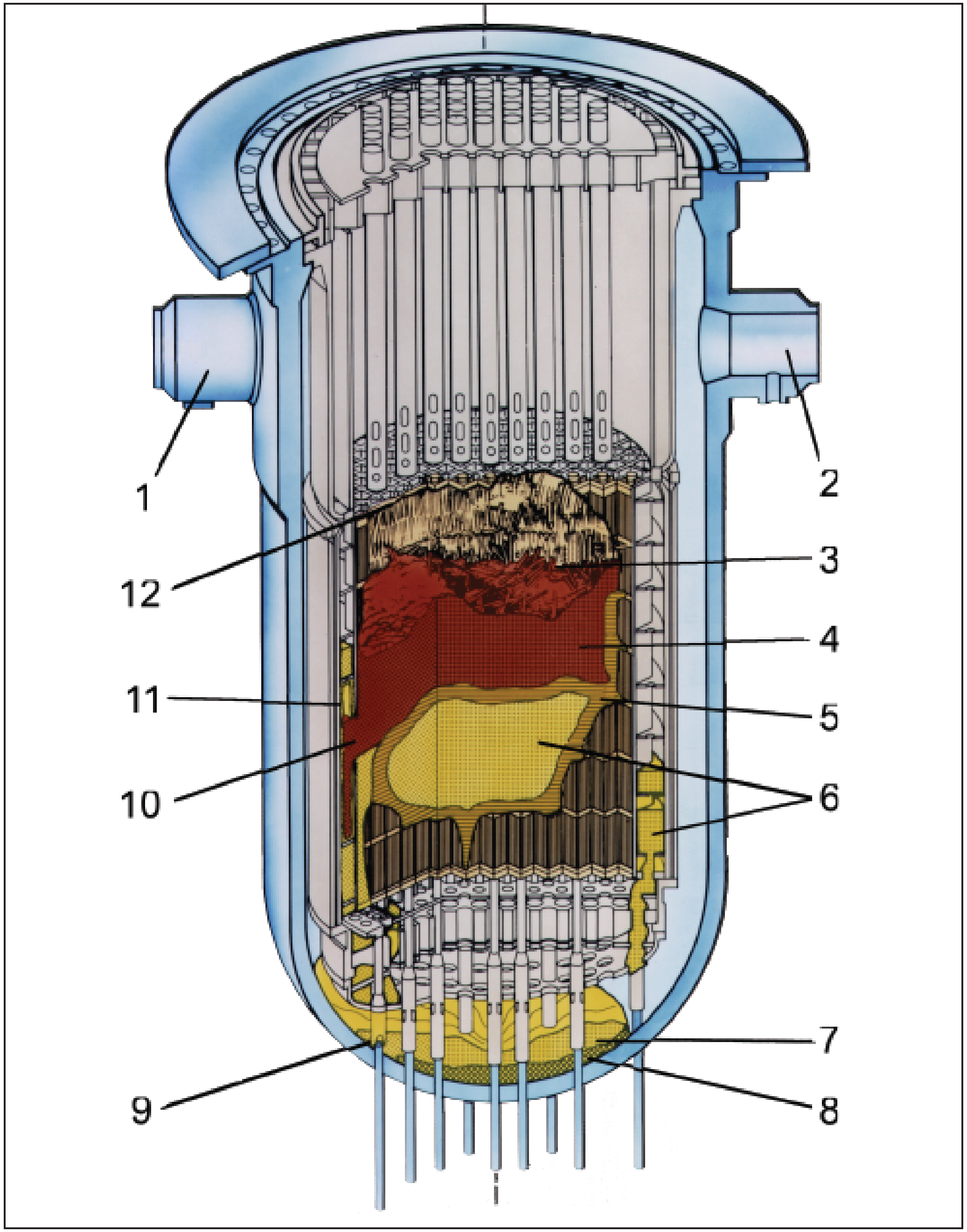
(Left is Dr. John G. Kemeny)



Typical B&W Reactor Vessel

(Babcock and Wilcox Cutaway View)





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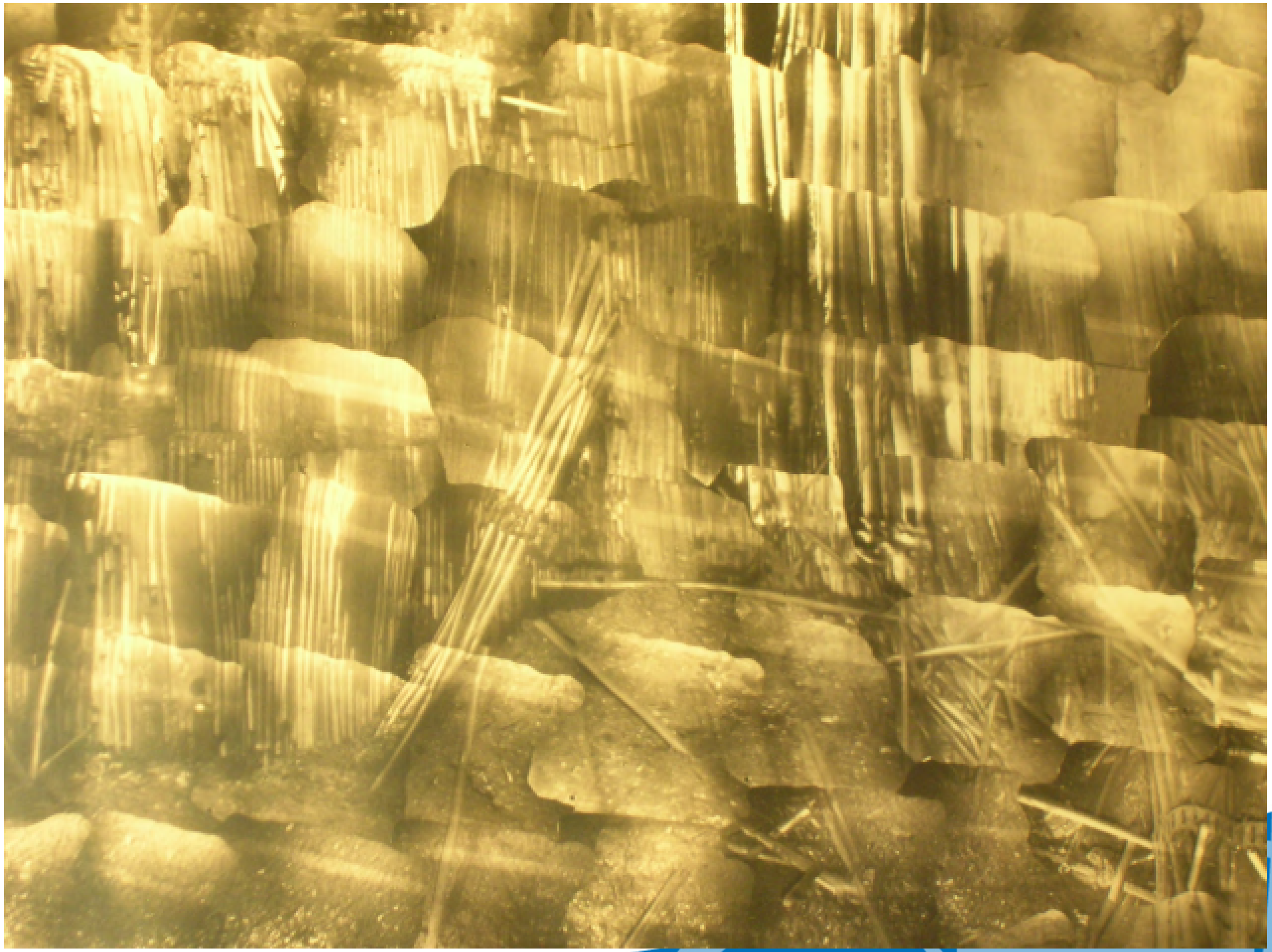
TMI-2 Core End-State Configuration

Notes (NUREG/CR-6042):
(1) Cold leg Loop 2B inlet
(2) Cold leg Loop 1A inlet
(3) Cavity
(4) Loose core debris
(5) Crust
(6) Previously molten material
(7) Lower plenum debris
(8) Hard layer debris
(9) Damaged in-core instrument guide
(10) Hole in baffle plate
(11) Coating of previously molten material on bypass region interior surfaces
(12) Upper grid damage

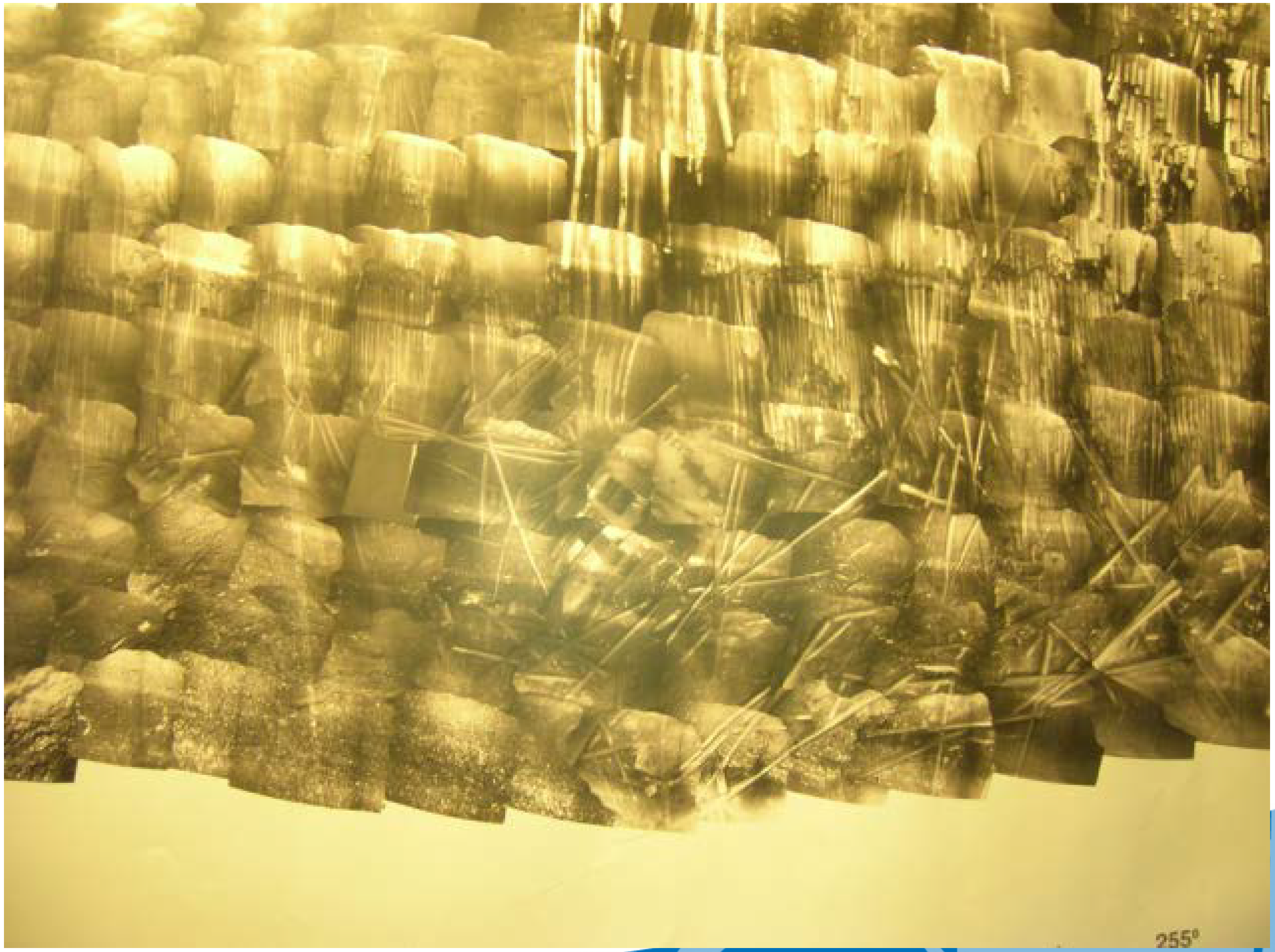
Mosaic Panorama View of Reactor Core Cavity

(Axial Power Shaping Control Rod Hanging at Top)



Mosaic Panorama View of Reactor Core Cavity

(Axial Power Shaping Control Rod Hanging at Top)



Mosaic Panorama View of Reactor Core Cavity

(Rubble Bed at Bottom)

Mosaic Panorama View of Reactor Core Cavity

(Control Rod Spider Fitting on Rubble Bed)

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Mosaic Panorama View of Reactor Core Cavity

(Broken Fuel Rods on Rubble Bed)

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Mosaic Panorama View of Reactor Core Cavity

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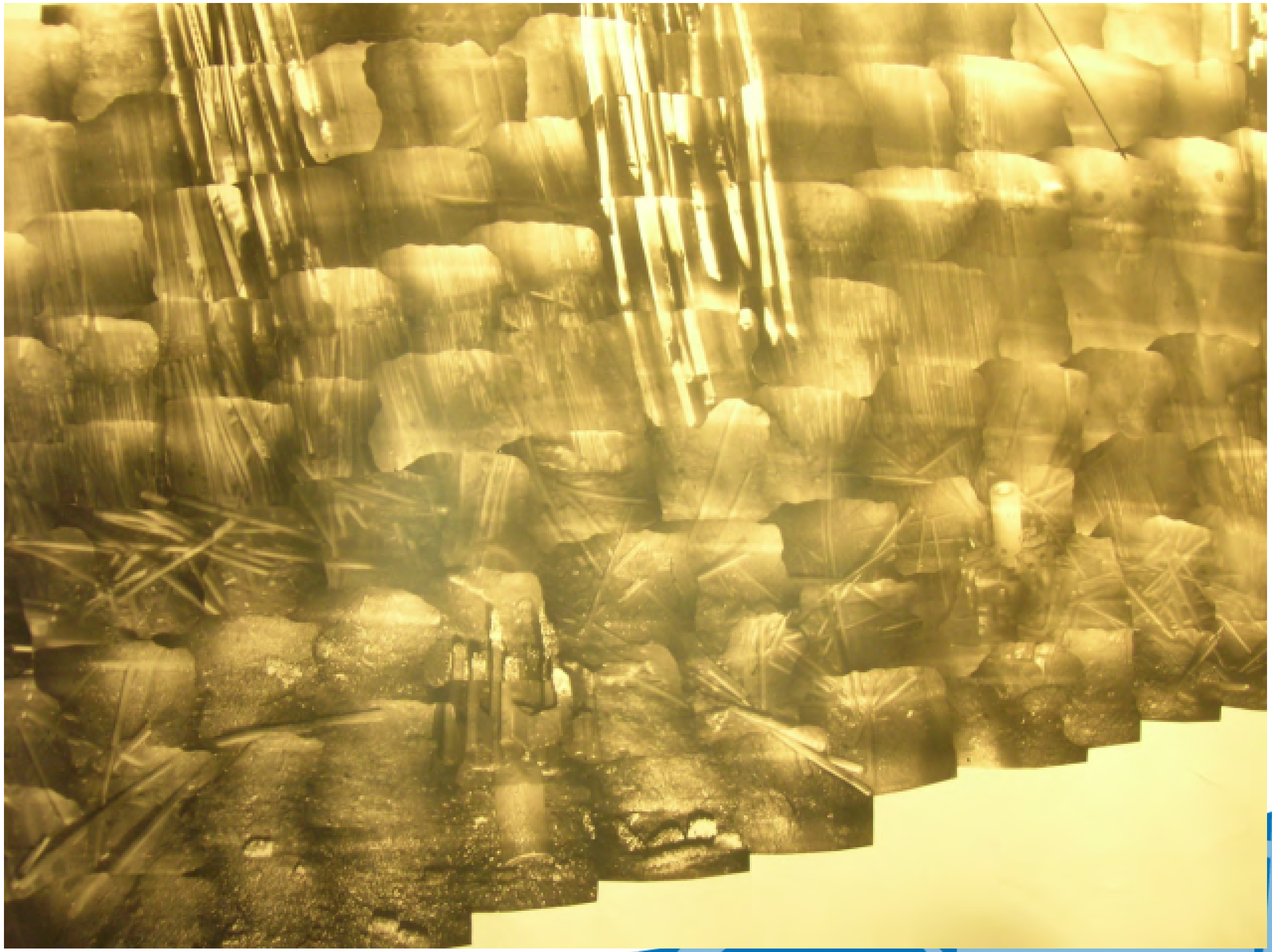


Channel 6 Action News

Image 30, looking west from the Visitor’s Center, is typical for a wet rainy, snowy March day.

1979 – March / April - Trailer City and Island Work Spaces

Slide 31 - TMI from ~5000 feet on April 9, 1979

The accident occurred at the end of winter in 1979. Many nights and mornings were below freezing, and most of the ground was frozen and icy. Getting around Trailer City was hazardous. Food was unavailable. Hygiene facilities were scarce. Some members of leadership had taken up offices in the Pennsylvania National Guard headquarters at the Harrisburg airport about 6 miles away. Early responders worked at makeshift desks and cubby holes in the Visitor’s Center. Early communications were stifled by absence of telephones. The phones we had were rotary phones. There were no cell phones.

Early responders to the accident worked ~16 hour days under primitive and demanding conditions, on varying shifts or schedules. Food was unavailable except by ‘delivery service’. That option was sometimes overwhelmed by an order for ’20 pizzas and some Cokes to go with it’ to be delivered to the Island’s north gate. As the response population increased it became imperative to provide some type of food service. GPU contracted a local restaurant operator to provide food in some form of a 24/7 arrangement. That restaurant operator set up a heated military style mess tent in the middle of the parking lot at the Visitor’s Center. It was there workers could get a hot meal, juice and coffee whether day or night. Additionally, GPU arranged to bring in a dozen 70 foot-long construction trailers to both Trailer City and onto the Island where responders could work. Most of the time the trailers were overwhelmed with workers, with most workers sitting elbow to elbow, all vying for chairs. We were working in cramped quarters, each with a different work assignment, and most responding to different information or action requests from our respective work leaders. Workers from GPU, from United Engineers and Constructors (the architect engineer for TMI-2), from B&W, Westinghouse, Combustion Engineering, from a national laboratory, and the NRC might all be seated in one trailer working on similar but not identical tasks.

Aerial of TMI on April 9, 1979

(Unit 2 Bottom Middle)

By the end of the third week of April 1979 some workers were able to relocate from Trailer City to work locations on the TMI site. Hygiene facilities were available on the Island, but not food. Those of us working at locations on the island would put in a request for food early in the day - and sometime during the day the restaurant operator in the Mess Tent would pack up Styrofoam containers that would be delivered to centralized work locations on the island with sometimes hot but normally cold, and sometimes nutritious, food.

Because site access was halted for essentially all vendors, including the vendors that refilled the vending machines that were located throughout the site at TMI-2, the food that was in the vending machines on March 28 remained in the un-serviced and now un-powered vending machines. As the weeks proceeded, several of the vending machines offered tempting and remarkable cuisine that had the distinguishing texture of penicillin-like growth, particularly on the aged hotdogs and hamburgers.

A lesson that we learned from physical presence at trailer city is that the landing ‘rotor whip frequency’ of an approaching Huey helicopter is approximately the natural frequency of a 70 foot construction trailer. The Pennsylvania National Guard was using 4 Huey helicopters to take turns monitoring the radiation levels over the TMI-2 Reactor Building 1000 yards to the west. GPU Health Physicists, along with Pennsylvania Dept. of Environmental Resources personnel, were tasked with monitoring those levels and did so by riding in one of the back seats of the Huey and, when the helicopter was positioned appropriately, lowering their detector onto the Reactor Building dome or into the Plant Vent discharge. The Huey’s take off was a non-event. But when the Huey would approach its landing pad adjacent to the trailers at Trailer City, the ‘rotor whip’ Doppler was in ‘tune’ with the trailer. The entire trailer, and its internals, would become harmonic with the rotor whip and vibrate so violently that chairs, books, typewriters and everything that was not bolted down would shake to the floor.

Working in trailer city was a communal exercise. Many highly qualified professionals responded promptly to TMI-2. Executives, contractors, technicians, laborers, and vendors were all working alongside one another out of necessity – there was no other place to work. Leaders that arrived at TMI-2 included those from GPU, executives from major utilities, early response workers, directors and managers from the NRC, from B&W and other Nuclear Steam Supply System (NSSS) vendors. The outpouring of response by Industry demonstrated Industry's recognition that the TMI-2 accident was an event of national importance, that responding effectively to the accident was critical, and that the weeks and months that followed would be a shared-pain event for all of Industry. There was also the recognition that the outcome at TMI-2, whatever it was, would have a profound Impact on the US Nuclear Industry's future.

Industry Impact

That Impact has had a lasting effect in the 35 years that have passed since the accident. Beyond NUREG-0737, that includes the NRC's guidance from TMI-2 lessons learned, there were other substantial impacts. Before the TMI-2 accident there was no Institute of Nuclear Power Operations (INPO); Emergency Procedures were embryonic; Emergency Planning was nascent; rigorous compliance with Appendix B (Quality Assurance Criteria for Nuclear Power Plants) to 10 CFR Part 50 was in its infancy; and early plants were tripping (Scramming) monthly. There were no real Technical Support Centers, degreed engineers were not in the control room, and NRC Resident Inspectors were not assigned full time to a site. What we expect as today's norm, including the rigor and accountability that we require today, for every facet of nuclear plant ownership, leadership, engineering, design, operation, maintenance, emergency planning, emergency preparedness, and security were at that time many years away.

1979 – March / April 1979 - Early Nuclear Response

Slide 32 - Original Core Contents

Early focus was on assurance of core subcriticality, provision of decay heat removal and continuance of Reactor Coolant System pressure control. Venting from the Pressurizer vent valve delivered the gas to the Reactor Coolant Drain Tank and out the blown rupture disk, and therefore directly to the containment.

TMI-2 Design Features

177 15x15 Fuel Assemblies:

- » 208 Fuel Rods, 16 Guide Tubes, 1 Instrument Tube
- » Assemblies (Enriched)*: 56 (1.98%), 61 (2.64%), 60 (2.69%)

61 Full Length Ag-In-Cd Control Rods

8 Axial Power Shaping Rods ¼ Ag-In-Cd

68 Burnable Poison Rods Al_2O_3-B_4C

0 Orifice Rods (38 Removed Prior Accident)

2 Neutron Sources Am-241/Cm-242

70 Hold-down Fixtures

52 Incore Instrument Strings:

- » Self-Powered Neutron Detectors, Thermocouples

Criticality

(Story – How much does an original Volkswagen Beetle weigh? Answer: Same as a 15 by 15 B&W Fuel Assembly, 1776 pounds.)

TMI-2 had 177 15 by 15 Fuel Assemblies, each weighing approximately 1776 pounds, with three batches of fuel of differing enrichments, a core average enrichment of ~2.5 % and 69 control rods, 61 of which were 'scrammable' and which constituted the control groups, and 8 control rods that were non-scramming Axial Power Shaping Rods (APSRs).

The 61 scrammable rods from the control groups had scrammed at ~0400 hours on March 28. We had no data with which to determine core condition or geometry, or whether there were local pockets of criticality shielded by others not critical. Guided by conservatism, our first move was to raise the RCS boron from the Refueling value of ~2,150 parts per million (ppm) to a concentration of ~3000 ppm, later to 3500 ppm, and by defueling in 1985 to 6000 ppm. Those numbers reflect our uncertainty regarding core conditions and whether there were local pockets, or volumes, of core configuration that might be more neutronically reactive than others, and we had no way of knowing whether the soluble boron was poisoning these pockets as it was intended. Hence we continued to increase boron concentration to prevent criticality. Multiple organizations reviewed the poisoning scheme and concurred that the higher levels of boron provided conservatism in shutdown margin.

Early Primary / Secondary Heat Removal /Pressure Control

In weeks following the accident heat removal was accomplished by manual adjustment of the feedwater flow to the steam generators. You will see in images of TMI-2 immediately following the accident that shows that the both cooling Towers had a small cloud or slight steam-haze above each, from their dissipation of decay heat, of Reactor Coolant Pump heat, and of Circulation Water Pump heat.

Importantly, the public thought this slight haze was a concentration of deadly radioactivity, so much so that they were convinced that the cooling towers themselves were the source of the accident and radioactive nightmare that they were terrified of. Even today, many of the anti-nuke symbols portray the ‘Towers’ as the evil menace, not the Reactor Building. There are individuals in the Harrisburg area that still consider the cooling towers as the ‘cause’ of the accident and the ‘source’ of the radiation.

TMI-2’s ~500 feet in diameter and ~8 feet deep cooling tower basins remained full of water for years, fed by rainwater and snow, throughout the 7 years of clean-up that I was associated with. For the several years that the ‘small clouds’ remained over the towers, we pumped Susquehanna River water into the tower basins as makeup. The two ‘towers’ communicated with one another through an interconnecting ‘flume’. This body of millions of gallons of water developed its own biological food chain in the years that the towers were idle. Only when we made the decision to empty the tower basins did we come to realize how significant the food chain had become. More about that later.

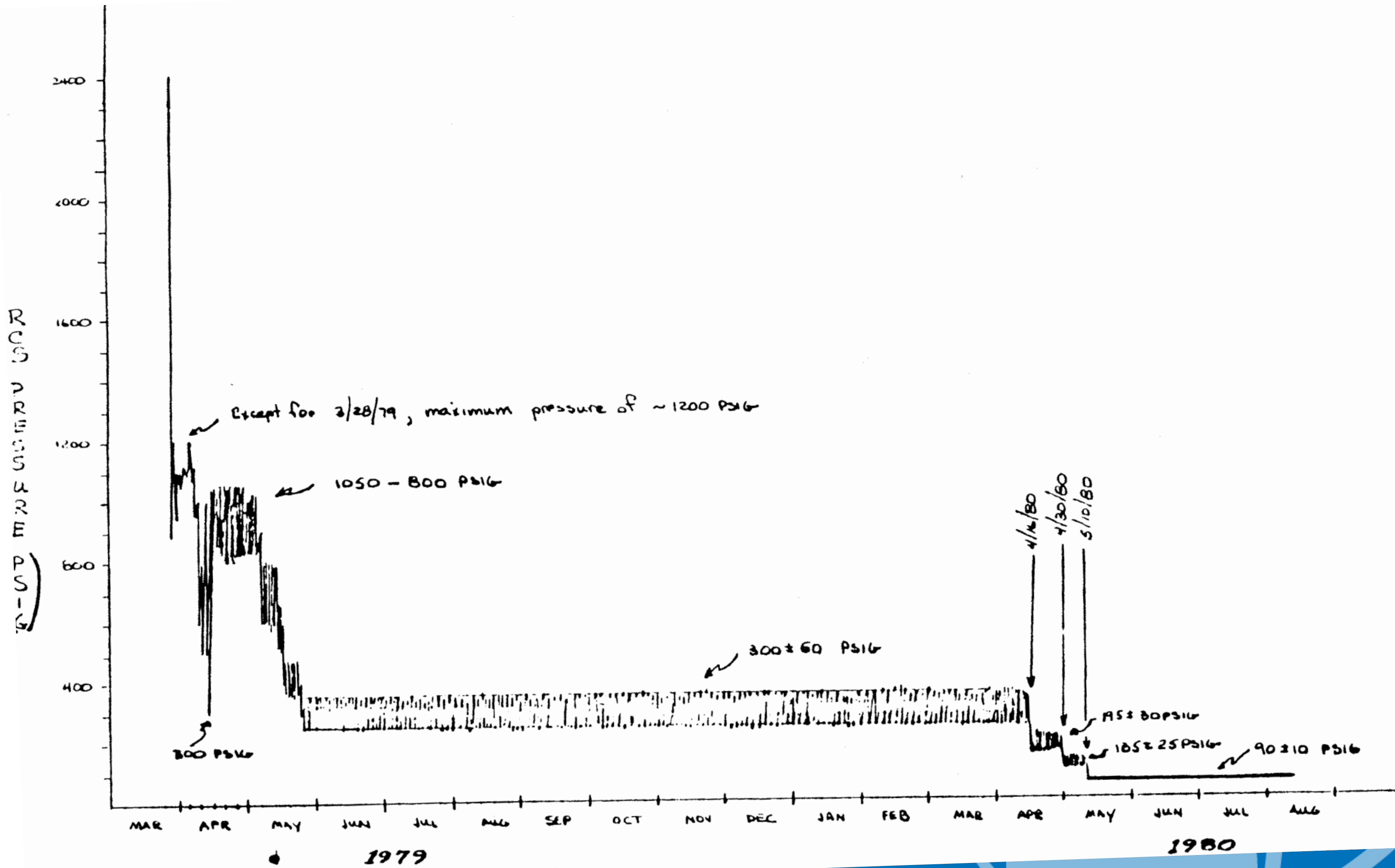
Slide 33 - RCS Pressure versus Time

Primary (RCS) Pressure Control

Primary pressure was initially controlled by the Makeup and Purification system. As concern increased regarding RCS mechanical integrity we reduced RCS pressure, gradually, from design conditions of 2150 psig, to ~1000 psig, to ~600 psig, then ~300 psig, choosing that number as providing assurance of sub cooling and Reactor Coolant Pump net positive suction head. We didn’t know the physical condition of the RCS and hence were taking precaution by reducing pressure thereby to not initiate another break.

We initially controlled the RCS pressure using the Reactor Coolant Pump Seal Injection bypass mini-valves. The challenge was that the seal injection valve packing glands were leaking to the Auxiliary Building floor, and, in time, the leakage created a massive boron crystal that contained thousands of curies of cesium-137 that had a direct shine of ~3,500 rad/hr at several meters. In time, one of the contractors decided to ‘decontaminate’ that crystal by installing 3 industrial sized water heaters in series

Primary Pressure vs. Time
(Months After Reactor Trip)



then hosing down, or ‘washing’, the crystal down the cork seam ‘gap’ between the Auxiliary Building and the Reactor Building. That action saturated the cork seam with Cesium and related isotopes and haunted GPU and its successor company for years.

Standby Pressure Control System

Slide 34 - Schematic of SPC

Slides 35 and 36 - SPC System in New Fuel Storage Area

We were not confident that the originally installed equipment would continue to provide RCS pressure reliably. We designed and built a passive system, known as the Stand by Pressure Control System that would control the RCS pressure. We assumed that we would be required to maintain RCS pressure for an extended time period.

Decay Heat Removal

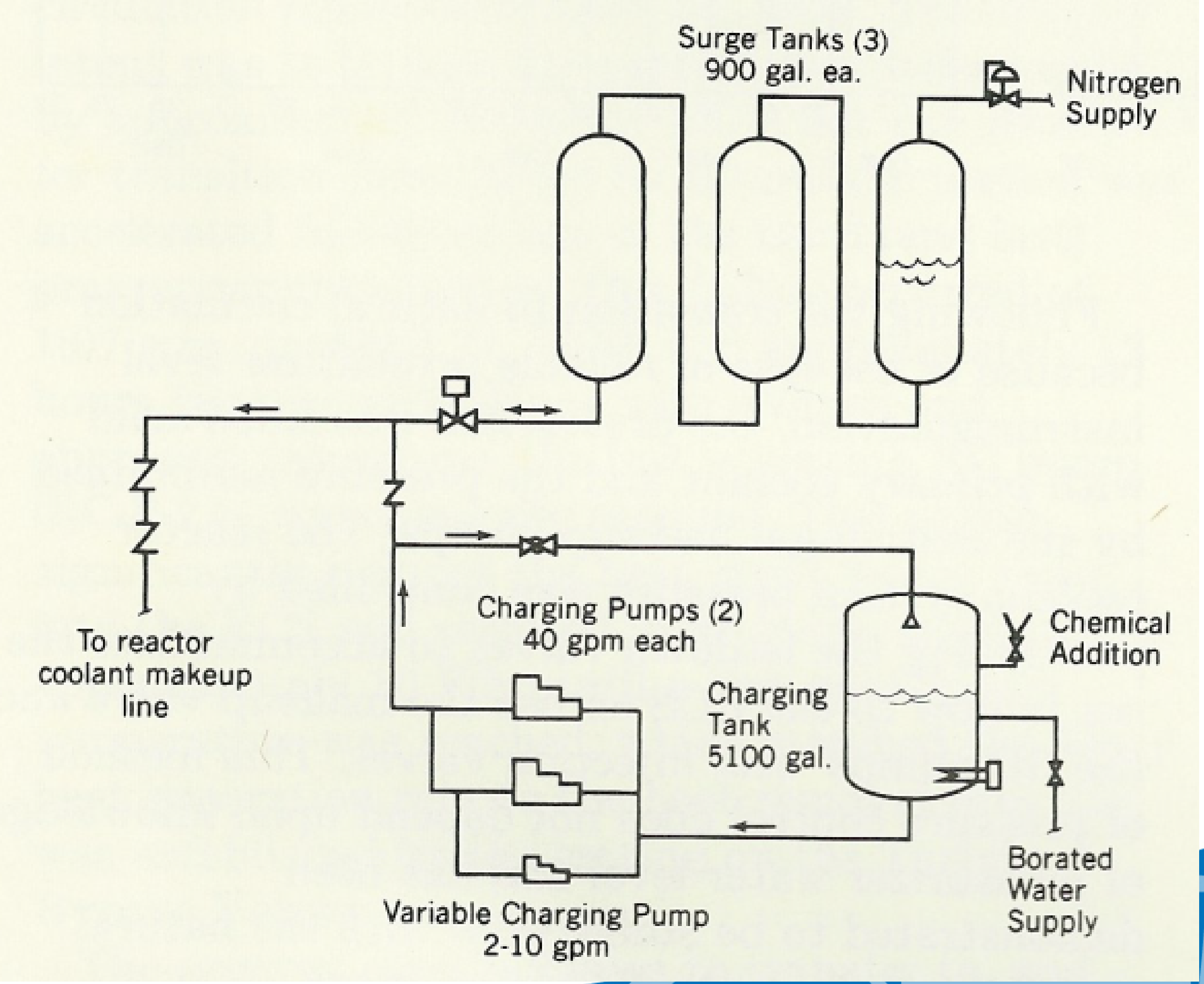
We didn’t know whether the core geometry would respond to the normal decay heat removal processes or whether the core geometry would continue to produce fission heat. Further, from March 28, 1979 at 0400 hours until April 27, 1979 we operated with various combinations of Reactor Coolant Pumps, finally operating only one. We accepted that pump’s contribution of an additional 4 megawatts of pump heat, combined with the instantaneous core-produced Decay Heat generation rate, because the Reactor Coolant Pump flow assured forced flow through the core.

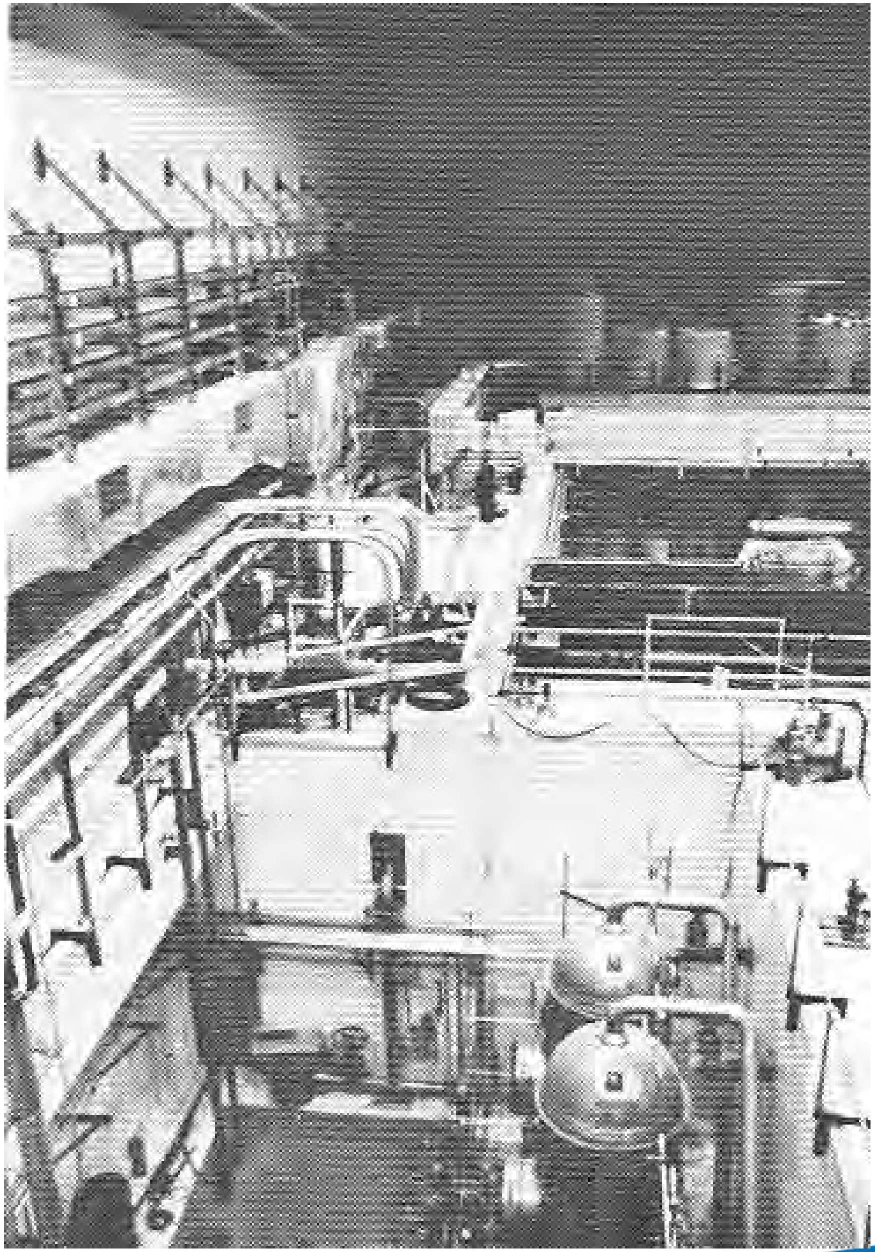
Long Term B

Slides 37 and 38 - Long Term B

Within days of the accident we had transported two large Feedwater Heaters from the Forked River site and ‘shoe-horned’ one of them into the “M20” area, a large wedge shaped vault, between the basement of the rectangular TMI-2 Turbine Building and the adjacent round TMI-2 Reactor Building, immediately below the TMI-s’ Relief Valve chase. We chose that location

Standby Pressure Control System (SPCS)





New Fuel Storage Area in Fuel Handling Building Modified for SPCS

(Surge Tanks Lower Right)

Standby Pressure Control System, 900-gal Surge Tanks

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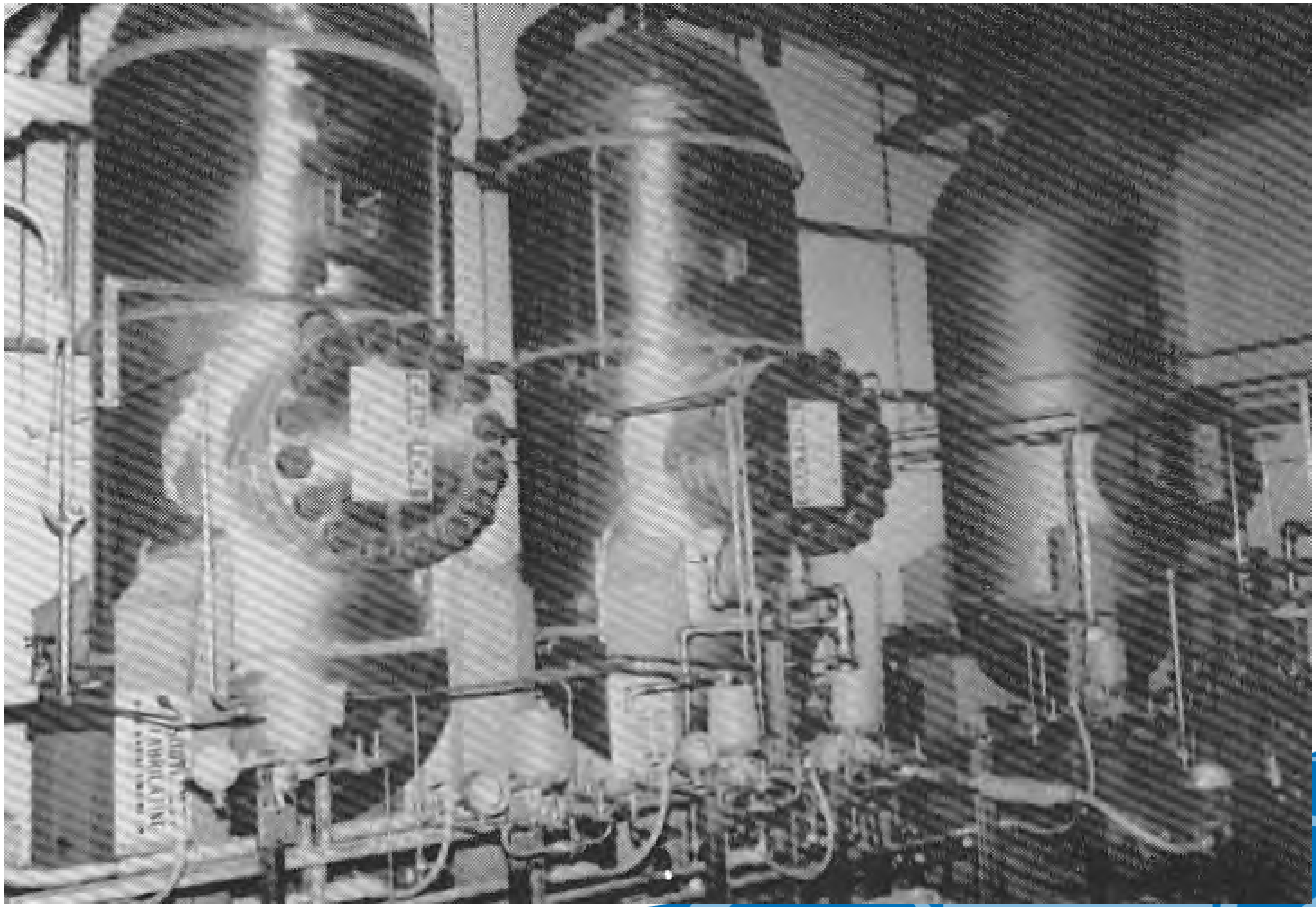

Long Term Backup Cooling System
(Cooler and Shell Side Cooling Lines)

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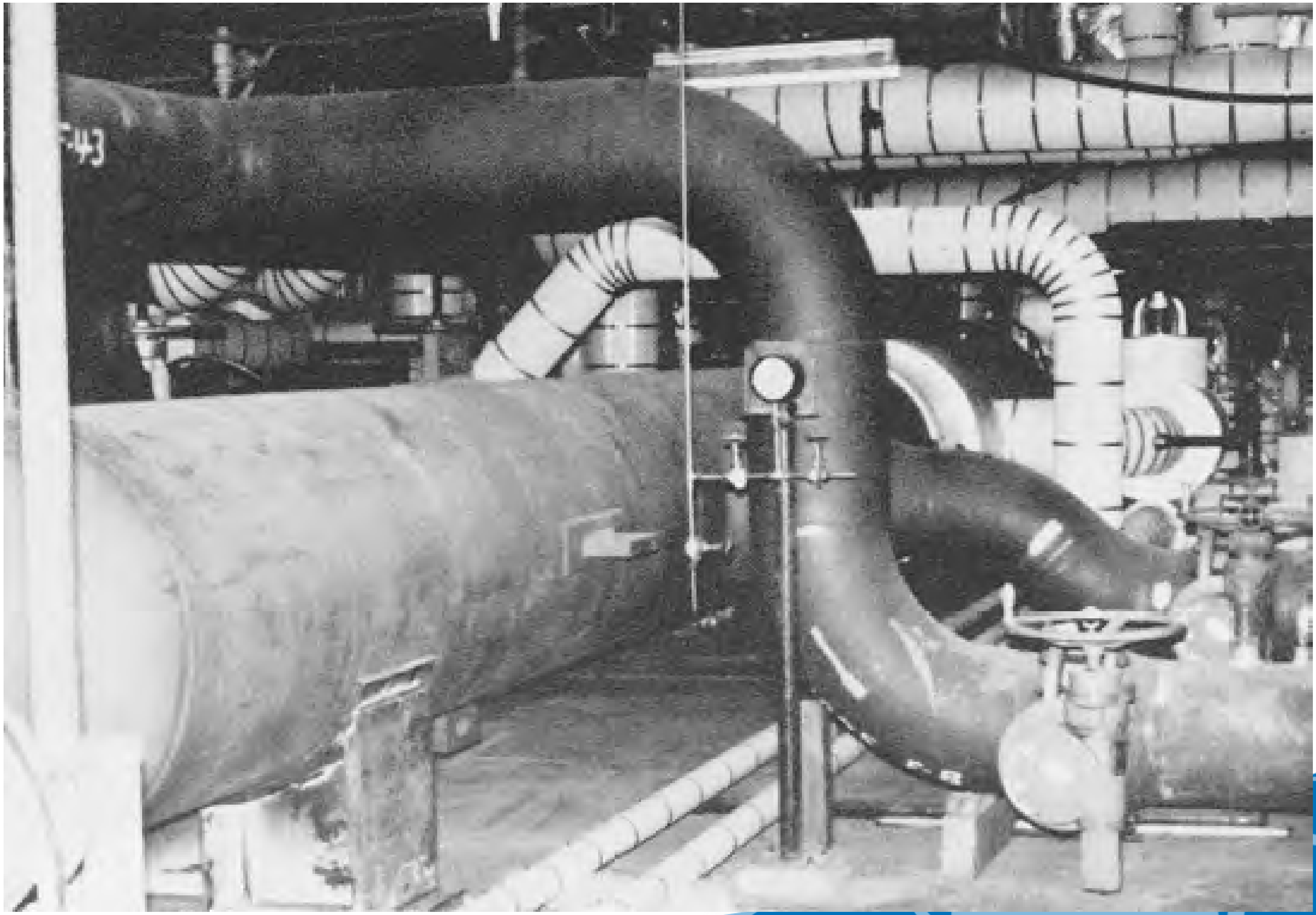
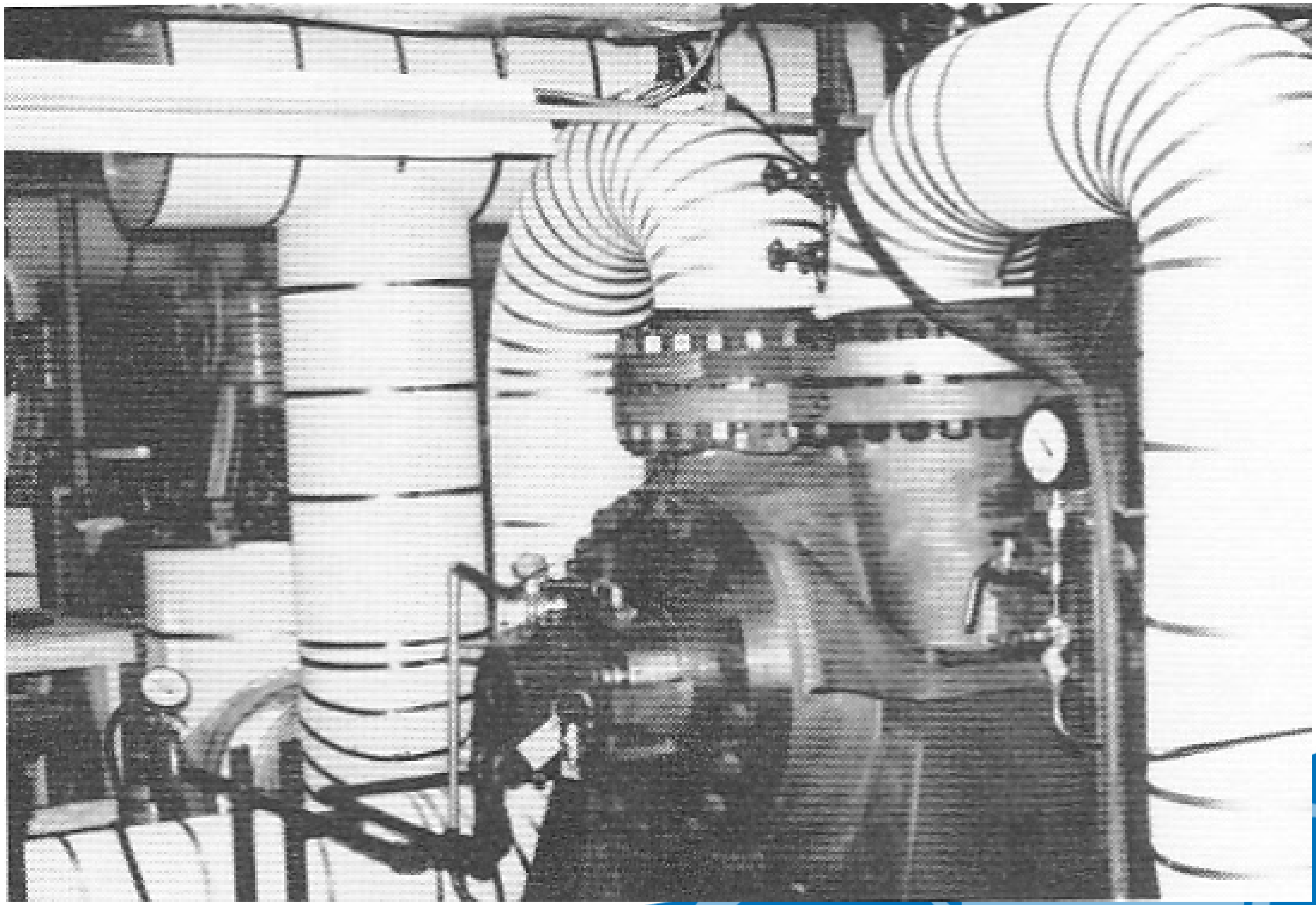


Long Term Backup Cooling System
(Tie-in Point New Pump)



because the main steam and feedwater piping routed through that area and we could tap into those lines and to set up a forced or natural circulation loop for heat removal on the secondary side of the plant. That system, called 'Long Term B', was installed; hydro tested, and turned over for use. It was never used. The piping stubs are still there today.

Alternate Decay heat Removal System (ADHRS)

We obtained a full size Decay Heat cooler from the Forked River project's equipment supplier. We bored holes, below grade, through the west wall of the Fuel Handling Building, at basement level, for the inlet and outlet piping, and installed a construction pad outside, on the west side of the Fuel Handling Building, in anticipation of mounting the full size Decay Heat Exchanger there. We did not complete with that modification although we completed the penetrations through the building wall.

Early in the construction period of the ADHR System I took one of our consultants into the earthen bunker that was to by the 'tunnel' into which we were going to route the Alternate Decay Heat Removal System piping. There we encountered a ~3 foot long snake. My colleague wanted to kill the snake using a shovel that was in the bunker. I wanted to grab the snake and toss it to the ground above us believing that was a wiser choice. I took my hard hat off and used it to trap the snake. The snake struck my hard hat two times. The snake was a Copperhead. The marks are still in my hard hat. The snake slithered away safely.

Mini-Decay Heat Removal System (MDHRS)

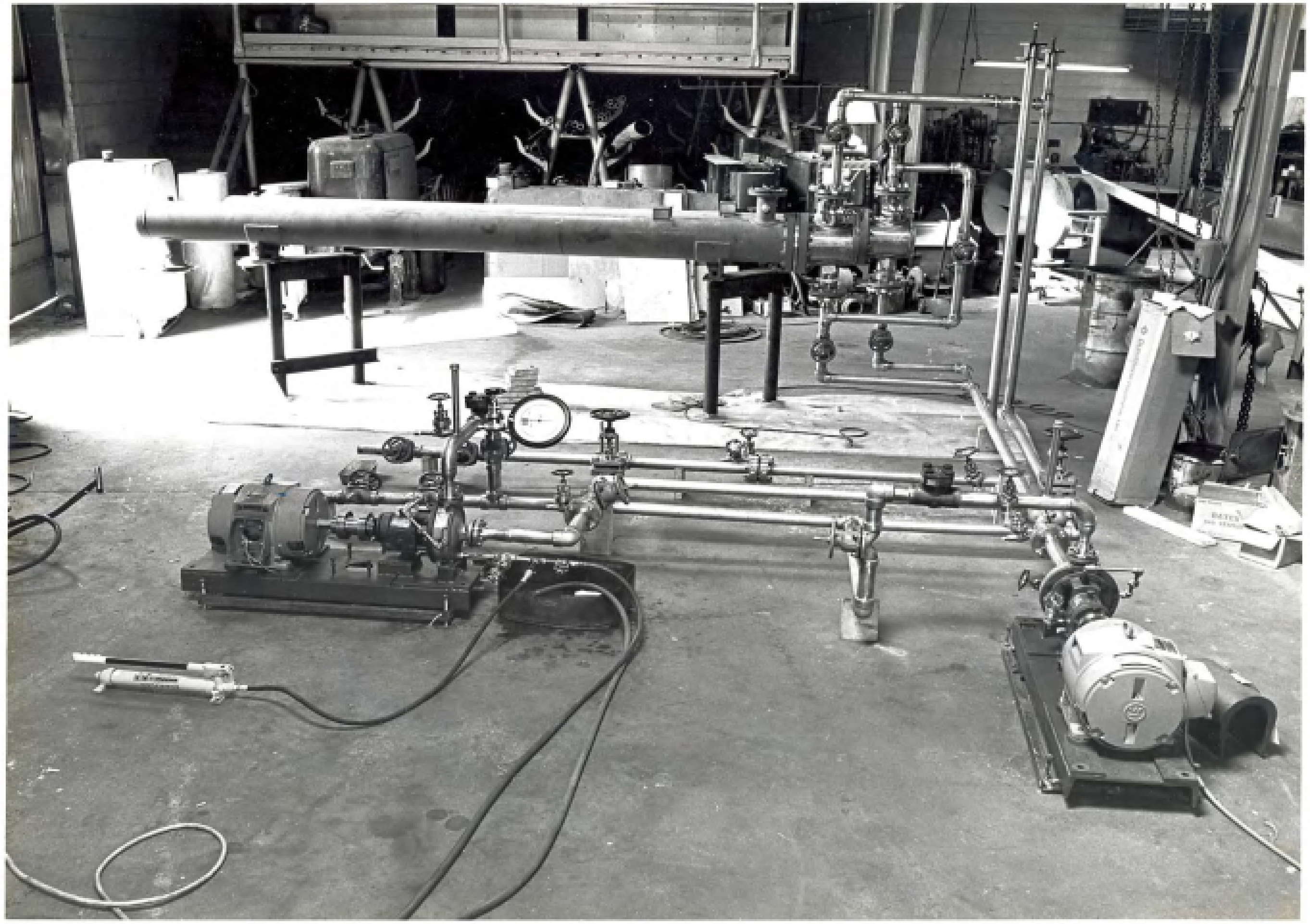
Slide 39 - Mini Decay Heat Removal System in Fabrication Shop in Lynchburg

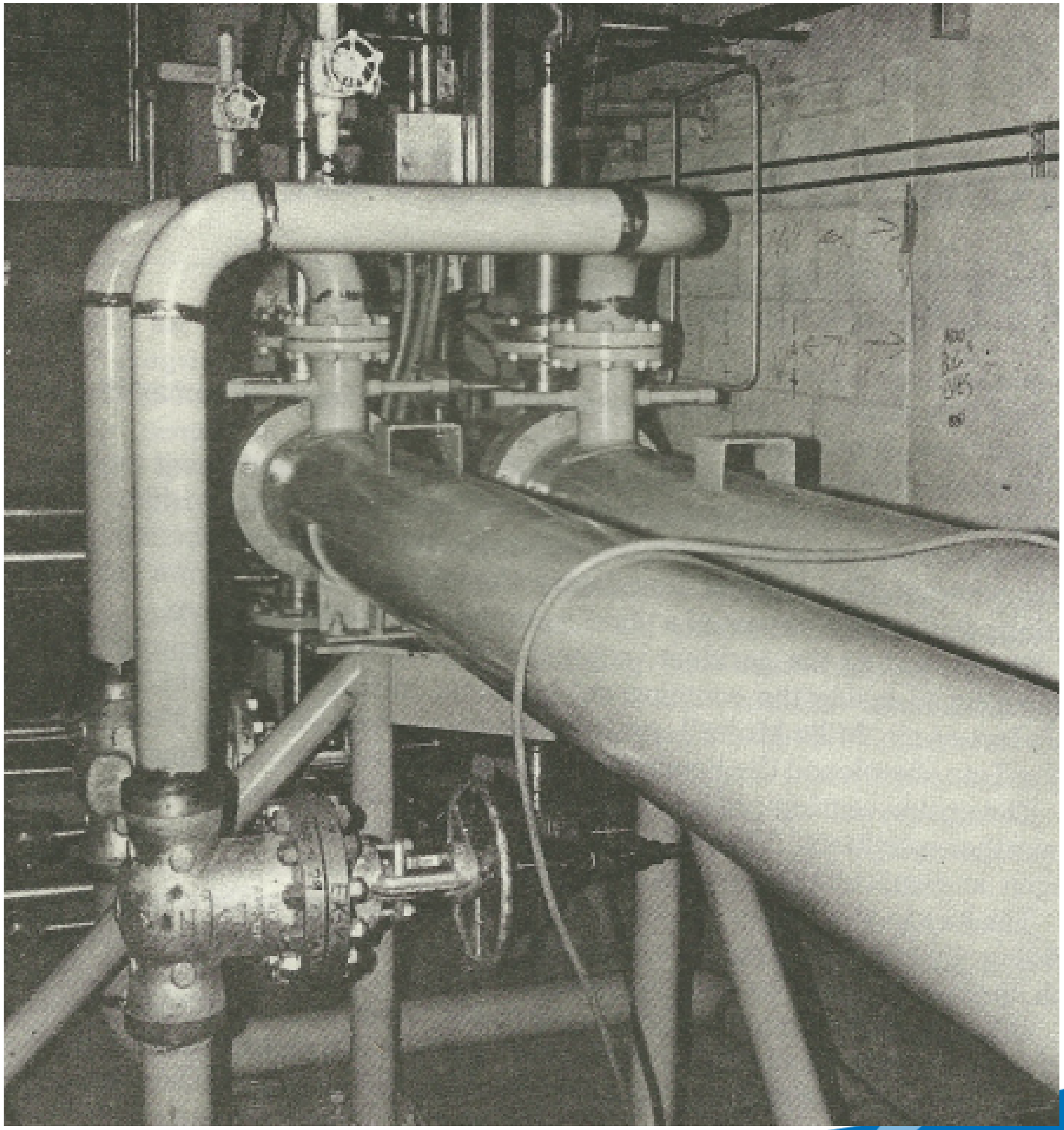
Slide 40 – Mini Decay Heat Removal System Installed at TMI-2 282' 6" Elevation AFHB

We built, hydro-tested, disassembled, transported and installed a mini-decay heat removal system that consisted of the Reactor Coolant Pump Seal Return Coolers and Demineralized Water Pumps from the cancelled Forked River plant. We pre-measured at the installation location in the TMI-2 Auxiliary and Fuel handling

Mini Decay Heat Removal System

(Fabrication at Lynchburg, VA)





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Mini Decay Heat Removal System

(Became Operational in October 1980)

Building compartment where we intended to install it. We then constructed the entire system in a shop in Lynchburg, Virginia, engaged an ASME III (nuclear power plant components) qualified welder, assembled it, hydro tested it, had it inspected, certified and stamped by a qualified ASME Inspector, took it apart, shipped it in pieces, and installed it in the Auxiliary Building Basement at TMI-2. It remains there today. It was never placed into service.

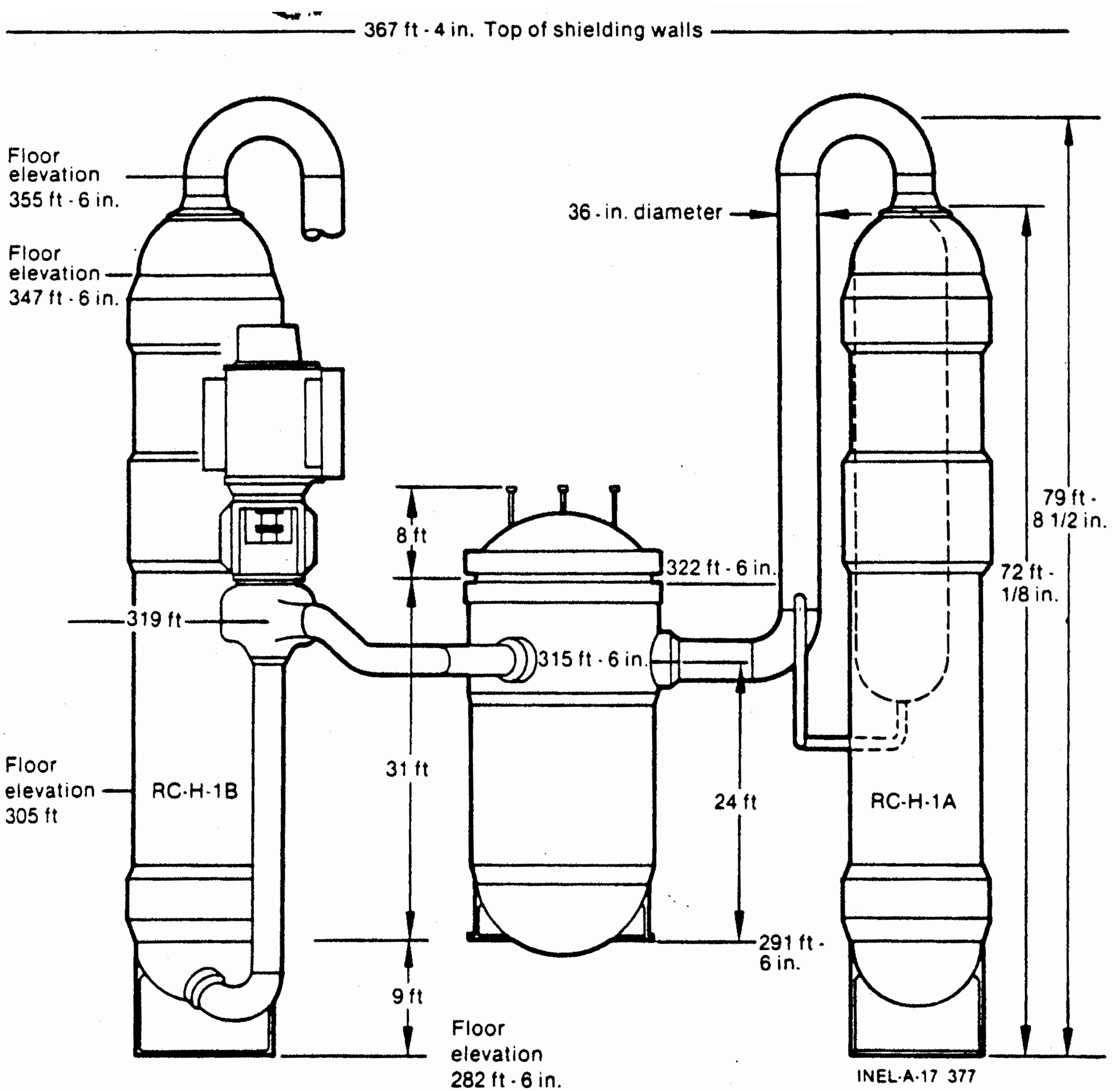
Natural Circulation Cooling

Slide 41 - RCS Elevations Core Versus OTSG Tubes

We knew we needed to maintain Reactor Coolant Pressure in order to provide net positive suction head for the Reactor Coolant Pumps. We also recognized that 'one pump operation' in the B&W loops configuration with 4 cold-legs and 2 hot-legs, all communicating, produced pump 'run-out' on that one pump, produced forward flow into the Reactor Vessel in only that one pump's cold leg, and produced backwards flow on the other three cold legs because the cold legs share a common hydraulic header in the (Reactor Vessel) down comer. What this exactly meant to the core's overall flow wasn't fully understood but we knew that maintaining forced flow with the Reactor Coolant Pump, even with the one pump at run-out, required ~200 psig net positive suction head.

On April 27, 1979 the final (last remaining) pressurizer level indication failed and we enacted the procedure to stop the 4th Reactor Coolant Pump. We did not know whether the RCS would transition to natural circulation or not. We had calculated the differential head requirement of about 0.004 psi differential, between the hot and cold legs, for natural circulation to continue. We had no computer modeling to assist us – we used the ASME steam tables, our own slide rules and our add /subtract /multiply / divide pocket calculators for this calculation.

On stopping the Reactor Coolant Pump, the organization held its collective breath to learn if natural circulation would succeed. The RCS 'forward flow' in both of the loops decreased exponentially as indicated on the then-operable flow instrumentation. Within a minute TMI-2 entered smooth natural circulation without incident. The driving head for natural circulation was the differential density



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TMI-2 Reactor Coolant System

(Physical Arrangement and Elevations)

between the ~12 foot core water elevation against a comparable ~12 foot cooler elevation of water in the tubes in either or both of the adjacent steam generators.

For those ~four weeks, between the accident and April 27th, our attention remained focused on developing the multiple back up Decay Heat removal systems in case we were unsuccessful in achieving natural circulation.

Slide 42 - Burps

Following halting operation of the final Reactor Coolant Pump on April 27, 1979 the Reactor Coolant System remained in smooth Natural Circulation for approximately half a year. In the fall of 1979 we began to experience intermittent (on/off) natural circulation. We called this form of natural circulation ‘burps’. Our first reaction was that there was some ‘plugging’ occurring, whether it was in the core or elsewhere, and were wary as to whether we would be required to operate one of the backup cooling systems. The first several occurrences of the phenomenon instilled concern from everyone involved, particularly those of us watching the core, and also the operators, the oversight groups, and the NRC. Everybody wanted to understand the ‘burp’ because it might be ‘telegraphing’ some new heat production or heat removal issue we hadn’t foreseen.

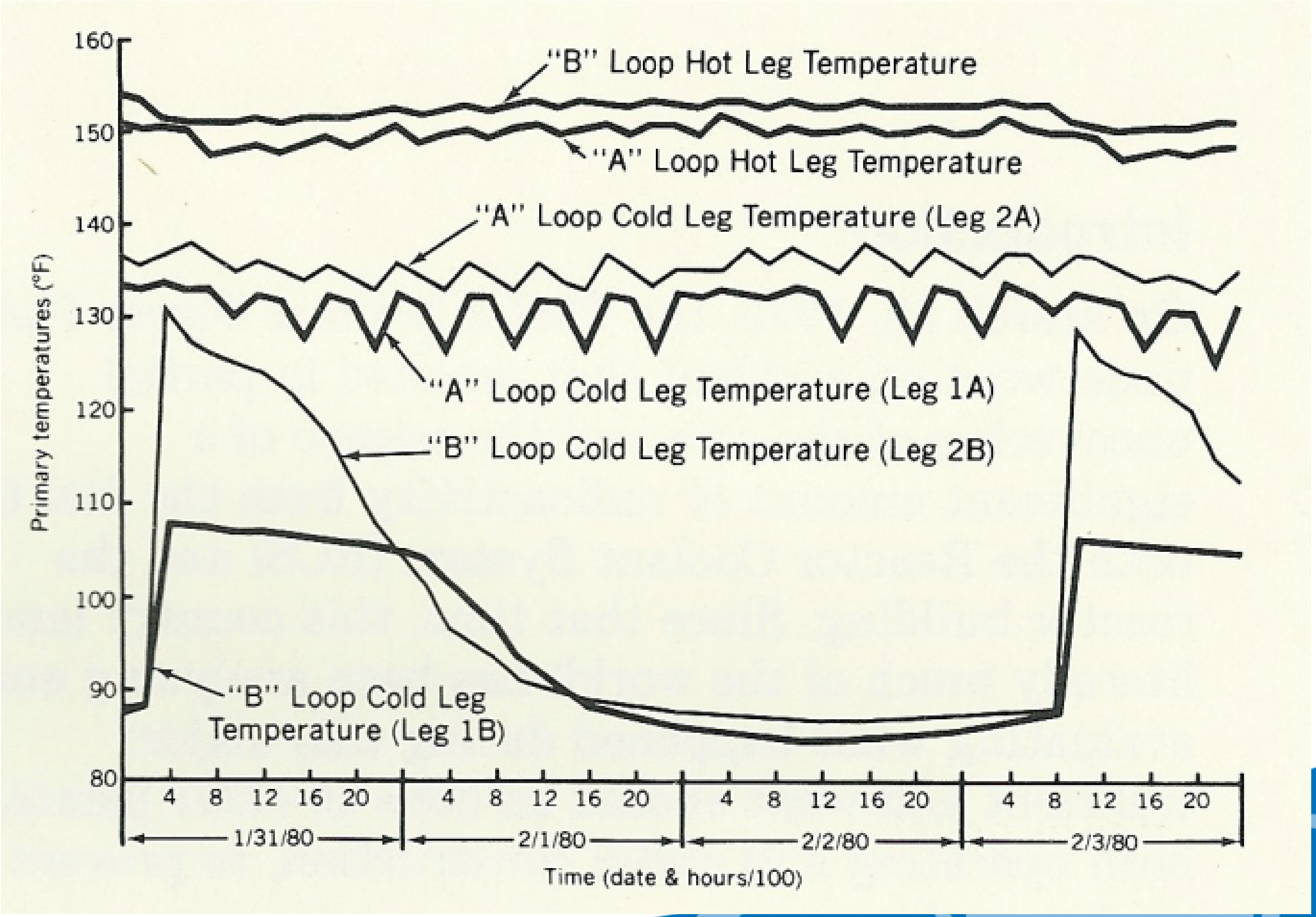
At first we thought the initiation of the ‘burp’ – defined as a sudden and spontaneous onset of fluid cascading into the reactor vessel through RCS piping ‘cold-legs’, - was associated with some onsite action, such as banging a door in the plant or by vibration caused by construction vehicles on site. Then we thought it might be initiated by the acoustical vibration that accompanied a jet plane ‘taking off’ from the Harrisburg airport several miles away. The lower temperature on the cold days in the late fall 1979 and early winter of 1980 seemed to increase the frequency of the burps.

Slide 43 - RCS Temperature and Decay Heat Load Versus Time

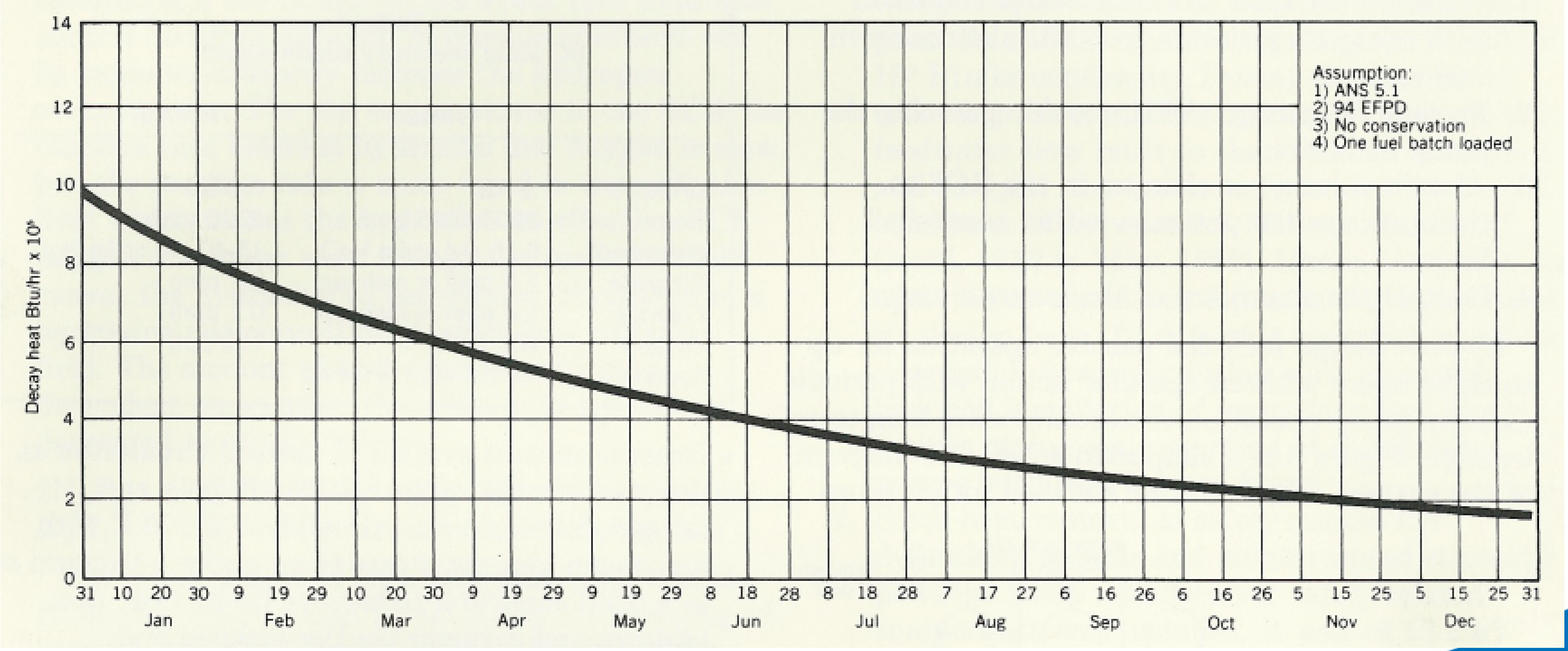
(1 Million Btu per hour, ~292 kilowatts, about 1.65 kilowatts per Fuel Assembly)

Primary Temperatures vs. Time

(B-Loop "Burp" Transients)



TMI-2 Expected Decay Heat Load vs. Time, 1980



In time, however, we learned that the ‘burps’ were random and were the result of decay heat generation in the RCS and the removal of the heat in the steam generators and in the Reactor Building - and were dictated by which loop was ‘cooler’ than the other - hence providing the driving head for the burp. It didn’t dawn on us until sometime later that the combination of the decreasing Decay Heat generation rate accompanied by lower building temperatures were the ‘drivers’ of the periodicity of the ‘burps’. The ‘burping’ continued through late 1980; in the months thereafter the burping continued, but at a much lower frequency.

1979 – 1980 - Lead Shielding

All workers entering the Auxiliary and Fuel Handling Building through doors, into compartments and sub-compartments were confronted by high radiation levels.

We recognized we did not have sufficient shielding to protect workers to accomplish the work that we considered necessary. GPU requested, from Industry, lead bricks – lots of them, and lead blankets, as many as we could find, to help us in our shielding actions. Naval Reactors, directed by Admiral Rickover, dispatched a C5A cargo plane with a load of virgin assorted lead bricks and blankets to the Middletown/Harrisburg airport. Those bricks were utilized throughout TMI-2 in various locations for numerous shielding configurations. Those bricks and shields remain throughout TMI-2’s Auxiliary and Fuel Handling, and Reactor Building, today.

Early 1980s

Slide 44 - New Tech Specs for TMI-2

TMI-2 Recovery Tech Specs - NUREG-0432 - February 13, 1980

As might be expected, the operating status and license for TMI-2 were changed. New Tech Specs were created for the site. The order is as follows:

> “The NRC has issued the enclosed Order for the Three Mile Island Nuclear Station. This Order (1) requires that

TMI-2 Recovery Tech Specs - NUREG-0432 - Feb 13, 1980

"The NRC has issued the enclosed Order for the Three Mile Island Nuclear Station. This Order

(1) requires that effective immediately the facility be maintained in accordance with the requirements of the attached proposed Technical Specifications and

(2) proposes to formally amend the Facility Operating License to include the proposed Technical Specifications taking into account the present condition of plant systems so as to ensure that the unit will remain in a safe and stable posture during the Recovery Mode."

> effective immediately the facility be maintained in accordance with the requirements of the attached proposed Technical Specifications and (2) proposes to formally amend the Facility Operating License to include the proposed Technical Specifications taking into account the present condition of plant systems so as to ensure that the unit will remain in a safe and stable posture during the Recovery Mode."

It is worthy to note that the TMI-2 Recovery Technical Specification that were re-cast for TMI-2 after the accident apply today - 35 years after the Accident. The present owners of TMI-2 treat the TMI-2 Tech Specs similarly as they presently treat the Tech Specs of their operating plants.

1980 - June - Reactor Building Venting - Krypton-85

Slides 45 and 46 - Reactor Building, TMI Site News Paper

The TMI-2 Reactor Building is a formidable structure. It is bolted into bedrock, is about 280 feet tall and 130 feet in inside diameter. It has four-foot thick reinforced concrete walls lined with ¼ inch steel. It contains a nominal ~2.6 million cubic feet of free volume.

Hydrogen wasn't the only gas released to the Reactor Building. While millions of curies of gaseous isotopes were released to the TMI-2 containment during and following the accident, few curies leaked from the building to the surrounding buildings or the atmosphere. Isotopes with short half-lives decayed promptly. Among the longer lived remaining isotopes that were released were approximately ~50,000 curies of krypton-85 radiogas that were contained within the approximately ~3,000,000 cubic foot interior volume of the TMI-2 Reactor Building.

The Beta radiological dose to a worker surrounded by this atmosphere was great enough to preclude long stay times inside the Reactor Building. GPU organization prepared a Safely Evaluation, and obtained NRC review of and approval of the Safety Evaluations and its accompanying environmental assessment. Only after legal hurdles were cleared, including permission from the US District Court, did venting begin. The release of the radioactive gas commenced on June 28, 1980 and

TMI-2 Reactor Building Vent Stack

Unit 2 Reactor Building Venting

(Purging Began June 28, 1980, and Completed July 11, 1980)

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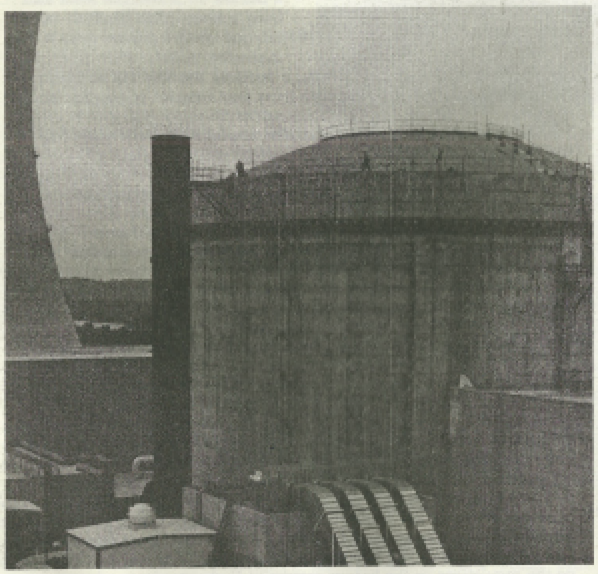
TMI today

VOL. 1, NO. 1 PUBLISHED BY THREE MILE ISLAND NUCLEAR STATION JULY, 1980



Planned release of krypton 85 gas from the TMI-2 Containment Building will take place through 160-foot vent stack at left. Venting was set to begin in late June and continue for two to four weeks, depending on weather conditions.

Unit 2 containment venting ready to go

Venting of 57,000 curies of radioactive krypton gas from the Three Mile Island Unit 2 containment building was scheduled for late June, following unanimous approval of the company's proposed plan by the Nuclear Regulatory Commission.

NRC approval ended nearly seven months of controversy surrounding the proposal and marked a significant forward step in the TMI cleanup.

The venting is expected to continue for two to four weeks in July, depending on weather conditions. Windy days would permit maximum gas dispersal.

The venting proposal submitted November 13, 1979, was endorsed by the Commission after studies by independent government agencies and scientific organizations showed the proposal would produce no radiation-induced health effects.

Disposal of the krypton will enable TMI workers to begin planning the cleanup of the Unit 2 containment building, and will permit easier access to the building for maintenance of equipment.

The release will be accomplished using existing systems, including a "hydrogen purge" system which leads from the Unit 2 containment building to the auxiliary building and into the vent stack.

Later in the venting program, a faster ventilation system will release krypton using the existing reactor building purge system which also leads directly into the vent stack and to the atmosphere. The slow and fast systems are routinely used during normal operations, but have not been used since the accident.

The venting system consists of a series of valves, dampers, filters and radiation monitors. As induction fans draw fresh air into the building, the contaminated air is drawn through particulate filters and past radiation monitors before discharging into the atmosphere.

completed on July 11, 1980. Originally expected to take four weeks, the release was completed in approximately two weeks.

The krypton-85 release was very strongly opposed by the community and by numerous anti-nuclear groups. GPU asserted that the venting was safe, and essential. Release was critically important to enable workers to enter the Reactor Building safely and proceed with data acquisition that would precede the stabilization and clean-up activities. In an attempt to assuage the public's outcry, the GPU president and his wife took up residence in a travel trailer specifically located on company property approximately 1000 feet from the TMI-2 stack. They lived there for the duration of the venting campaign.

1980 - July - Containment Entry #1

Slide 47 - Entering the Building - Inside the Equipment Hatch, door to inside of Reactor Building

Slides 48 and 49 - Inside the Reactor Building, Same Door from Inside

Approximately two weeks following the completion of the Krypton 85 venting two GPU workers made the first entry into the TMI-2 containment. Their entry, and the resulting data that they gathered, paved the way for subsequent entries

1979 – 1980 - Water Processing

Slide 50 - EPICOR Flow Sheet

Slide 51 - EPICOR Liner

If nuclear fuel is the heart of the fission process, coolant is the life blood. At TMI-2 regular demineralized water was that coolant. Whenever or wherever the water leaked, or spilled, it became a challenge proportional to its isotopic contents. There was enormous focus on water processing throughout the entire TMI-2 cleanup – just as there is at Fukushima today.

As previously mentioned, TMI is located on an island in the Susquehanna River 10 miles south of Harrisburg. The

Inside Reactor Building Airlock

(First Entry on July 23, 1980 by Two TMI Engineers with Backup Team on Standby)

Inside Reactor Building (1980)

Inside Reactor Building

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EPICOR II Flow Path Schematic (1980)

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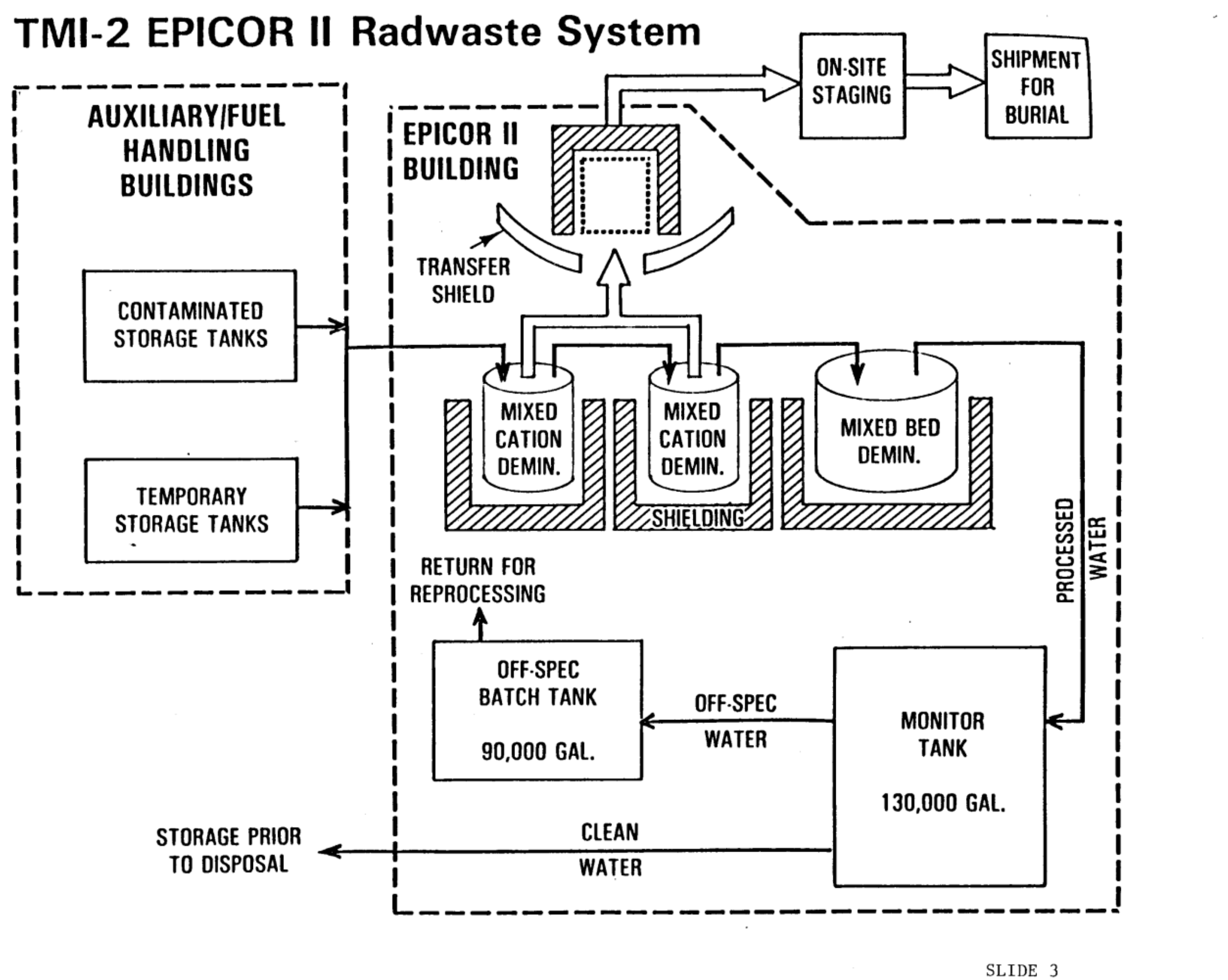

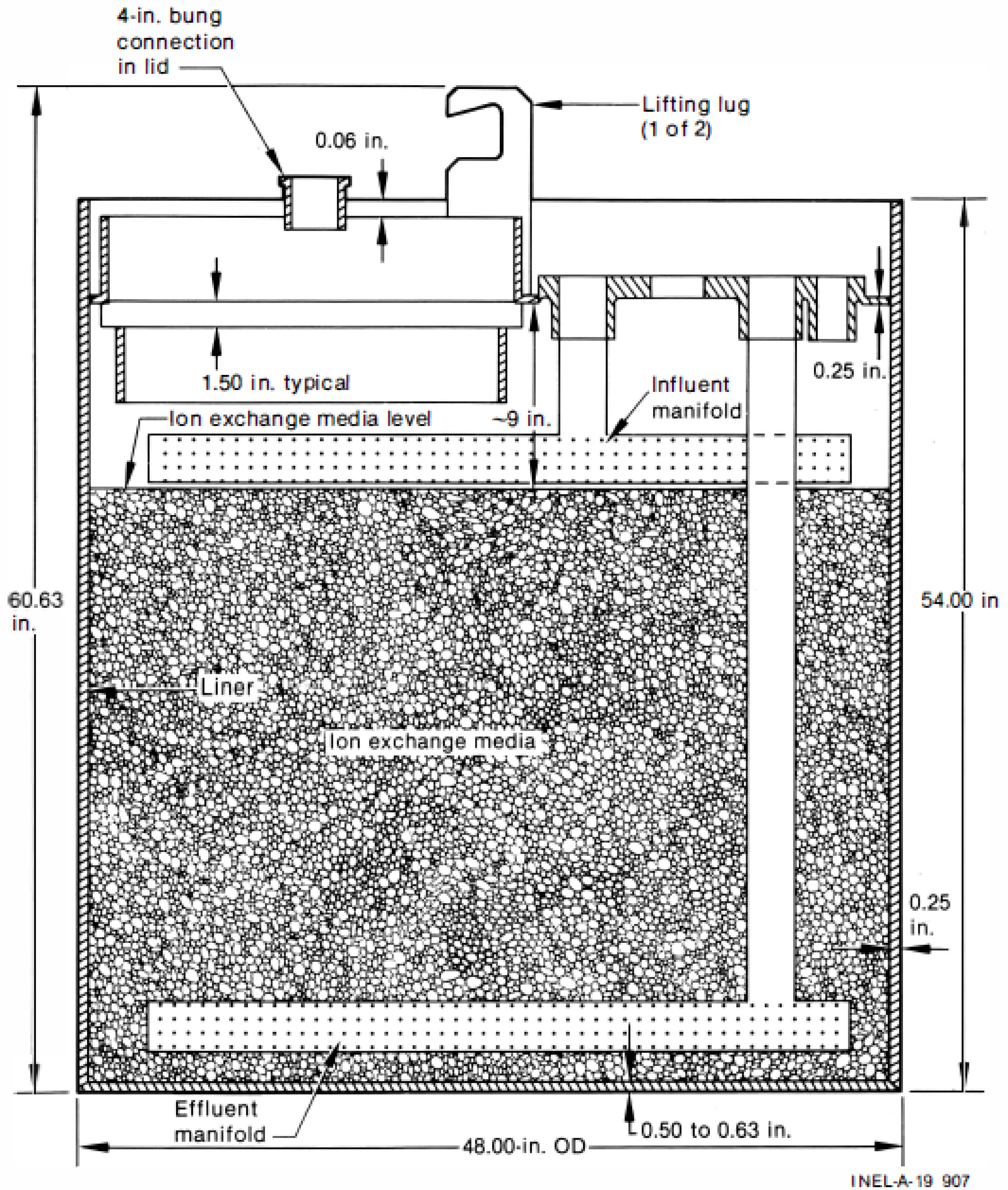

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Typical EPICOR II Liner

(Cross-Section View, GEND-29)

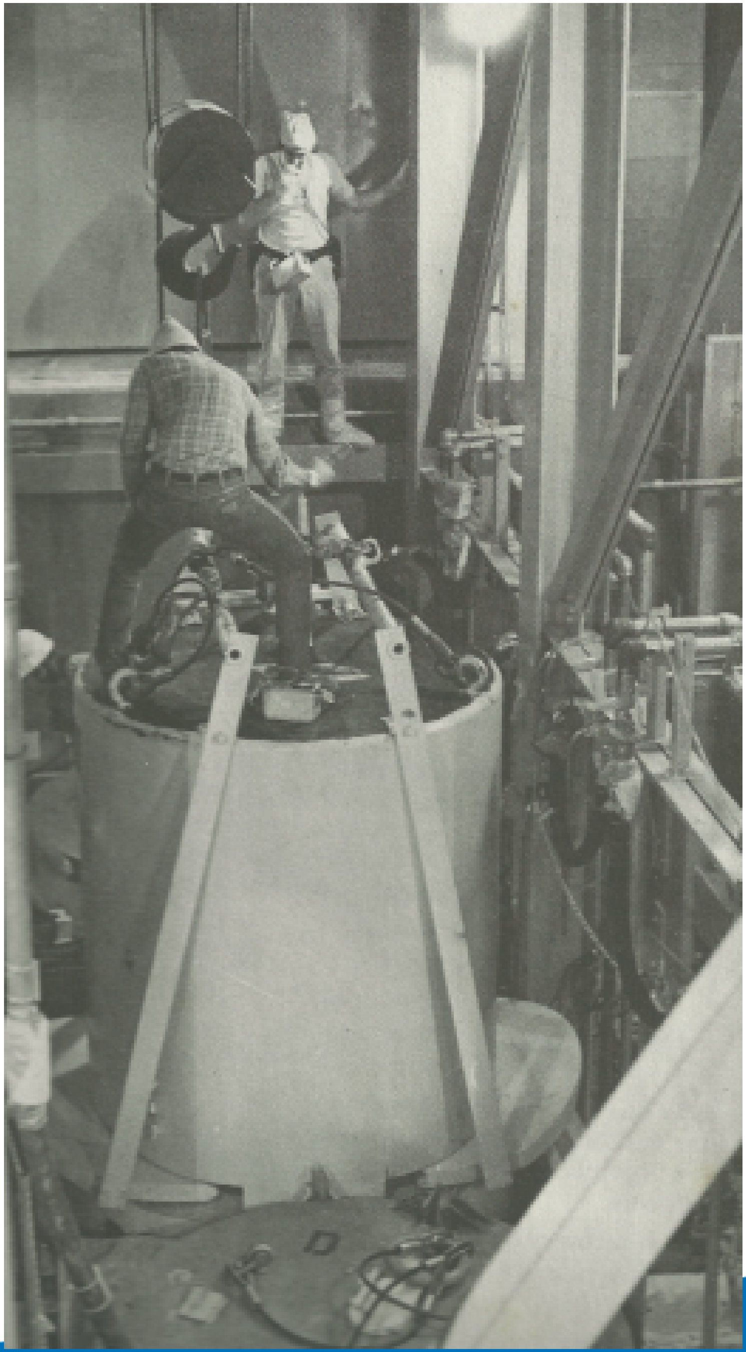
combination of events at TMI-2 that include the recognized fuel failure and the hydrogen explosion caused credible concern regarding the Reactor Building's integrity, including the integrity of the basement, and the accompanying concern regarding release of the contaminated sump water to the Susquehanna River. Apart from the fact that the downstream communities draw their drinking water from the Susquehanna, the Susquehanna also feeds one of the most vibrant natural water resources in the eastern United States – the Chesapeake Bay. The potential for TMI-2's accident generated radioactive water to leak into the Susquehanna River contaminating both the River in Pennsylvania and the Chesapeake Bay was a major concern for the GPU leadership and the leaders and residents of communities downstream, and the state and local governments that include Pennsylvania and Maryland. The importance, and urgency, of removing the contaminated water from the entire TMI-2 site, as well as the TMI-2 Reactor Building basement, took on a life of its own.

Slide 52 - EPICOR Operations, Workers

Early actions were undertaken to treat the AGW in the Auxiliary and Fuel Handling Buildings. The system that was designed and installed was first called EPICOR 1, then EPICOR 2.
These were designed and built to process the early low to intermediate activity accident generated water from TMI-2's Aux and Fuel Handling Building. These two systems utilized hose/quick disconnect/plumbing systems where the demineralizers were charged with organic anion/cation resins that would capture the isotopic content of the contamination in the AGW.

Refinement of Process from EPICOR I Led to EPICOR II

GPU's accident water management efforts began with processing of water in the Unit 2 Auxiliary Building using EPICOR I, and then a modified system called EPICOR II. The EPICOR II system was designed to purify medium-specific activity-level water. By December 1981, EPICOR II generated 50 pre-filters and 22 resin liners while removing approximately 55,000 curie from 565,000 gallons of contaminated water in the Auxiliary and Fuel Handling Buildings.



Change of Filter Liner in EPICOR II

Slides 53 and 54 - EPICOR Layout, Actual Images

Creation of procedures and conduct of training, principally of the Waste Handlers and Radiation Control Technicians (or “Rad Con”), led to early success of these systems until it was discovered, through a dangerous incident, that some of the EPICOR demineralizer liners contained both organic and inorganic resins. The incident was a flash ignition of hydrogen at the Waste Packaging and Handling Facility that was the EPICOR II cask loading station. This was a ‘near-miss’ for the workers and a wake-up call for how sensitive the waste forms would be to air ingress, hydrogen out-leakage, hydrogen auto-ignition and explosion. Storage of the expended liners required further action – because disposal for the waste form was uncertain.

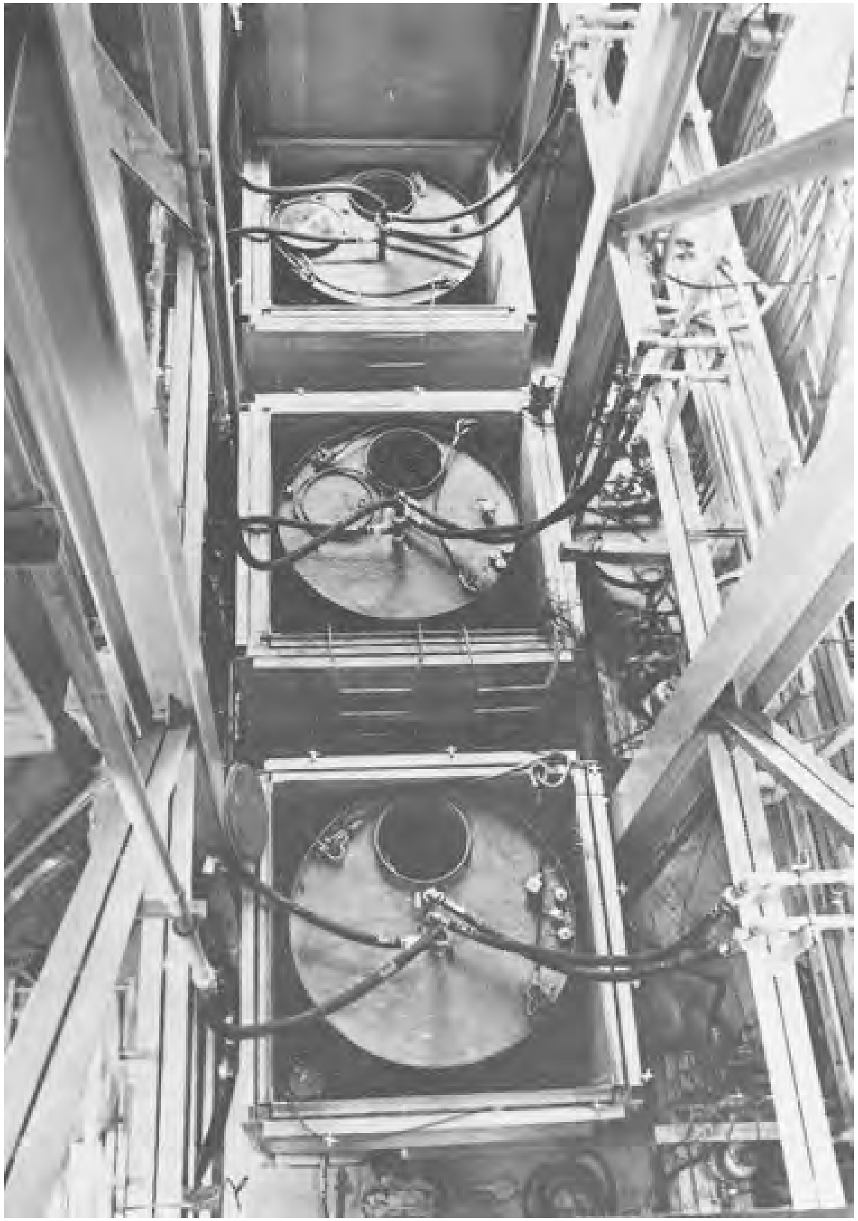
Slide 55 - Storage Facility Concept

Slides 56, 57, and 58 - EPICOR Storage Facility

In time GPU constructed two concrete pads, each containing 60 cells large enough to accommodate over 120 EPICOR liners, thus making provision for the liners to be stored on the south end of the TMI-2 property adjacent to the NRC trailers.

The two storage pads were adjacent to the NRC’s TMI-2 site trailers. As the consequence of the earlier flash ignition incident, the NRC requested GPU undertake, in addition to ensuring sufficient concrete to shield the liners, that we undertake prompt carbon dioxide (CO_2) inerting of the active cells. At about the same time an unfortunate event occurred in Ohio where a large cloud of CO2 escaped from an industrial facility during the night and suffocated about a dozen inhabitants in a nearby neighborhood while they slept. NRC promptly withdrew their request for GPU to provide the CO_2 cover gas on the EPICOR pad.

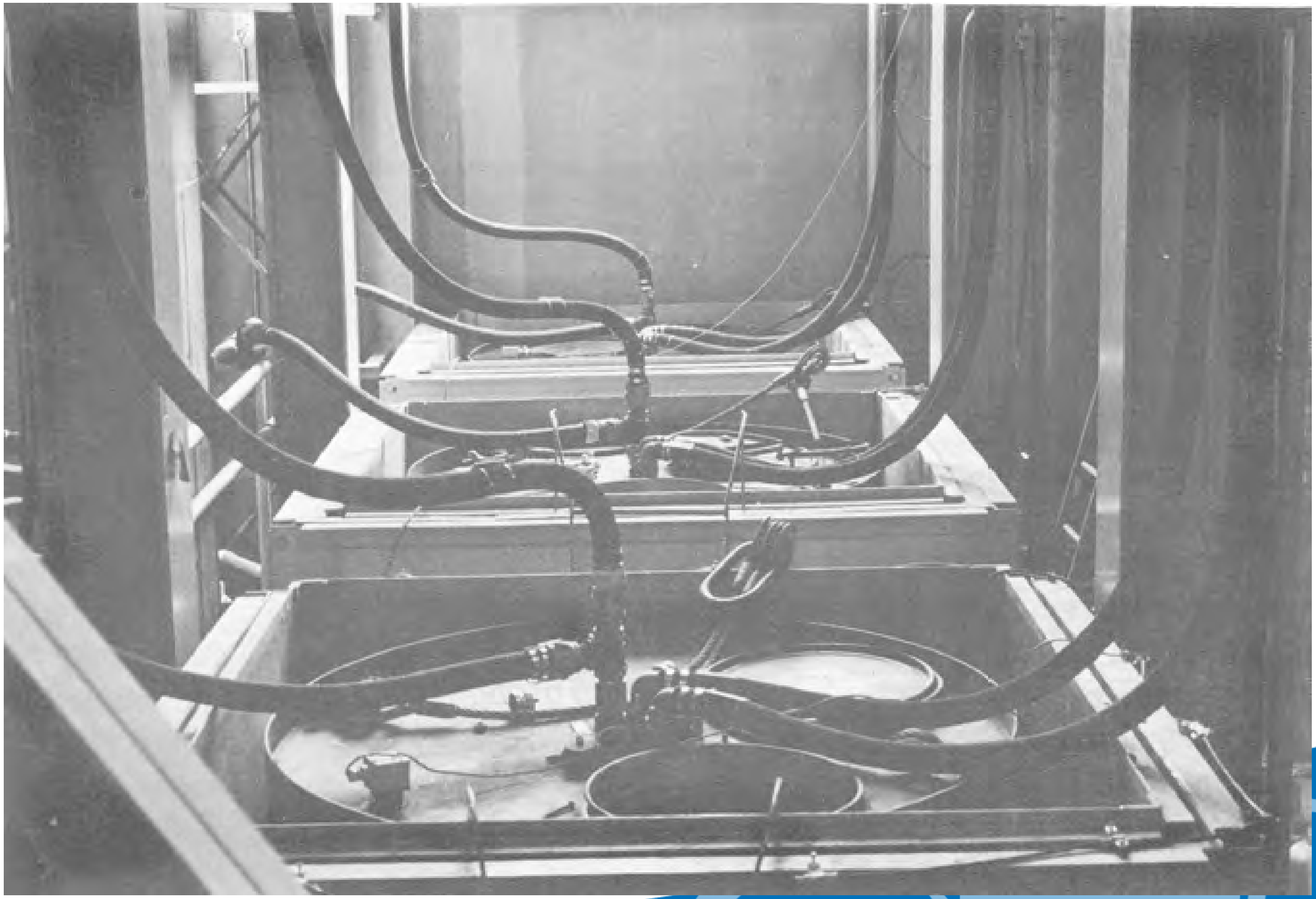
In its final configuration EPICOR II was utilized in conjunction with Submerged Demineralizer System (SDS) operations for final polishing of all of the remaining water.



EPICOR II System Filters

[Pre-filter (Top), Cation Ion-exchanger (Center), Mixed-bed Polishing Ion-exchanger (Bottom)]

EPICOR-II System
(Process Vessels Containing Ion-Exchange Resins,1979)



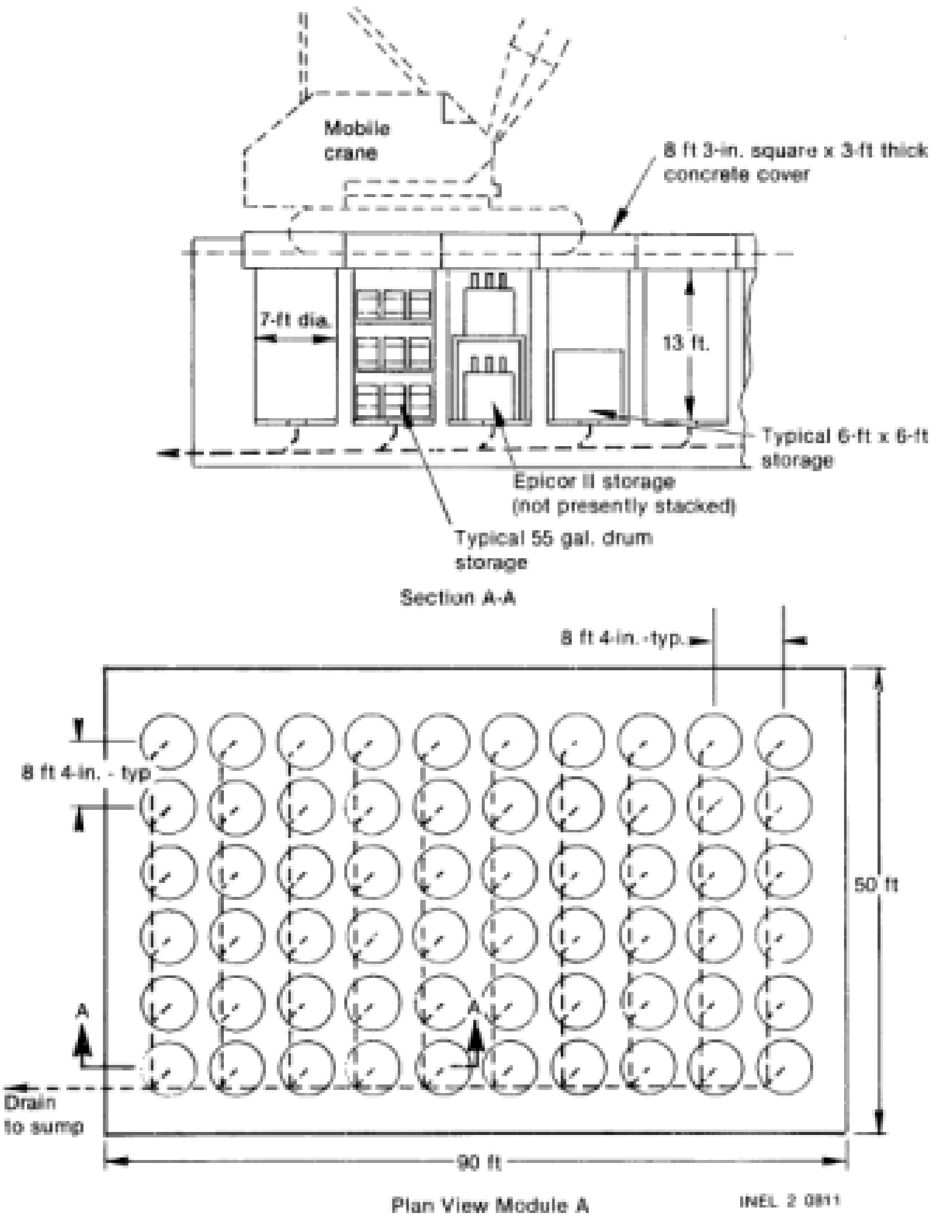


Figure 1. Solid Waste Staging Facility.

Solid Waste Staging Facility

(Schematic, GEND-029)

Solid Waste Staging Facility

(Temporary Radwaste Staging Area along Bottom; Located South of Unit 2 Cooling Towers)

Solid Waste Staging Facility
(Under Construction)

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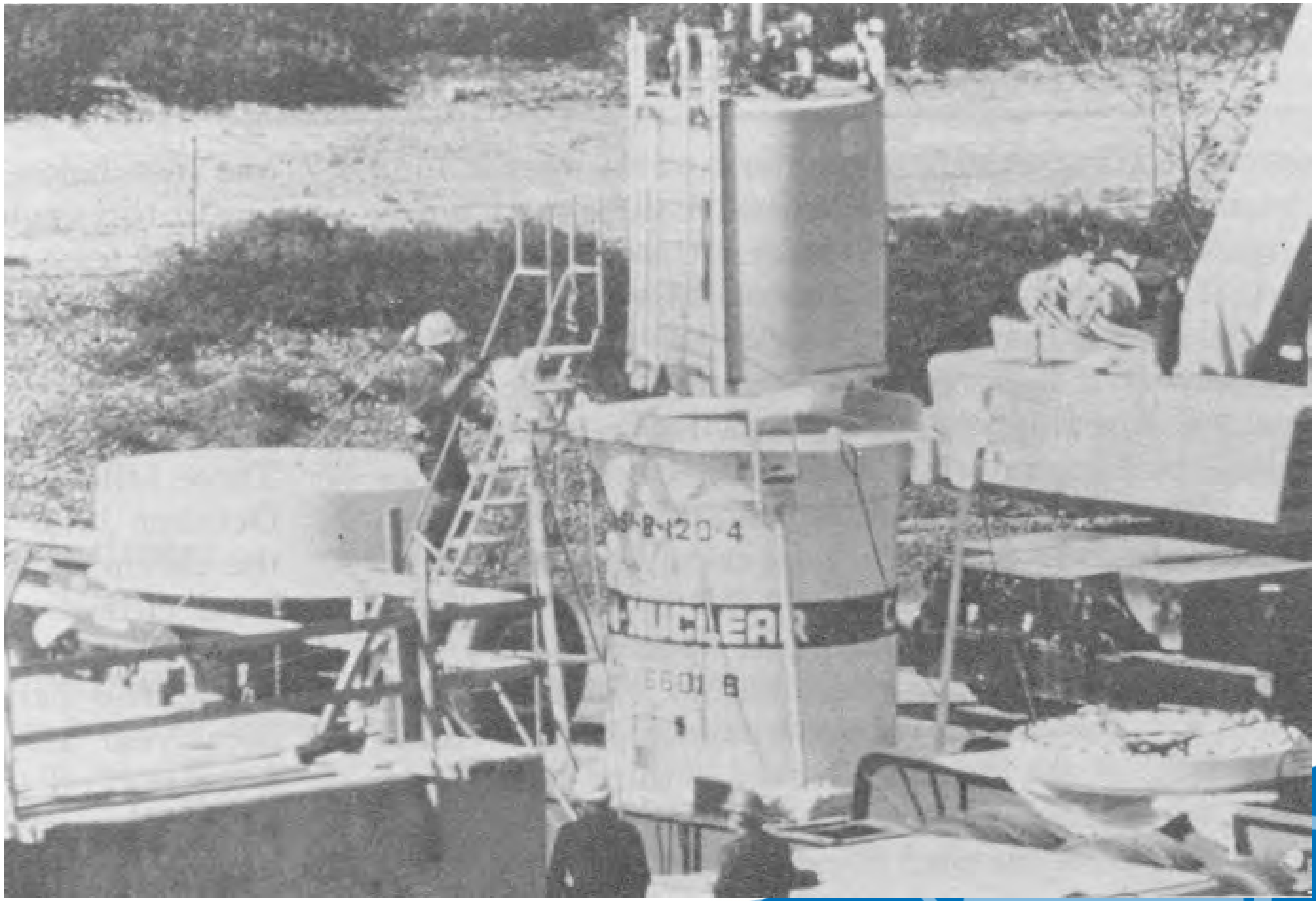
EPICOR-II Spent Liner Lowered into Shipping Cask

(Liner Inside Transfer Cask)



Hope Prevails

Slide 59 - Restart Plans

Throughout late 1979 until mid-1982 the entire organization, while recognizing that there had been significant damage to TMI-2's core, maintained the vision, that that the plant would one day be restarted. While that hope fizzled out during the first several minutes of the Quick Look exam in 1982, until that time GPU forged onward with plans for restart. Importantly, that hope provided persisting incentive to 'clean up' and move on. All the while the Reactor Building sump level continued to increase.

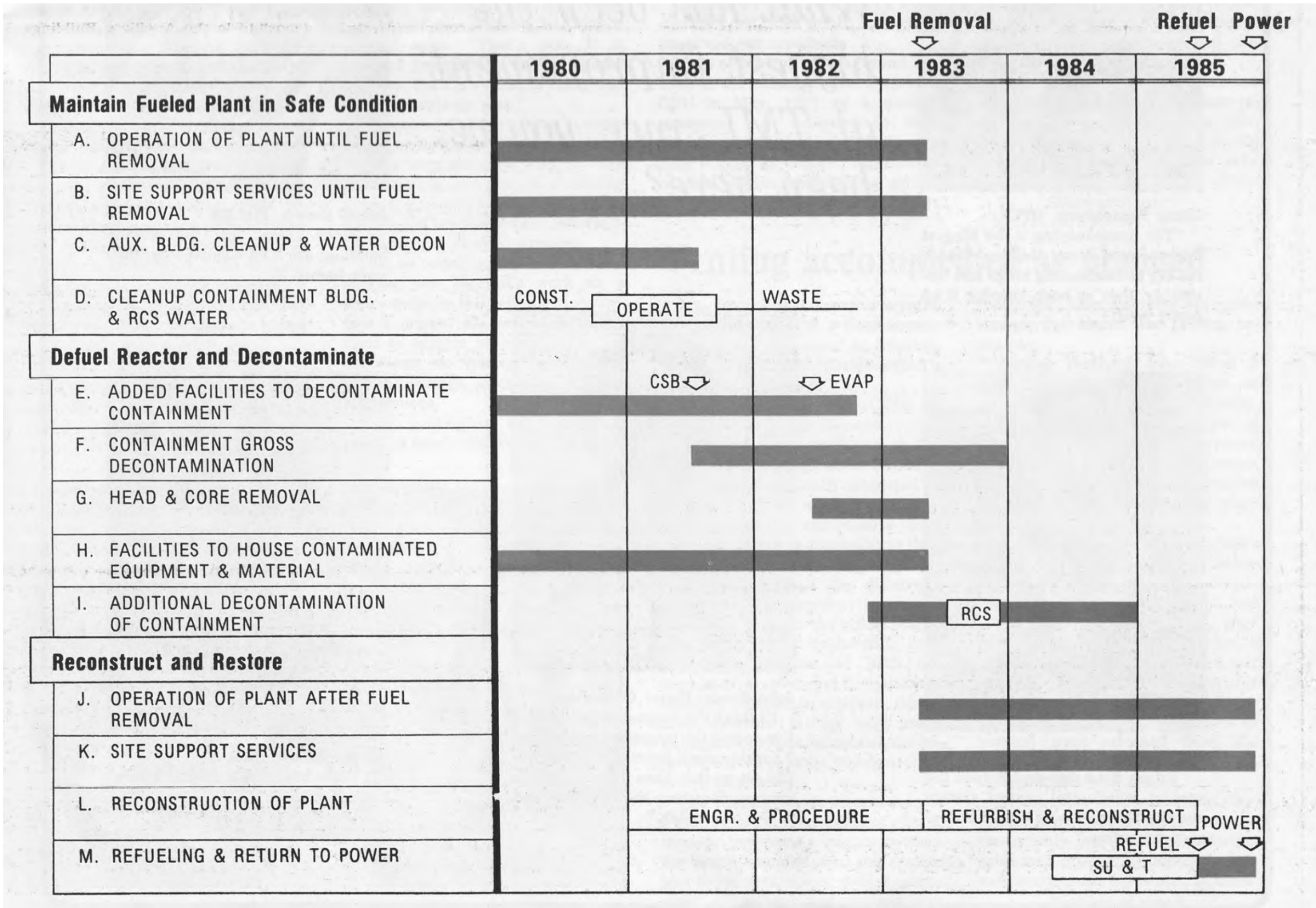
Slide 60 - Sump Level Versus Time

As described earlier, the Reactor Building Water Level caused significant corporate and public anxiety and compelled GPU to find a way to empty (pump the sump) and process the 8 ½ feet of highly contaminated water, 630,000 gallons contained within it.

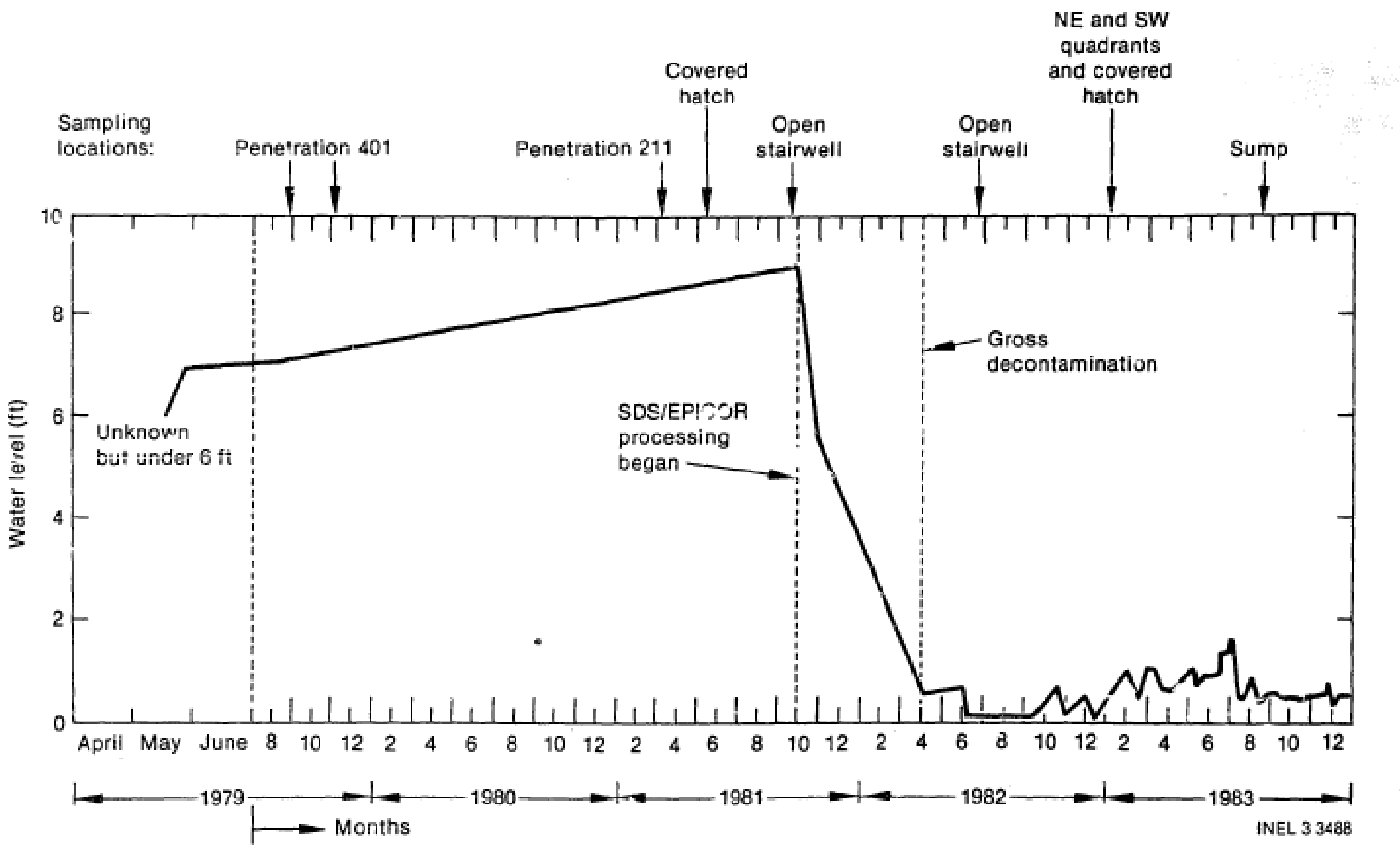
The Water

To refresh our memories, here is the origin of the Reactor Building sump water inventory. PORV to Reactor Coolant Drain Tank (RCDT); RCDT Blowout manhole bursts. ~220,000 gal Primary Water spilled to Reactor Building Basement Floor at 282'6" elevation, hydrogen burn creates pressure wave. Pressure wave triggers Reactor Building Spray at Reactor Building pressure of ~35 psig. Spray contributes an additional ~16,000 gallons to Reactor Building, spraying a mixture of Borated buffered with Sodium Hydroxide into the building and ultimately to the Reactor Building sump. RCS continues to leak and contributes another ~170,000 gallons of water. Boxcar Fan Cooling unit cooled by Reactor River System sustains ~1.5 inches by 1 inch thermal protection relief valve failure (open) – contributing an additional ~220,000 gallons of Susquehanna River water to the Reactor Building sump. The Reactor Building now contained about ~630,000 gallons of ~140 microcurie per cubic centimeter specific activity water predominately contaminated with cesium-134/137 and strontium-89/90. A 30 cubic centimeter sample of this water under our radioactive chemistry laboratory hood contained

GPU Cleanup Schedule (August 1980)



Reactor Building Water Level
(GEND-042)



approximately 150 microcurie per cubic centimeter of cesium/strontium; the radiation level from that 30 cubic centimeter sample was ~8 R/hr at a distance of 1 meter. In brief, we couldn't go near it. We had 630,000 gallons of this water.

An unrecognized feature at the time of the accident was that the Susquehanna River was at spring flood flow. The river's water contained all contaminants from upstream including both municipal sewage overflow and farm runoff. The biological content of the river water, now in the Reactor Building, would haunt us several years later.

Pumping the Sump

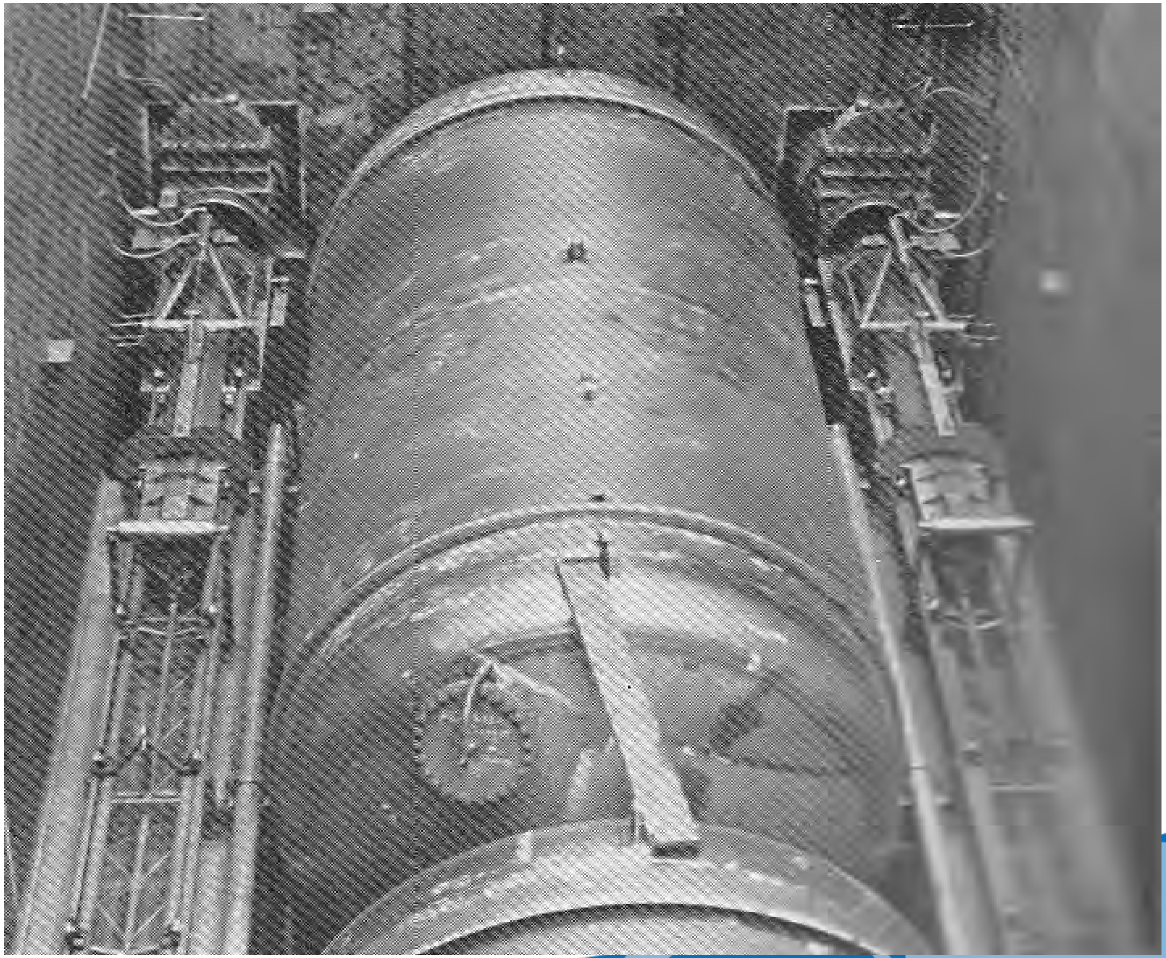
Slides 61 and 62 - Tank Farm, SDS layout

The original approach to pumping the TMI-2 Reactor Building sump utilized a tortuous route of welded 2-inch Schedule 40 piping throughout multiple compartments and stairwells of the TMI-2 Auxiliary Building and Fuel Handling Building. This system was fully completed, from the 282' 6" elevation of the basement to the 347 foot elevation of the Fuel Handling Pool deck and to the upper tank farm. The contamination level of the water necessitated copious lead <see lead shielding, above> each inch of the way, and the installed piping system consumed half of the width of multiple staircases of the Auxiliary and Fuel Handling Buildings. The final ~50 feet of that piping, at the Fuel Handling Pool deck, remains there today. The goal was to pump the sump water to tanks located in the now vacated (of racks) original TMI-2 spent fuel pools. With the racks removed, and installation of six new tanks, two axially aligned, four laterally aligned, the tanks would contain ~110,000 gallons of water, 1/6 of the reactor sump inventory.

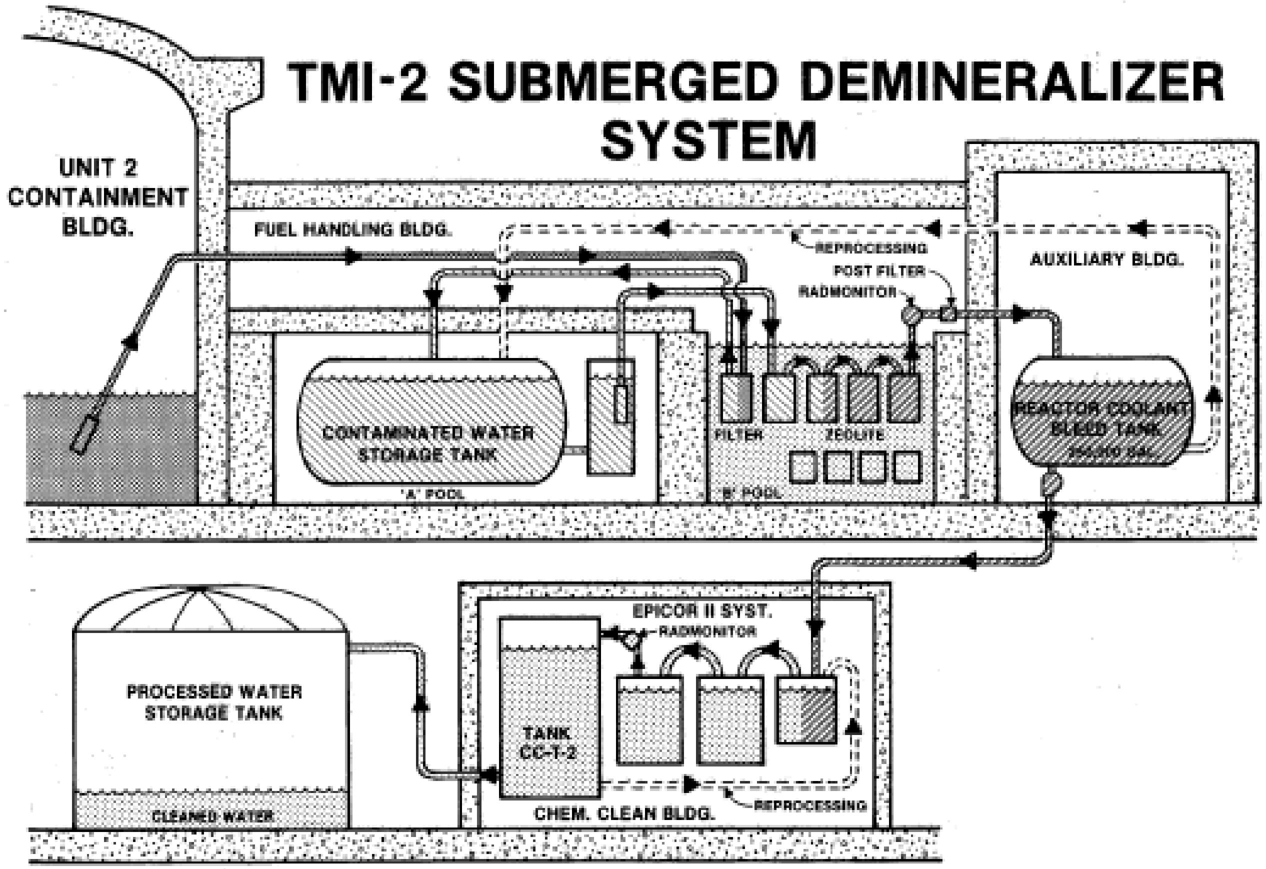
The small team that I was part of determined that pumping the Reactor Building sump through the 2 inch pipe, up and around the stairs and compartments, could create, in spite of the shielding, potentially prohibitive high radiation levels throughout the buildings and that a spill or leak would be unmanageable and would render the Auxiliary and Fuel Handling buildings as highly contaminated as the Reactor Building sump. My team and I conceived a plan to pump the sump from INSIDE the Reactor Building using cheap

Water Storage System "Tank Farm"

(Lower Level Tanks Between Fuel Transfer Mechanisms in Spent Fuel Pool "A")



Submerged Demineralizer System (SDS) Flow Path Schematic



equipment and simple procedures. We proposed using a long rubber hose, a dependable commercial well pump, a floating platform that intentionally hung at about a 75 foot (versus 90 foot – vertical) angle, and sufficient electrical cable to power the pump. We made the floating platform purposefully 'crooked' to ensure the pump wouldn't 'roll over' or 'flip on its back' and we wanted to ensure that it would continue to pump even when it connected with the Reactor Building floor.

We proposed to install this floating pump manually by 'swinging it' into the sump water in a particular open stairwell in the Reactor Building. We committed to practice until we were confident that we could swing the pump over the stairwell handrail about 10 feet below us within about a minute.

Most of the individuals in the oversight groups (see below) considered this plan as nonsense. There was major opposition for several reasons. Those reasons included that the Reactor Building sump water would be radiologically too hot for the proposed equipment (melt it due to radiation damage), or that it would be chemically adverse for the equipment (dissolve it) or that debris in the Reactor Building sump would jamb the pump (block it). In time the opposition escalated from technical reservation to personal ridicule. We maintained our position that pumping from inside the Reactor Building was worth the risk, and that the plan was viable.

We persevered and wrote a safety evaluation. We defended use of a submersible pump, a 300 foot long rubber hose, conversion of an existing spare containment electrical penetration on the more habitable 347 foot elevation of the Reactor Building (top floor) to a piping penetration though which the sump water would flow from inside the Reactor Building to the tank farm, immediately below the outside end of the penetration, located above the waiting tanks below in the Fuel Pools. We evaluated and defended (early 10 CFR Part 50.59) to the NRC, the change to the penetration – and gained approval to modify the penetration from an instrument penetration to a piping penetration. We built a simple float made of several laminations of 1 inch thick standard building insulation (Styrofoam), encased the float in fiberglass that we scavenged from a Corvette repair kit; we purchased a quality industrial grade Gould's submersible well pump; we drove to Baltimore and purchased a 300 foot length of one inch new red rubber hose; we acquired from the warehouse about 300 feet of electrical cable and connectors capable of immersion; we hooked them all together, and tested the completed apparatus in the TMI-2 cooling tower flume. We used a yard crane to hold the upper end of the hose at the proper elevation. The device functioned exactly as designed.

Working with Rad Con, we formed a four person 'sump pump placement team'. All four were volunteers. Our task was to place the sump pump into the open stairwell inside the TMI-2 Containment. The radiological survey identified that the streaming from the TMI-2 Sump at the intended 'drop' location was ~60 R/hr, about 1 R/minute. We targeted our dwell time over the open stairwell at 60 seconds or less. We rehearsed daily for several hours beginning a month prior to pump insertion using a dummy sump pump/hose/electrical cord, lowering the pump into an identically configured open stairwell in the TMI-2 Turbine Building, knowing that for safety and success we would have one chance to insert the pump. In the first weeks of practice it took us and hour, then ~30 minutes, then ~15 minutes, then ~5-10 minutes to insert the pump/apparatus. After days and hours of practice, where we used head-nods and cadence-timing to cause the pump/apparatus to 'swing' like a pendulum, we were successful in placing the dummy pump/apparatus over the stairwell handrails into what would be the Turbine Building sump in about 50 seconds. Our challenge was to duplicate the same successful outcome inside the TMI-2 building wearing hoods, safety glasses, breathing protection, multiple protective clothing (or "PCs"), Fireman's Turnout gear and heavy boots.

1981 - Containment Entry Nos. 7, 9, 11, and 13 - Pumping the Reactor Building Sump

Each of the four of us signed dose extension forms for "beyond ~4 rem". Each of us were physically fit – and needed to be - we were adding to our normal weight about 75 additional pounds of weight consisting of the protective equipment just mentioned plus the additional shared weight of the pump/apparatus.

On entry day we entered the Reactor Building with escort from Rad Con, found our way to the target stairwell, and proceeded as we had rehearsed, placing the pump/apparatus into the TMI-2 Sump. We couldn't see into the water in the sump because there was no lighting – but we repeated what we had rehearsed, counting and nodding, swinging the pump/apparatus; and when we released the apparatus it disappeared over the handrails below us and we heard a splash. Our 'dwell time' over the stairwell was about 60 seconds. On exit we surrendered our dosimeters; each member of the team had absorbed approximately 1000 millirem (or 1 rem).

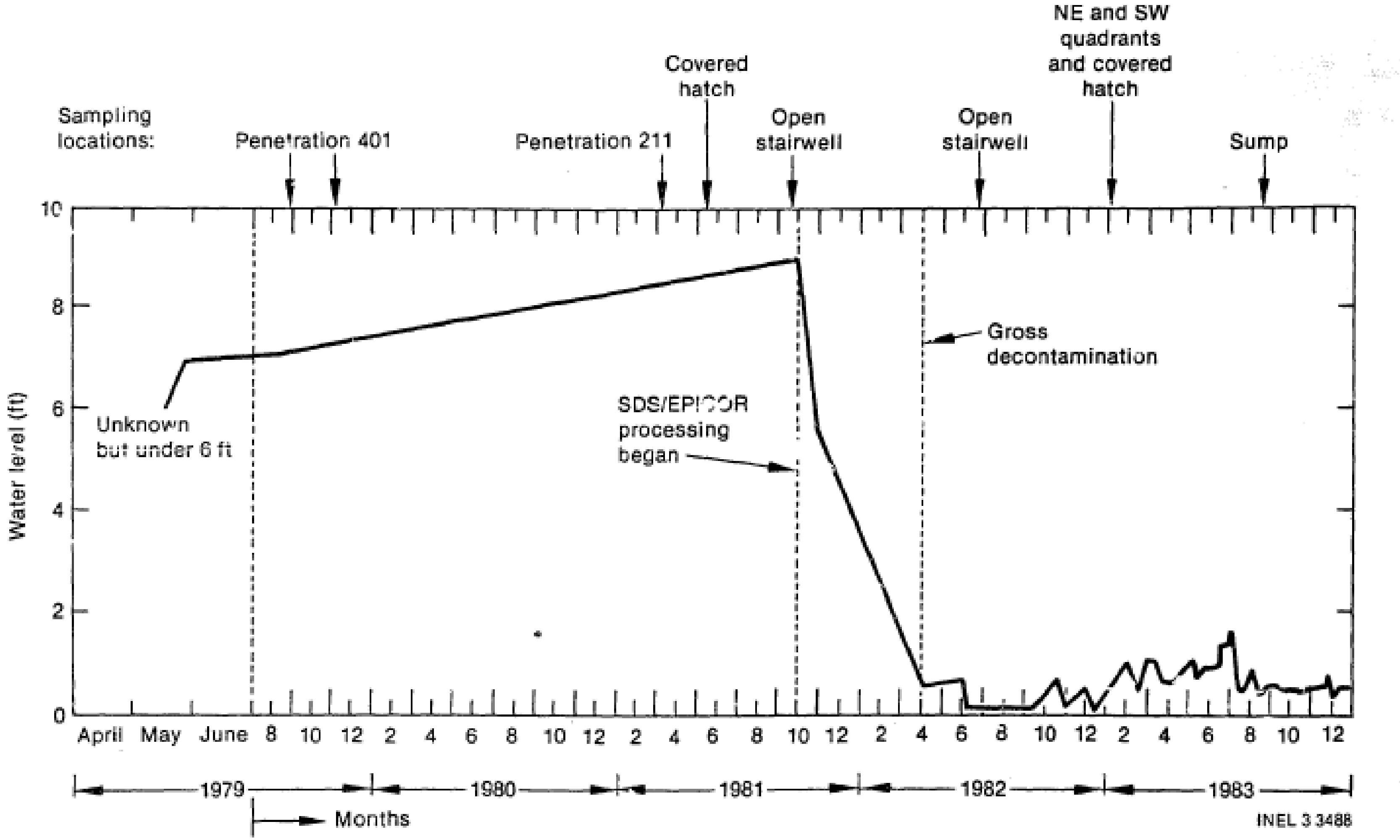
Shortly thereafter a colleague and I made an additional containment entry to connect the rubber hose to the piping at the upper penetration 347 foot elevation, and connected the electrical plugs that powered/controlled the pump. At that point Operations took control of the installed equipment. Weeks later, when the organization was ready, particular Rad Con, for the high activity fluid to enter the Fuel Handling Building, Operations started the pump.

!! Slide 60 - Sump Level Changes

The pump and rubber hose successfully pumped all ~600,000 gallons. The equipment remains in the TMI-2 sump today.

Water remained in the In-Core detector trench that lies below the Reactor Vessel and runs under the primary shield. In that trench were an additional 30,000 gallons of water. On two subsequent entries a team mate and I installed a second sump pump, one that you can buy at Home Depot, modified for the hose connections of the first sump pump. That entry produced less personnel exposure because the Sump water level was now ~8 feet lower than it had been during the first campaign. We had to crawl out on structural beams in the 'eclipse area for the Reactor Building to install the pump. We installed the second sump pump and received about ~40 millirem of exposure. The second pump successfully pumped the remaining ~30,000 gallons of water. The second pump remains in the trench area today.

Reactor Building Water Level
(GEND-042)



June 1981 - SDS Campaign - ‘Cleaning the Sump Water’

Slides 63, 64, and 65 - SDS Construction, Layout and Design

The Submerged Demineralizer System demineralizers were the final location of the radioisotopes in the TMI-2 Reactor Building Sump Water. The general process is simple – develop and deploy an underwater demineralizer system to capture and retain the ~300,000 curies of cesium-137 remaining in the Reactor Building sump water, and enable its transportation to another location not at TMI. Planning assumed that each SDS liner would remove and retain ~10,000 curies of cesium-137 so GPU contracted with Buffalo Tank Company in Baltimore for 30 – 2 foot diameter and 4 foot long cylindrical containers, each fitted with an inlet and outlet flange, a drain and vent fitting (vented to a common header), and lifting lugs.

Slide 66 - Image SDS Liner

The specification called for code stamped ASME VIII Unfired Pressure Vessels. I am the certified Professional Engineer (PE) that affixed the PE stamp to the Tank Specification in accordance with ASME NA 3250. The process piping, valves and controls were located in an adjacent pool next to the spent fuel pool that had been used for the tank farm. Early studies for resin selection chose a resin mix that site actions demonstrated would not succeed. Chabazite Zeolite was proven to succeed and quantities sufficient to fill all 30 containers were procured.

Inadvertent Criticality in SDS Liners

Concern remained regarding criticality. In the approximately two years preceding SDS construction there were two major schools of thought regarding the status of fuel fines in the water in the Rector Building. One school of thought argued that fuel fines were distributed on the Reactor Building floor hence the Reactor Building water was the shield over the fuel fines. The other camp argued that there might be some fuel contained in the sump water in a gel or colloid, whereby moving (pumping) the containment water carried with it the risk of moving fissile material to a location where it could aggregate and cause criticality. SDS vessels were to be the target for aggregation so action was taken to ensure

Submerged Demineralizer System Located in TMI-2 Spent Fuel Pools

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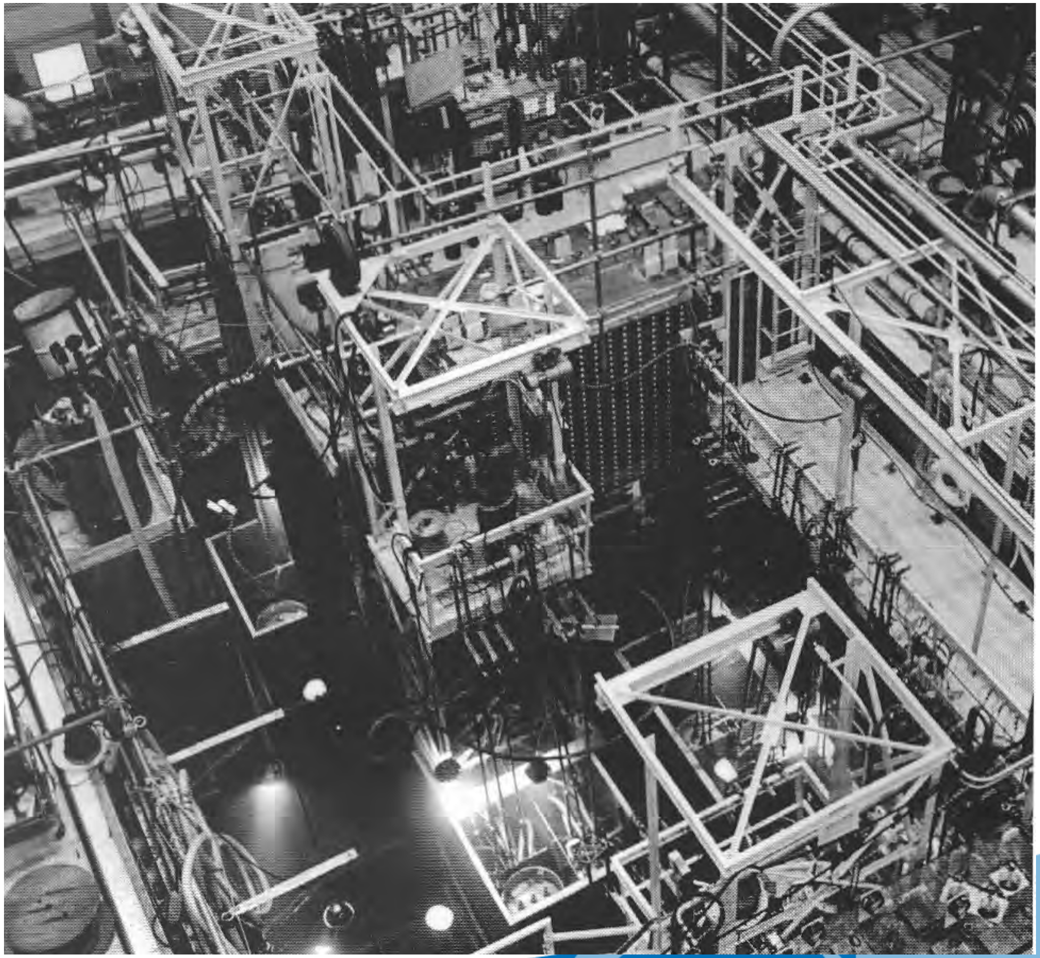
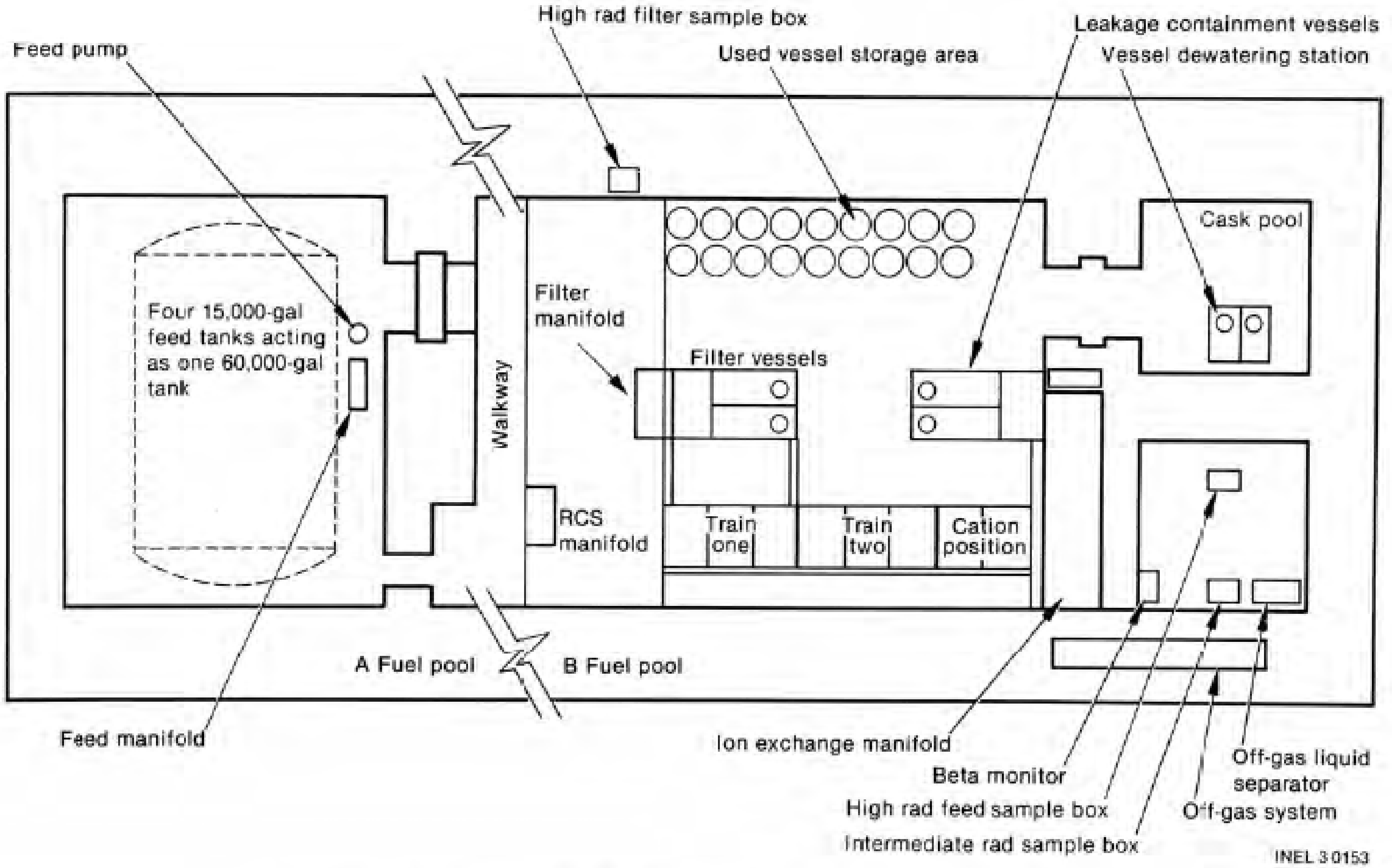
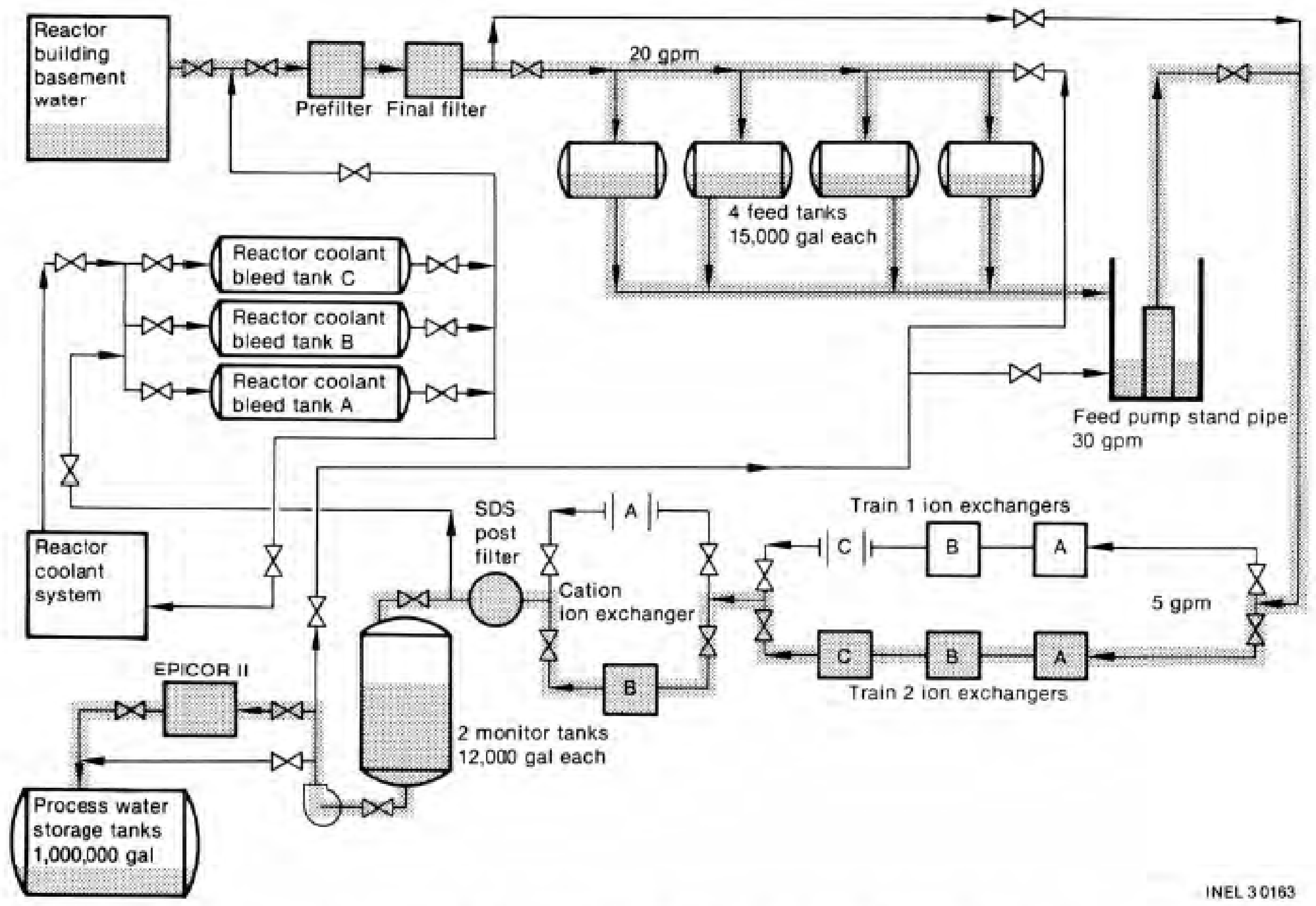
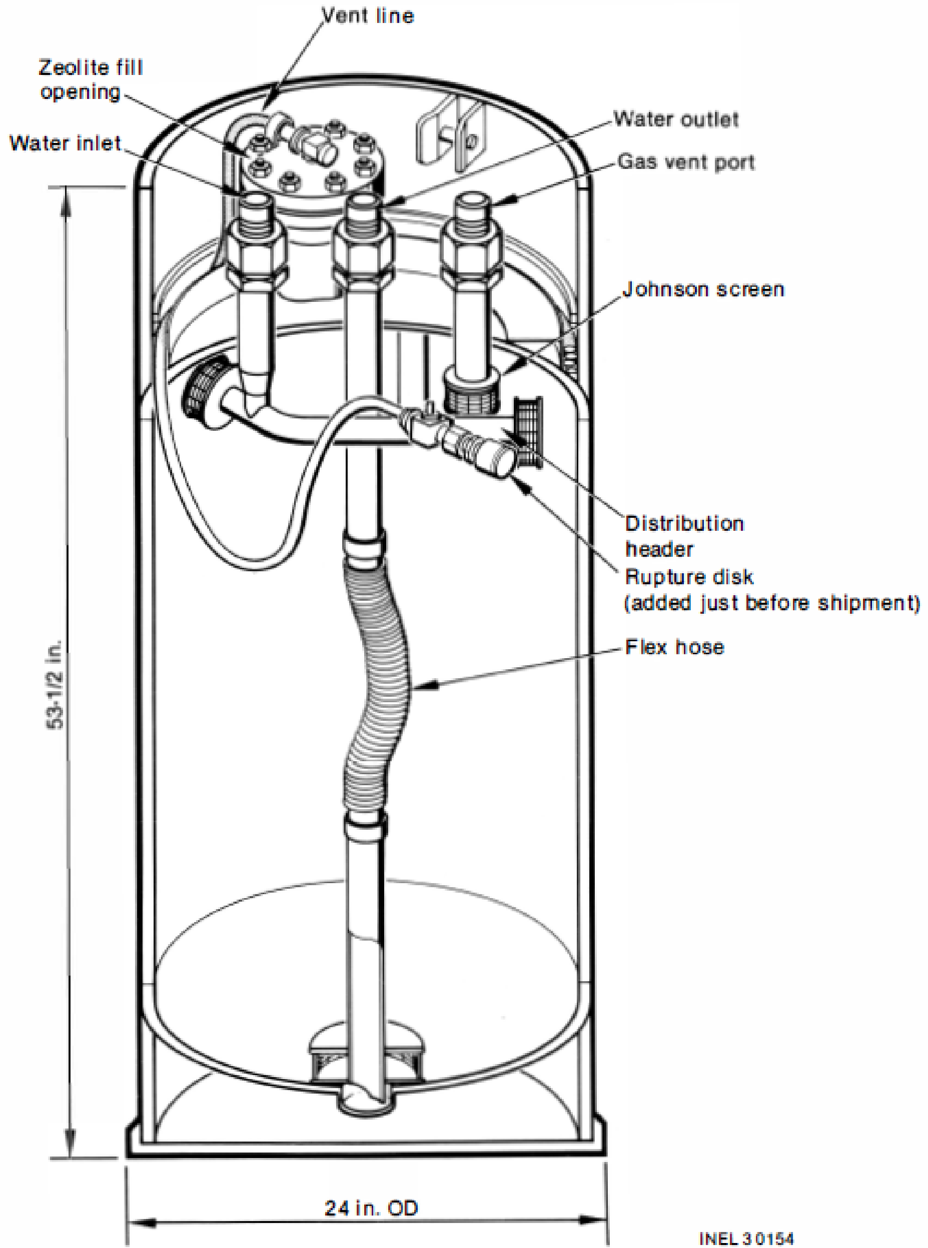


Submerged Demineralizer System Arrangement in Spent Fuel Pools
(GEND-031B)



Final Flow Path for Reactor Building Basement Water Processing Via SDS (GEND-031B)





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Typical Submerged Demineralizer System Liner

(Cross-Section View, GEND-031B)

criticality could not occur. Analyses showed that a fuel layer of particulate fuel would be spatially self-shielding and neurotically non-reactive for thin disks of fuel less than 4 centimeter thick, but that same fuel layer at the thicknesses of greater than 4 centimeter could possibly become critical or could support criticality. We addressed this by emplacing a 10 centimeter thick layer of Pyrex glass, with particles of the same size and shape as the Zeolite (~1 millimeter particle size) in the void between the top surface of the Zeolite and the SDS liner inside top cap. Pyrex glass contains Boron, and our calculations showed that the amount of naturally occurring Boron 10 in the Pyrex glass would ensure subcriticality. Glass is predominately silica that had neither chemical nor neurotic participation in either criticality or chemistry. Our safety evaluations demonstrated that a fuel- fines layer less than 10 centimeter precluded criticality assuming the highest enrichment ~3% fuels had aggregated to this location.

SDS Surprises

There were two major surprises that accompanied SDS early operation. The first was the degree to which the zeolite removed the isotopes; and the second is closely related regarding how much stoichimetric hydrogen and oxygen were being produced inside the SDS liner.

SDS Hydrogen Generation

Our intention was to load each liner to ~10,000 curies of cesium-137. We had not recognized that the zeolite is a willing recipient of all isotopes, and for each cesium-137 atom SDS removed a cesium-134 atom, and for each strontium-89 atom that SDS removed a strontium-90 atom. So also were the other soluble isotopes dissolved in the containment water. Unintentionally we loaded nearly ~30,000 curies of isotopes into the first SDS liner, and with those isotopes the local radiant field within the zeolite crystal disassociated the local water (H_2O) molecule thus producing copious, stoichimetric H_2 and O_2. The SDS design vented the SDS liners to an open header in the side of the Fuel Pool hence open to the Fuel Handling Building atmosphere. The organization was driven into an around-the-clock campaign to design and install accommodation to safely vent and dissipate the hydrogen away from the open-atmosphere combined TMI-1 and

TMI-2 Fuel Handling Building. We accomplished this by building a dilution fan/duct system to dilute and therefore lower the concentration of the H2 to less than 4% where conflagration/explosion was not likely. We also installed platinum/palladium recombiners in all new SDS liners to drive the chemical reaction to recombine the hydrogen and oxygen.

Pyrophoricity either in SDS Actions or Defueling

Several individuals on one of the Oversight Committees communicated concern regarding the potential for a hydrogen explosion based on the known pyrophoricity of zirconium fines. There had been explosions at the national laboratories determined to be zirconium / hydrogen ignitions. The concern was that we had a copious quantity of zirconium in an unknown status, whether fines or not, and we had already experienced one hydrogen explosion and one hydrogen conflagration, and that there could be another event. The concern was primarily directed at the zirconium that remained in the reactor vessel with the fuel, and the concern was that the submerged zirconium fines could ignite. We were not successful at dispelling this concern in spite of arguments that the submerged zirconium, while surrounded by copious oxygen within the water, had no way to reach conditions that would support conflagration or detonation.

In a final attempt to bring the topic to closure, we procured zirconium fines from a chemistry experiments supplier, brought the fines into the Oversight meeting while all were in attendance, carefully poured the fines on overlapping fire bricks, and attempted to light the zirconium fines using a 4th of July fireworks punk. The fines would not ignite. If we held the punk on the fines long enough we could get several small zirconium fines to 'ember', but not ignite as one might ignite magnesium fines. The arguments ceased.

Slide 67 - PWSTs Under Construction

The processed water was 'final demineralized' though EPICOR 2 and then pumped to the processed Water Storage Tanks that we built on the east side of TMI-2. Those tanks are there today and are now owned by Exelon for use in TMI-1.

Processed Water Storage Tanks
(Each 370,000 Gallons, Epoxy-Coated Carbon Steel)

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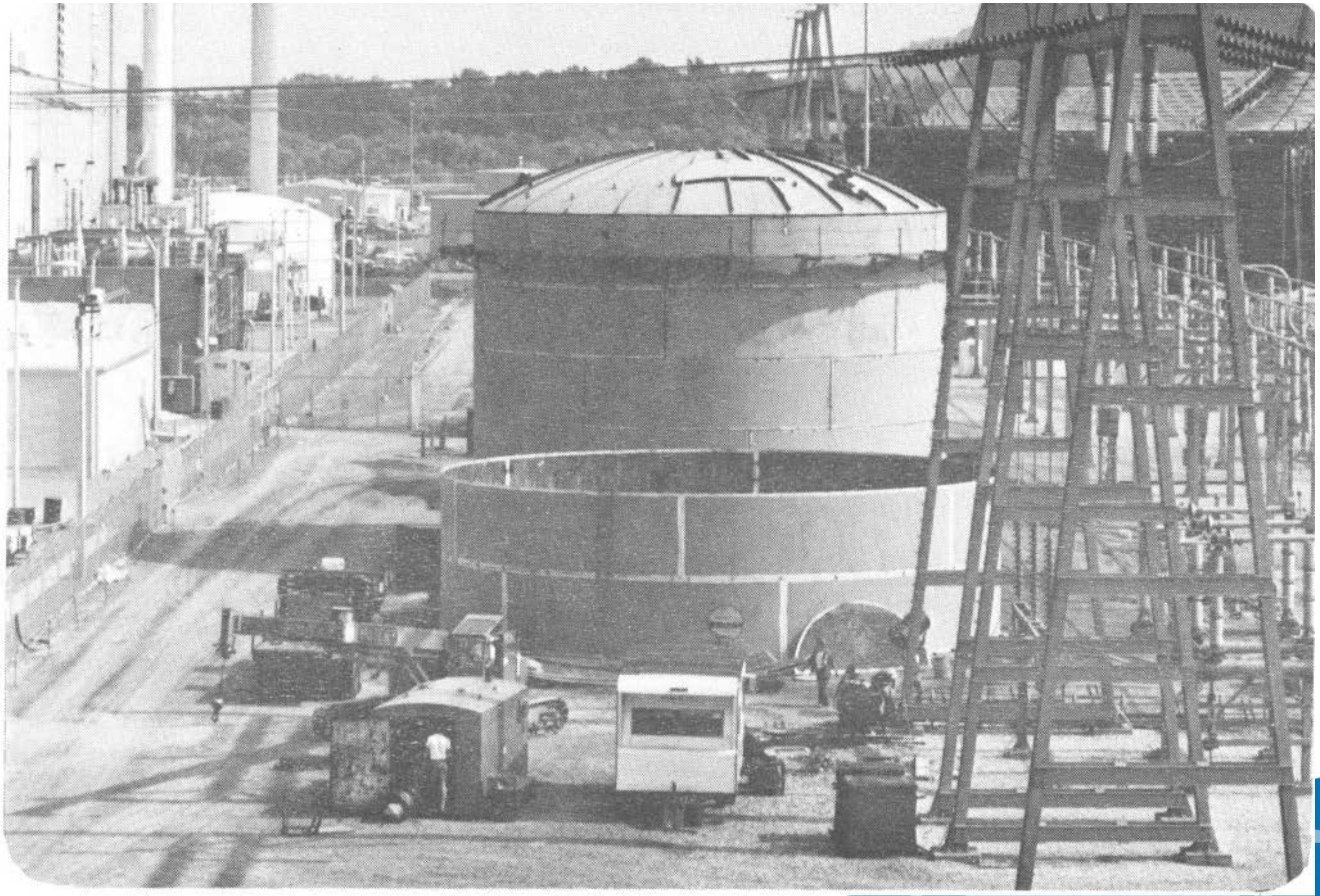

Slide 68 - Loading SDS Liner in Cask Underwater

Loaded SDS liners were placed in their custom-made shipping cask underwater. Surface / contact reading of a bare loaded liner was approximately 250,000 R/hr. Within the sealed shipping cask the cask contact reading was approximately 10 mR/hr.

Bankruptcy

Aside from the technical challenges the site teams were facing, the executives from GPU were dealing with financial issues as crippling as the accident itself. While the financial status of the company didn't present itself as part of our technical concerns, it was a persisting backdrop that caused caution regarding expenditures and planning for future work.

1982 – 1985 – Actions Leading to Defueling

Quick Look

Slides 69, 70, 71, and 72 - Quick Look - July 1982

Planning for defueling TMI-2 evolved for several years, finally solidifying as the result of the Quick-Look examinations in July 1982. The concept was simple. We needed an 'eyeball on the end of a long string, with enough lighting to observe what we were looking at.'

The TMI-2 Reactor Building radiation levels and contamination levels precluded access for any but the most critical tasks. It is worthy to note that it required over 3 years to find a method to 'look' into the TMI-2 core, and then only on a very limited basis. Three workers trained for and executed the Quick Look exam using a 1 ½ inch diameter camera lowered by its power cable, through the removed Control Drive Lead Screw at the H-8, center of Reactor Vessel head, center rod location. The Quick Look exam revealed a 5 ½ foot crater in the top of what would have been the original core, revealed 'pick-up sticks' of fuel and control rods on the top of a rubble bed that had once been the uniform 15 by 15 fuel pin core and upper end fitting, and among those 'pick-up sticks' was granular debris intermingled with broken fuel pins,

Loading Spent SDS Liner into Empty Shipping Cask

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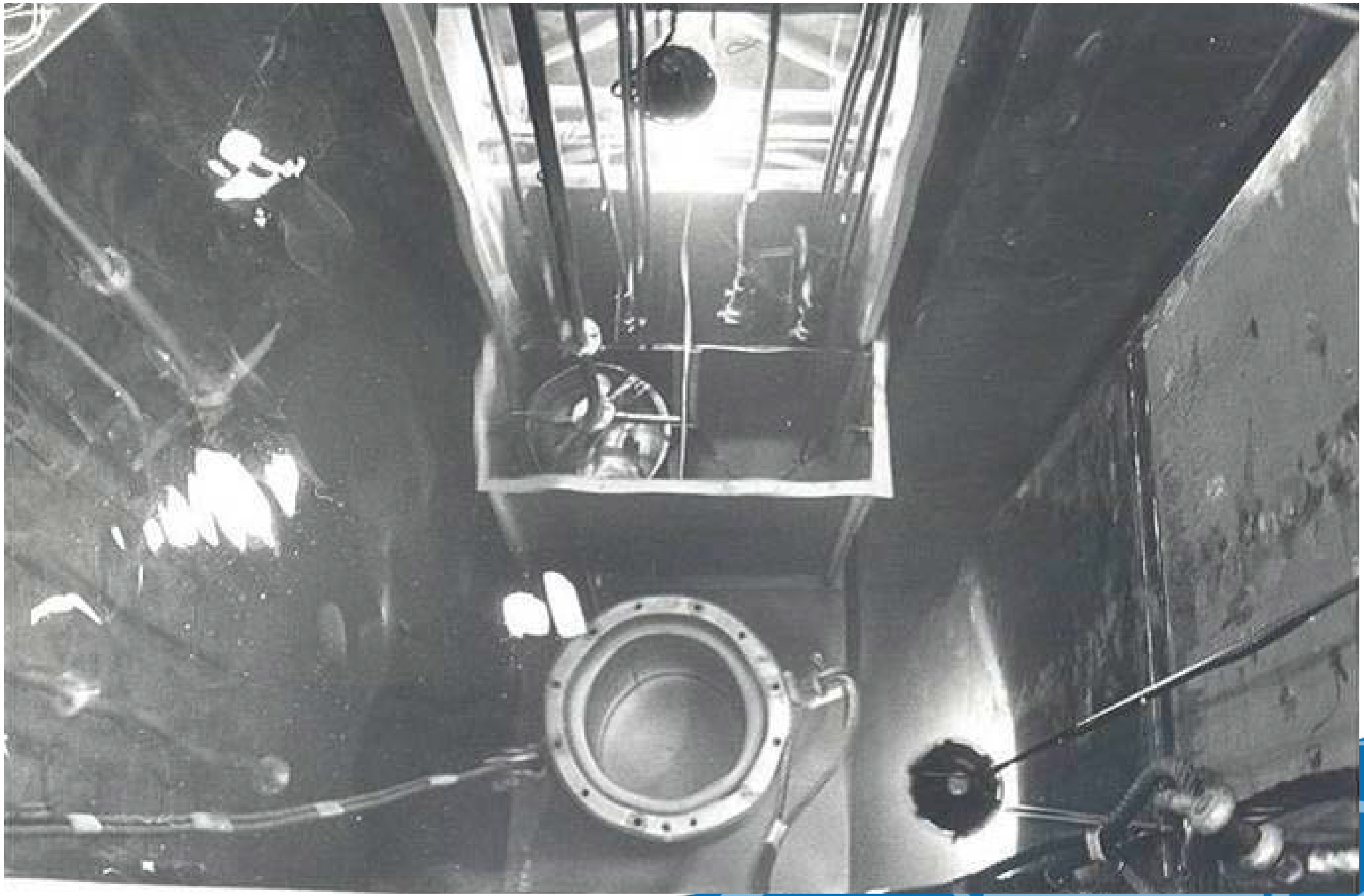
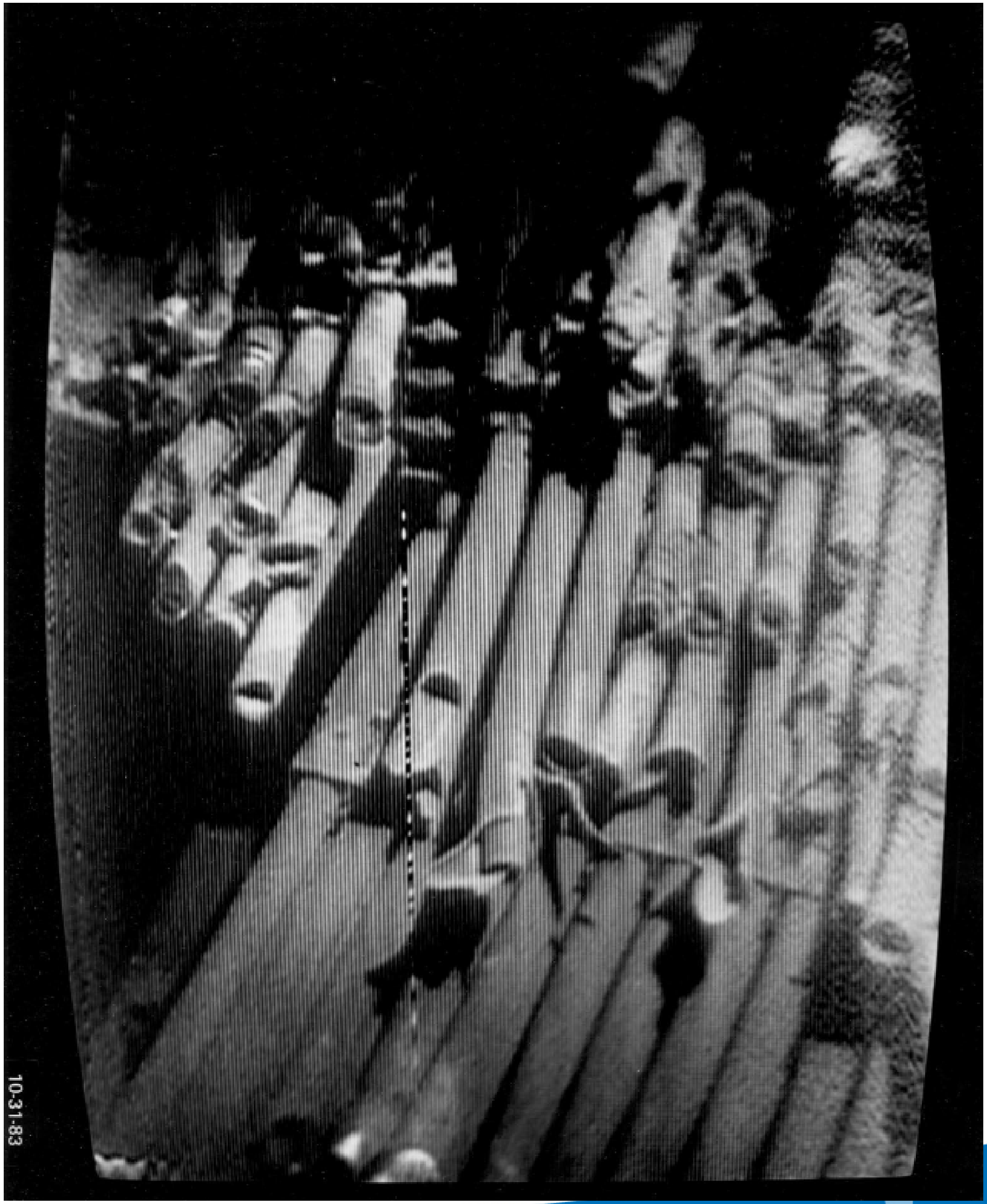


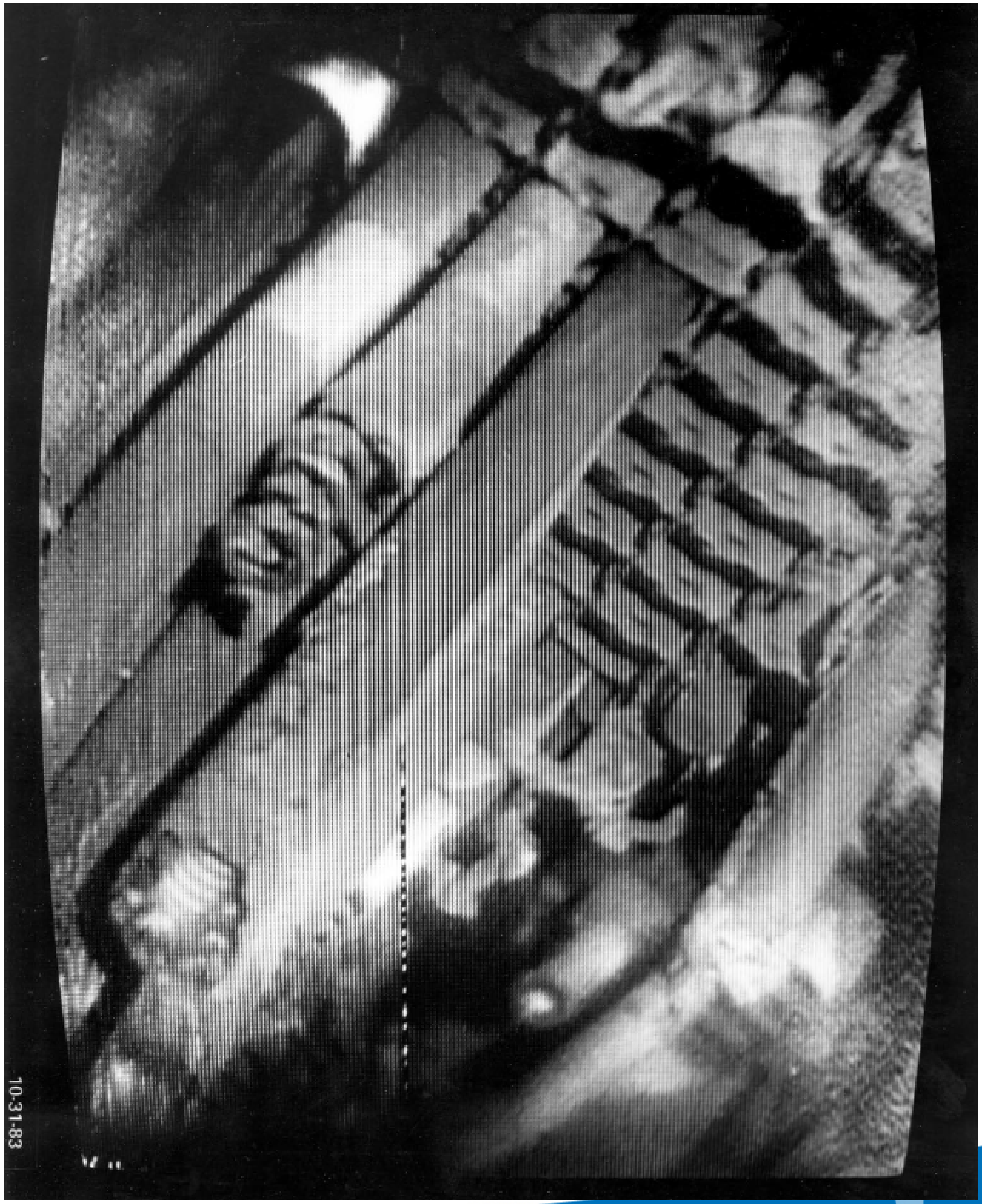
View Inside Reactor Core Cavity

(Portions of Fuel Rods Lying on Rubble Bed with One Rod Protruding from the Bed)



View Inside Reactor Core Cavity

(Stubs of Fuel Assemblies Hang from Underside of Plenum Assembly)



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View Inside Reactor Core Cavity

(Close-up of Damaged Fuel Assembly Showing Broken and Missing Fuel Rods, End Fitting Exposing Fuel Rod Plenum Spring)

View Inside Reactor Core Cavity

(Fuel Rod Plenum Springs on Rubble Bed)

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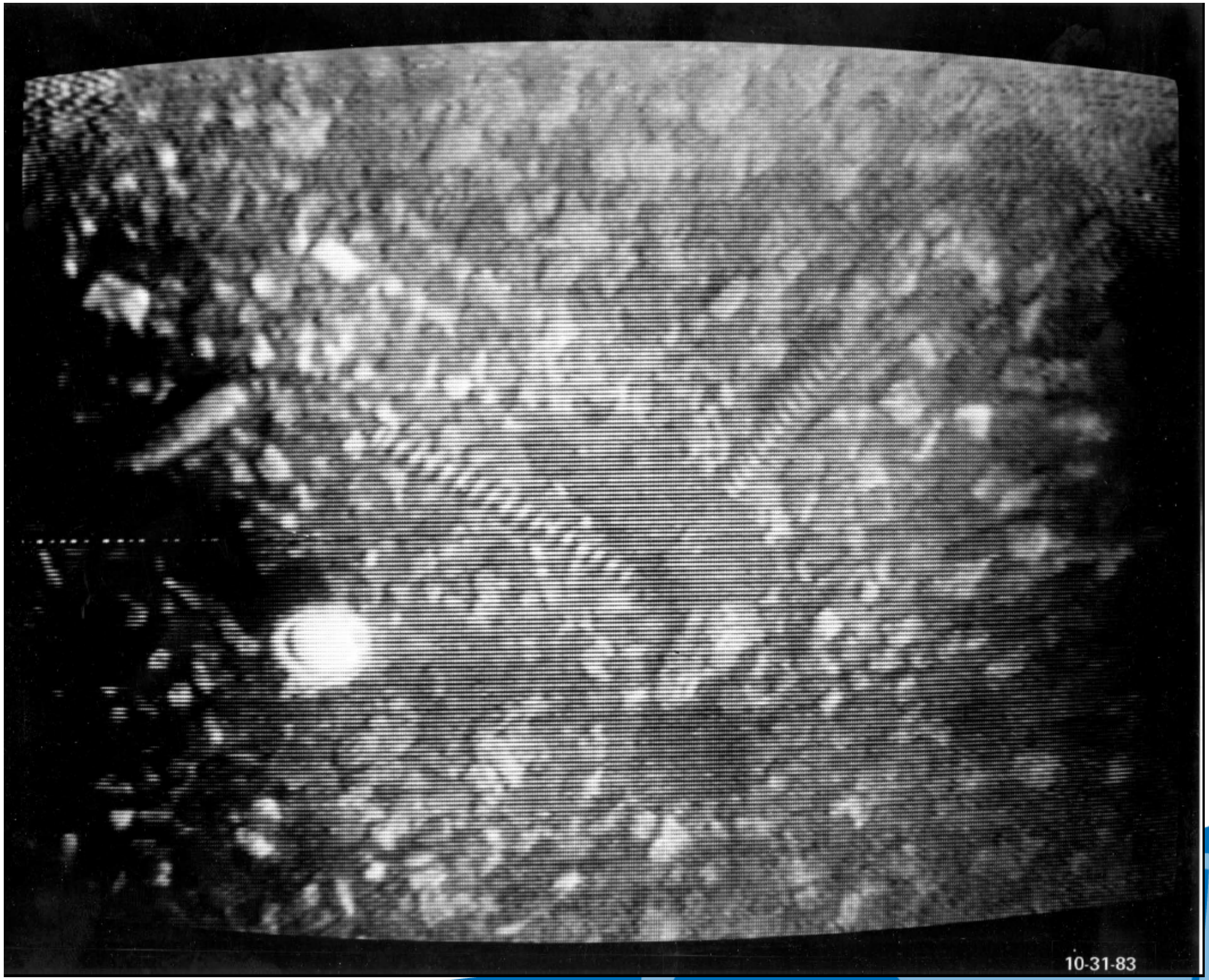


separated control rod remnants, end fitting remnants, and structural steel from the overlying 55 ton Plenum.

As the consequence of this finding, the early Defueling plans focused on 'Pick and Place', working top to bottom, whereby we would develop and train operators to use long handled tools to grasp, rotate, cut, lift and place fuel and other debris into containers that would later be sealed and shipped to a location off site.

Slide 73 - Tethered Worker on Polar Crane

Polar Crane

Getting to the fuel required removal of the Reactor Vessel Head and the Plenum. Removing these require qualification of the Reactor Building Polar Crane. Each of these challenges presented serious obstacles and in some cases legal challenges. All were addressed and resolved leading to the following events:

February 1984 - Polar Crane Tested and Accepted as Ready for Use

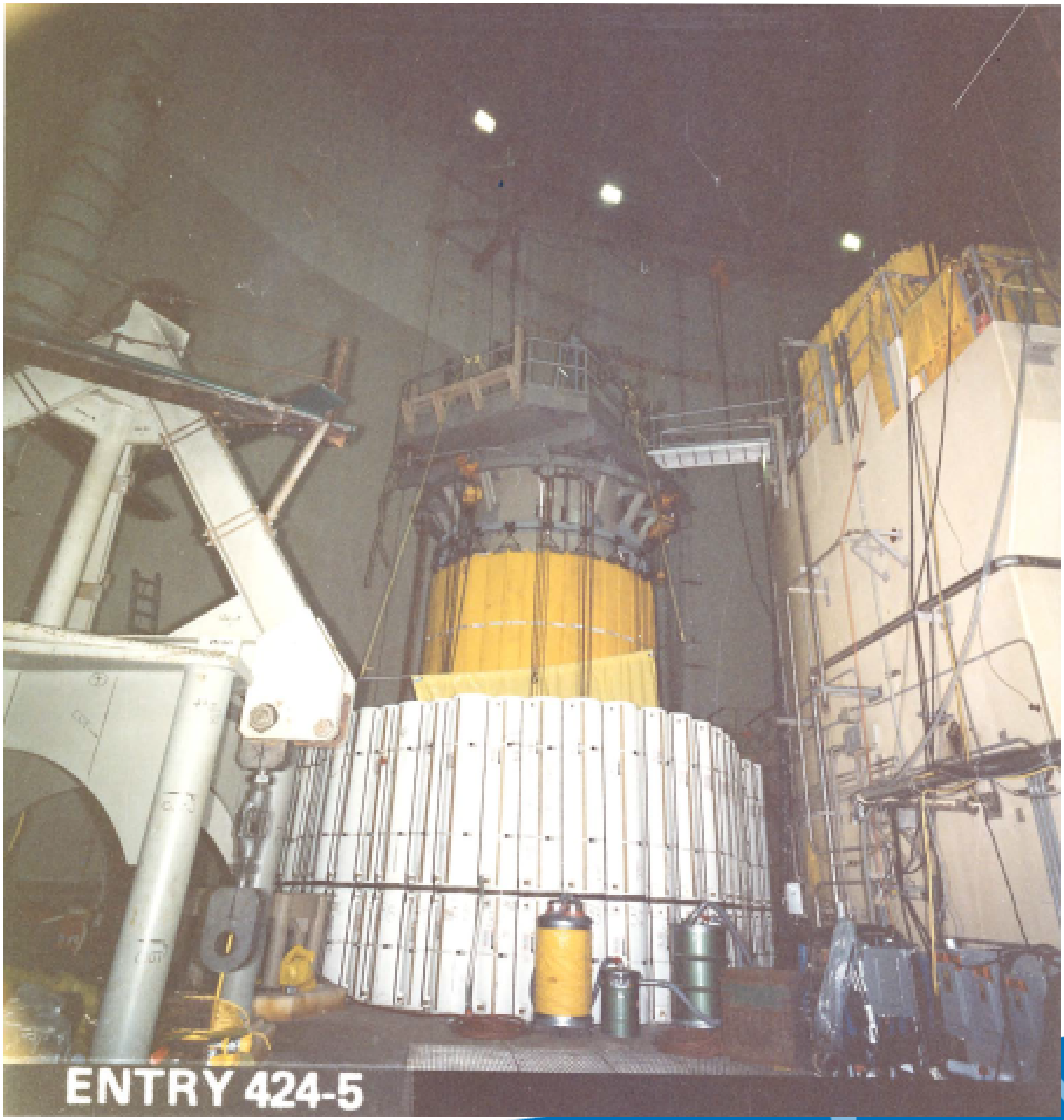
Inspection inside the Reactor Building confirmed that the 500 ton Polar Crane required repair. The 'Pendant' had been damaged by the hydrogen explosion. There were questions and concerns regarding the operability and dependability of the main pulley braking system. The TMI-2 organization took months to address each of these. Repairs were completed that ultimately lead to a successful load test of 200 tons. The successful load test paved the way for removal of the 156 ton Reactor Vessel Head.

Reactor Vessel Head Removal

Slide 74 - Reactor Vessel Head on Stand with Sand-Log Shielding

The next major task was to remove the Reactor vessel head. This task required removal of the head along with 69 control Rod Drive mechanisms, the service structure, and attached appurtenances, altogether weighing 156 tons. The lift would require removing the overlying shield blocks and lifting the head from about ~320 foot elevation, over the primary shield wall, and parking it on its

Inside Reactor Building, Polar Crane Inspection (1981)



Reactor Vessel Head and Service Structure

(Removed from Reactor Vessel, Placed on Stand with Sand-filled Curtain Shield) storage stand on 347 foot elevation. Once there the task was to shield it with column sand shielding. This required workers to climb onto the Reactor Vessel Head, utilize stud tensioners to detension the 60 studs, remove the studs and nuts, and attach the lifting pendants to the head. The head was removed in July 1984, over five years after the Accident.

Reactor Plenum Removal

Slide 75 - Plenum Removal Concept

The 55 ton Plenum sits immediately above the 177 Fuel Assemblies and is supported by the 'springs' at the top of the fuel assemblies. In the B&W design the Plenum actually sits several inches higher than its flange-face intersection, locked in its keyway in the Internals, supported vertically by the fuel assembly springs. Only when the Reactor Vessel head is lowered into place is the Plenum 'clamped' into its 'locked' position. When locked, the fuel assembly springs retain capability to hold the fuel firmly in place yet allow the fuel to grow as the plant is heated up and brought to power. The upper grid, that is the lower structure of the plenum, assures precise fuel assembly spacing alignment. I make this point because removing TMI-2's plenum was going to be complex because the fuel had collapsed hence the plenum had to be 'jacked' out of the internals so that the lifting pendant could be attached. This series of events took place in May 1985 when the Plenum was removed from the Reactor Vessel and placed in its storage stand in the deep end of the Refueling Canal inside the Reactor Building.

Slides 76, 77, 78, and 79 - Pristine Plenum, Upper Grid

Slides 80, 81, and 82 - Damaged Upper Grid

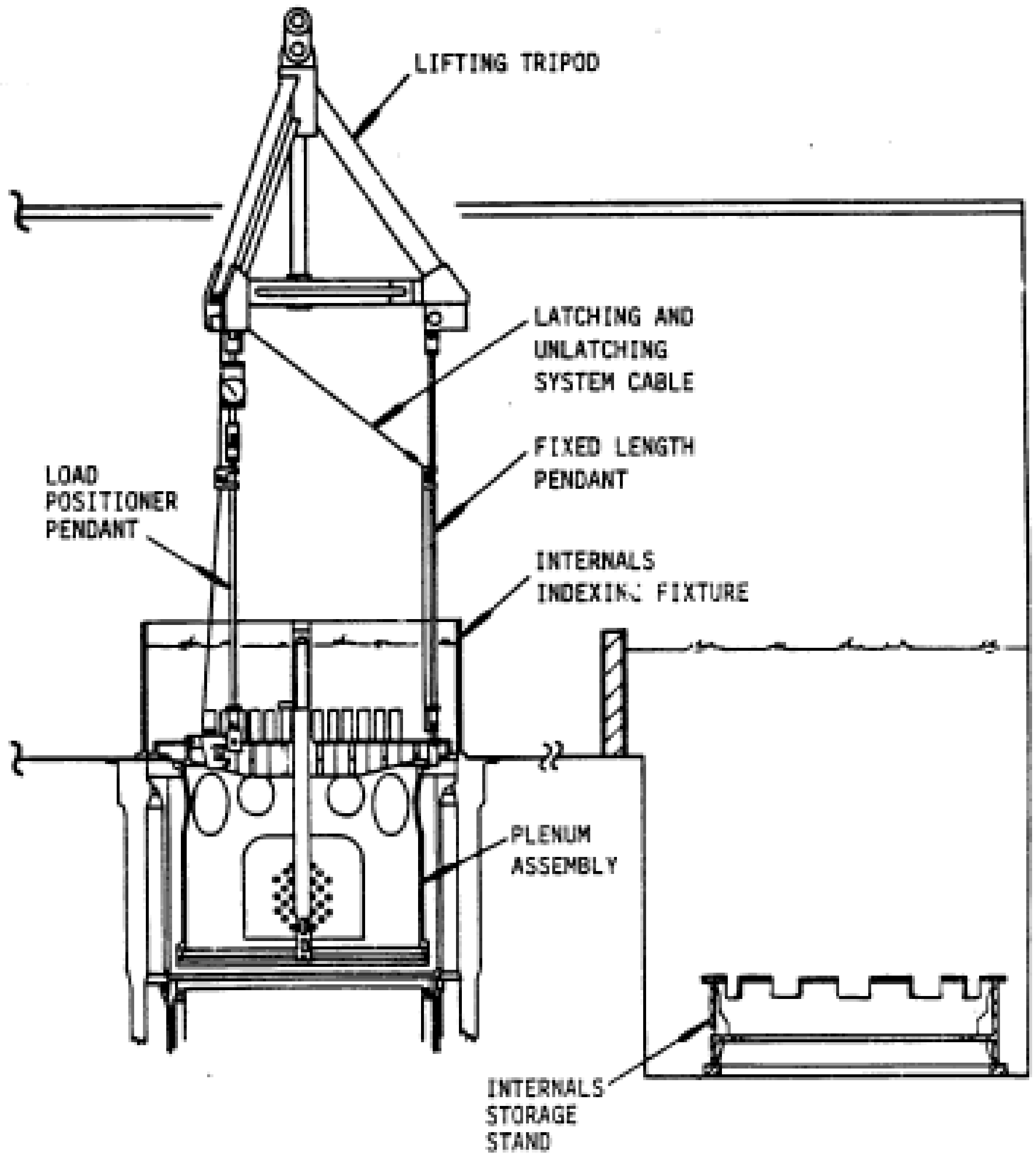
Preparations for Defueling

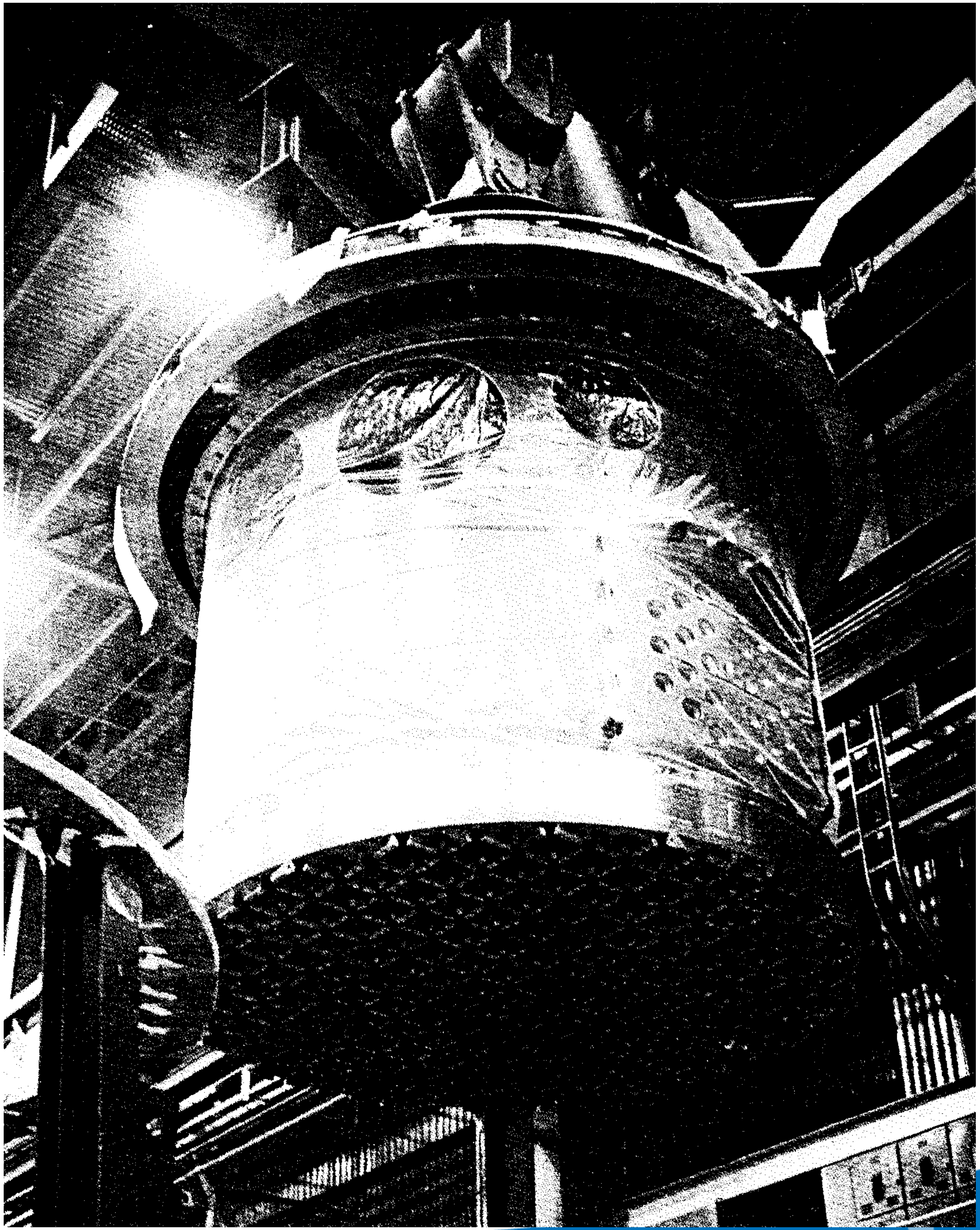
Slides 83, 84, 85, 86, 87, and 88 - Quick Look II and Lower Internals Images

Formal preparations for defueling began in 1984 as the organization digested the implications of the Quick Look information and additional camera exams. The exams lead us to

Plenum Assembly Lift Schematic

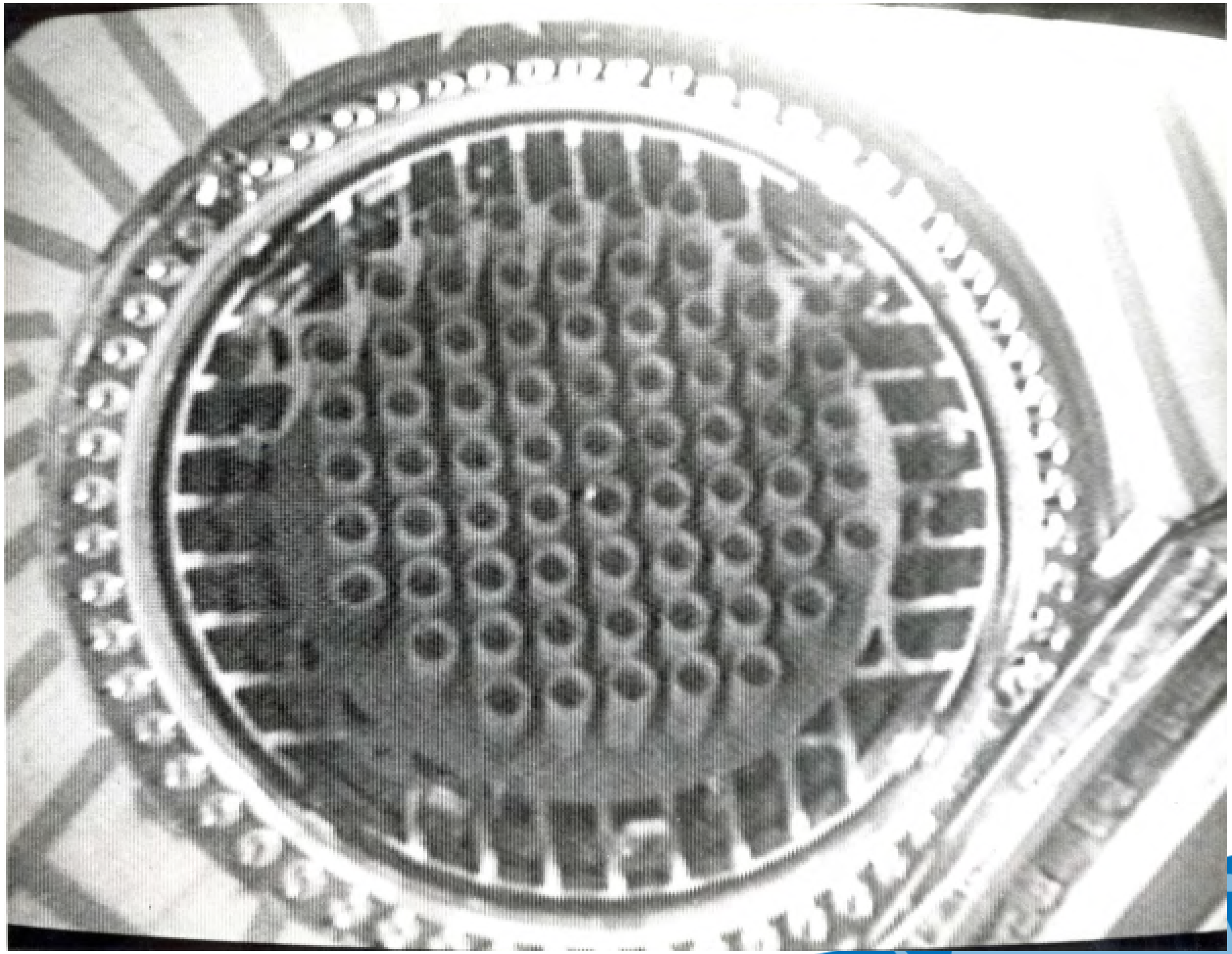
(GEND-054)





Typical Fabricated Plenum Assembly in Preparation for Shipment

Upper Plenum Assembly Inside TMI-2 Reactor Vessel



Upper Plenum Assembly Inside TMI-2 Reactor Vessel (Close-up)

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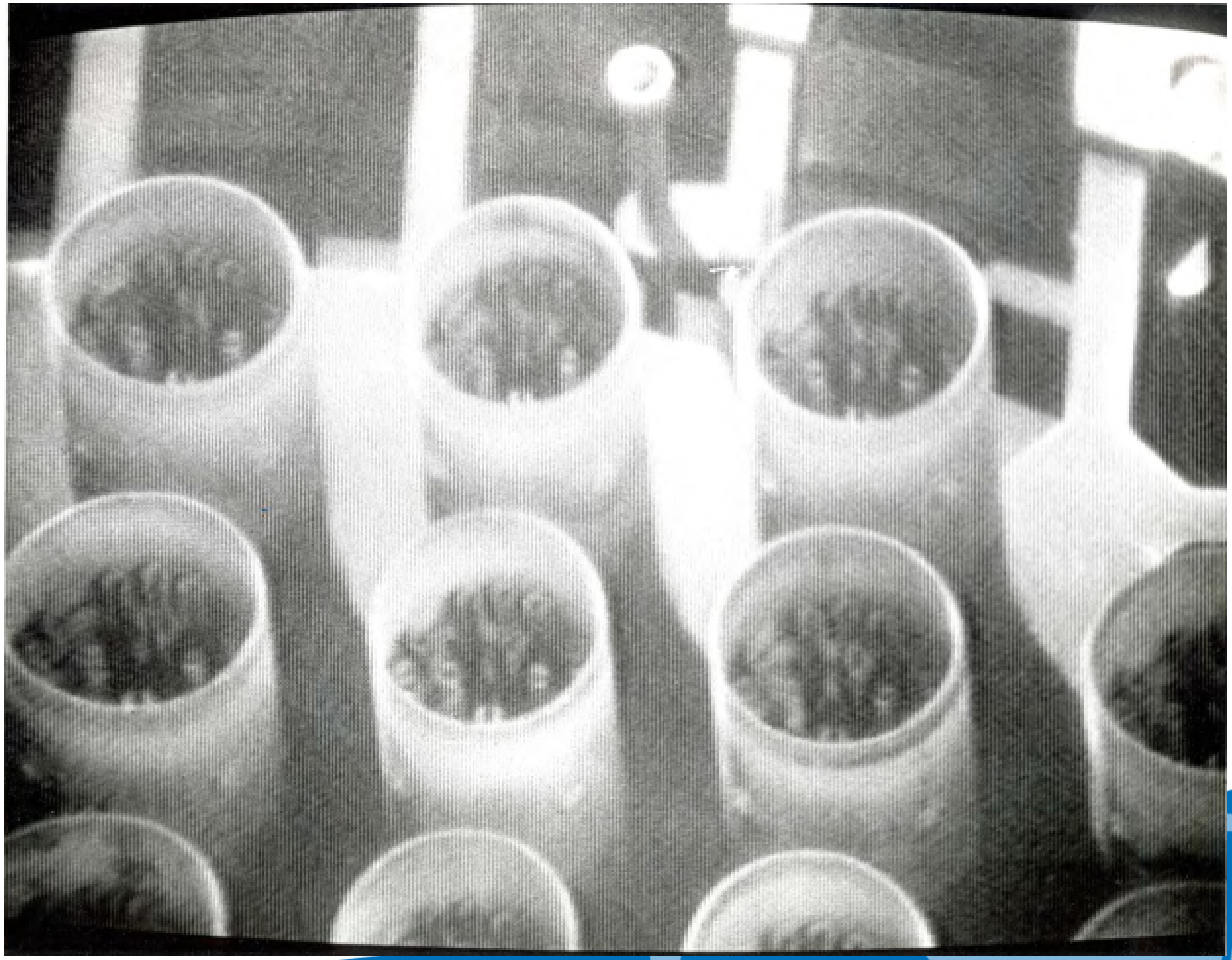
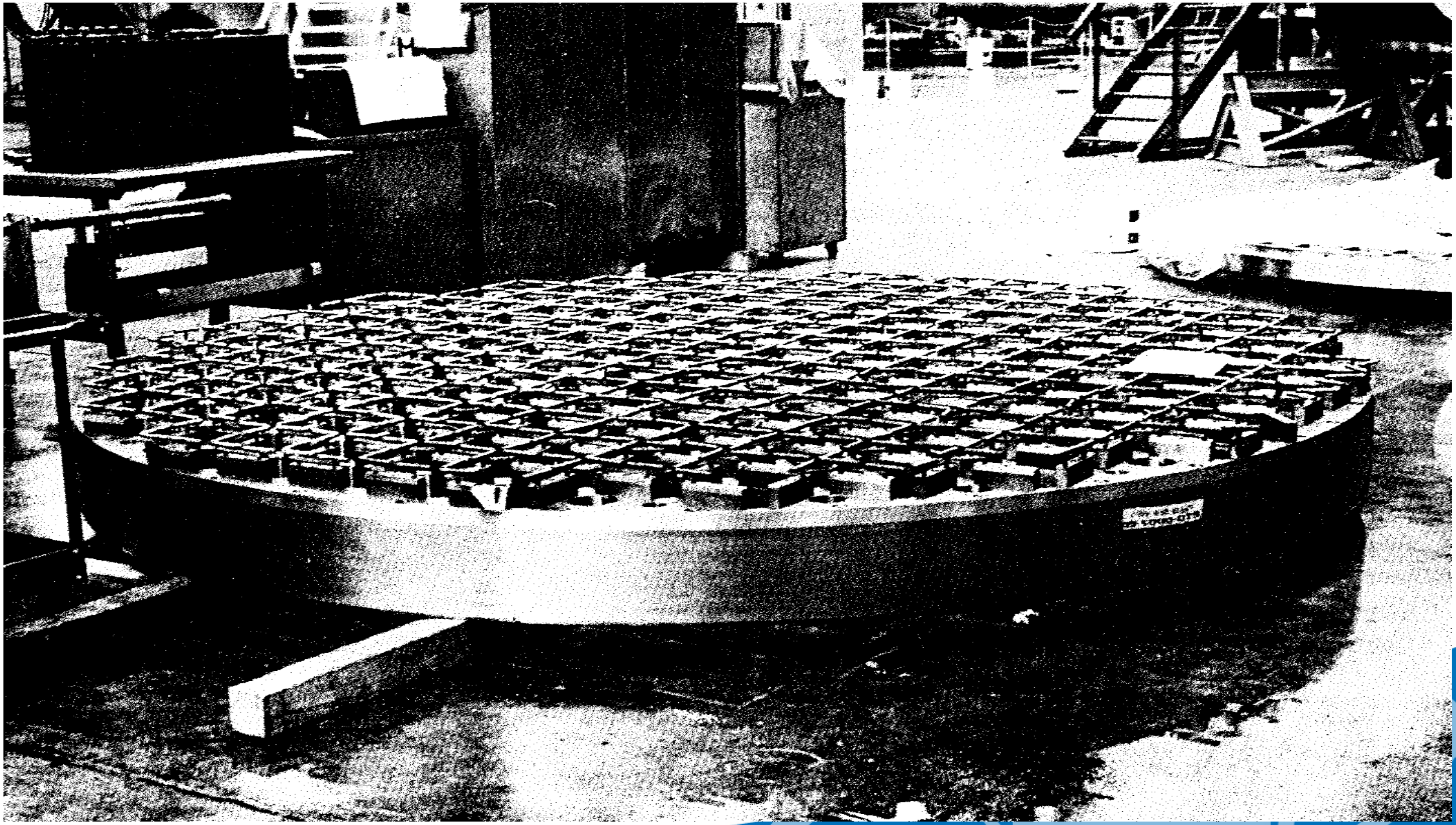
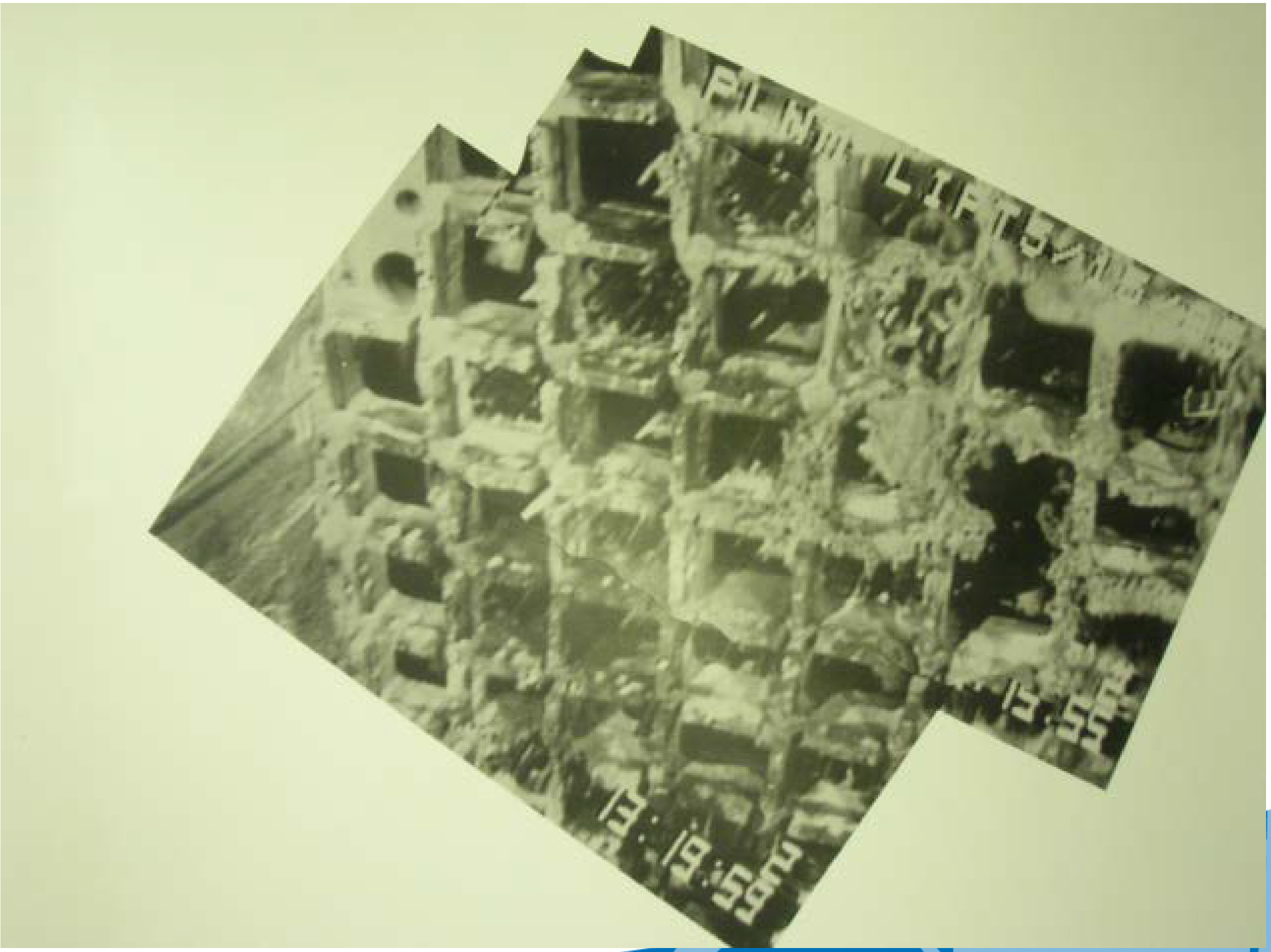


Bottom Side of Typical Upper Grid Rib Section Being Fabricated



Upper Grid Damage at TMI-2



Upper Grid Damage at TMI-2

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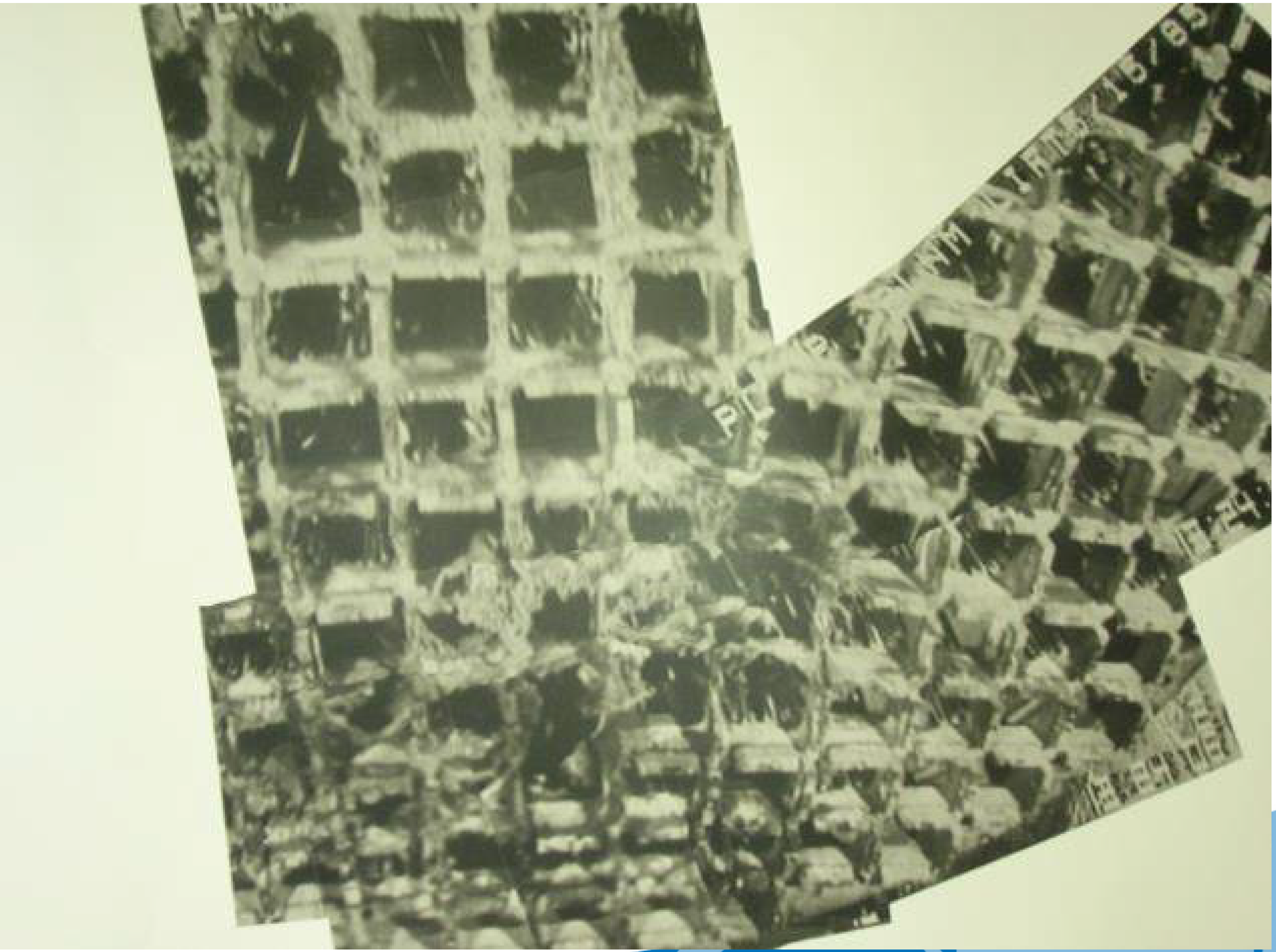
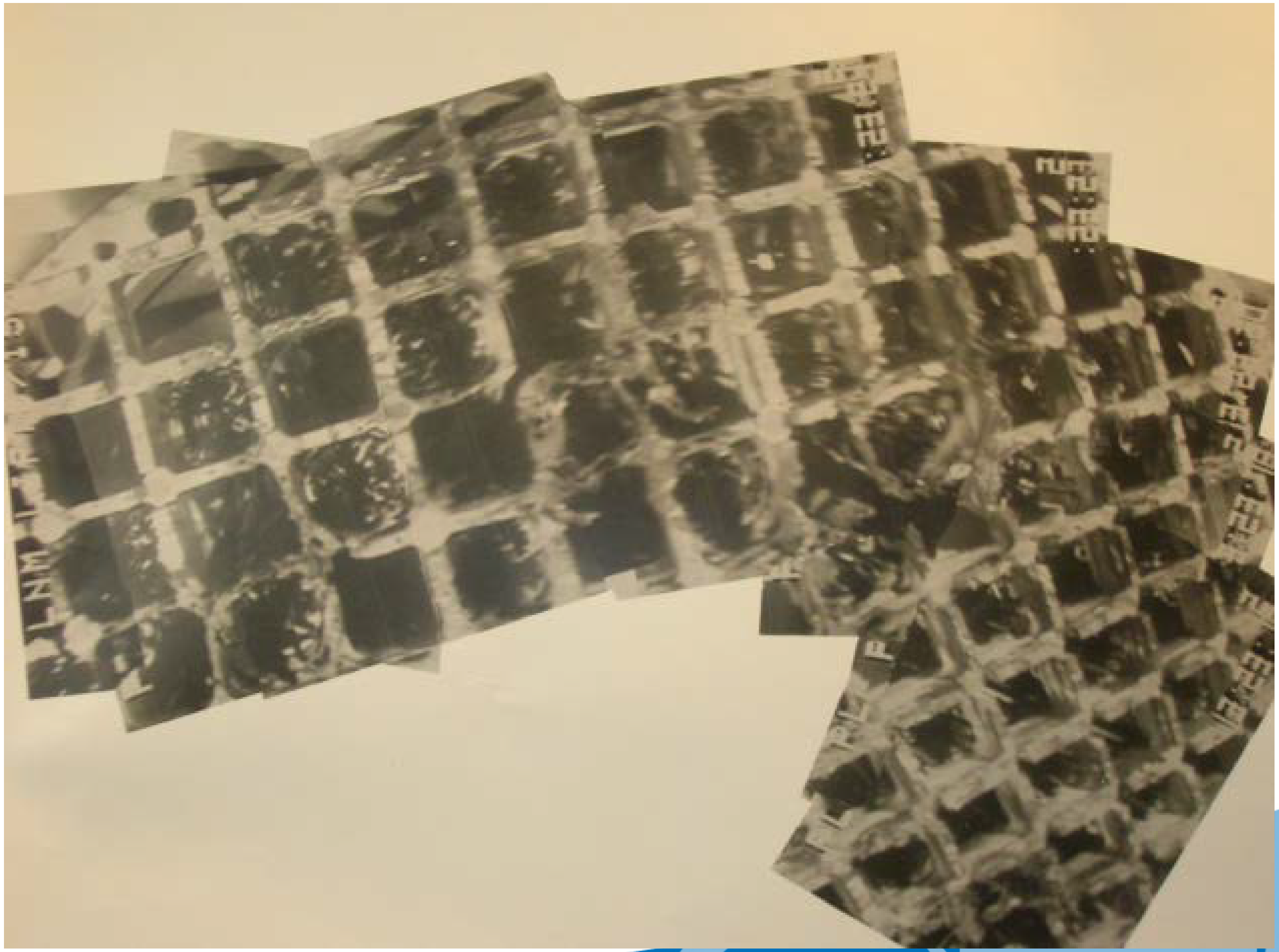


Upper Grid Damage at TMI-2



View of Lower Reactor Vessel Head (1985)

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Lower Reactor Vessel Head Look

(Camera Passes By Bolts that Connect the Lower Grid Assembly to the Core Barrel Assembly, 1985)

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View of Lower Reactor Vessel Head (1985)

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View of Lower Reactor Vessel Head (1985)

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View of Lower Reactor Vessel Head (1985)

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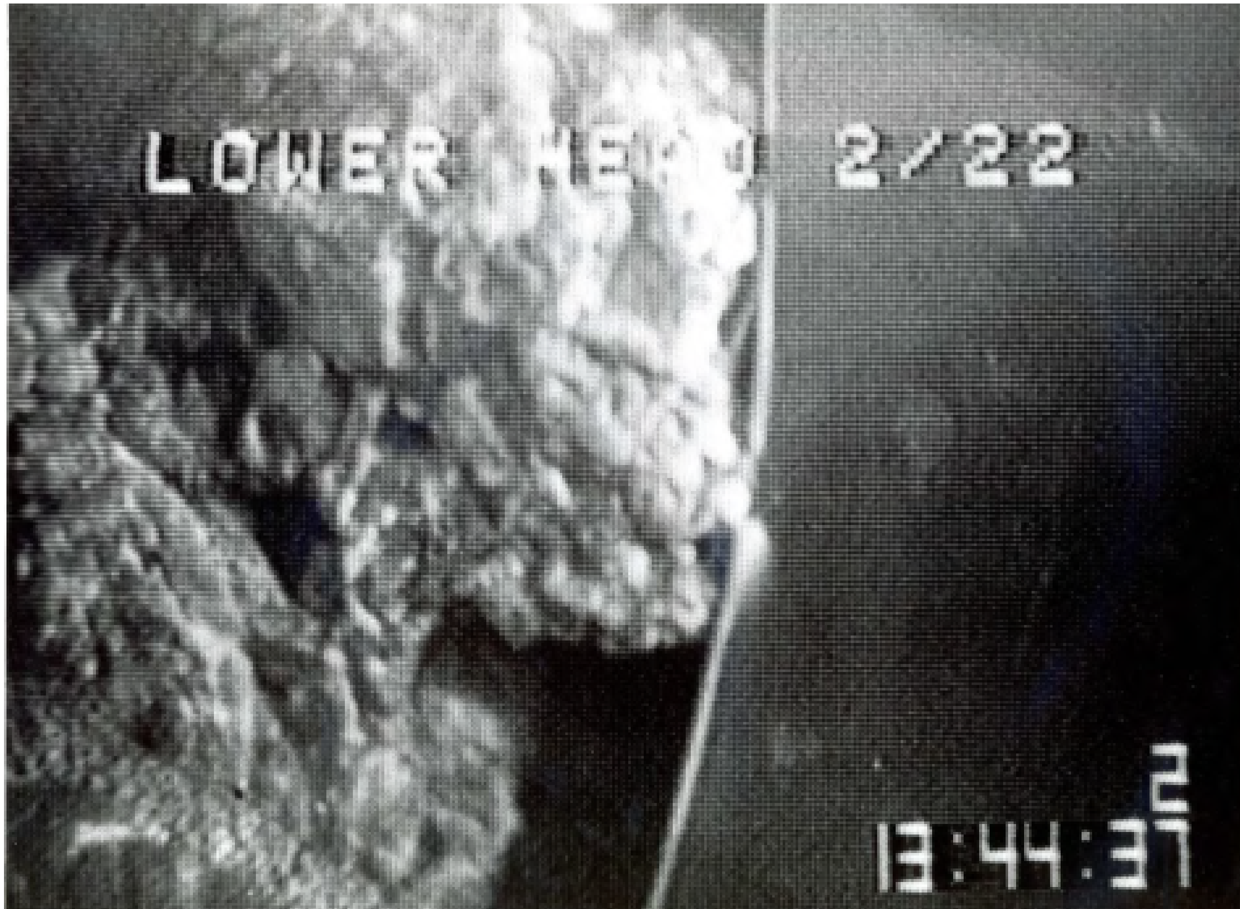

View of Lower Reactor Vessel Head (1985)

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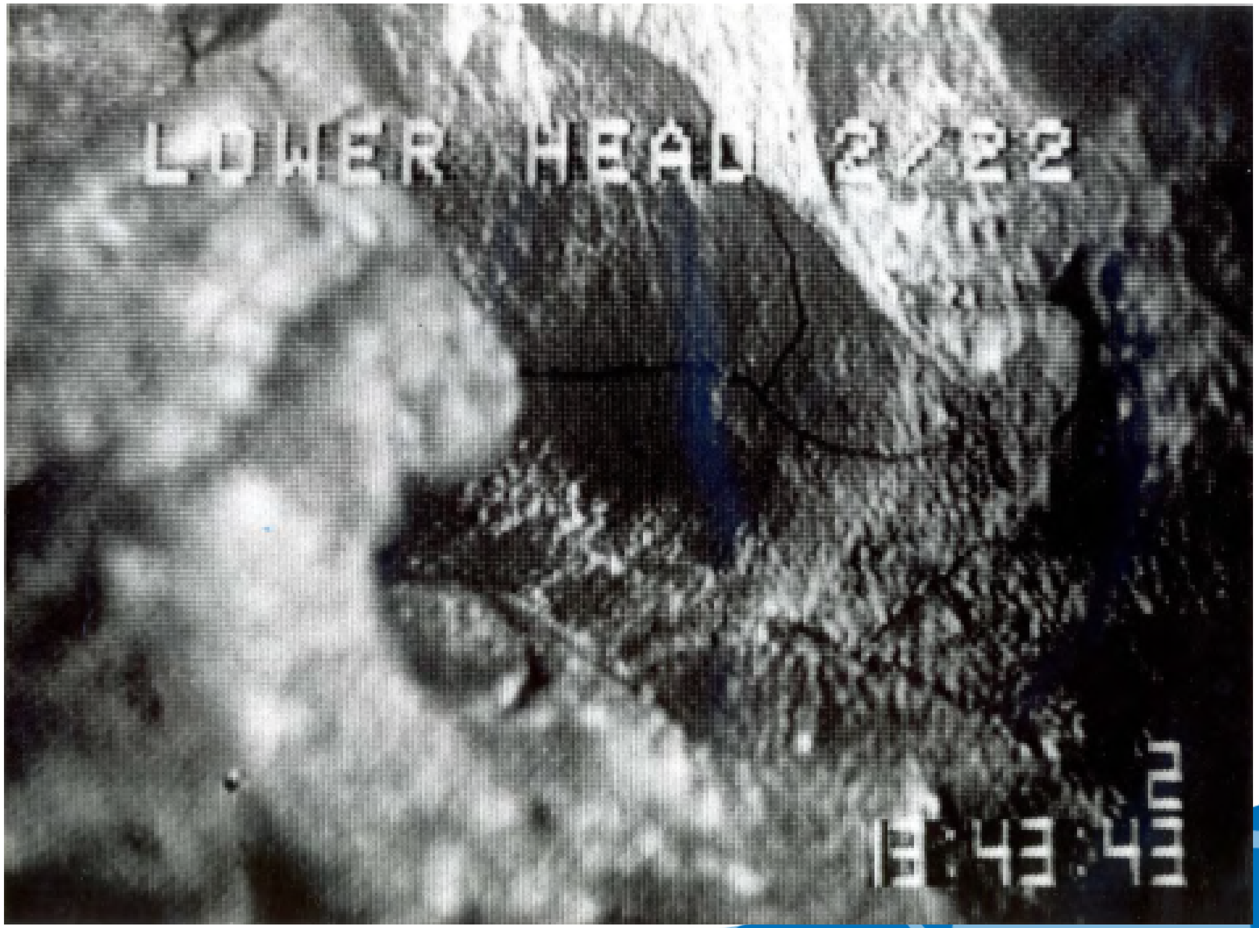


know that not only had the upper parts of the core been destroyed but that fuel had molten and had flowed out of the core region in to the lower portions of the reactor internals.

We knew we would be required to remove some depth of granular fuel co-mingled with partial fuel pins, springs, burned end fittings, control rod spiders, and other mechanical debris. We required custom made equipment, custom procedures, specially qualified personnel, and NRC agreement on our strategy. Our concept, that became a reality, was the Rotating Work Platform.

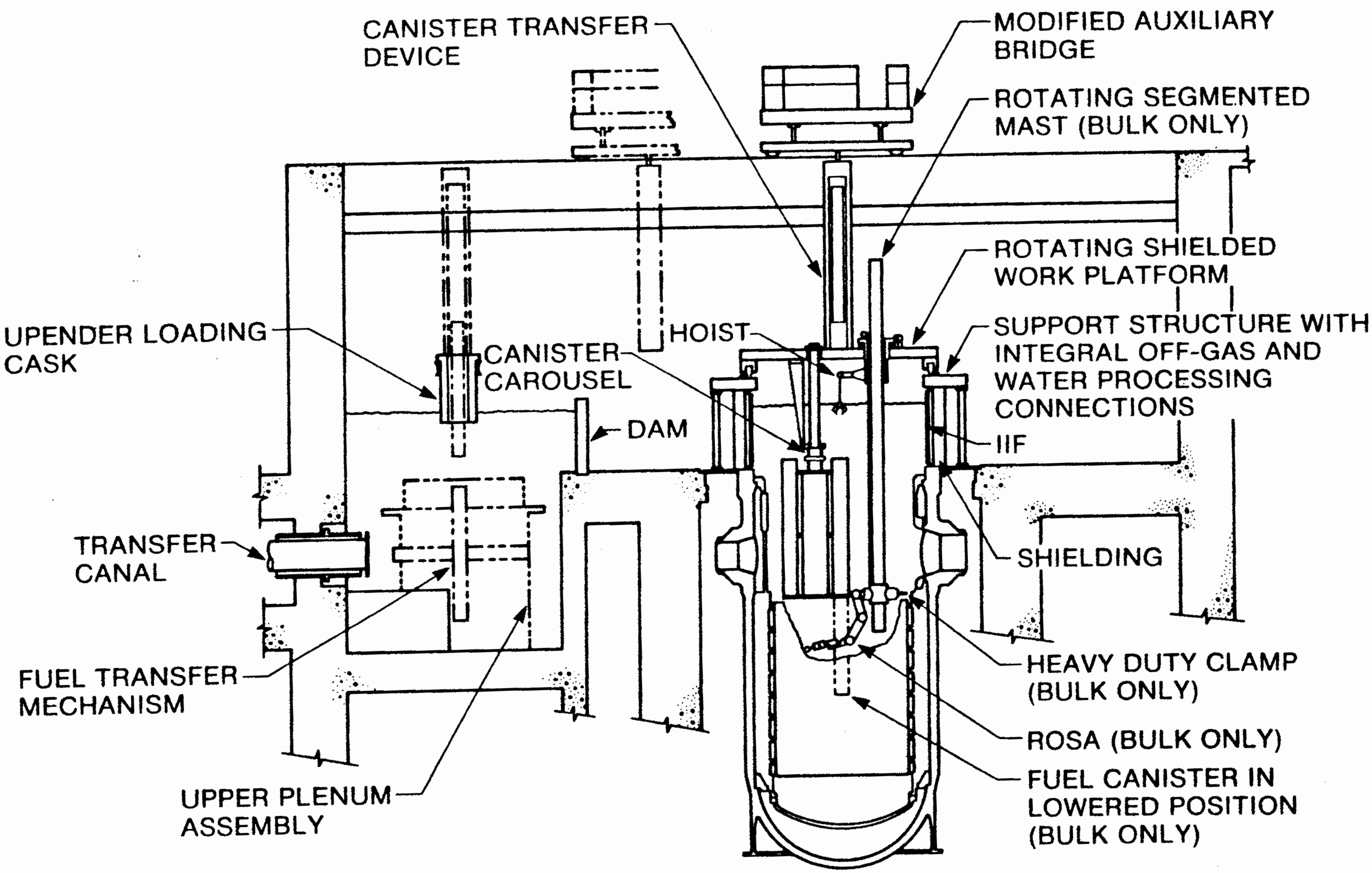
Slides 89 and 90 - Conceptual Fuel Handling Rotating Work Platform

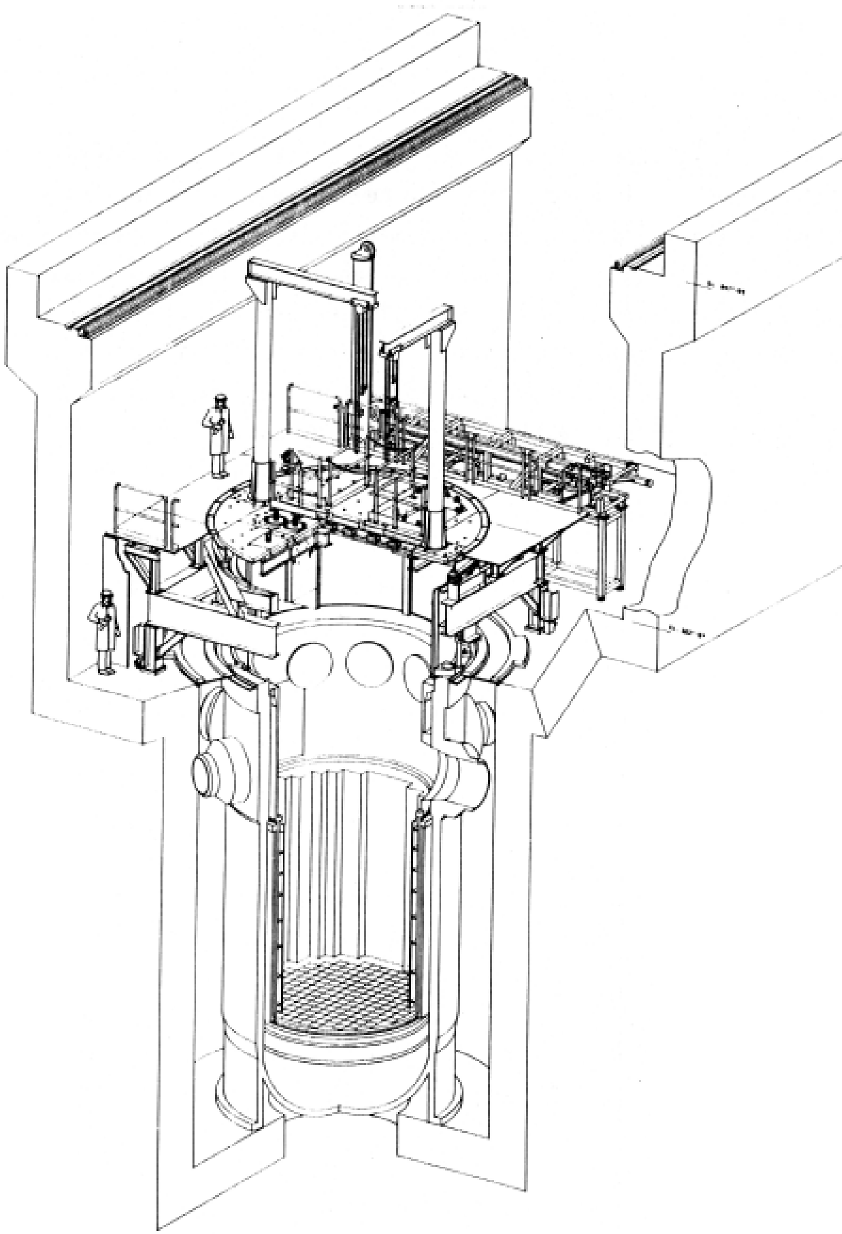
The NRC regulations required an NRC license to handle fuel and that fuel handling be conducted under the supervision of an NRC licensed person, whether a Reactor Operator or a Senior Reactor Operator. We proceeded to select and qualify 6 individuals as Fuel Handling Senior Reactor operators. These 6 individuals would have the shift supervisory duties to oversee the operators that would perform the hands-on fuel removal actions. We developed a 6 shift rotation, same as the rotating shifts that were in the TMI-1 and TMI-2 control rooms, comprised of teams consisting of Auxiliary Operators and other shift personnel from both units. It is those men and women that actually defueled TMI-2.

Slide 91 - Oversight Committee Members on Full Size Mock Up in TMI-2 Turbine Building

We undertook a major effort to compose, dry-run and implement the fuel handling procedures, including handling debris from the core debris bed. We wrote procedures for months preceding the initiation of defueling and tested them on a defueling mock-up that we had assembled in the TMI-2 turbine building. The mock up duplicated the rotating work platform, the tool racks, the overhead crane required to handle the 40 foot long tools, and the ‘training’ week crews developed their sense of ‘feel’ for the tools, the balance of the tools and the effort required to ‘pull’ or ‘shear’ fuel, while working on the mockup.

Bulk Defueling System
(Cross-Section View)





Defueling Work Platform

(GEND-IN-65)

Oversight Committee on Mock-Up of Rotating Work Platform for Fuel Removal (1985)

October 1985 - Pick and Place Defueling Campaign Begins.

In October 1985 we began round the clock defueling operations using three rotating shifts.

Slide 92 - Rotating Work Platform in TMI-2 Reactor Building Fuel Transfer Canal

Slides 93 and 94 - Conduct of Operations - Removing TMI-2 Fuel

Slides 95 and 96 - Core Debris Samples and Tool

December 1985 - Several Defueling Canisters filled with debris

January 1986 – First Group of Defueling Canisters sealed, dewatered and transferred to storage racks in Spent Fuel Pool A in the Auxiliary and Fuel handling Building.

Core Accountability

Many in this room may have participated in some form of 'accountability' discussion regarding nuclear fuel. That subject was highly important as we 'digested' the implications of the 'Quick Look' examination. The annual accountability requirement for fissile material on site remained in place but we had no clear cut method of performing accountability. I am the author of the first TMI-2 core accountability plan and defended it to the NRC Office of Nuclear Material Safety and Safeguard (NMSS) in Silver Springs, Maryland. We took the potion that all of the originally loaded uranium-235 was in the RCS somewhere, likely most in the Reactor Vessel, but possibly some in fines throughout the RCS and possibly in the Reactor Coolant Drain tank. While we were convinced that the fuel would retain its original density, we didn't know how 'fine' the fines could be. We told NMSS that we would account for fuel by weight measurement of the fuel that was to be removed from the RCS in the defueling canisters and anticipated that the aggregate sum net weight would be around ~315,000 pounds accounting for all original core contents along with oxide debris from the upper grid. That became the GPU plan and NMSS agreed with the approach.

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Defueling Work Platform
(Installed Over Reactor Vessel)

Defueling, Removal of Fuel Debris Using Long-Handled Tools

Defueling, Removal of Fuel Debris Using Long-Handled Tools

Defueling, TMI-2 Core Grab Sample Tool with Fuel Debris

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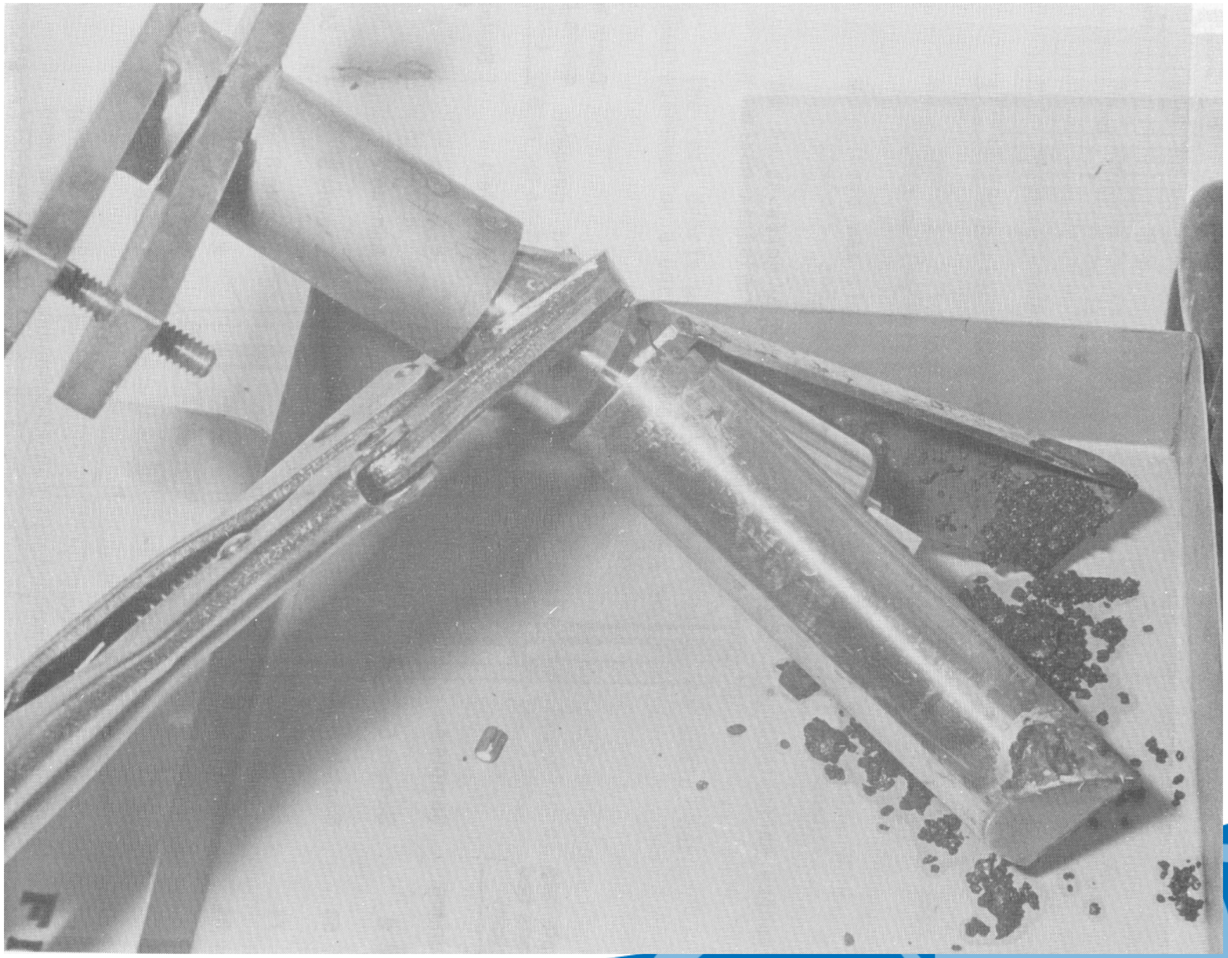
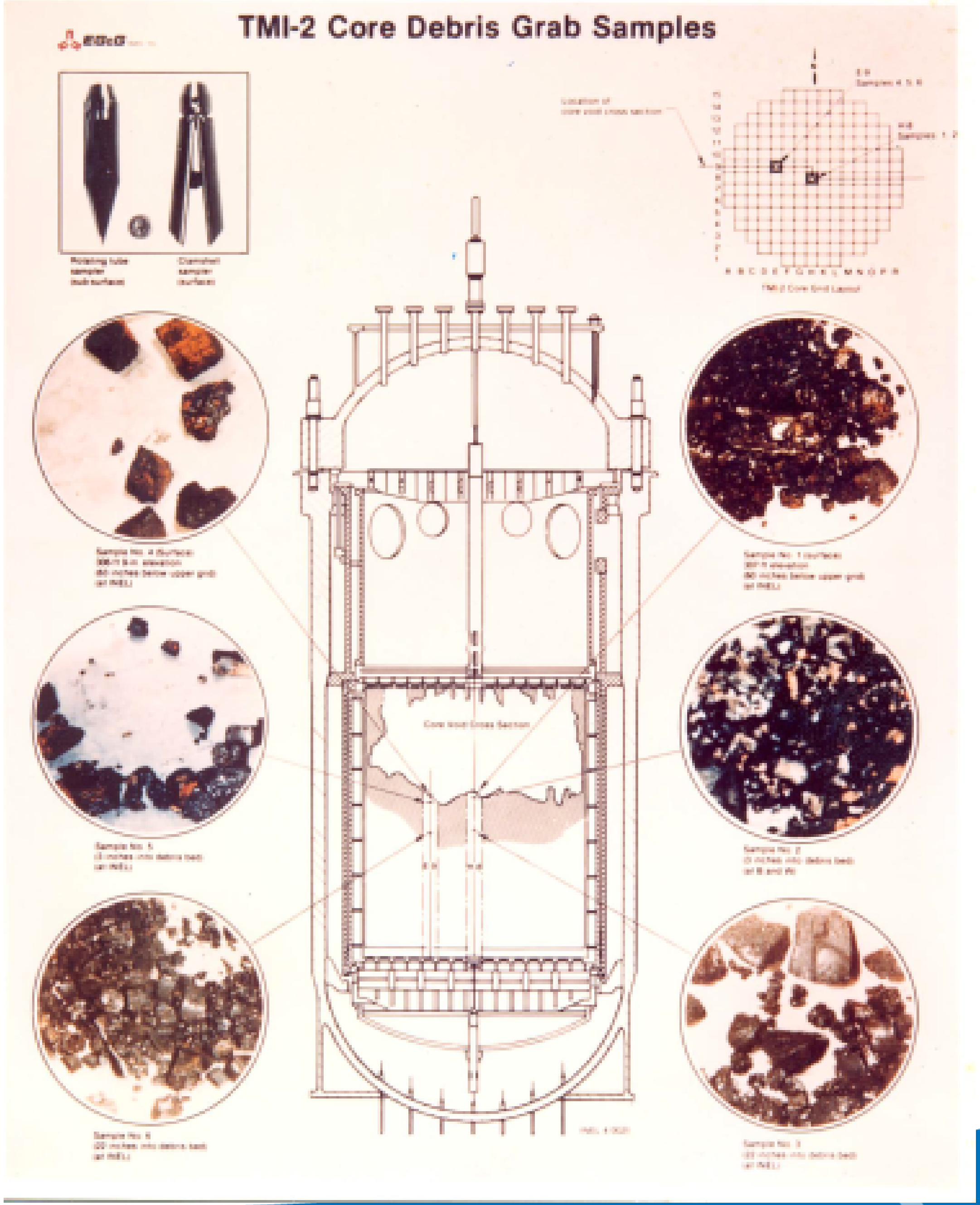




TMI-2 Core Grab Samples Obtained in 1983

(GEND-INF-060)

February / March 1986 - Biological Contamination Presents Itself

You might remember my discussion earlier about the water in the Reactor Building and its content of the Susquehanna's 'spring flood runoff'. The processed accident water had by now been stripped of radionuclides in SDS and had been polished though EPICOR II. It was now as clean and useful as normal demineralized water. We used this recycled water as makeup to the Reactor Vessel as the radiological shield for the defueling workers. Importantly, as discussed earlier, the recycled accident water was ~30% Susquehanna River water that contained coliform and other bacteria.

The defueling tools use hydraulic fluid as their main operating medium. When we changed tool 'end effectors', a fraction of a cubic centimeter of hydraulic fluid leaked into the ~90 degrees Fahrenheit water in the Reactor vessel. While it had been over 7 years since the accident, the core continued to produce decay heat thus heating the water to a temperature where microorganism growth began. The first indications of the microorganism growth appeared as fuzz or moss on the metal surfaces. Within weeks the structures inside the reactor vessel were overgrown by leafy-green vegetables that appeared the equivalent of the 'hanging gardens of Babylon – leafy plant structures that now begin to feed on the atmospheric oxygen in the water (~8 parts per million) and each other. The visibility in Reactor Vessel dropped from meters to millimeters; visibility, even with excellent lighting, was virtually eliminated by microorganism decay, and the reactor vessel water became septic. Defueling operations ceased.

GPU eliminated the microorganism remains and growth by bleaching the reactor vessel water with hydrogen peroxide, common bleach, destroying the microorganisms. We used the SDS filters to filter the water back to clarity.

Additional Comments - Living in Central Pennsylvania During the Cleanup

Slide 97 - May 26, 1986 - Chernobyl

A stark and chilling reminder of the challenges of nuclear technology occurred as the result of the Chernobyl accident in the spring of 1986. While the local Harrisburg community had generally processed the TMI-2 accident and accepted the ongoing work at TMI-2 as a necessity, the media reporting of Chernobyl re-kindled concerns by many members of the public. While the consequences of the two accidents were and are starkly different, the public saw both as related. I am confident many in the general public who are watching the unfolding events at Fukushima see the same relationship.

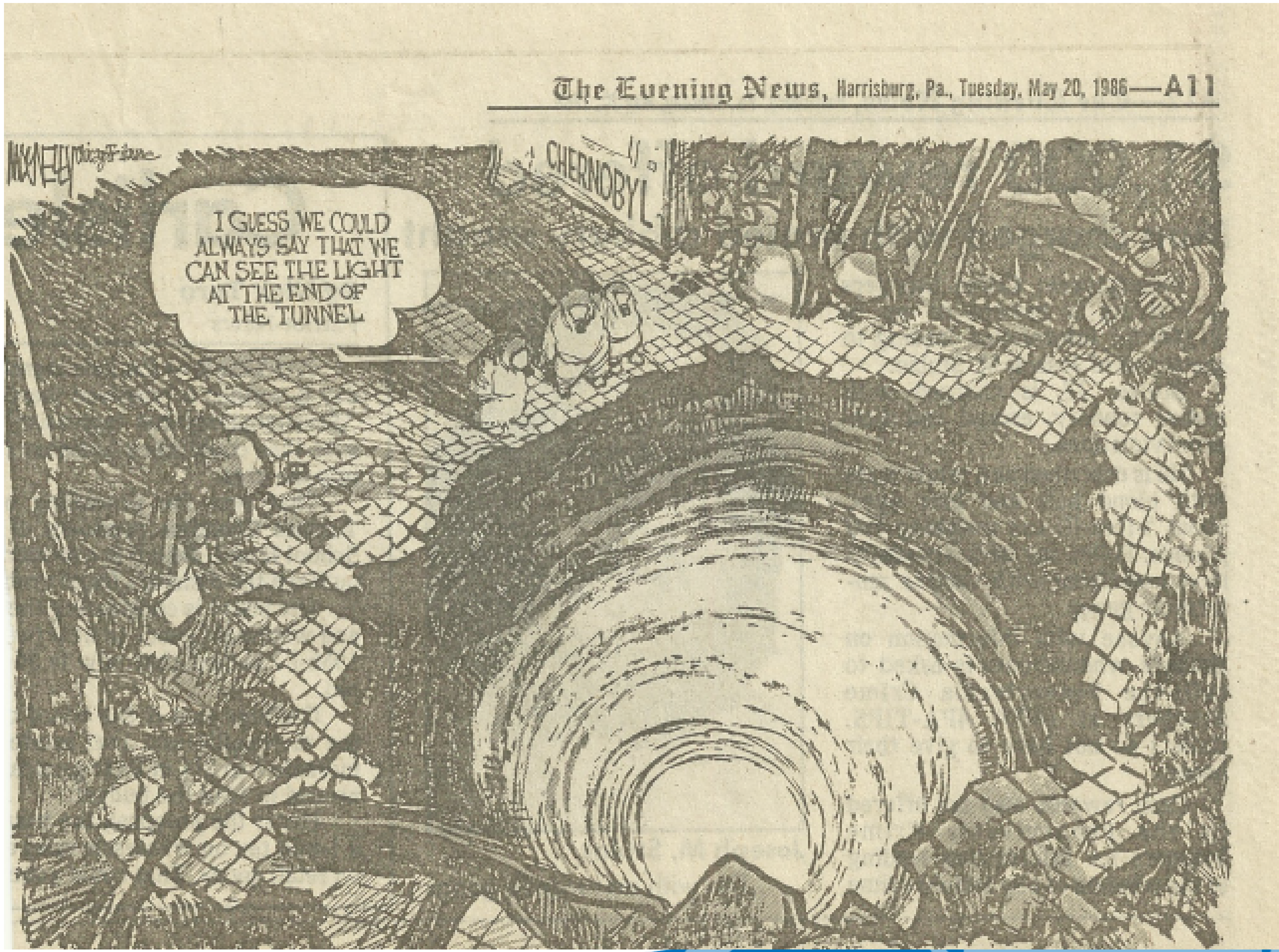
1980 – 1986 - Living in the Community

My colleagues and I were challenged or confronted by local politicians and residents numerous times in the years immediately following the accident, whether at school meetings, church, or elsewhere in the community. Some communicated that nuclear power is immoral and fundamentally unsafe, and that the workers at TMI and other nuclear plants were thugs and felons. Others thought our collective ‘moral compass’ was broken. The community remained skeptical of many of the TMI workers. Only after some level of trust had been established did the community seem accepting - but even with that acceptance individuals often communicated lingering concerns about TMI. It took years for the community to move onto other issues and allow TMI to become a memory. Even today there is often a comment regarding TMI’s workers and their propensity to ‘glow’ as the result of working at TMI.

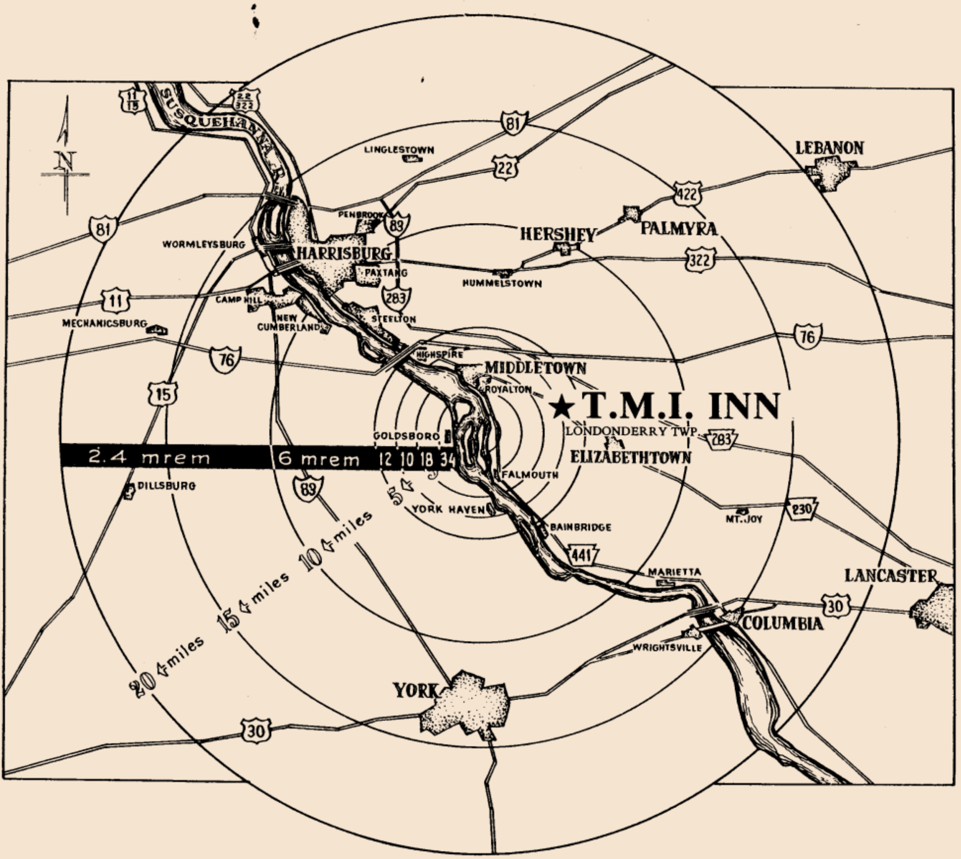
Slides 98 and 99 - Menu at TMI Inn

Entrepreneurs found the TMI accident to be a source of revenue. One local eating establishment changed its name to the TMI Inn. Only about 3 miles from TMI, this establishment decided to offer a menu unique to the community.

The Evening News (Chernobyl)



T.M.I. INN



Route 230 & Geyers Church Road
Phone: 944-2145

Turbines

CHILI .... **Cup $.85** **Bowl $1.20**
SOUP DU JOUR ...... **Cup $.65** **Bowl $1.00**

Meltdowns

REM **$3.00**
American cheese, imported European ham, bacon strips. Served open face on a hard roll.

CURIE **$3.00**
Italian provolone, Swiss, cheddar with a bite to it, spinach, imported black olives and tomato slices. Served open face on rye.

RAB **$3.00**
Delicate chunks of white tuna, cheddar cheese, sweet juicy pineapple rings. Served open face on whole wheat.

ROENTGEN **$3.00**
Tasty thinly sliced roast beef, Swiss cheese, sliced mushrooms, green peppers smothered with au jus on a special house roll.

PICO **$3.00**
Real Italian style meatballs covered with provolone cheese and delectably sweet cherry peppers. Served on house roll.

MILLI **$1.50**
Rems, Curies, Rabs, Roentgens, Picos are our childrens portions.

Primary Loop

CORE .... **Small $3.00** **Large $4.50**
Fresh pizza dough, Italian style tomato sauce and lots of mozzerella cheese. Oven fresh to you.

HYDROGEN BUBBLE
Large .... **$4.25** **Small** **$2.25**
Cooked salami, American cheese, picnic ham, mustard sauce and mozzerella cheese wrapped gently in our fresh pizza dough and baked till that traditional Italian flavor comes through.

CONTROL ROOM
Large .... **$8.00** **Small** **$6.00**
An engineering miracle: all our T.M.I. extras chosen carefully and placed strategically to create a masterful combination to delight the taste and satisfy the stomach.

T.M.I. Extras

Pepperoni	Green peppers
Cheese	Onions
Mushrooms	Hamburger
Sausage	Anchovies

Available on Cores and in Hydrogen Bubbles
Small $.75 Large $1.25

HEAT UP .... **3 for $2.00**
Lettuce, tomato, chili, grated melted cheddar cheese on a hard taco shell.

ALPHA RAYS **$2.75**
Separate or in combination: provolone, Swiss, sharp or cheddar. Crackers and cladding.

GAMMA RAYS **$3.50**
In combination or separate: pepperoni, Lebanon bologna, kielbasa, ring bologna. Crackers and cladding.

ALPHA & GAMMA—make your own ... **$4.00**

Secondary Loop

Pies—ask your waitress for pies of the day
$.60

Coolants

Iced Coffee	$.50	Ginger Ale	$.50
Iced Tea	.50	Fresca	.50
Lemonade...........	.50	Tab	.50
Coca Cola	.50	Sweet Milk	.50
Beer		Chocolate	.50

Beer by the bottle, glass or pitcher; draught beer to go—see blackboard for brands and prices.

Steam

Coffee $.40 Sanka $.40 Tea $.40

Utility Commissions

N.R.C. . . . . Small $.75 Large $1.25
Plump tomatoes, fresh cut carrots, crisp lettuce, shredded cabbage tossed to perfection and topped off with your favorite dressing

A.E.C. $2.00
Imported European ham, turkey breast, provolone cheese, sliced hard cooked eggs, tomatoes, onions and your choice of dressing on a bed of fresh lettuce.

P.U.C. $2.00
Rich green spinach leaves, sliced mushrooms, imported black olives, croutons, bits of bacon all carefully blended and laced with our special house dressing.

T.M.I. $2.00
All white meat tuna, succulent green peppers, onions, tomatoes, green beans, bite size potatoes, sliced hard cooked eggs, imported black olives, tangy anchovies. All this served on a bed of crisp lettuce with your choice of dressing.

Cold Shutdowns

PRESSURIZER
Whole Life . . . . $4.00 Half Life $2.00
Provolone cheese, cooked salami, onions, hard Genoa salami, olive oil, capicolla and just enough oregano to give it that zesty Italian flavor.

AIR LOCK
Whole Life . . . . $4.50 Half Life $2.25
Cold roast beef, crisp lettuce, plump juicy tomatoes, cheese: American, Swiss, or provolone, your choice.

COOLING TOWER
Whole Life . . . . $4.00 Half Life $2.00
Lots of imported European ham, cheese: Swiss, American or provolone, fresh tomatoes, lettuce and mayonnaise. Just the right combination to cool your hunger.

CONTROL ROD
Whole Life . . . . $4.00 Half Life $2.00
Turkey—white breast meat only, sliced thin with lettuce, tomato, mayonnaise and choice of American, Swiss or provolone cheese.

CONDENSER
Whole Life . . . . $4.00 Half Life $2.00
All white meat tuna, not Charlie, crisp lettuce, cheese, tomatoes and mayonnaise.

Nuetrinos

FUEL ROD $1.90
Hot and juicy foot long hot dog on a roll with your choice of cladding—
Relish, Pickels, Cheese, Onions, Sauerkraut, Ketchup, Mustard

UNIT #1 . . . . $2.50
Lean roast beef, sliced thin and piled generously on white, rye, or whole wheat bread. Garnished with lettuce, tomato and mayonnaise.

UNIT #2 . . . . $2.25
A handsome helping of imported ham on white, rye or whole wheat. Topped off with lettuce, tomato and whole egg mayonnaise.

OBSERVATION TOWER $2.25
All white meat turkey breast, lettuce, tomato, mayonnaise and cheese piled high enough to be seen from Three Mile Island.

CONTAINMENT BUILDING. $2.25
Meat ball, tomato sauce, provolone cheese stuffed into a roll barely able to contain them.

REACTOR VESSEL $2.00
Roasted beef in a thick, rich Bar-B-Que sauce. Served hot to lock in that tangy flavor.

GENERATOR $1.90
Your standard unradiated BLT served on white or whole wheat toast.

Three Mile Highs

Includes lettuce, tomato, mayonnaise, bacon strips and three slices of bread.

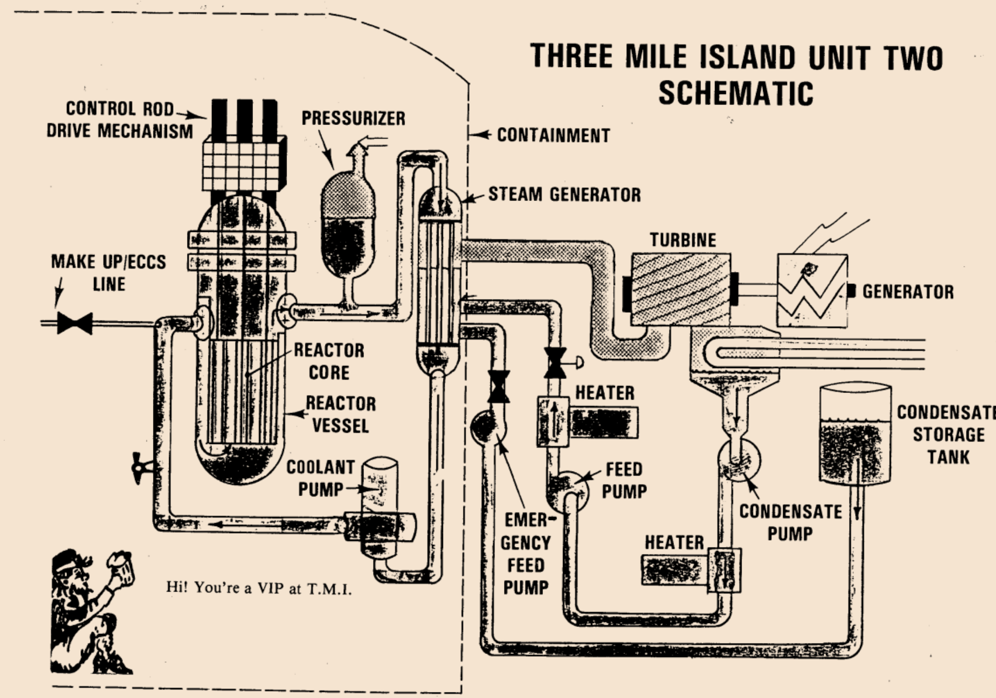
PROTRON $2.75
Roast Beef & Swiss

NUETRON $2.50
Ham & Swiss

ELECTRON $2.50
Turkey & Provolone

PHOTON $2.50
Tuna & Provolone

THREE MILE ISLAND UNIT TWO SCHEMATIC



Menu by CAFRA PROMOTIONS, 297 E. MAIN STREET, HUMMELSTOWN, PA.

Life on the Island - 1979 – 1986

Organizational Challenges

Work at TMI-2 was proceeding on multiple fronts during these busy times in the early 80's. Hundreds of contractors came to the site from all portions of the US and foreign nuclear community. Bechtel was the largest and brought to the Island a large supervisory and craft work force. All of the Nuclear Steam Supply System vendors had participation in one way or another. DOE and the national labs played a critical role by providing counsel and support, innovation and guidance. Participants arrived from France, Germany, Japan, Netherlands, Switzerland and others. Private contractors and consultants arrived from every corner of the US Industry. We built an organization that integrated each of these although managing the organization was difficult. There were times when the organization seemed to be aligned and cooperative and other times when there was outright infighting and warfare. Making progress early in 1980 and 1981 was very difficult – and only when the organization agreed to a common plan of 'attack' did the organization begin to function. In my mind it was 'quick look' in 1982 that galvanized the attention of all participants and provided the common focus that was needed to move forward.

Each year immediately following the Accident, and years later, the community remained skeptical regarding activities at TMI and they, and several anti-nuclear organizations, organized a 'vigil' each March 28 at 0400 hours to remember the event. There will be one this Friday, March 28, 2014 to recognize the 35th anniversary.

Communications - Public Affairs

The first, and in my judgment the most important action that we took after the Accident to address pubic concerns, is that GPU created a Public Affairs Organization led by a seasoned Public Relations professional. That team then hired a small group of competent teachers and educators. Those teachers and educators spent their time in the community speaking to school groups, civic clubs and numerous groups throughout the Harrisburg, Pa area. They offered to teach science courses at local schools at the school's invitation, and held seminars in the summer for school science teachers. What resulted was the beginning of the 'turnaround' in public thinking and confidence in (now) GPU's ability to clean up the damaged TMI-2 – and restart the undamaged TMI-1.

Reactor Run By

Slide 100 - Reactor Run By

The second, and likely as important in non-measurable ways, action to address public fear was the establishment of the '5 Mile Reactor Run By'.

Running foot races was popular in the early 80's. There was a 10K race nearly every weekend. Several runners trained at TMI nearly every day, schedules permitting, using the Maintenance locker room and showers. The new Public Affairs Organization noticed our behavior and recognized the health benefit of the exercise. In time they came up with the idea that we could conceivably organize and successfully execute a reactor 'Run By – a full 5 miles, open to all members of the public, that would start and end at the Visitors Center, and where runners would run across the south bridge, cross onto the Island, run the length of the Island, exit the north bridge, and return to visitors center.

Both TM-1 and TMI-2 were fenced off from the service road way – and the task would be for Security and volunteer staff to direct the runners to the west of the units.

We conducted the 'Reactor Run By' two times – and each was a huge success. The positive PR that resulted from the event, particularly the recognition by 'regular public participant runners', that being close to the RBs and cooling towers, was safe - was priceless. Many of the hundreds of runners exclaimed that they had cheated death by running onto the Island, by the cooling towers, and by the two Reactor Buildings. Most didn't understand the functional difference. In time the public recognized that the runners were safe and unharmed. And if they were safe and unharmed having been on the island, the public was probably safe miles away. The community began to recognize that the dangers on the Island were minimal and that regular people could be next

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TMI Reactor Run-By

to and work at the plants and be safe. That was a turnaround for large numbers of people who previously thought that everything on the Island, and about the Island, was dangerously radioactive.

1979 – 1986 - Interaction with NRC Resident / Regulator

Promptly following the accident the NRC established a TMI-2 Program Office on the island. Numerous NRC personnel served at TMI-2, and many of those were already in, or moved on to, key leadership positions in the Agency. My experience is that interaction with the TMI-2 Program Office staff and TMI-2 Residents was different than interactions with other NRC staff and Residents. My conviction is that this grew out of a sense of urgency to create successful outcomes for the key safety issues at TMI-2 that confronted both the GPU staff and the NRC staff. Often the TMI-2 resident inspectors, or headquarters based NRC staff accompanied by the TMI-2 resident inspectors, would participate in planning or strategy meetings, sometimes offering points of view relative to the contemplated path forward. Those interactions were usually highly constructive and beneficial. While the NRC personnel maintained their arms-length business dealing, and did so professionally, they added value to the interactions.

1979 – 1986 - Interaction with Oversight Committees

TMI-2 had three independent oversight Committees constantly in force for the seven years that I was part of the TMI-2 organization.

The General Office Review Board (GORB) was equivalent to a current plant's Nuclear Safety Review Board with formal meetings every ~two months. The Chairman of the GORB was a senior officer from GPU. The GORB generally focused on GPU business and risks that were associated with the TMI-2 Stabilization and Clean Up activities.

The Technical Assistance and Advisory Group (TAAG) met monthly and focused on technical progress. The Chairman of TAAG was the retired General Manger of Bettis Atomic Power Laboratory. This group often attempted to direct actions at a micro or personal level. Interaction with that group was difficult because the TAAG assumed that the line organization would promptly comply with its direction. There was great resistance to responding to this group because the suggestions were intended to be directives; the line organization resisted because of the accountability that the line organization had for the work products and outcomes, and the dissonance that the Group sometimes inserted.

The Safety Advisory Board (SAB) met every 3 months and was broadly focused on overall plant and nuclear safety issues. One Chairman of the SAB was Dr. John Fletcher, at the time Chairman of the Mechanical Engineering Department at the University of Pittsburgh, and past Administrator of the National Aeronautics and Space Administration (NASA). Dr Fletcher returned to NASA following the Challenger Shuttle Disaster. Dr. Norman Rasmussen from Massachusetts Institute of Technology and 10 other very highly regarded scientists and engineers were also on that Board. The SAB brought to TMI-2 a respectful and respected maturity that enabled significant organizational progress and success.

The daily workload at TMI-2 was demanding in and of itself. Meeting attendance for presentations on topical subjects to GORB, TAAG or SAB was mandatory, either in a proactive or defensive sense; when all three committees schedules coincided to meet in the same month the GPU organization struggled to respond.

Elbows and Behinds

Slide 101 - Incarcerated Carp

Earlier in my presentation I described the cooling towers and their substantial basins of approximately 500 feet diameter and 8 foot depth. When we finally decided to empty the tower basins we discovered a thriving fish population, composed of predominately but not exclusively carp. The carp came into the cooling tower basins either as fry or fingerlings in the years following the accident, while we were making up to the tower with river water to compensate for the haze or the 'small cloud' above it. However we also discovered a Tiger Muskellunge living there. Somehow they all lived there together in the two basins for all of those years.

Carp

Pumping the ‘basins’ required a water discharge permit and Pennsylvania Department of Environmental Resources (DER) came to oversee the operation. The carp were classified as ‘incarcerated carp’ because they had been in a non-river environment for an undetermined time period. They could not be released to the Susquehanna River. A TMI worker offered to adopt the carp and impound them in his private pond. DER accepted this solution. The environmental workers were enjoying their fish-saving adventure, wading in the flume in their bare feet and shorts, on one fine spring day when an unsuspected and unwelcome e visitor show up. He or she had been living in the same enviro-system.

Slide 102 - Incarcerated Tiger Muskellunge

While trying to ‘round up’ the carp in the flume and trying to remove each one by hand, a Tiger Muskellunge showed up. Elbows and behinds were all that you could see. In time the Muskie was also netted and transferred to the pond. Somehow those fish lived together in that water system for years.

Slide 103 - Lessons 1-3

Lessons I learned from those 7 years:

1. Men and women that are immersed in the use of nuclear energy for the production of power of any kind are well advised, above all, to develop and retain, constantly, an abiding, accountable respect for nuclear technology.

2. Containments can do what they are designed to do; millions or curies of activity were released from TMI-2’s core into TMI-2’s Reactor Building; few were released to the environment. The hydrogen explosion was contained.

3. Containment design and construction is critical. Over the years I’ve developed the personal conviction that the design requirement for containment is equivalent in importance to the requirement for fuel integrity and for RCS pressure boundary integrity. The requirement must be for a robustly designed, durable and dependable containment for each plant design that considers the most

Tiger Muskellunge

Lessons (12) I learned from those 7 years

1. Men and women that are immersed in the use of nuclear energy for the production of power of any kind are well advised, above all, to develop and retain, constantly, an abiding and accountable respect for nuclear technology.

2. Containments can do what they are designed to do; millions or curies of activity were released from TMI-2's core into TMI-2's RB; few were released to the environment. The Hydrogen explosion was contained.

3. Containment design and construction is critical. Over the years I've developed the personal conviction that the design requirement for containment is equivalent in importance to the requirement for fuel integrity and for RCS pressure boundary integrity. The requirement must be for a robustly designed, durable and dependable containment for each plant design that considers the most severe conditions we can responsibly defend using combined deterministic and probabilistic design tools.

Lessons (Continued)

4. Our requirements, codes and standards were effective at the time of the TMI-2 accident, and remain effective today. The TMI-2 ECCS systems and controls, as rudimentary as they were in 1979, functioned successfully.

5. The reactor vessel held.

6. Keeping the fuel and the reactor vessel surfaces wet will save the day.

7. The behavior of some Isotopes will surprise us. Some Isotope behave differently than we thought before the TMI-2 accident.

8. More shielding is better than less.

Lessons (Continued)

9. Gas generation, particularly Hydrogen generation, from any source, and from any location, deserves respect equivalent to criticality safety, and requires immediate attention, decisive action and thorough treatment.

10. People are willing to take risk if they think the risk is worth it.

11.Qualified personnel are important and rigorous training matters.

Thorough planning, preparation, and practice are worth the investment.

12. Words matter. Responsible behavior and accountable actions matter more.

severe conditions we can responsibly defend using combined deterministic and probabilistic design tools.

Slide 104 - Lessons 4-8

4. Our requirements, codes and standards were effective at the time of the TMI-2 accident, and remain effective today. The TMI-2 Emergency Core Cooling System systems and controls, as rudimentary as they were in 1979, functioned successfully.

5. The reactor vessel held.

6. Keeping the fuel and the reactor vessel surfaces wet will save the day.

7. The behavior of some Isotopes will surprise us. Some Isotope behave differently than we thought before the TMI-2 accident

8. More shielding is better than less

Slide 105 - Lessons 9-12

9. Gas generation, particularly hydrogen generation, from any source, and from any location, deserves respect equivalent to criticality safety, and requires immediate attention, decisive action and thorough treatment.

10. People are willing to take risks if they think the risk is worth it.

11. Qualified personnel are important and rigorous training matters. Thorough planning, preparation, and practice are worth the investment.

12. Words matter. Responsible behavior and accountable actions matter more.

1986 - Departure from TMI-2

I departed from TMI-2 in late spring 1986 to lead a team responding to an NRC directive that unless the B&W Owner's Group took firm and accountable actions to ensure the B&W plants weren't prone to another TMI-2-like accident, all of the B&W plants would be shut down. I managed that very successful activity for three years to its successful conclusion. I returned to TMI-1 in 1989 as Plant Engineering Director and remained at TMI-1 as a Director through the transition of GPU to AmerGen, the new owner, and through the first sale of an operating nuclear power plant in the United States.

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