The 35th Anniversary of the Three Mile Island Accident of 1979

Working at TMI During and Following the Accident

Speaker: Gordon R. Skillman
Member, Advisory Committee on Reactor Safeguards

U.S. Nuclear Regulatory Commission
TWF Auditorium
March 25, 2014
10:00 am–11:30 am

Office of Nuclear Regulatory Research

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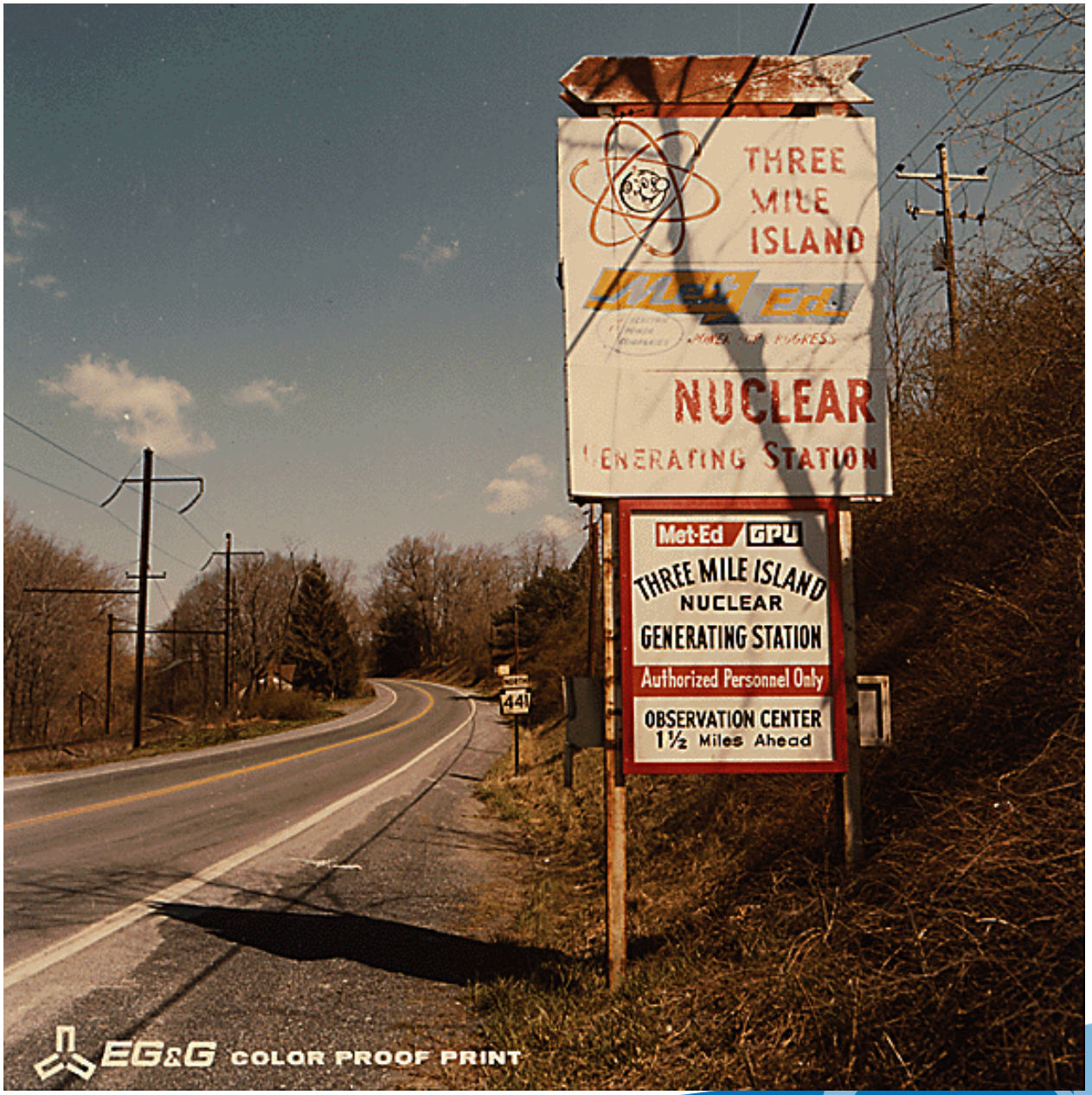

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TMI Sign at South Bridge Turnoff

(Pennsylvania Highway 441 on April 6, 1979)

Aerial View of Three Mile Island through Unit 2 Cooling Towers

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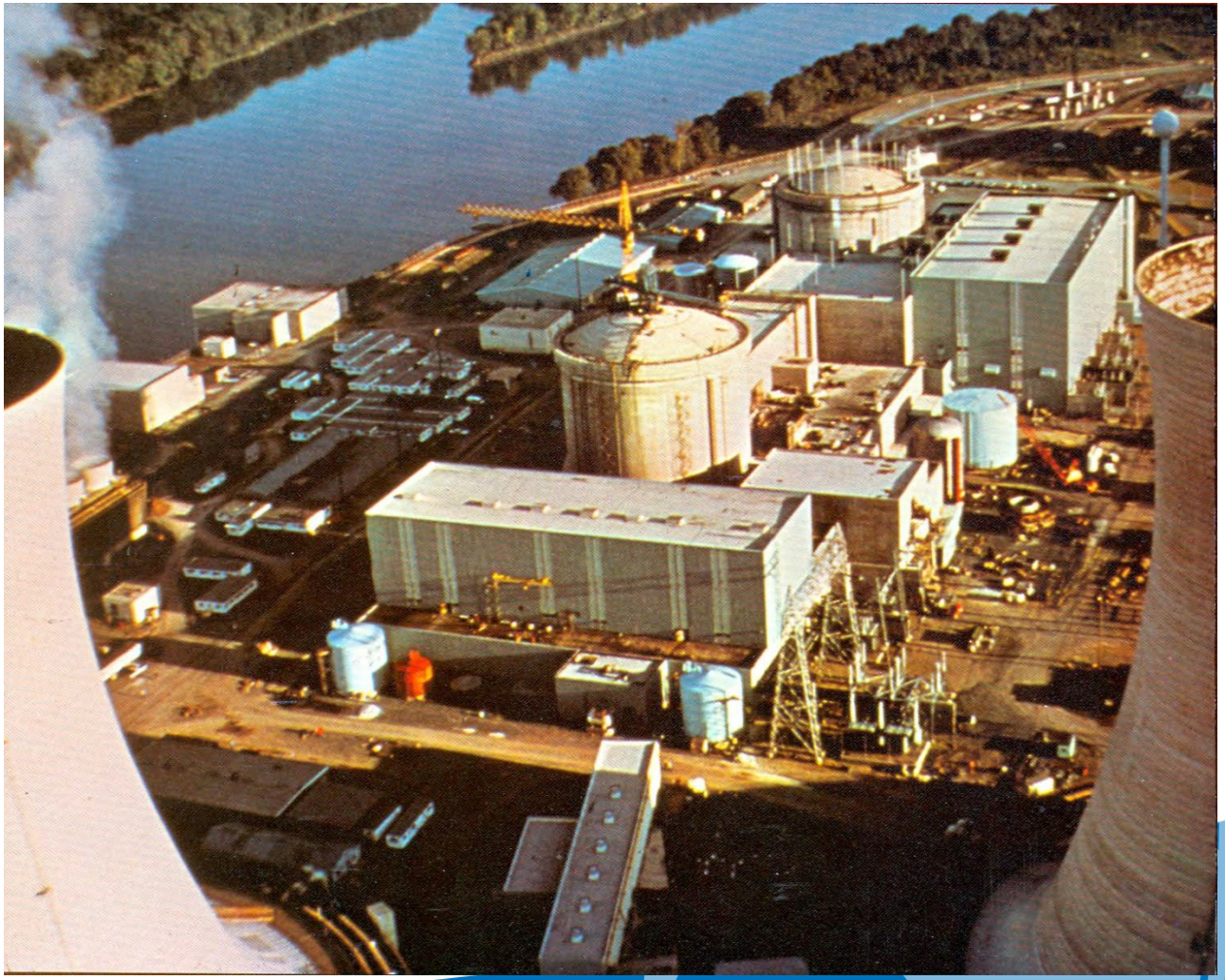

TMI-2 Control Room During the Accident

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Schematic of TMI-2

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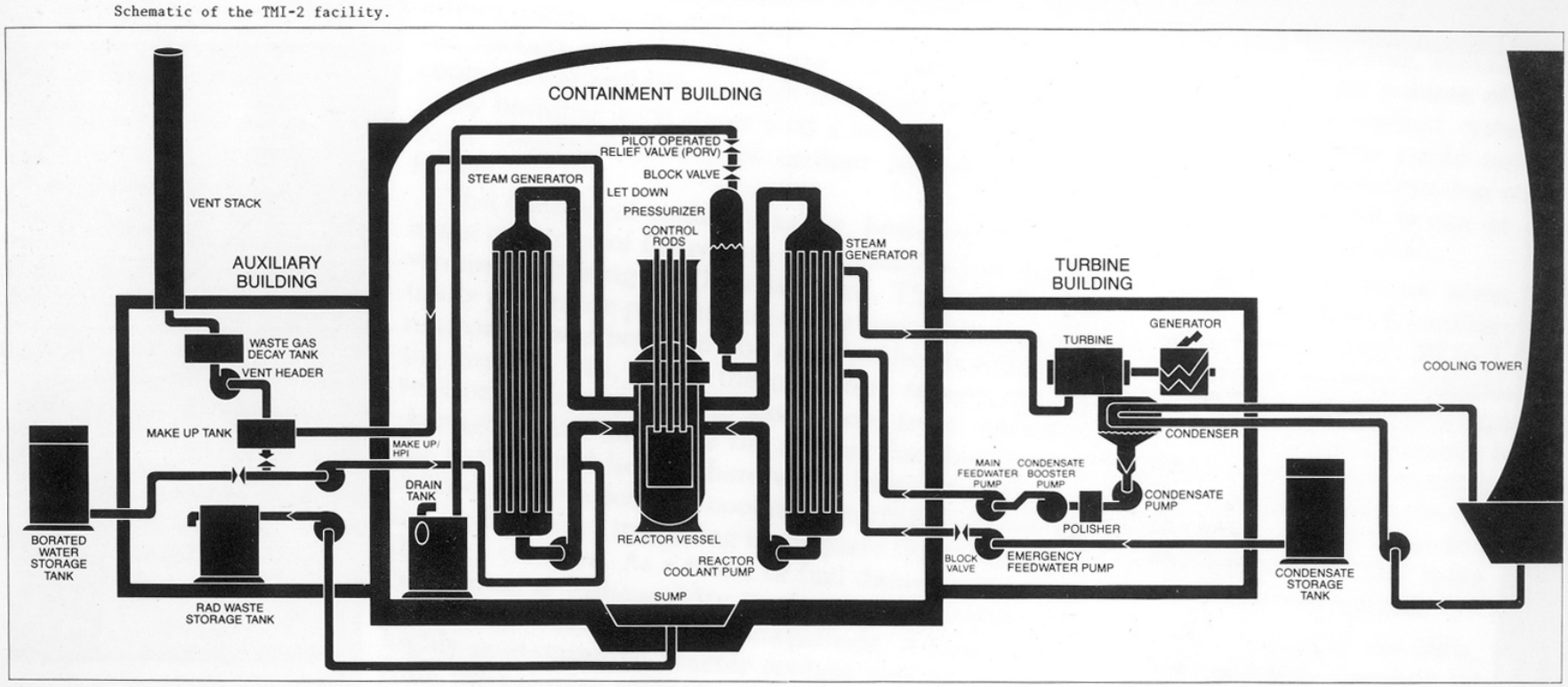

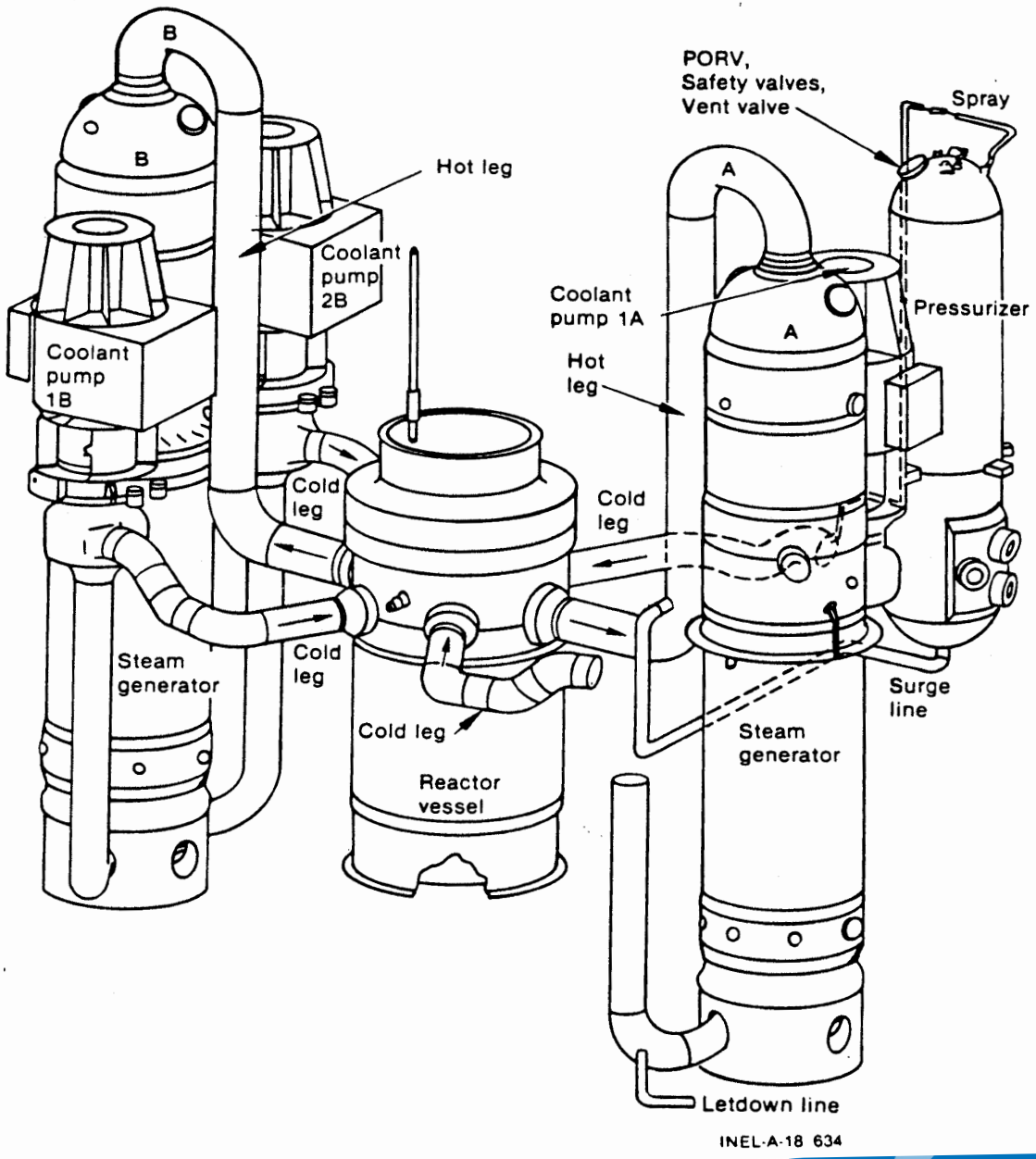

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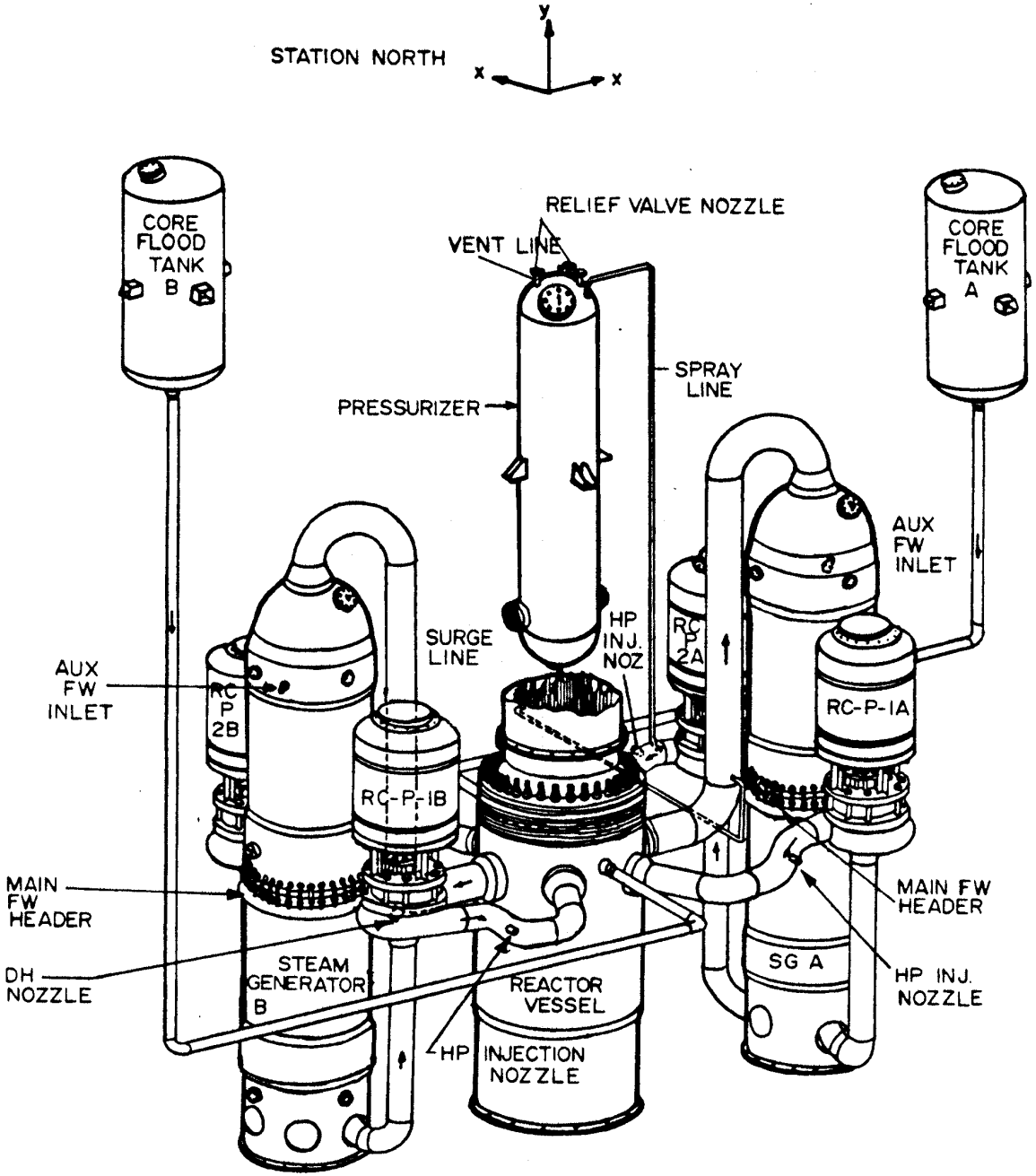
TMI-2 Reactor Coolant System

(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)

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TMI-2 Primary Pressure vs. Time

(Minutes After Reactor Trip)

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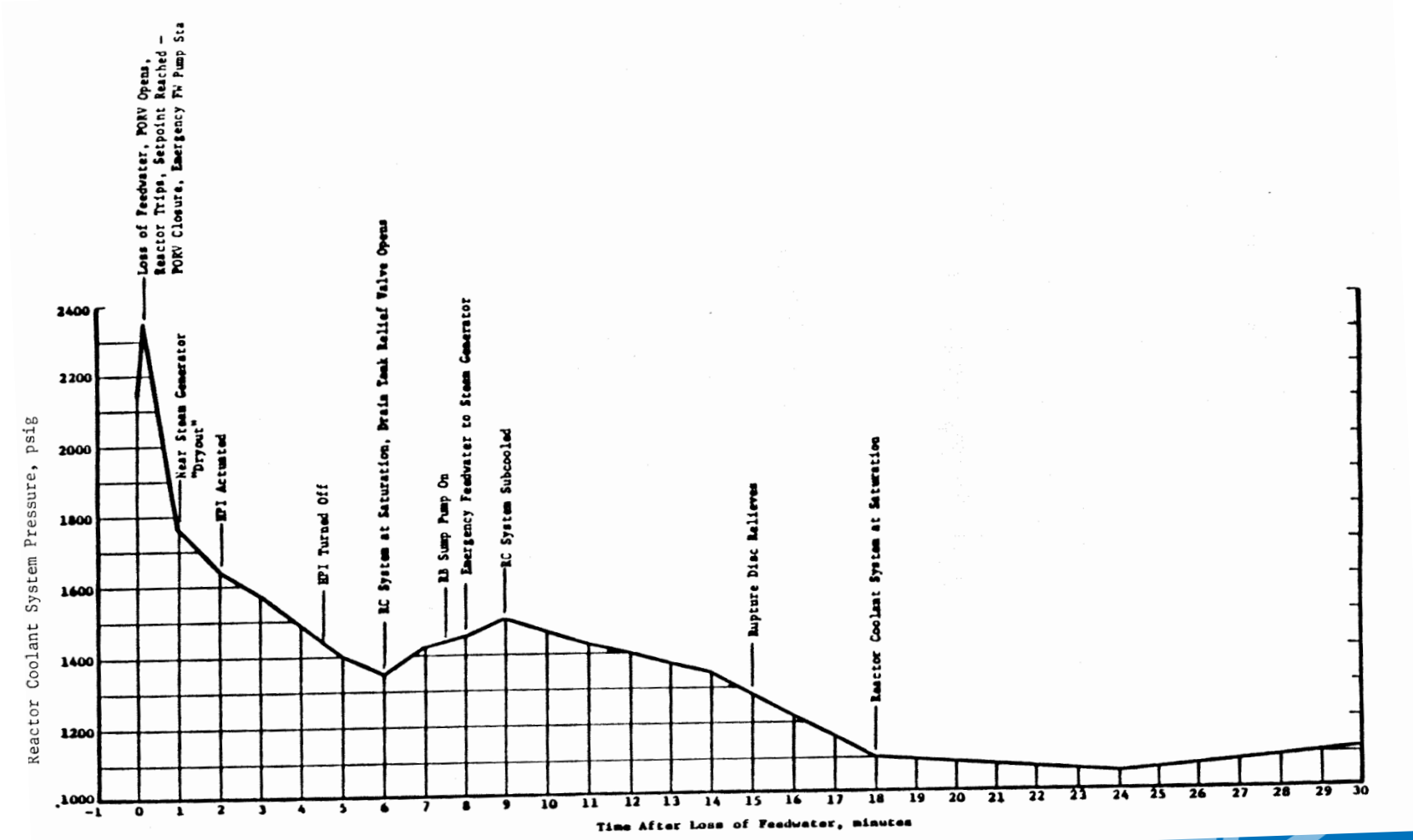

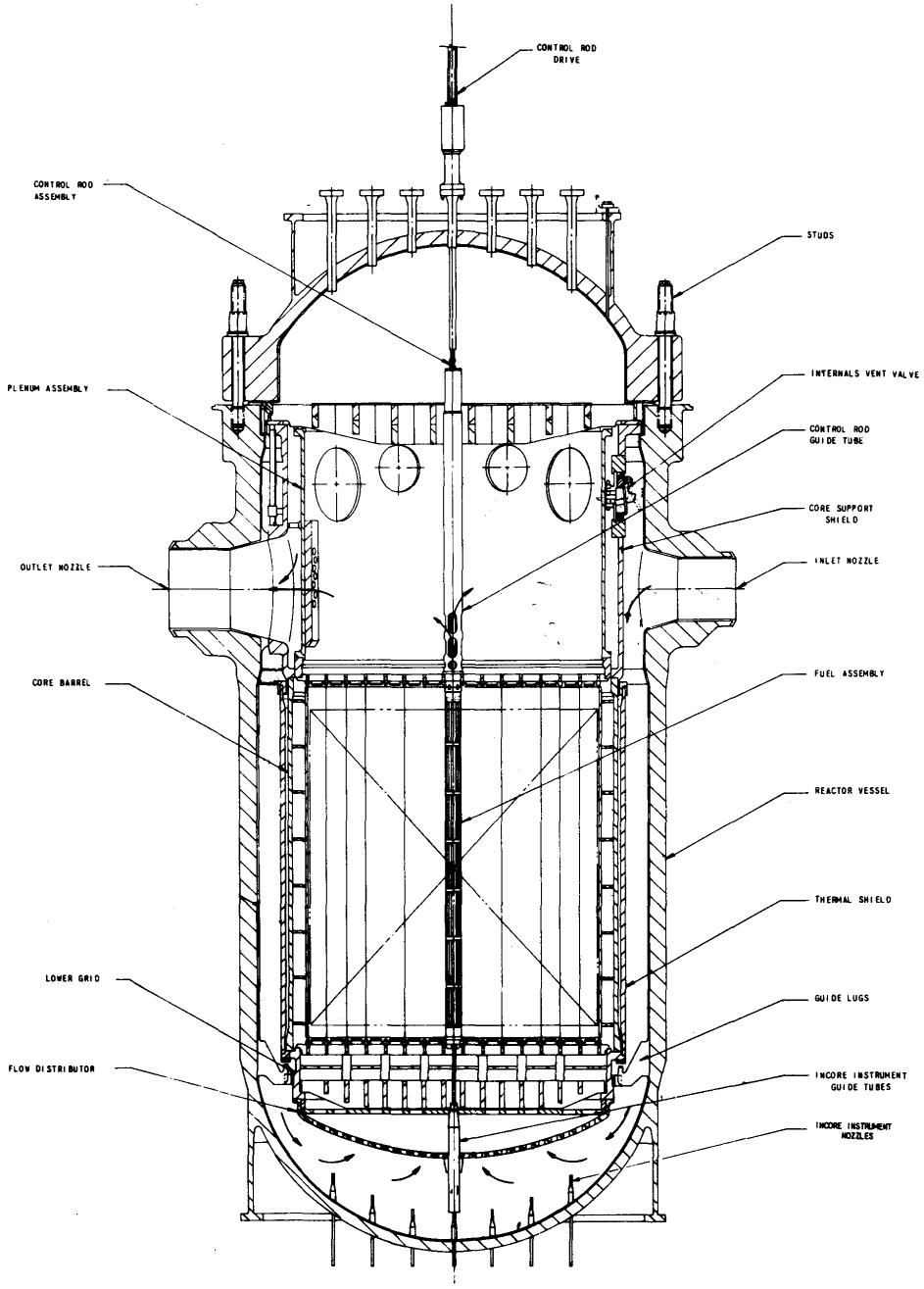

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TMI-2 Reactor Vessel

(Sectional View Showing Internals)

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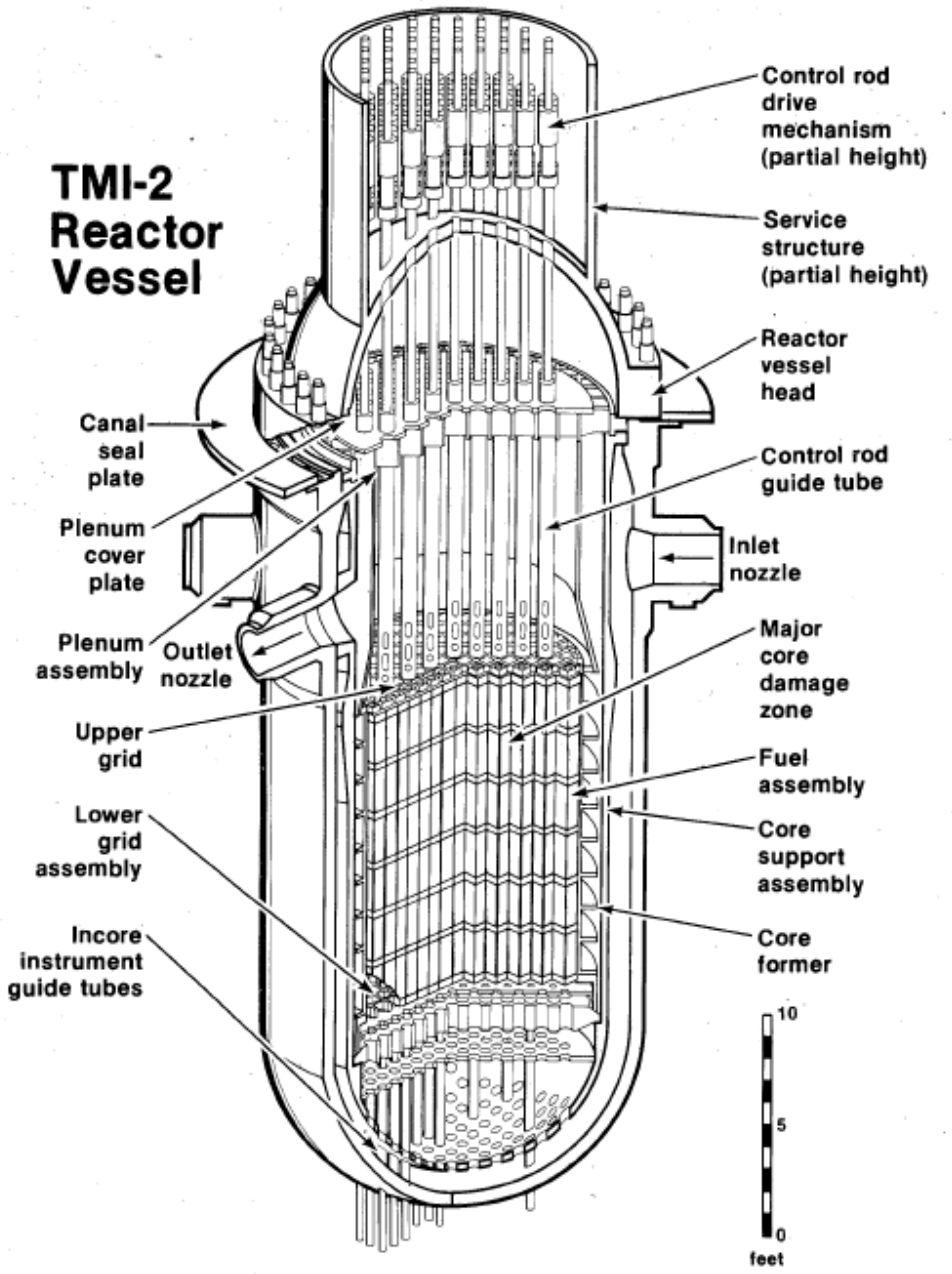
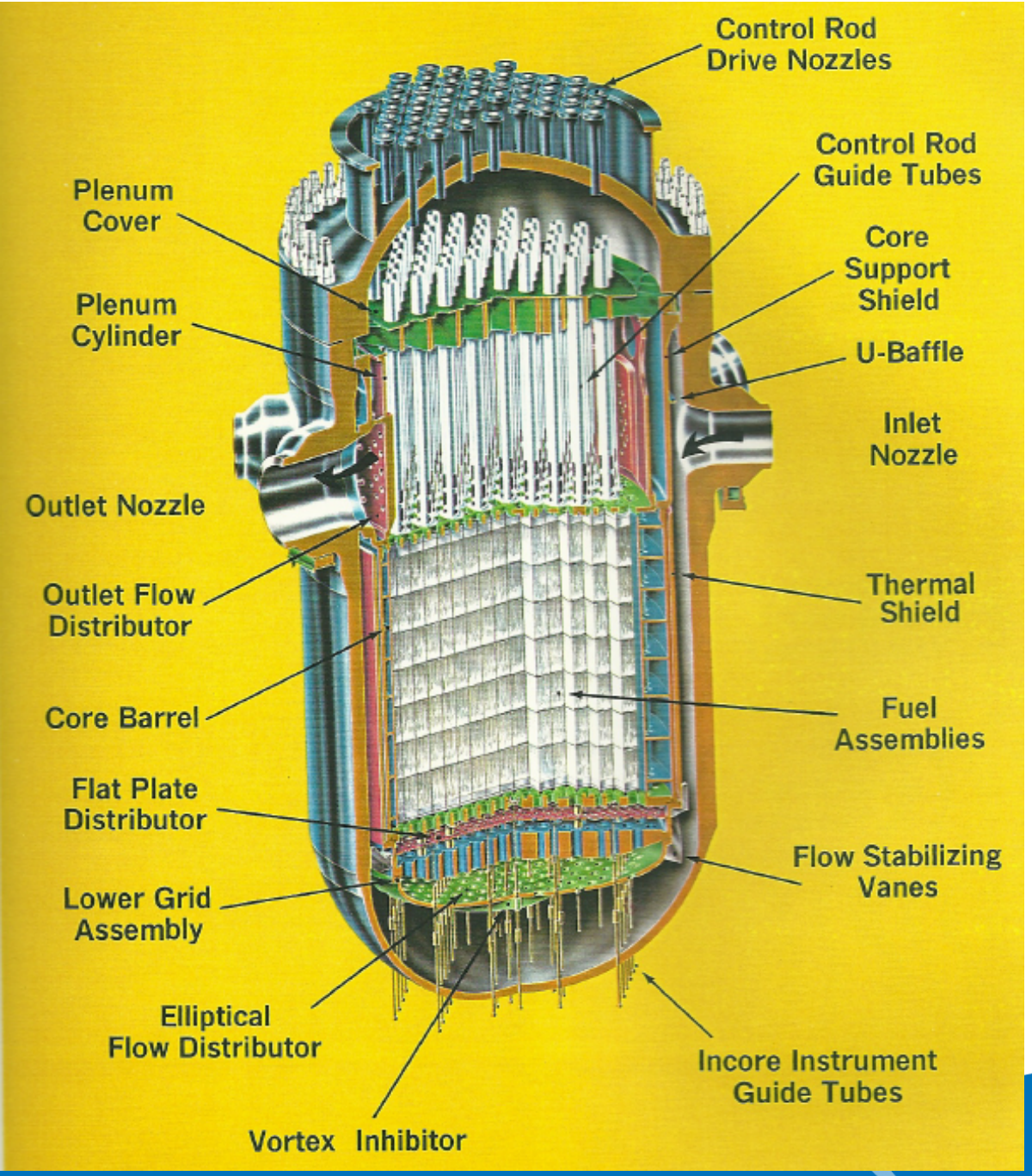
TMI-2 Reactor Vessel
(Pre-accident Cutaway View)





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TMI-2 Reactor Vessel

(Pre-accident Cutaway View)

Primary Pressure vs. Time
(hours after reactor trip)

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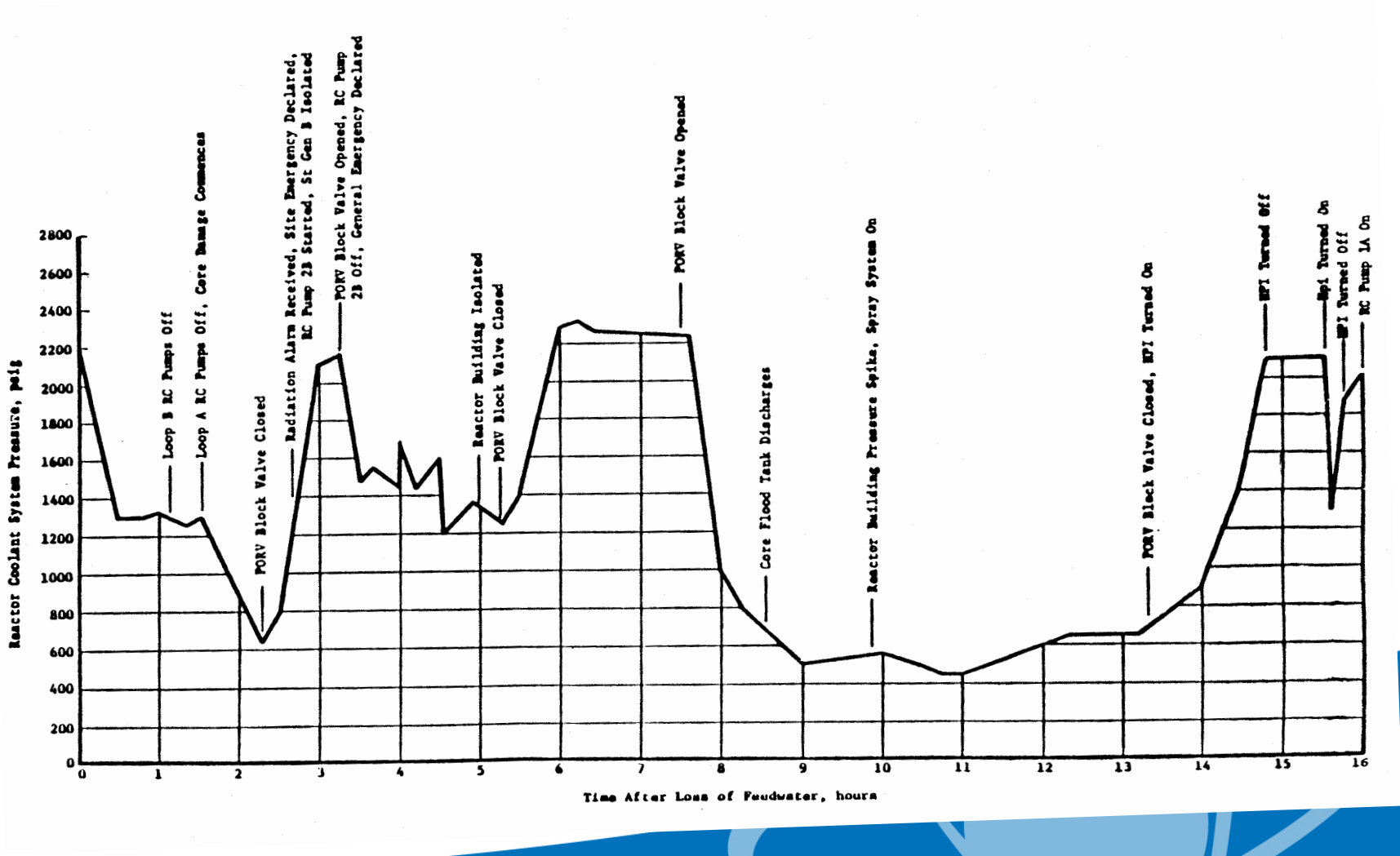

Radionuclide	Half-Life[b] (yr)	Radionuclide Activity (Ci)[a] At Shutdown (t_d = 0)	After Decay (t_d = 63 months)
^{3}H [c]	12.33	4.1×10^{3}	3.1×10^{3}
^{85}Kr	10.7	9.7×10^{4}	6.9×10^{4}
^{90}Sr-Y	28.8	7.5×10^{5}	6.6×10^{5}
^{106}Ru-Rh	1.01	3.3×10^{6}	9.0×10^{4}
^{125}Sb	2.7	1.2×10^{5}	3.3×10^{4}
^{134}Cs	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.

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Radionuclide Activities for TMI-2

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

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

Telephone Bench, Inside Reactor Building

(Due South Against Liner, GEND-006)

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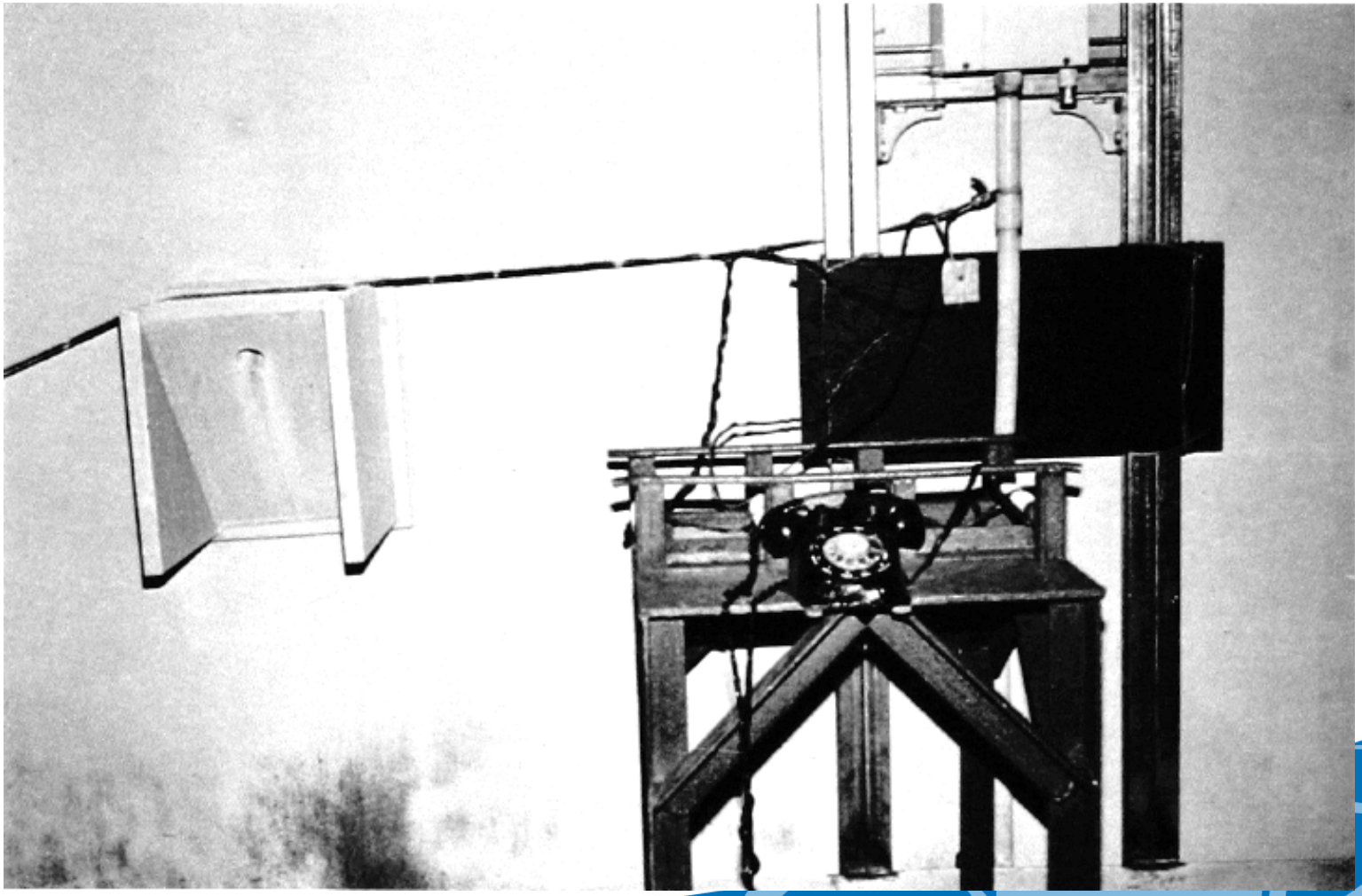

Telephone Bench (Continued)

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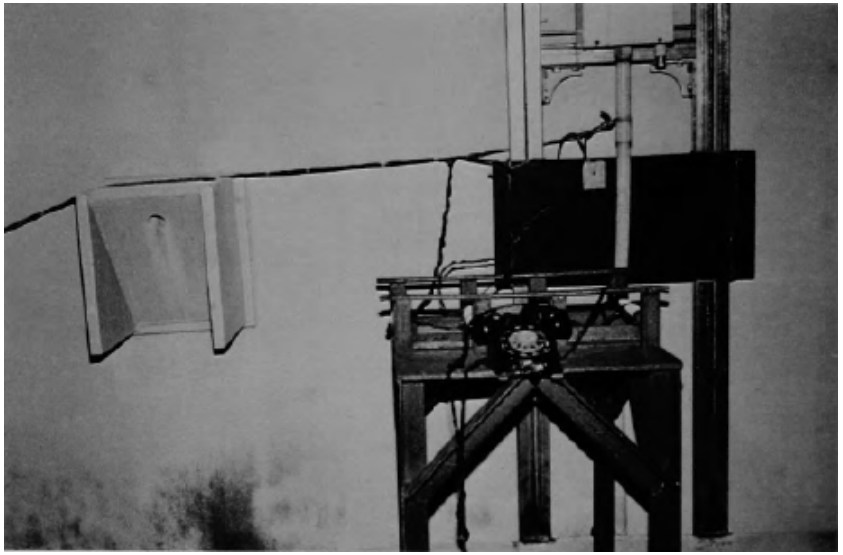

55 Gallon Drum, Inside Reactor Building

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

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

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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)

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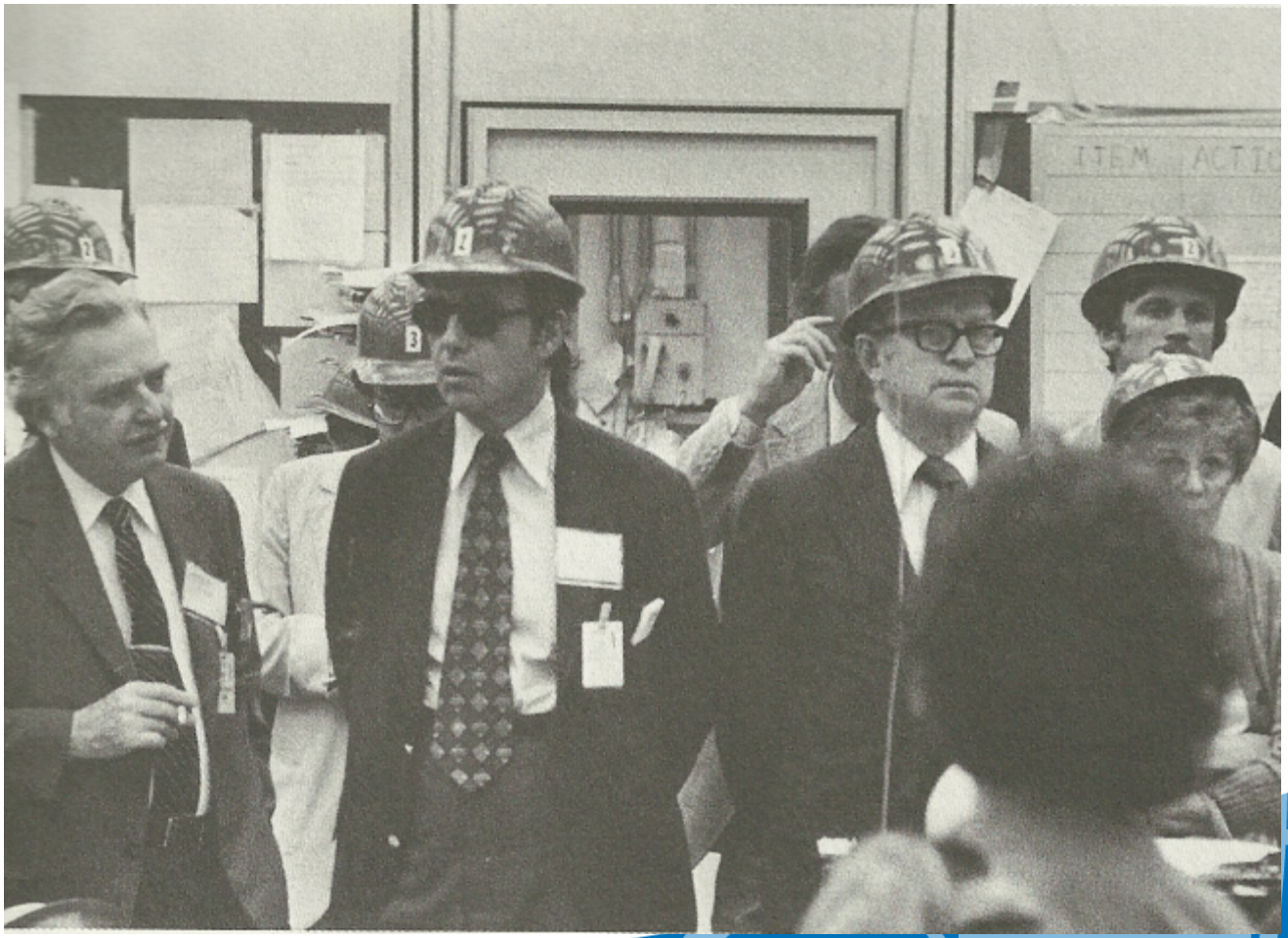

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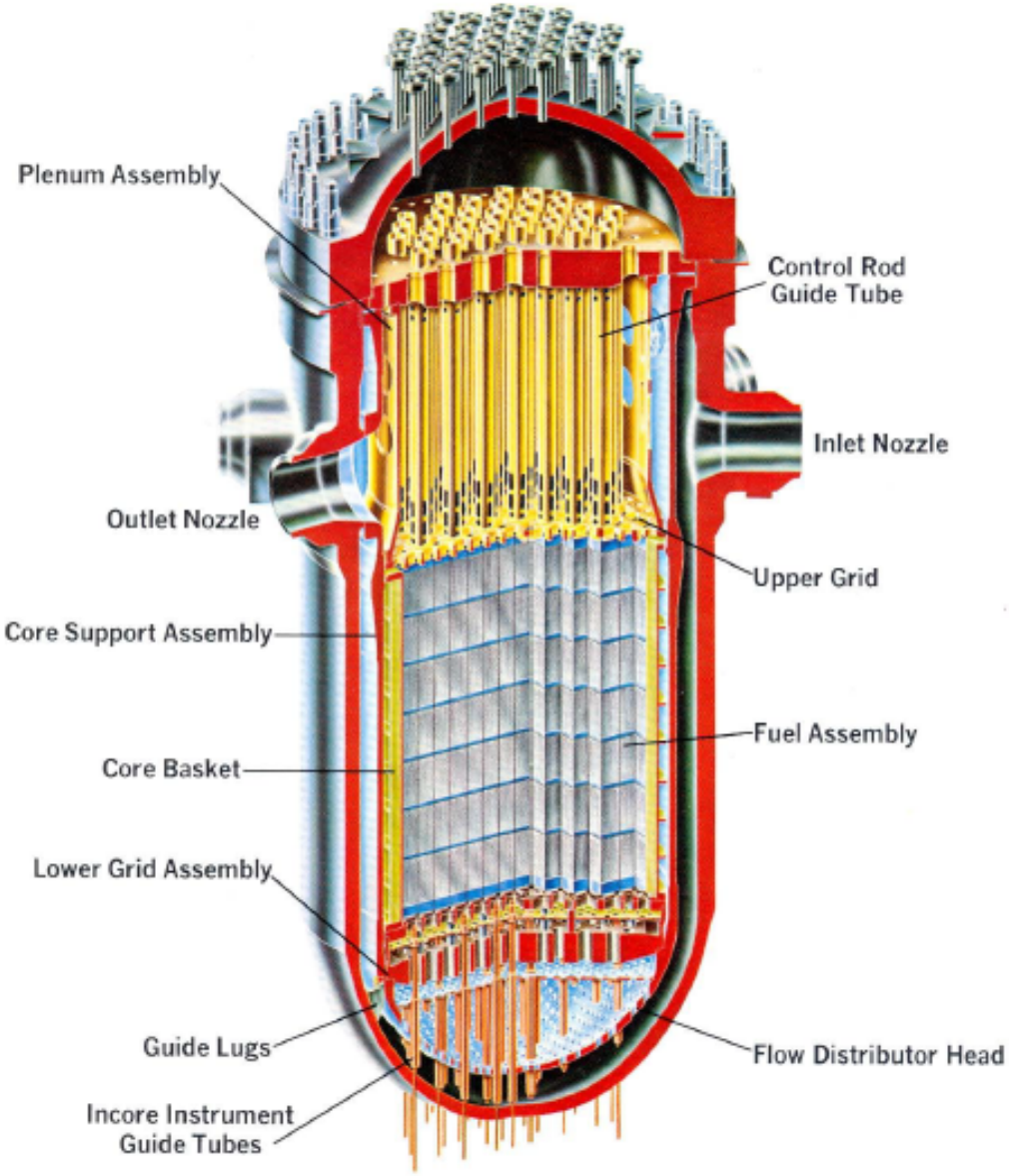
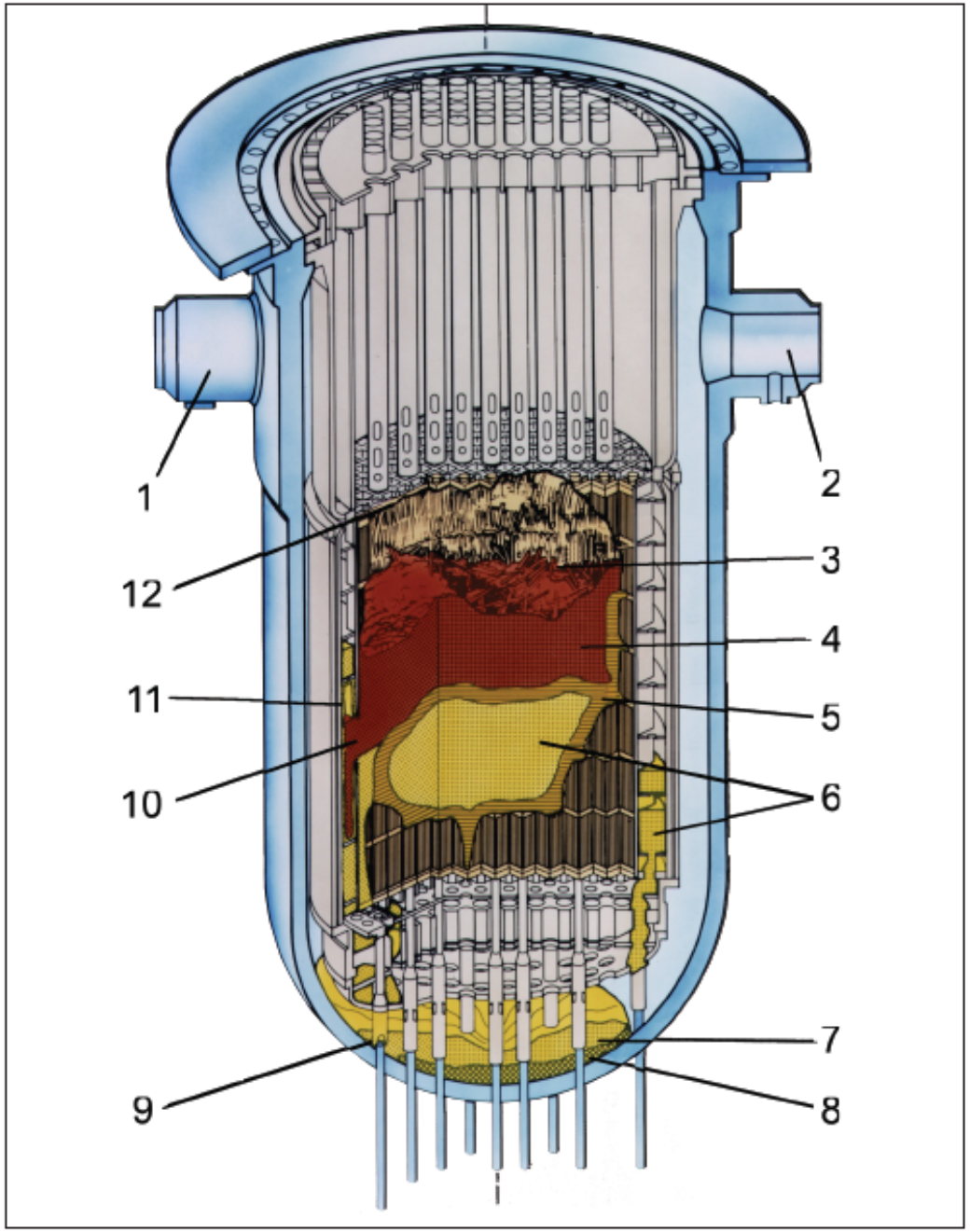
Typical B&W Reactor Vessel

(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)

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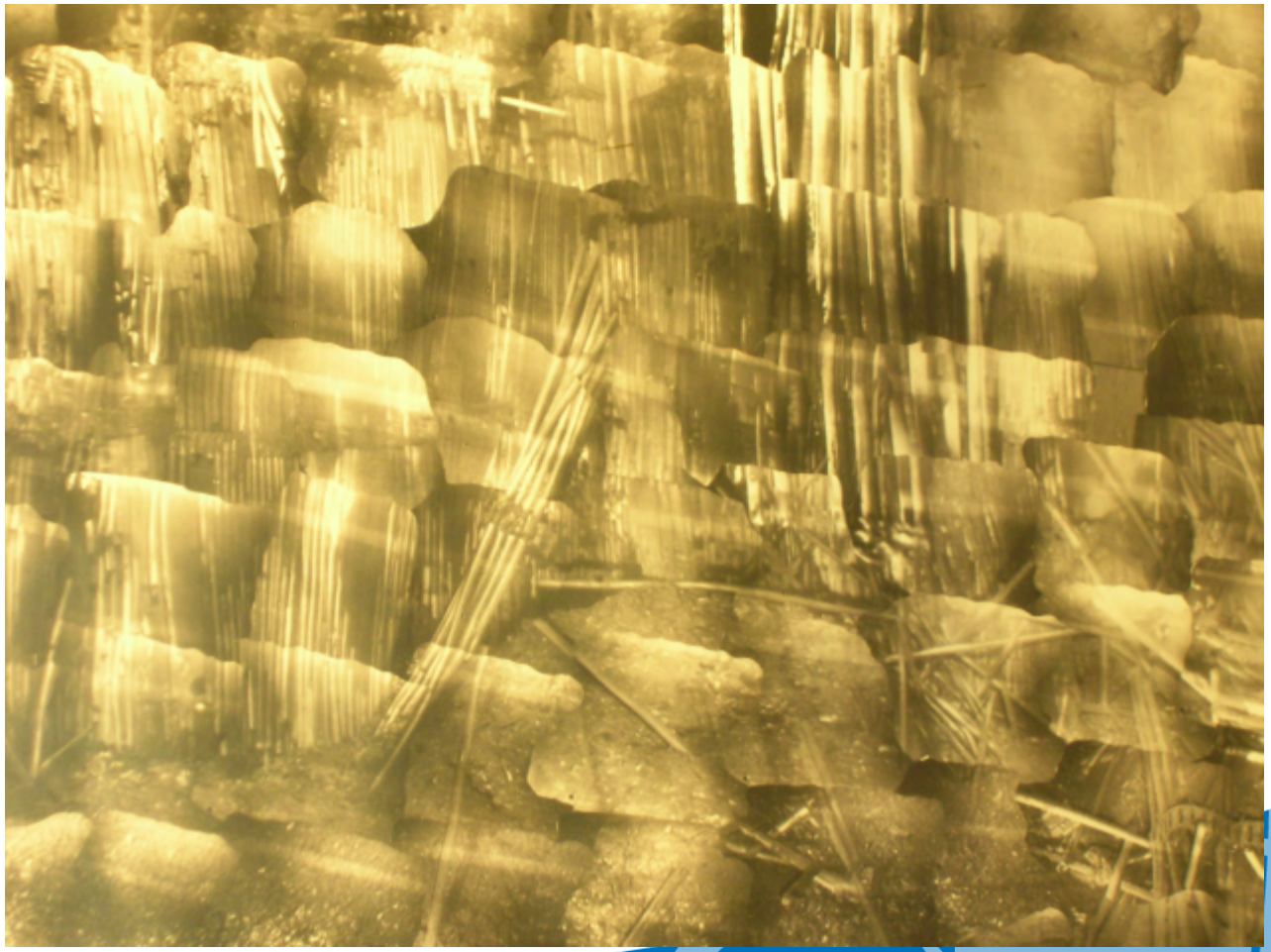

Mosaic Panorama View of Reactor Core Cavity

(Axial Power Shaping Control Rod Hanging at Top)

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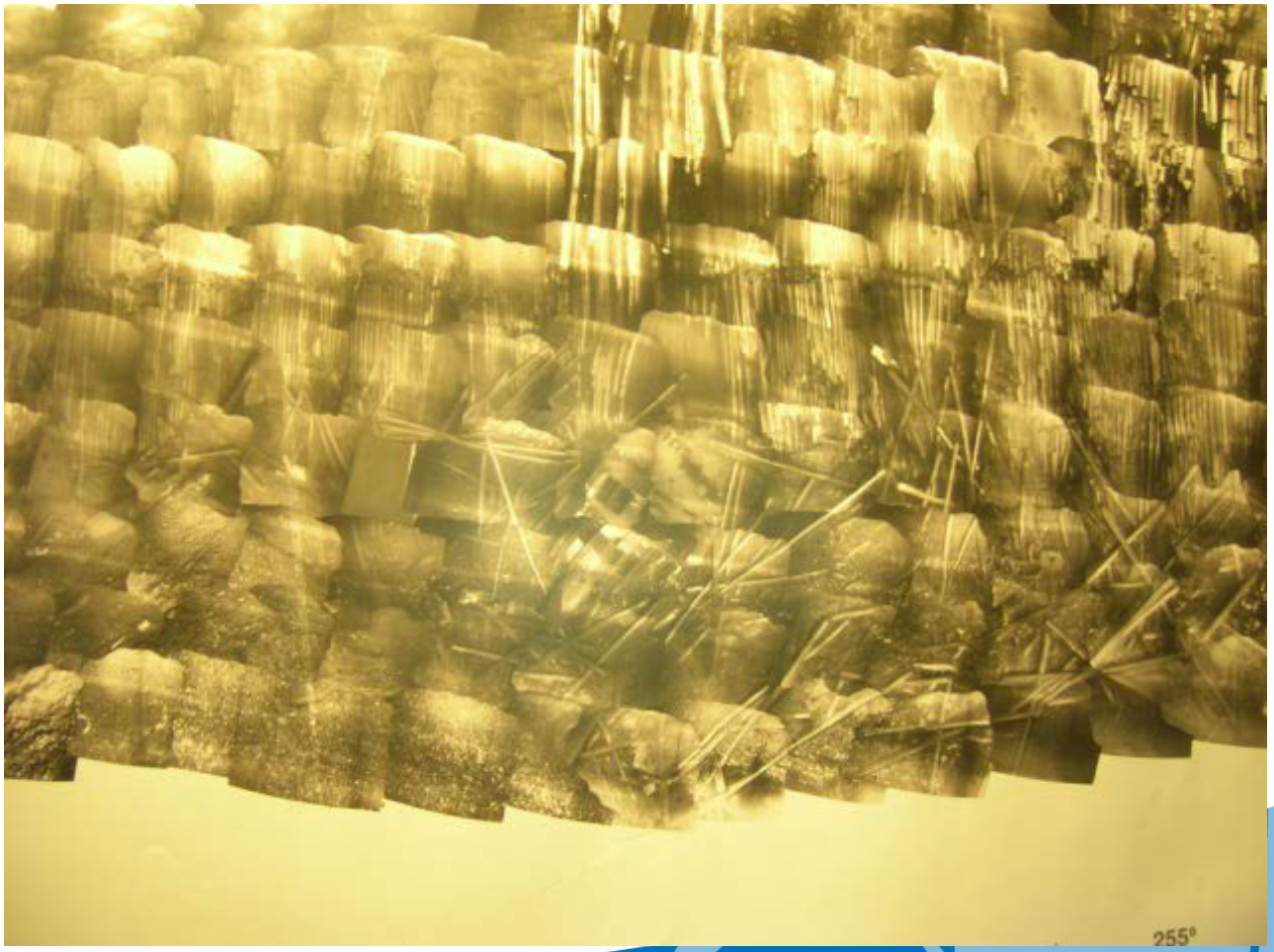

Mosaic Panorama View of Reactor Core Cavity

(Rubble Bed at Bottom)

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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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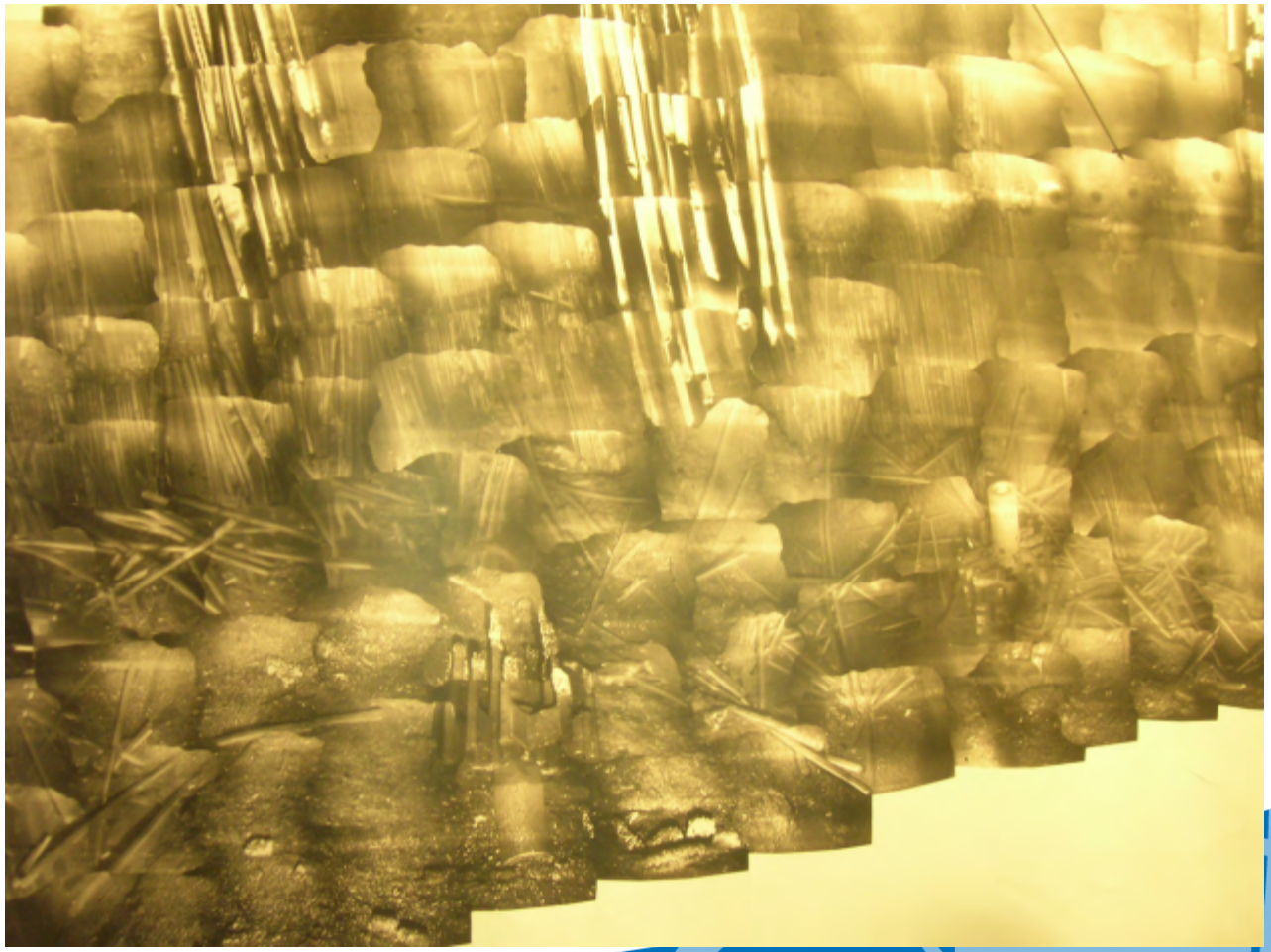

Channel 6 Action News

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Aerial of TMI on April 9, 1979
(Unit 2 Bottom Middle)

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TMI-2 Design Features

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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

Primary Pressure vs. Time
(Months After Reactor Trip)

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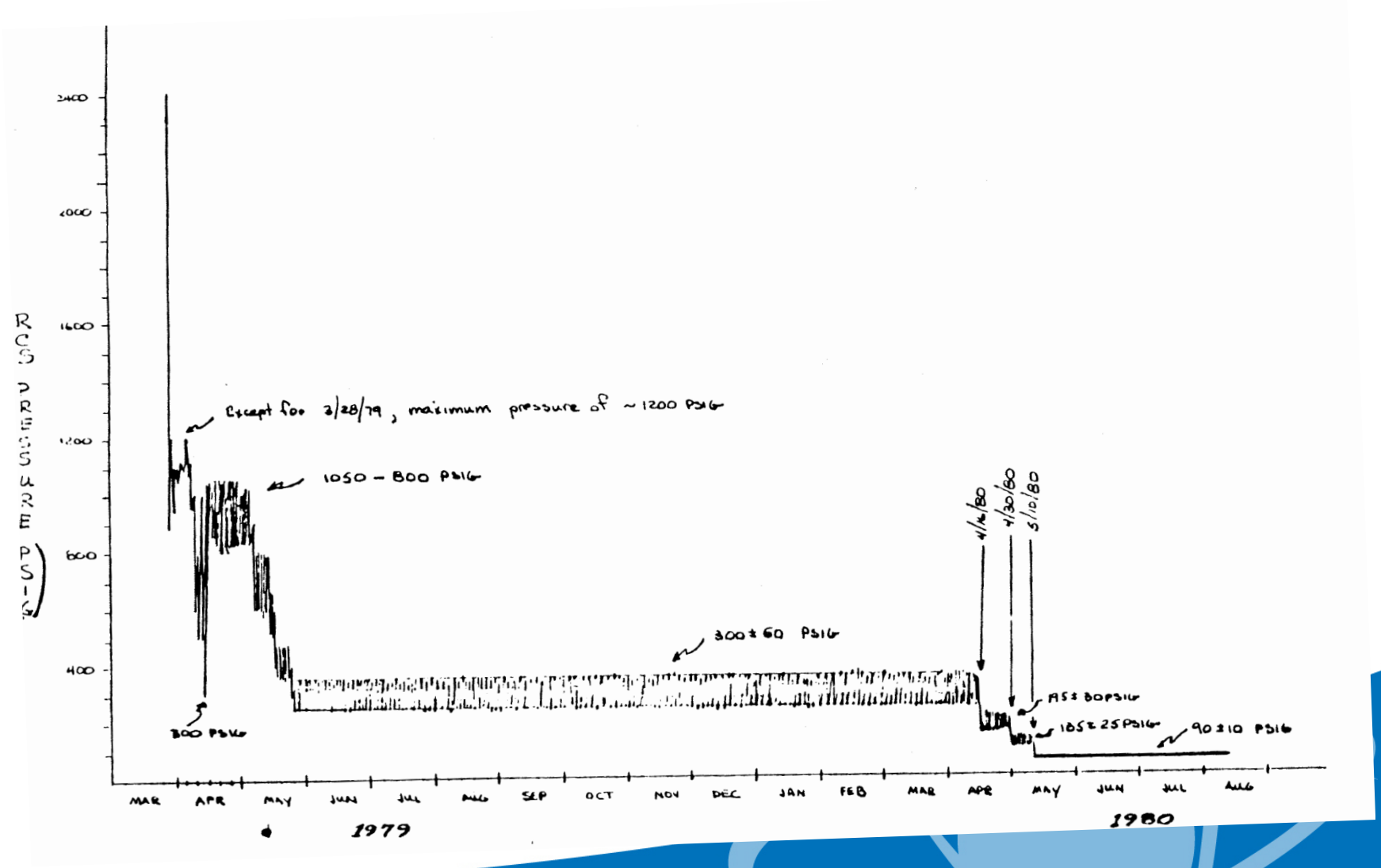

Standby Pressure Control System (SPCS)

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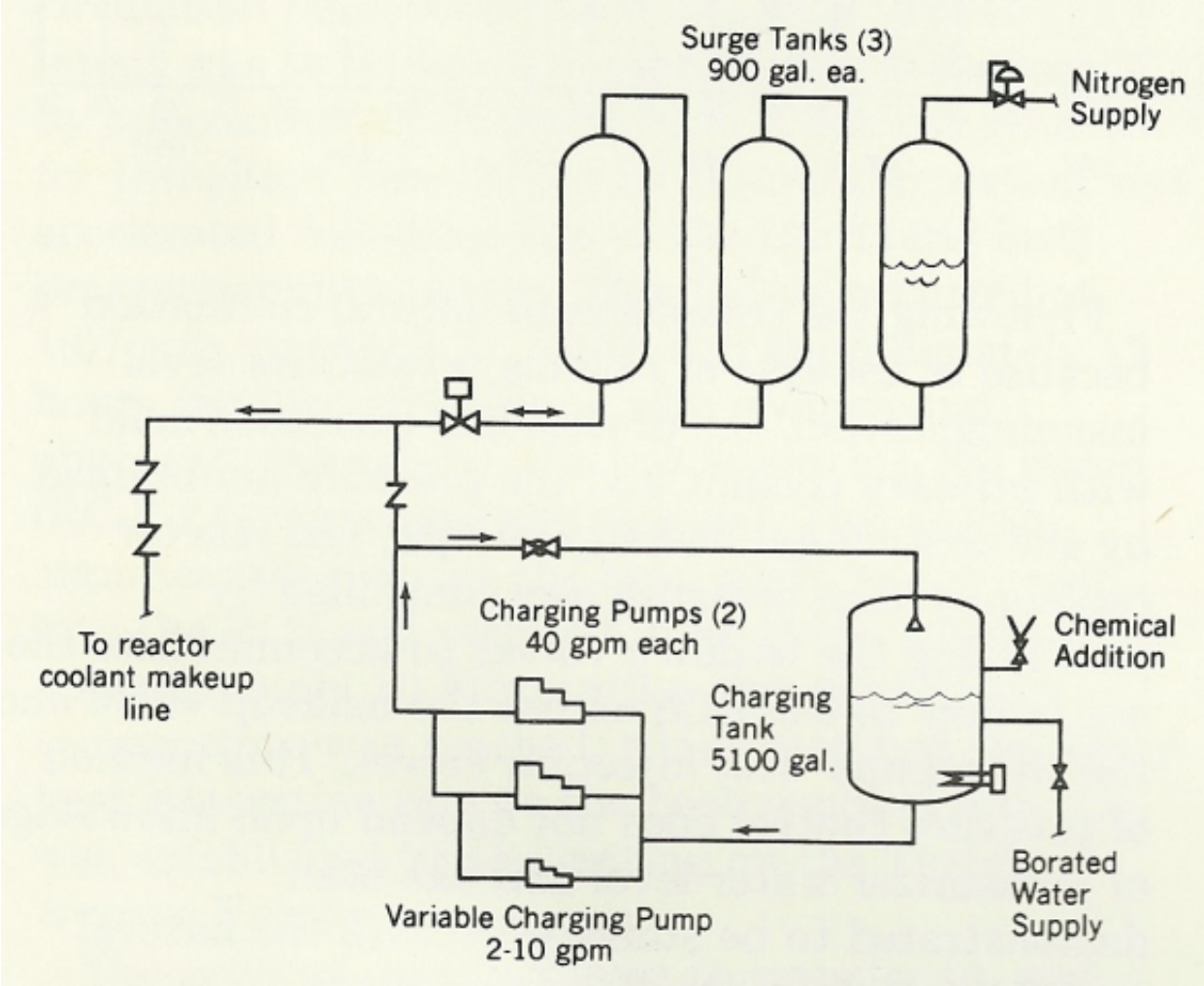

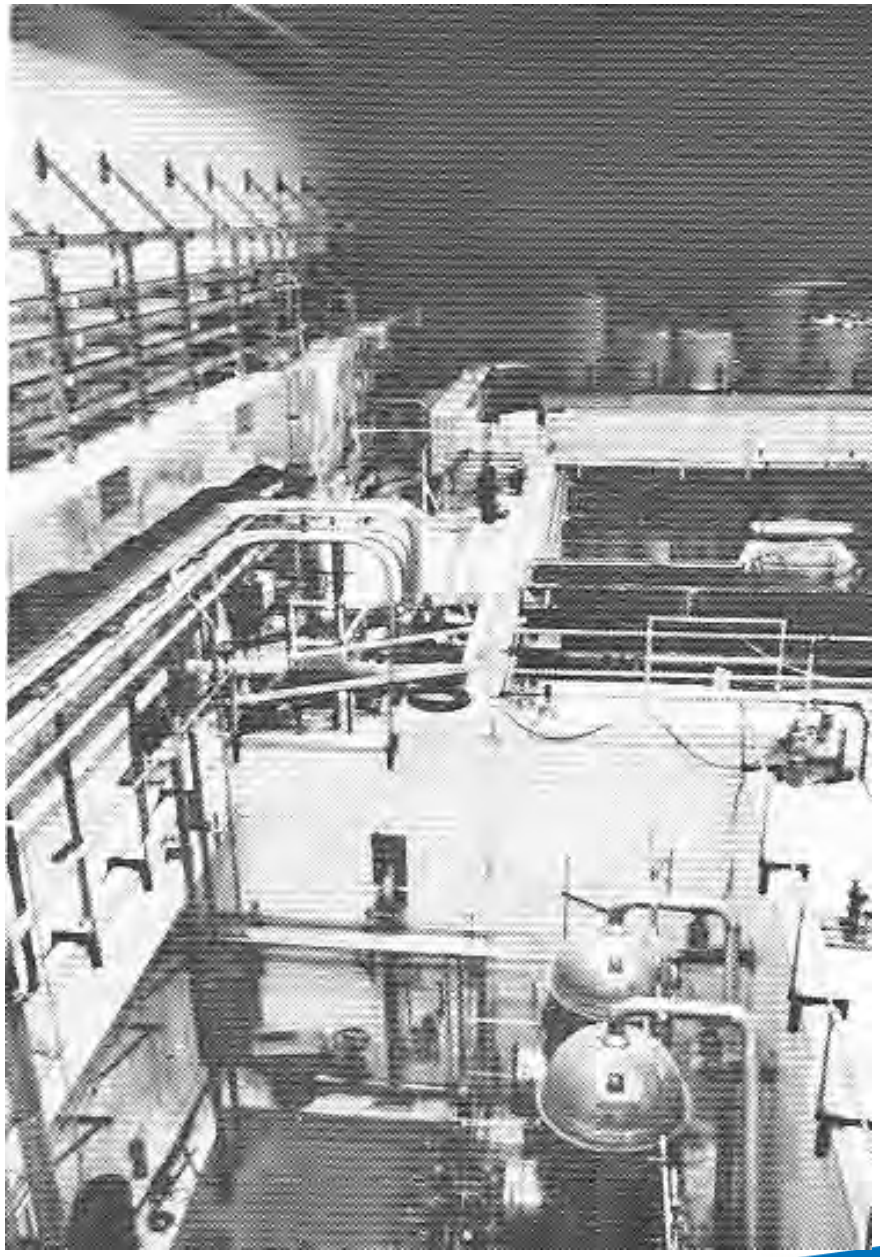

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New Fuel Storage Area in Fuel Handling Building Modified for SPCS

(Surge Tanks Lower Right)

Standby Pressure Control System, 900-gal Surge Tanks

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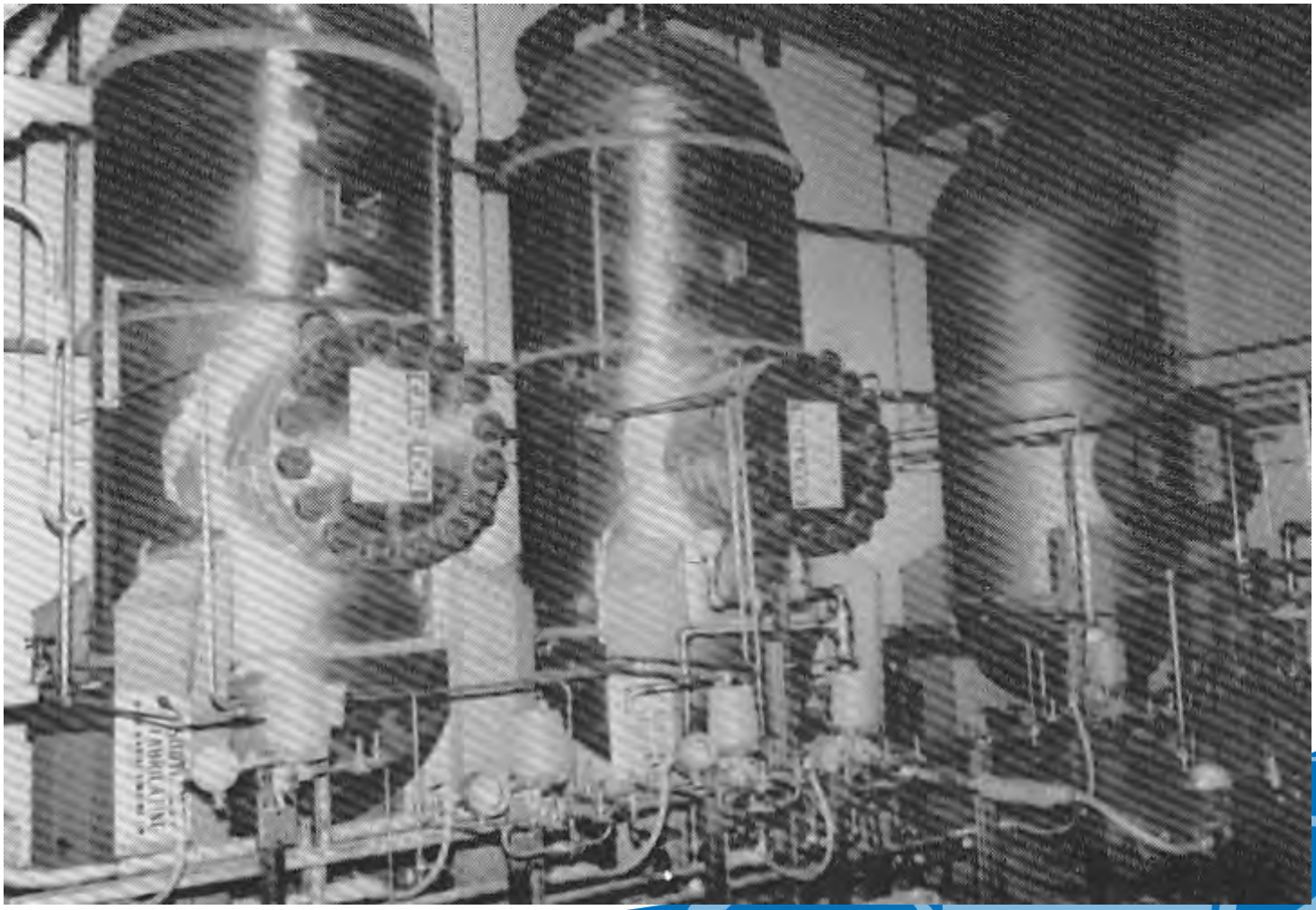

Long Term Backup Cooling System

(Cooler and Shell Side Cooling Lines)

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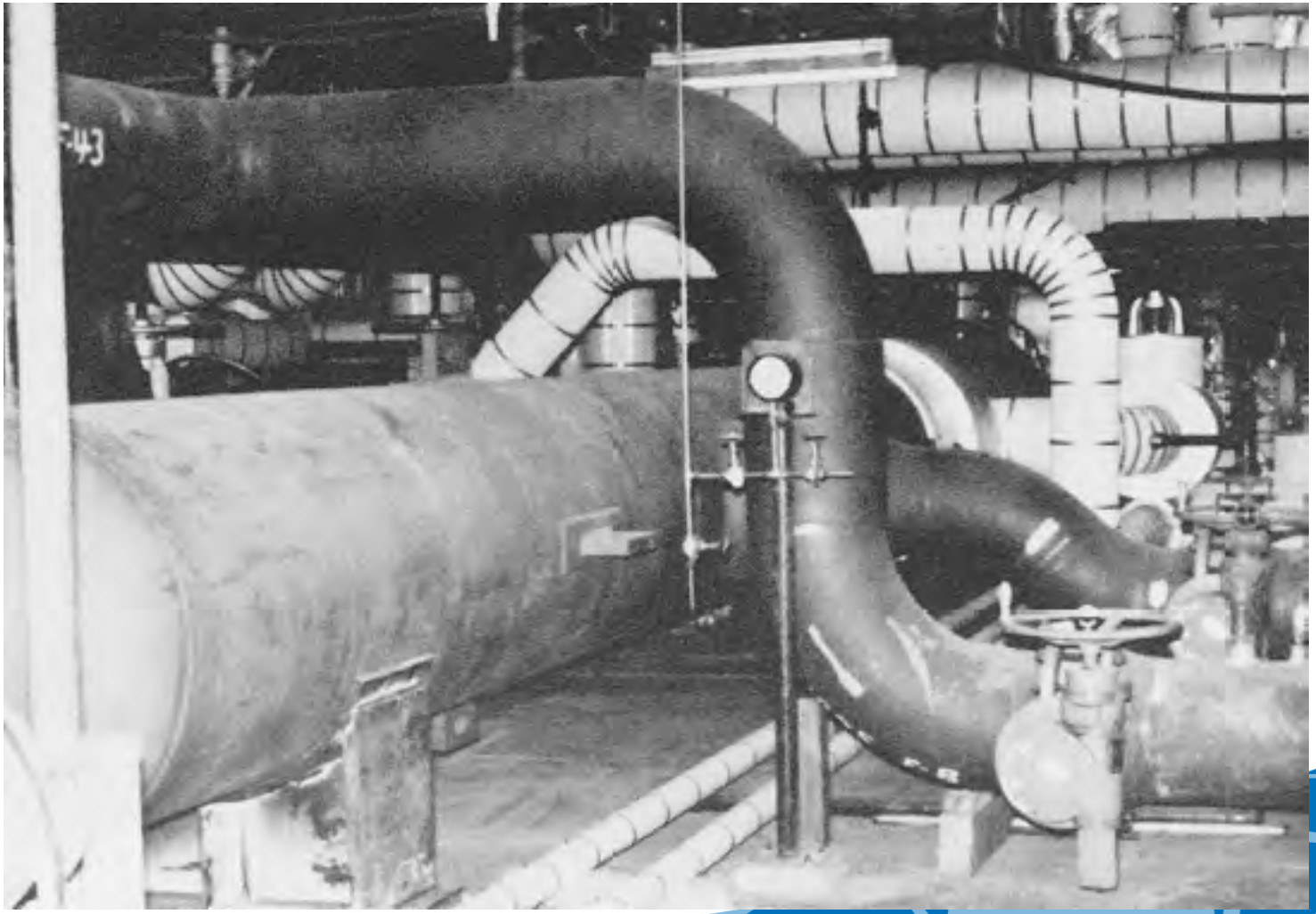

Long Term Backup Cooling System

(Tie-in Point New Pump)

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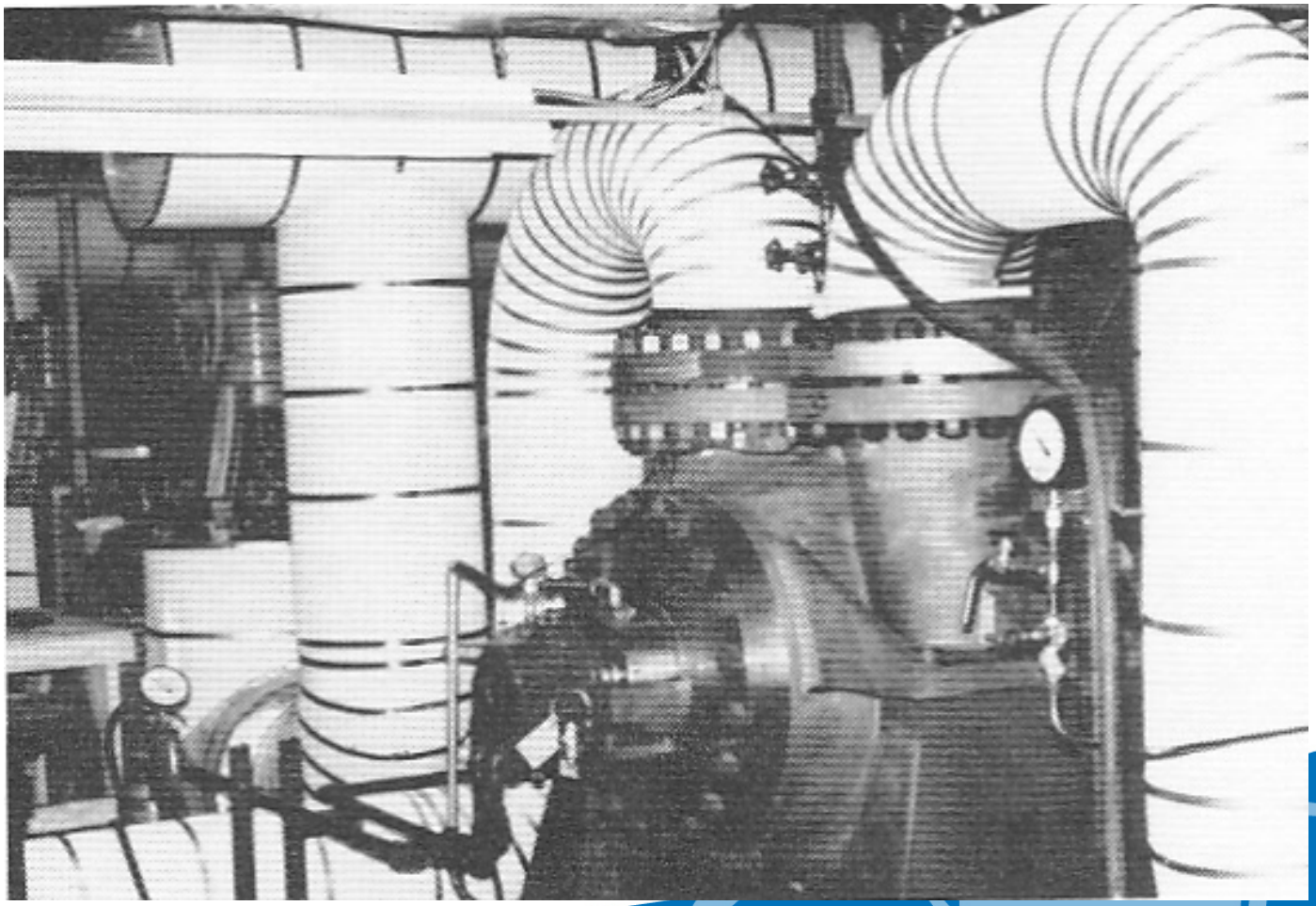

Mini Decay Heat Removal System

(Fabrication at Lynchburg, VA)

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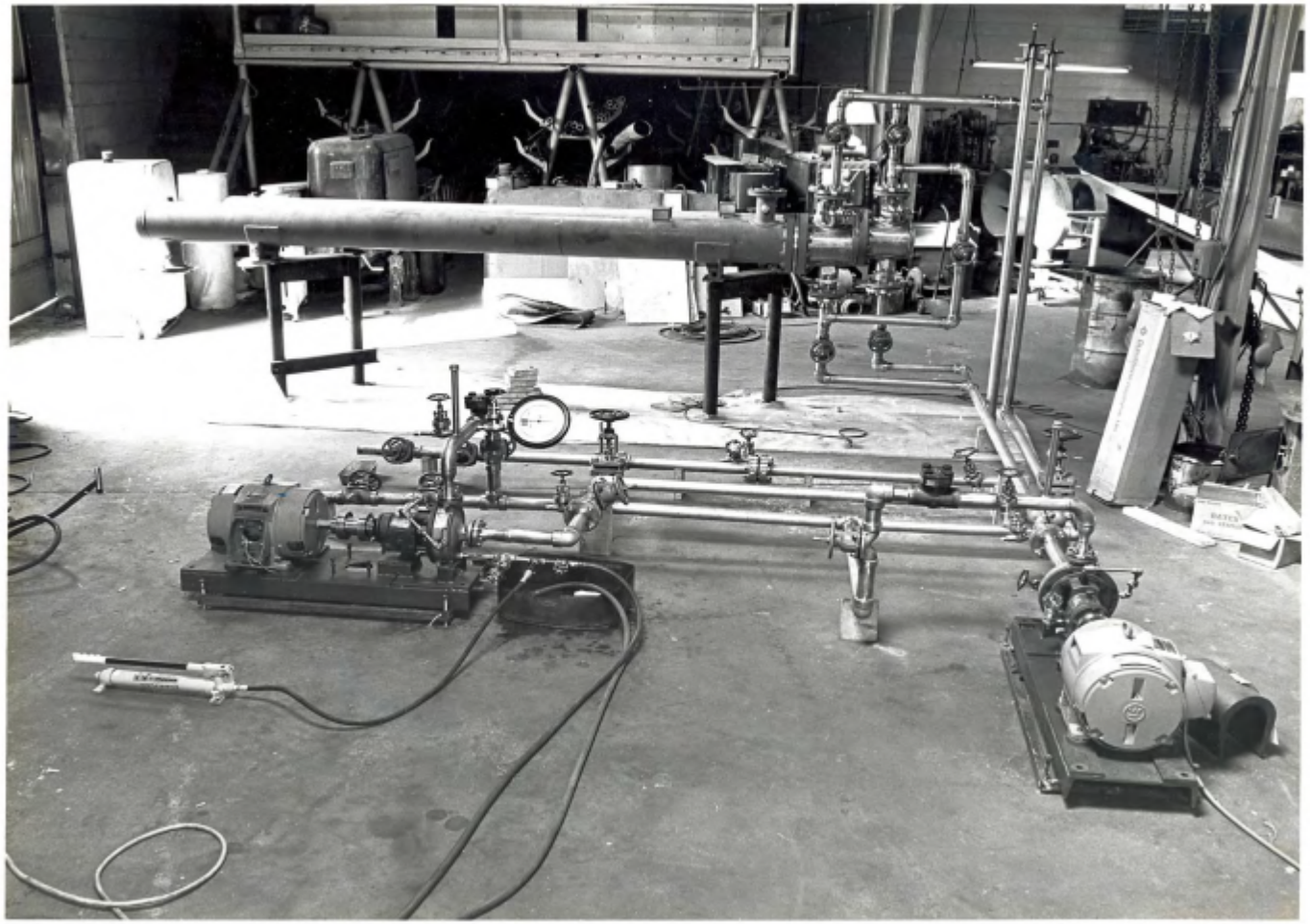

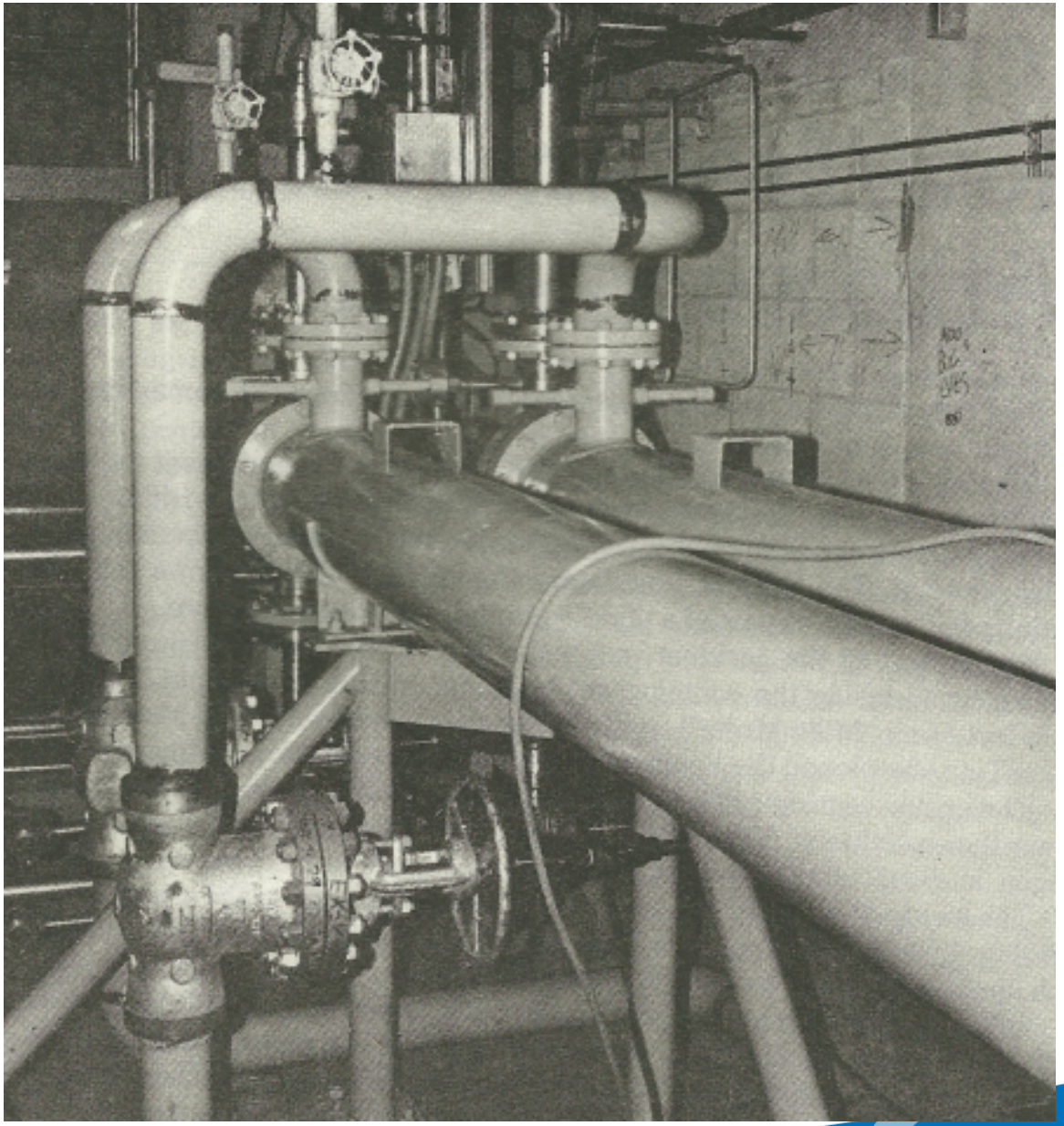

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Mini Decay Heat Removal System

(Became Operational in October 1980)

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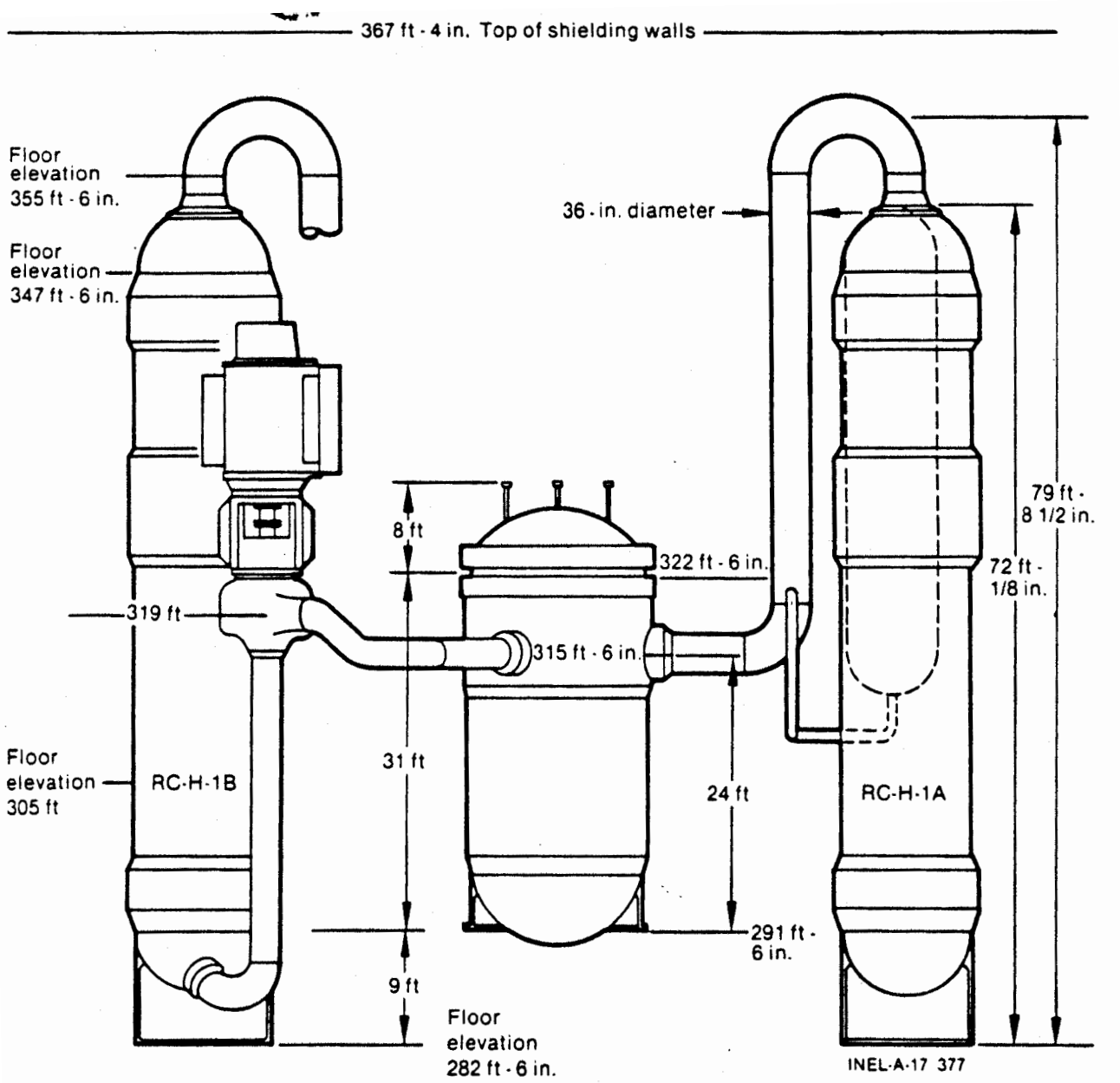
TMI-2 Reactor Coolant System

(Physical Arrangement and Elevations)



Primary Temperatures vs. Time

(B-Loop "Burp" Transients)

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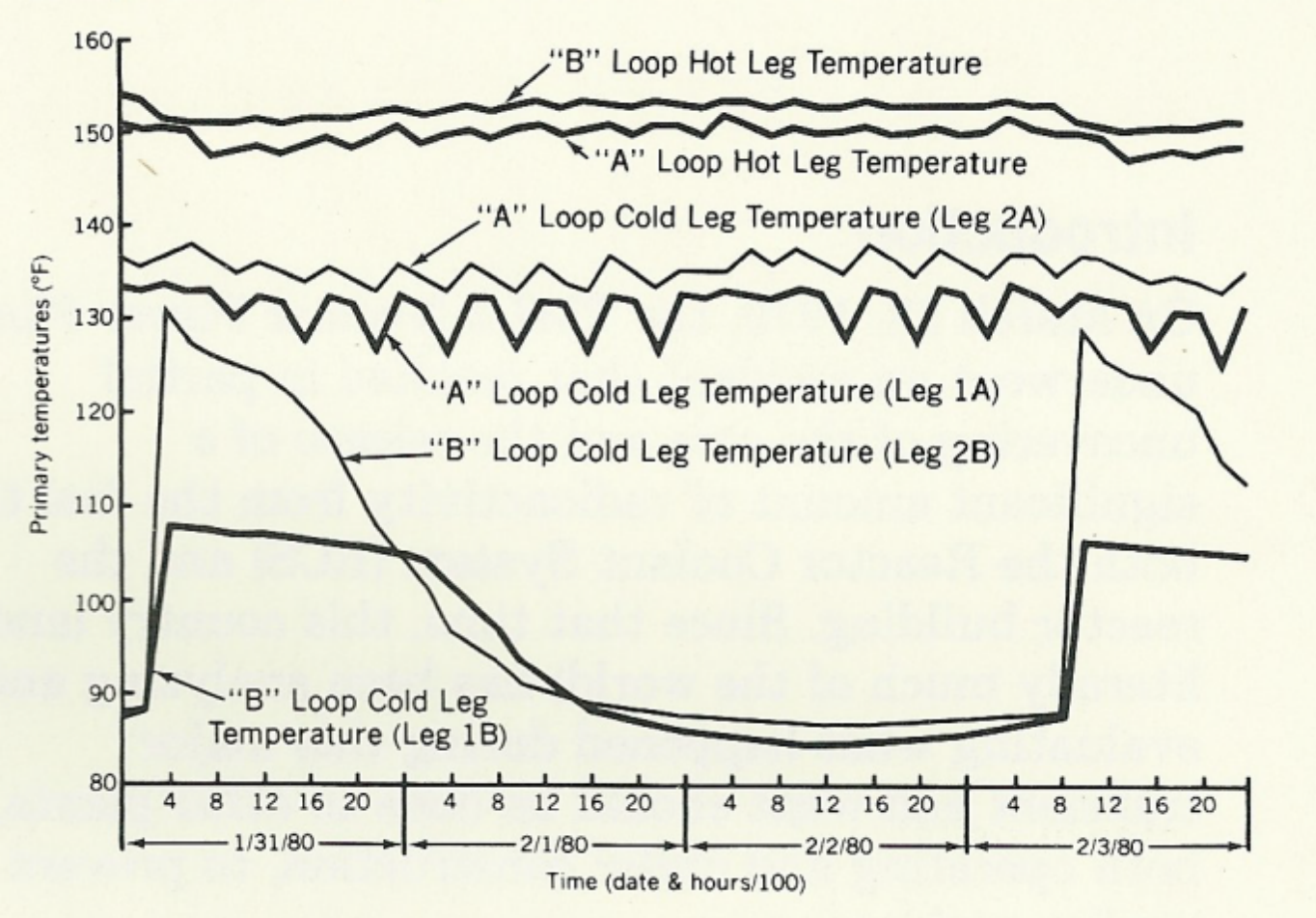

TMI-2 Expected Decay Heat Load vs. Time, 1980

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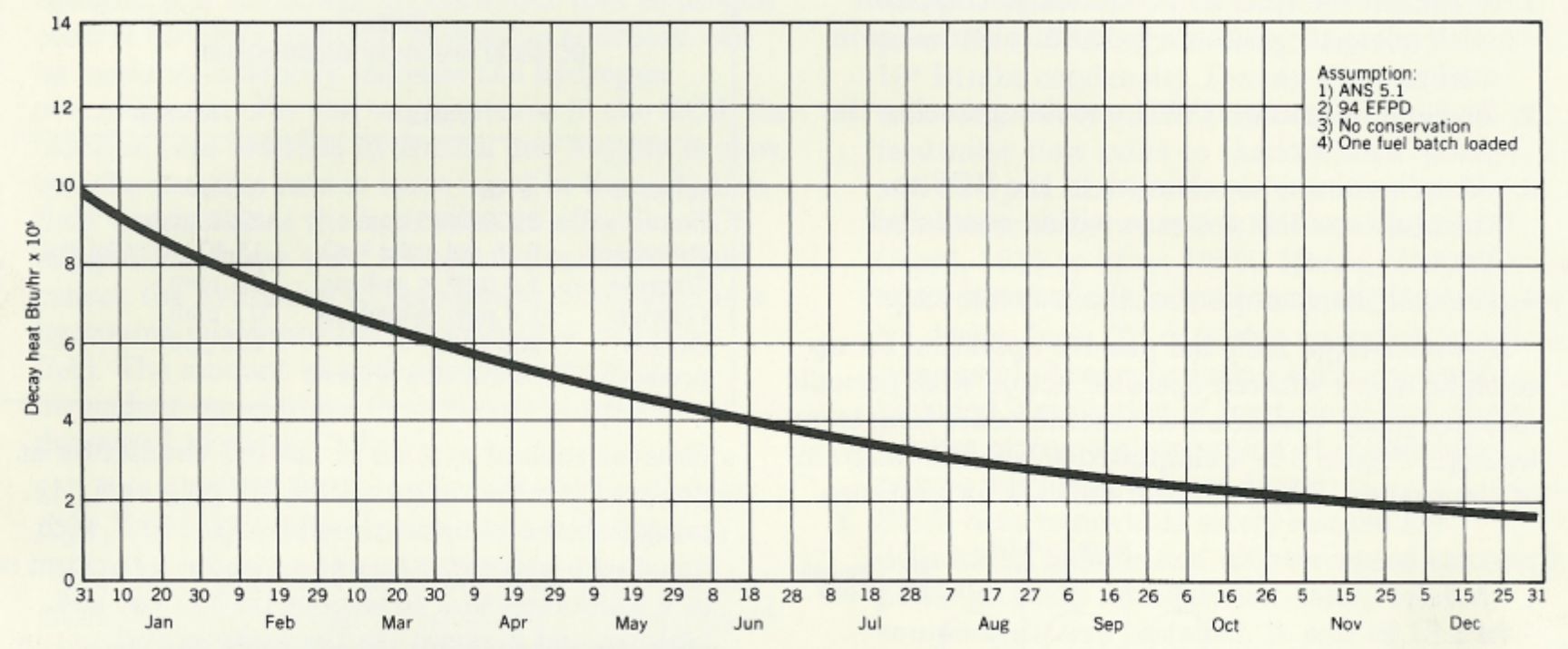

TMI-2 Recovery Tech Specs - NUREG-0432 - Feb 13, 1980

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"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."

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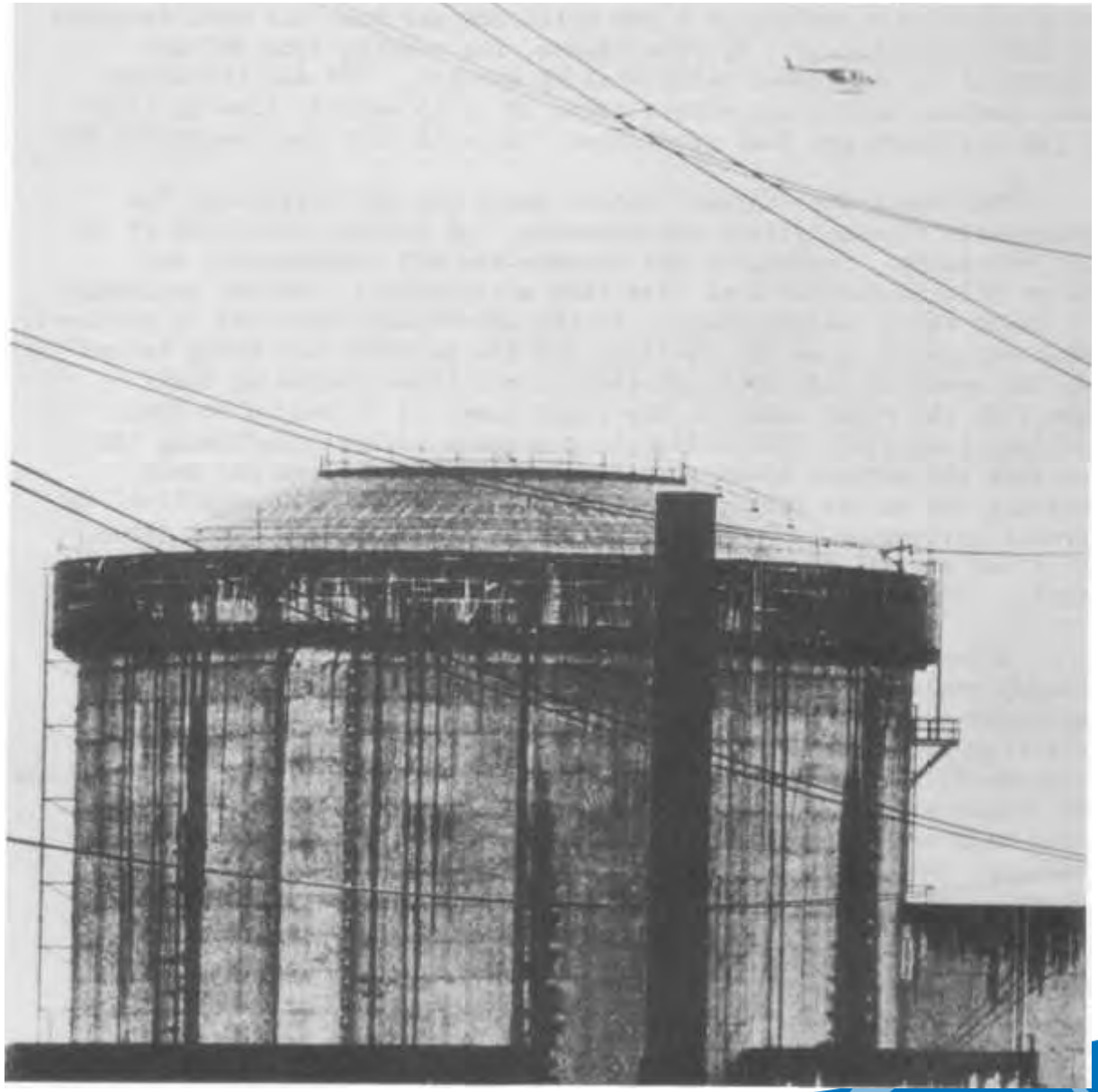
TMI-2 Reactor Building Vent Stack



Unit 2 Reactor Building Venting

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

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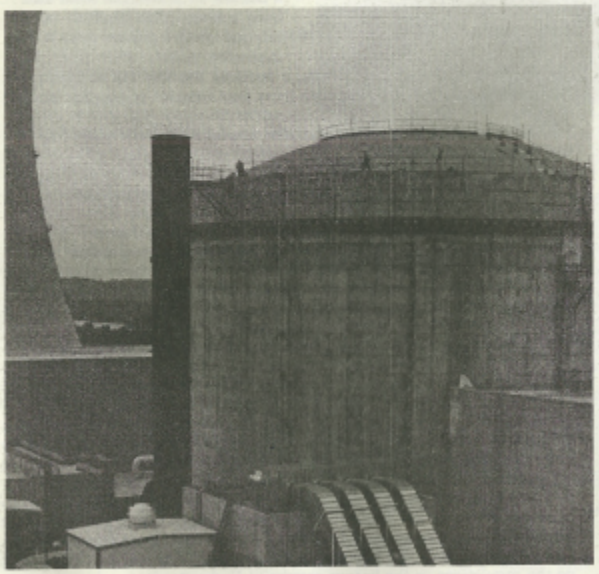
TMI today

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.

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Inside Reactor Building Airlock

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

Inside Reactor Building (1980)

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Inside Reactor Building

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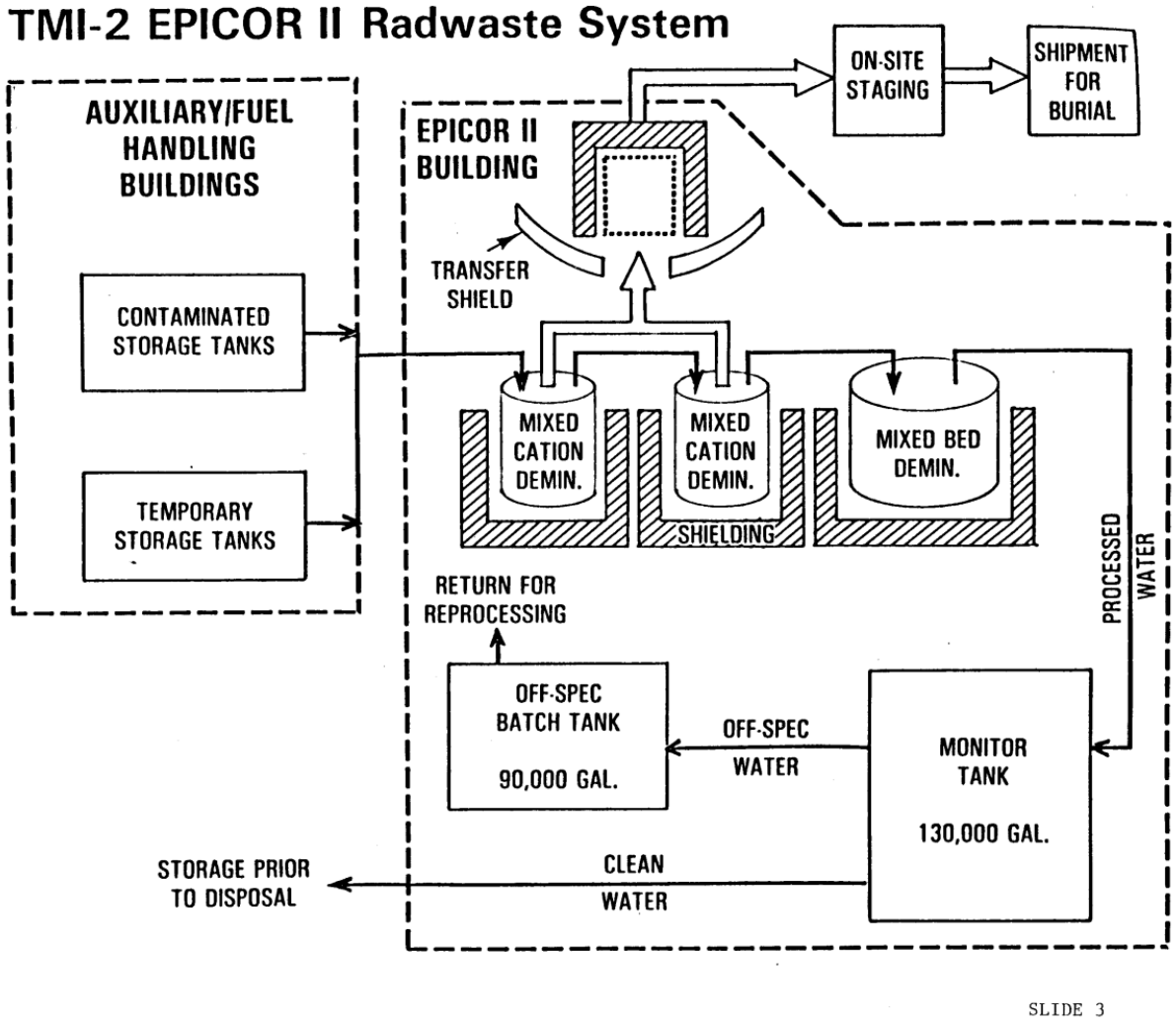
EPICOR II Flow Path Schematic (1980)



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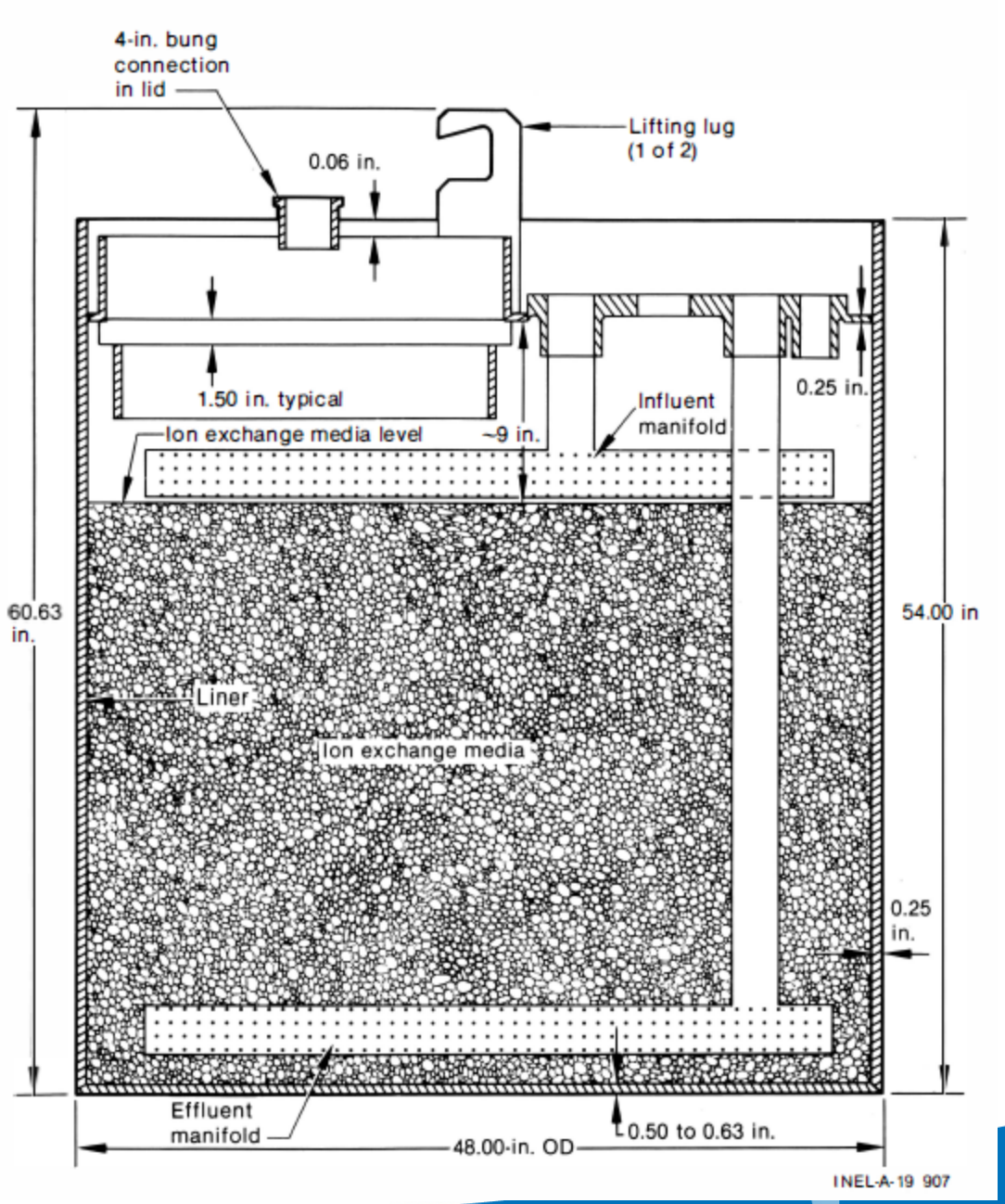
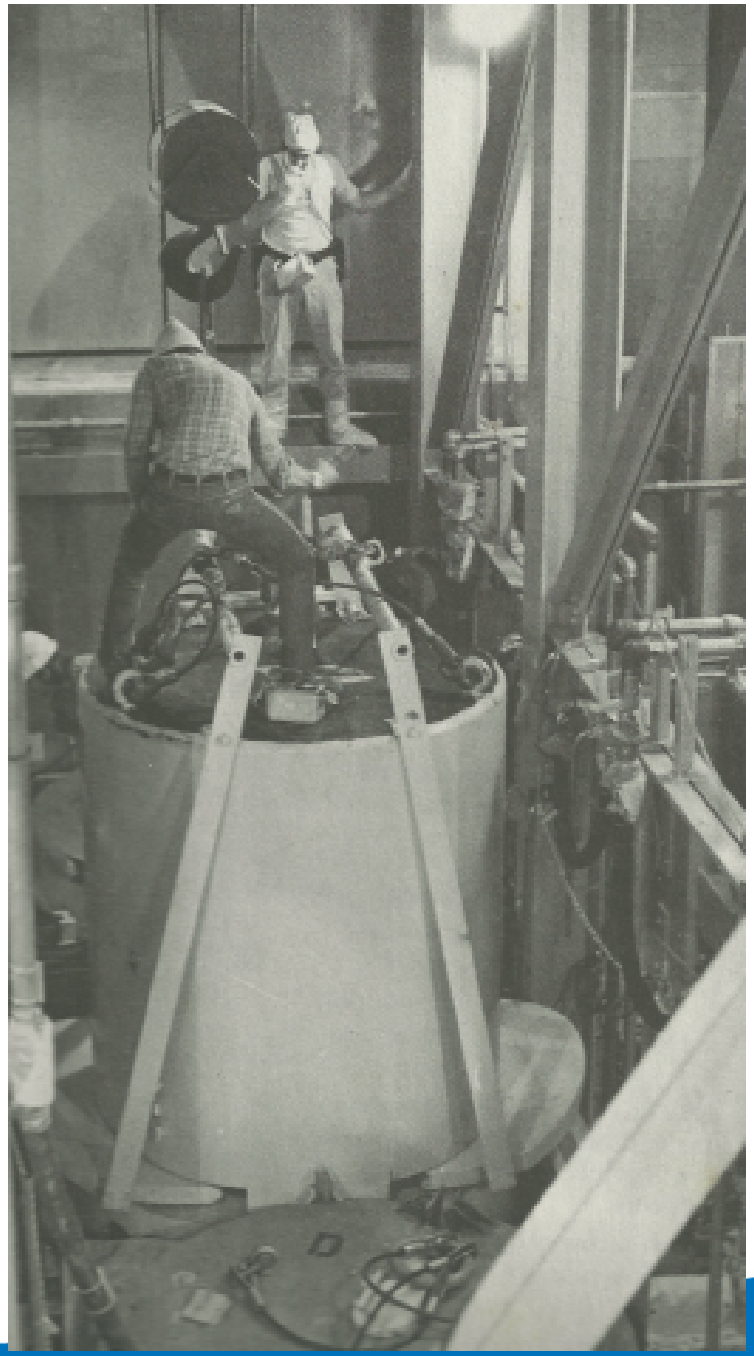
Typical EPICOR II Liner

(Cross-Section View, GEND-29)





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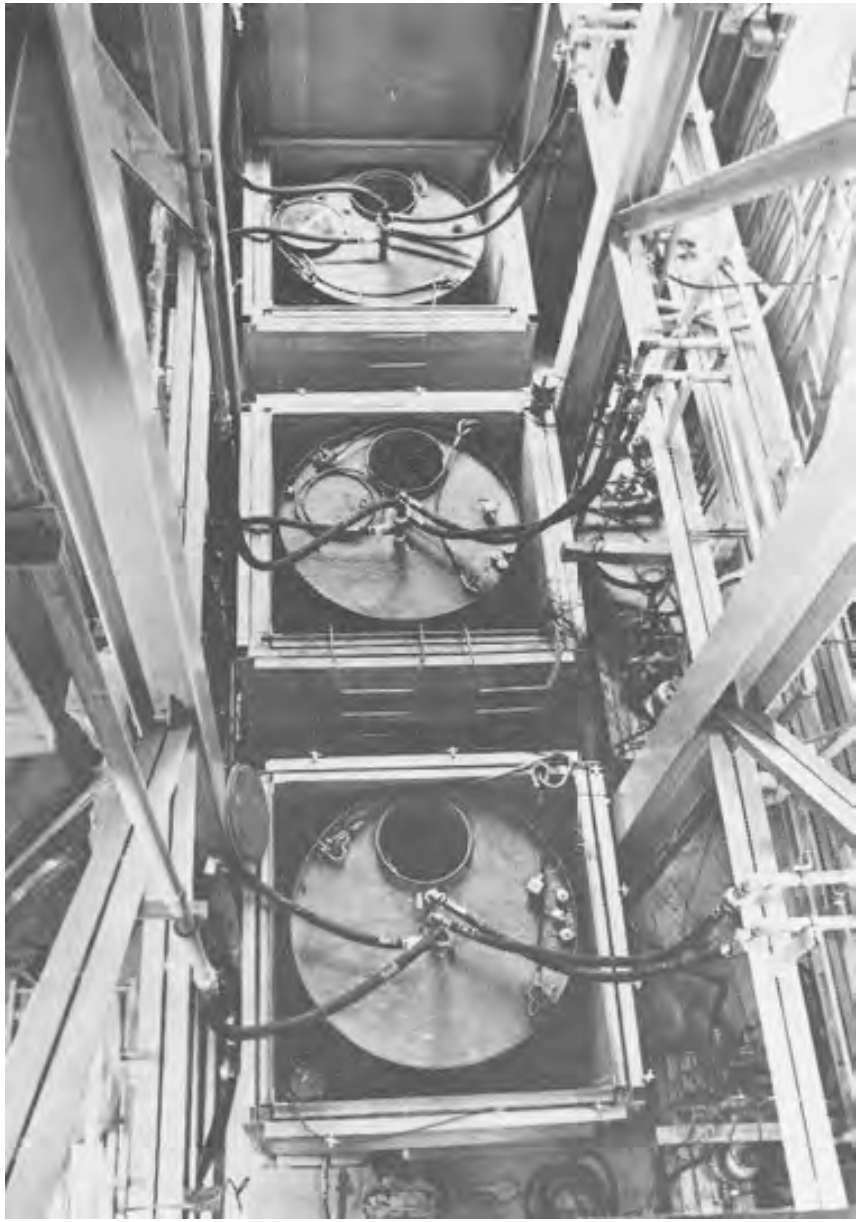
Change of Filter Liner in EPICOR II



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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)

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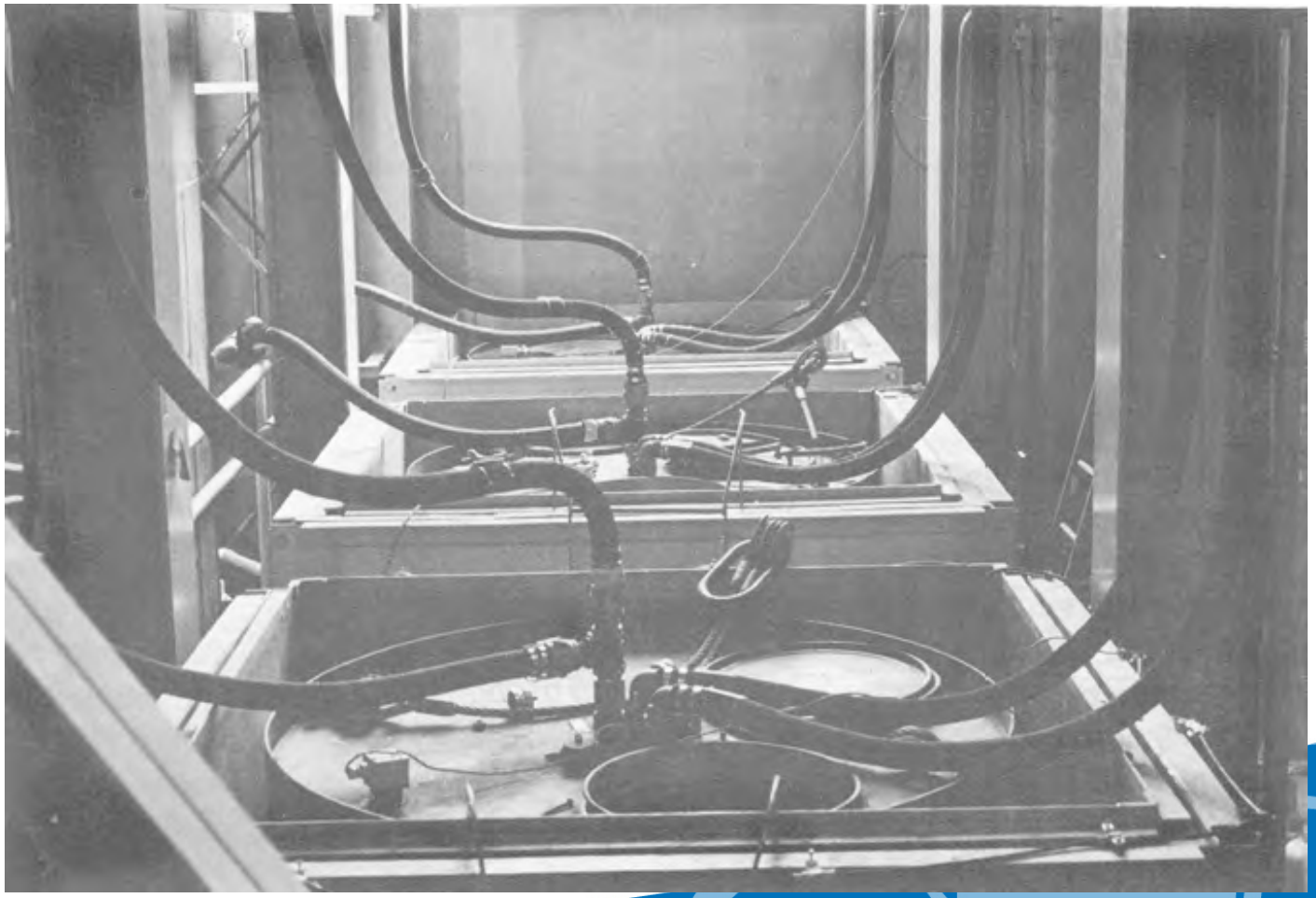

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Solid Waste Staging Facility

(Schematic, GEND-029)

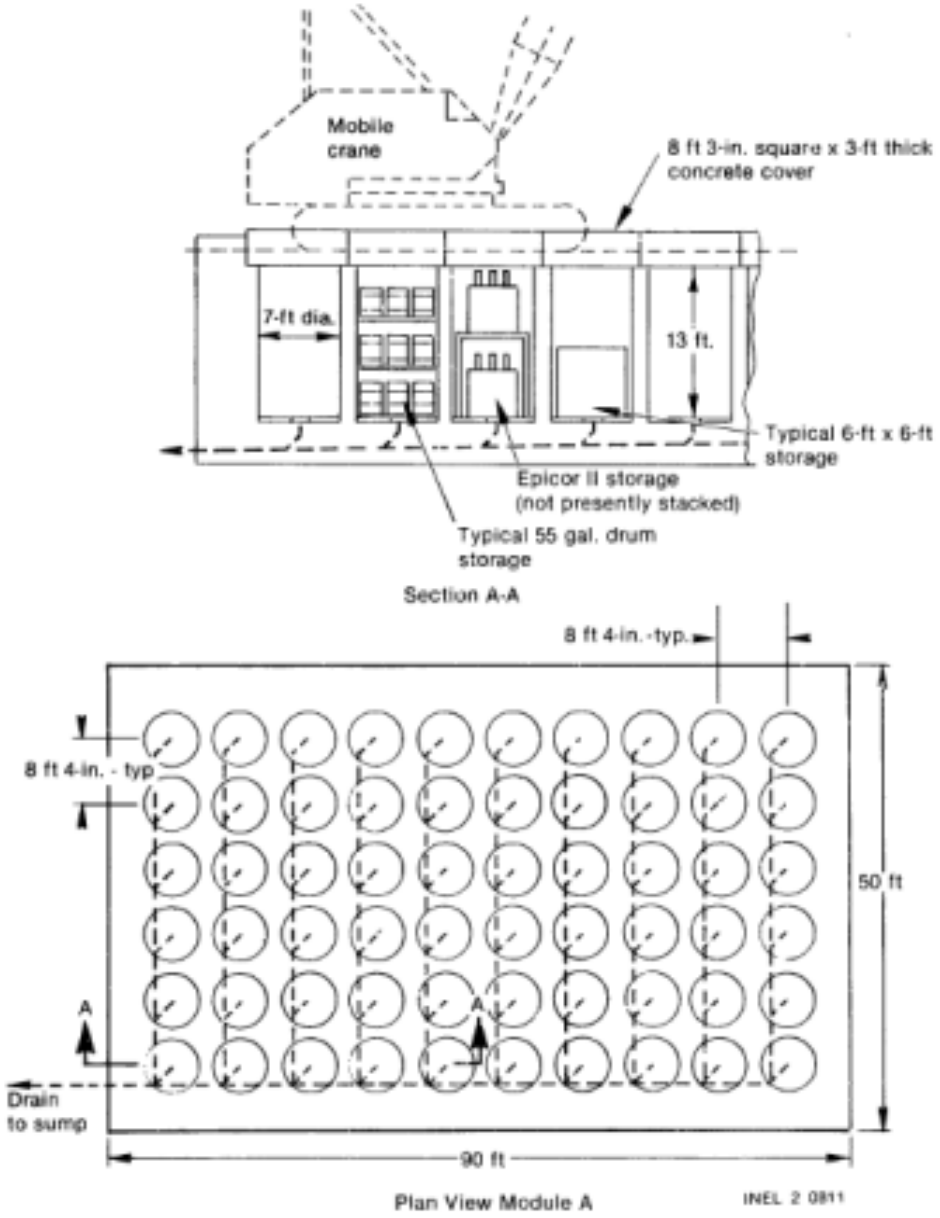

Figure 1. Solid Waste Staging Facility.

Solid Waste Staging Facility

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

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Solid Waste Staging Facility
(Under Construction)

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EPICOR-II Spent Liner Lowered into Shipping Cask

(Liner Inside Transfer Cask)

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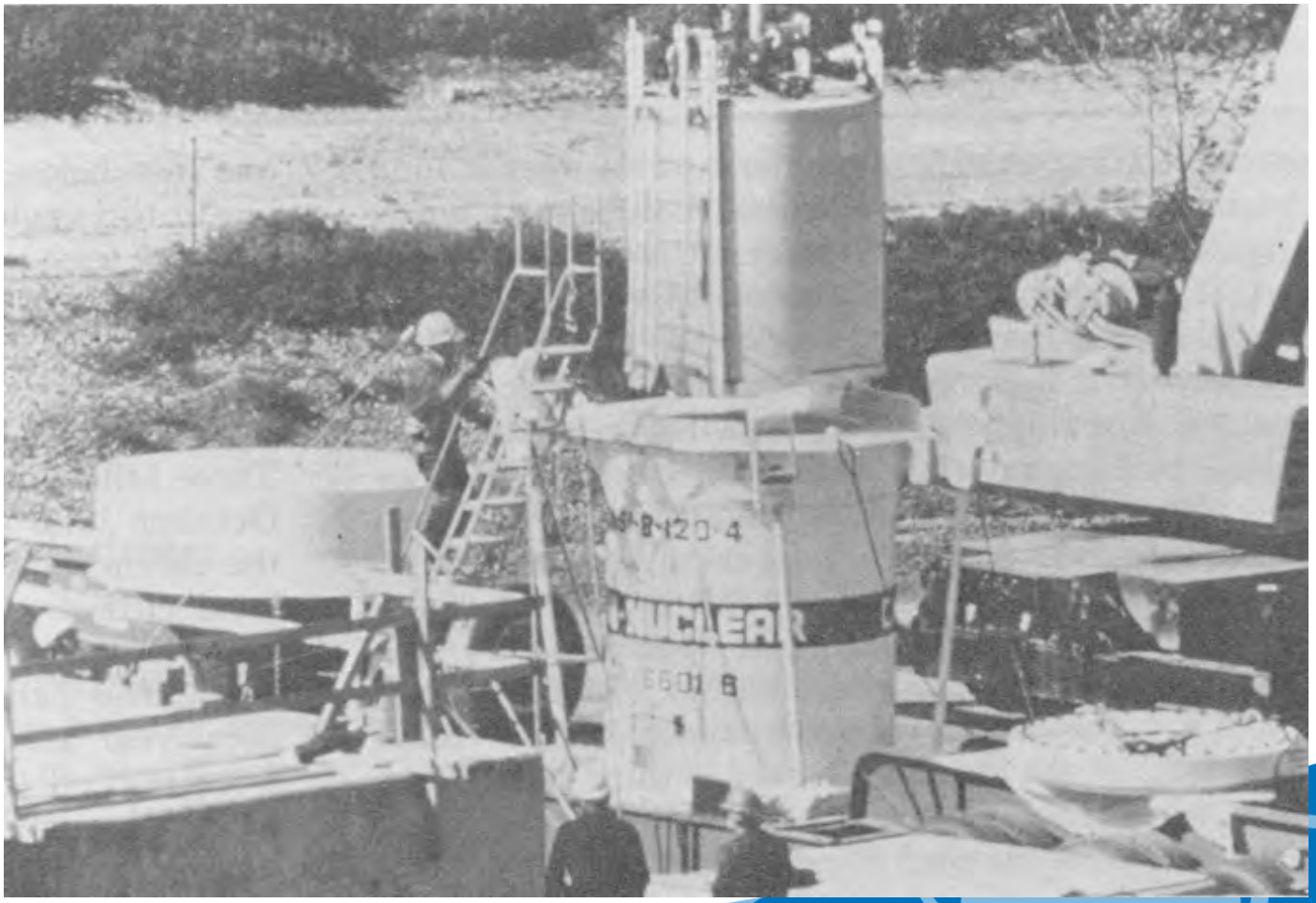

GPU Cleanup Schedule (August 1980)

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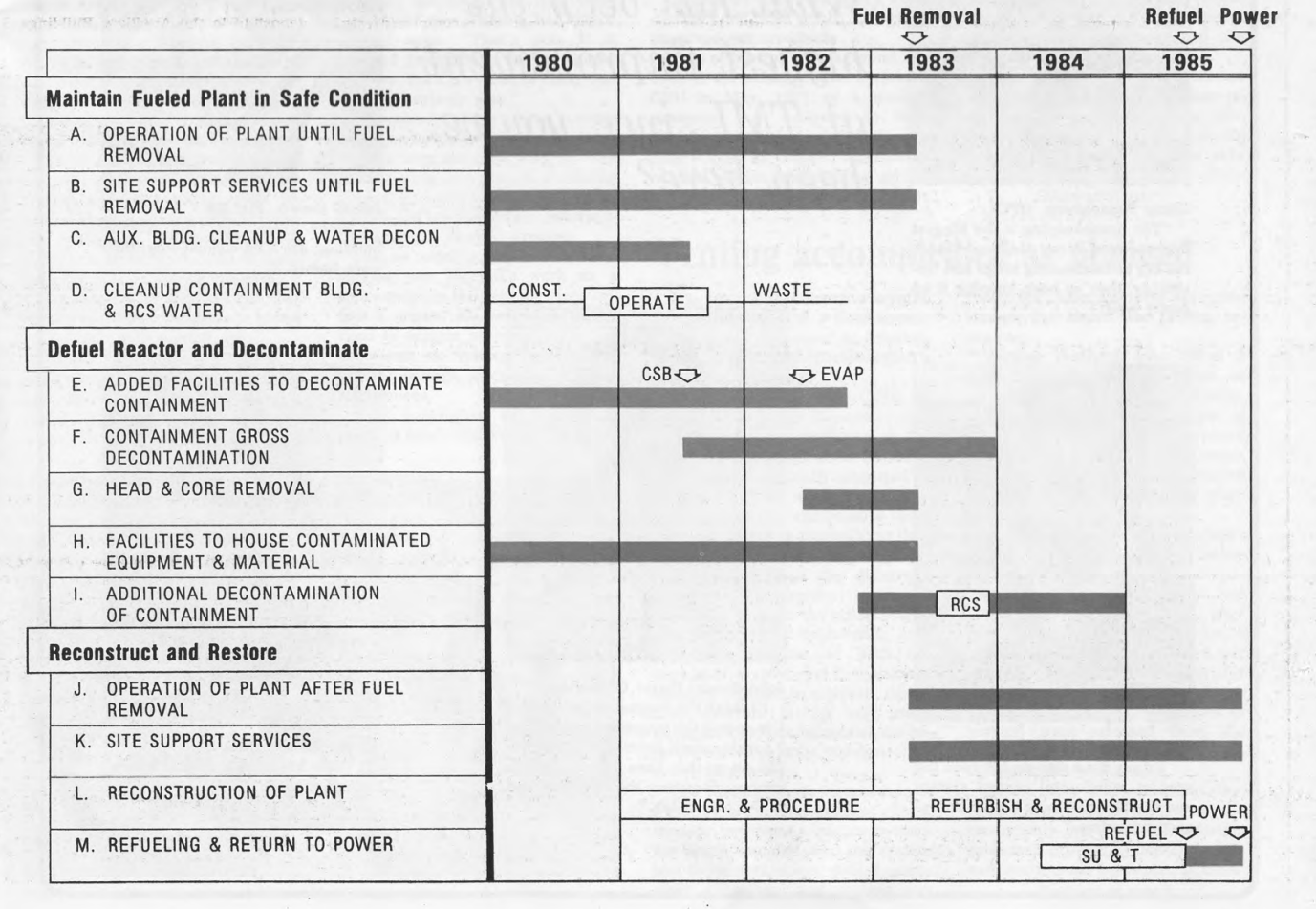

Reactor Building Water Level
(GEND-042)

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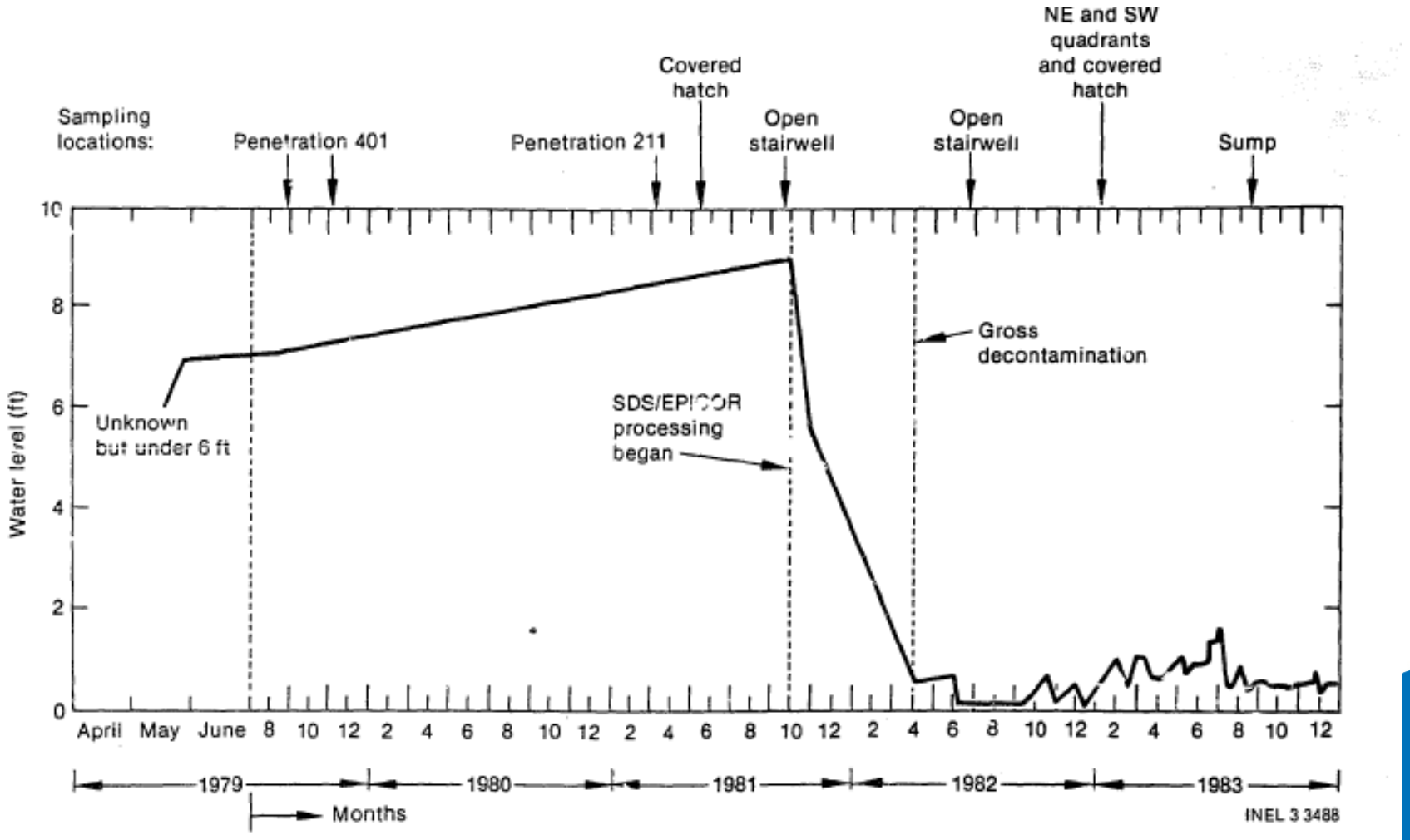

Water Storage System "Tank Farm"

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

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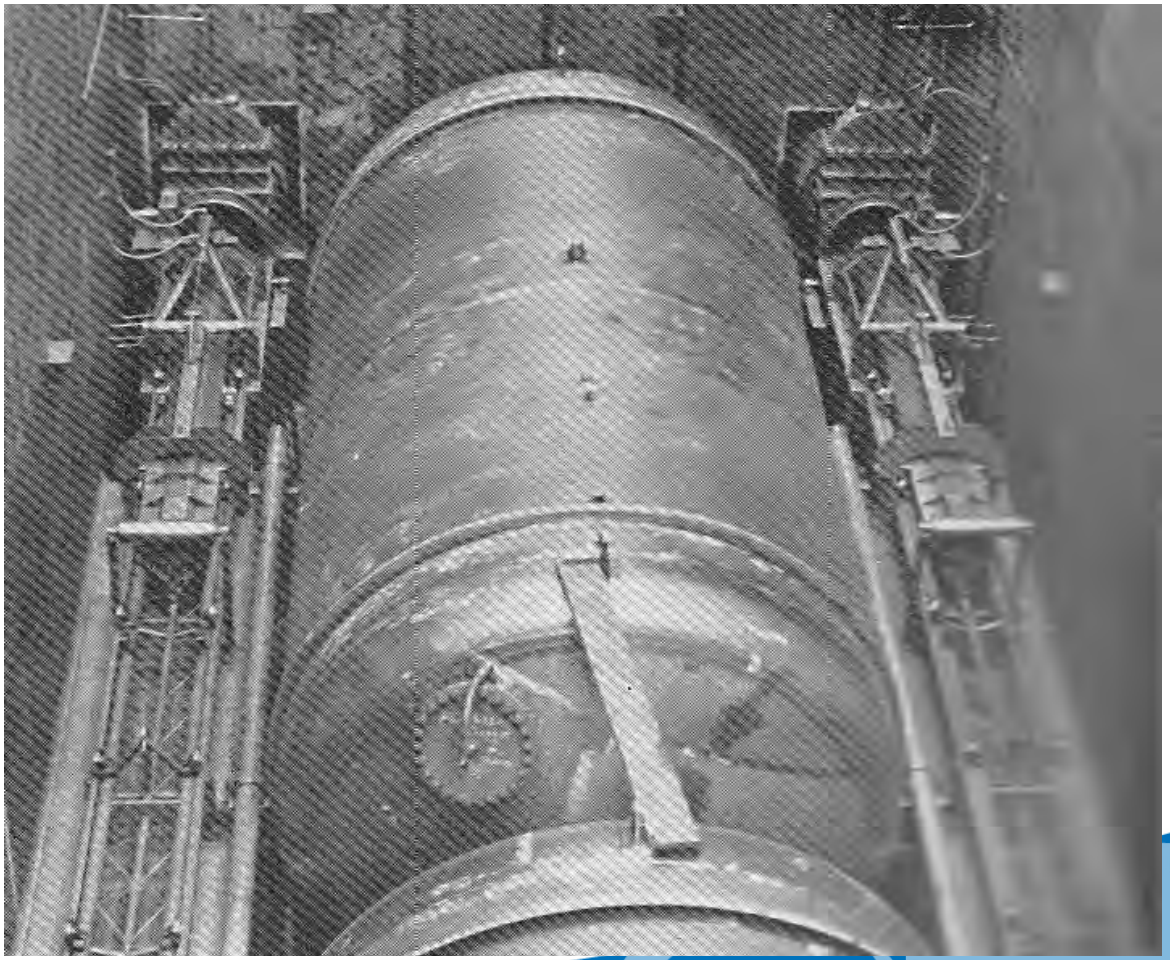

Submerged Demineralizer System (SDS) Flow Path Schematic

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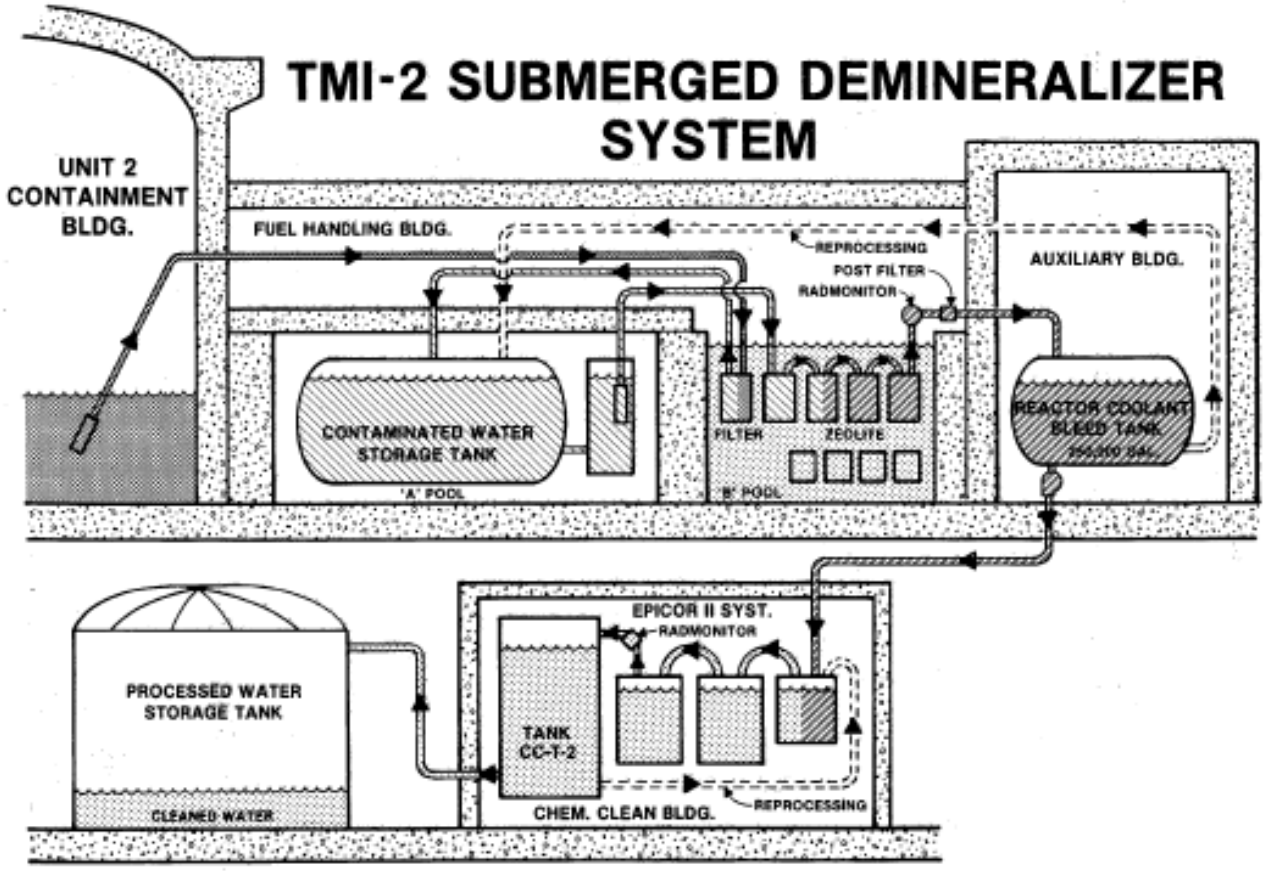

Submerged Demineralizer System Located in TMI-2 Spent Fuel Pools

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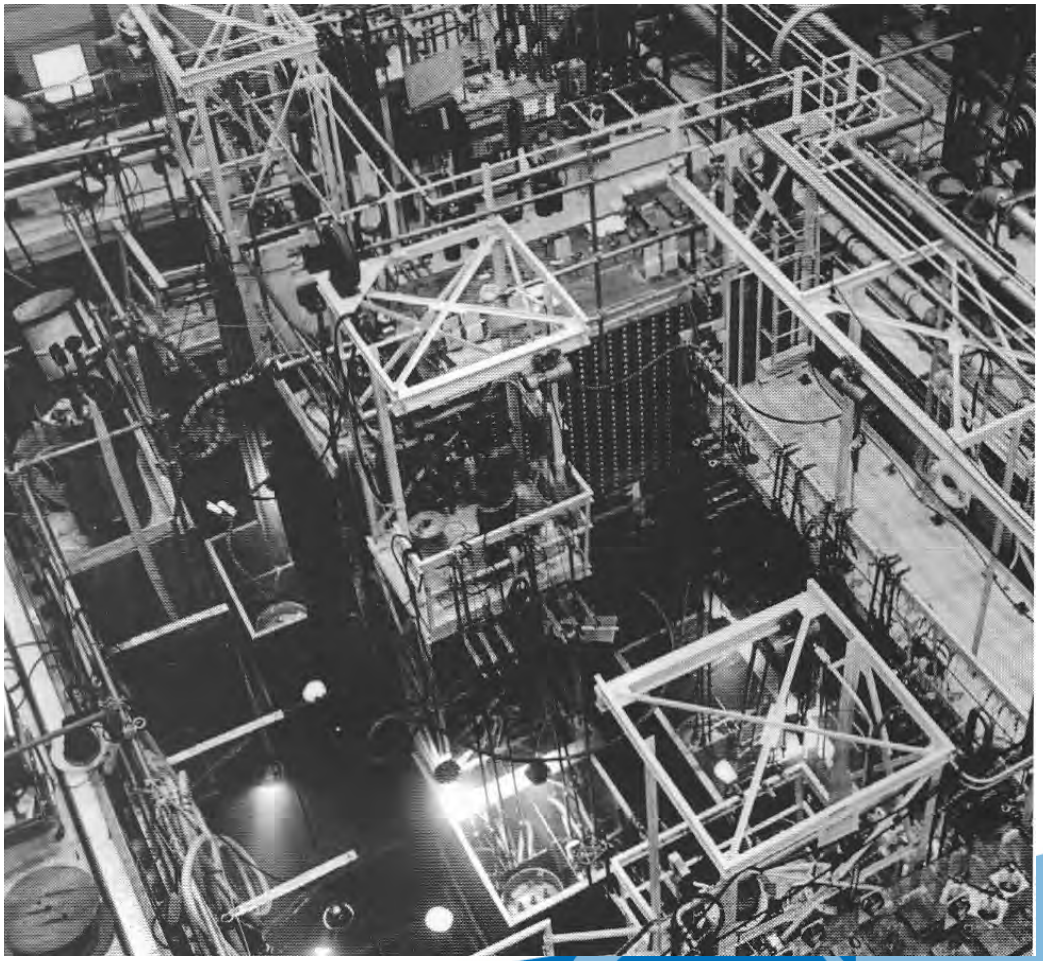

Submerged Demineralizer System Arrangement in Spent Fuel Pools

(GEND-031B)

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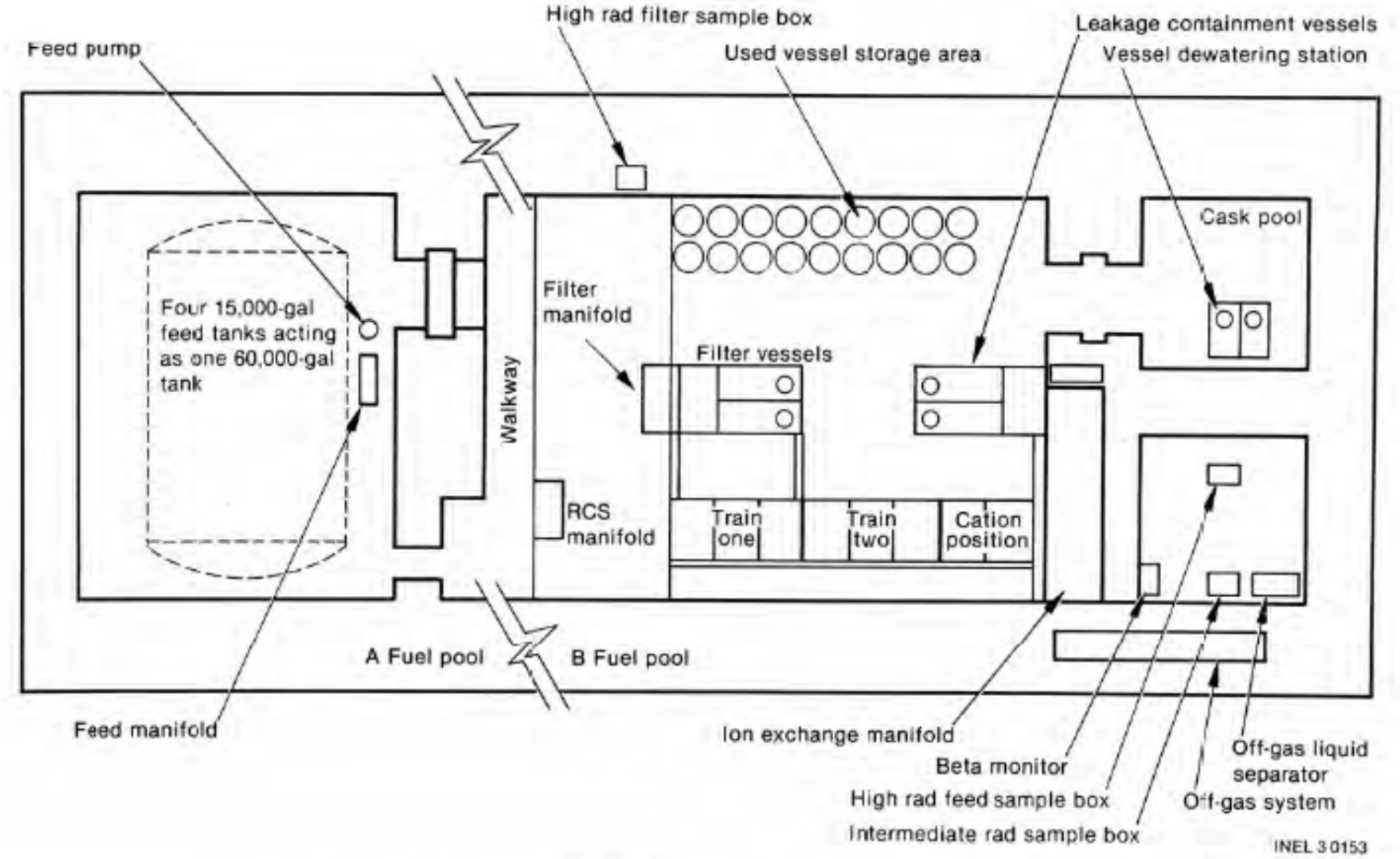

Final Flow Path for Reactor Building Basement Water Processing Via SDS

(GEND-031B)

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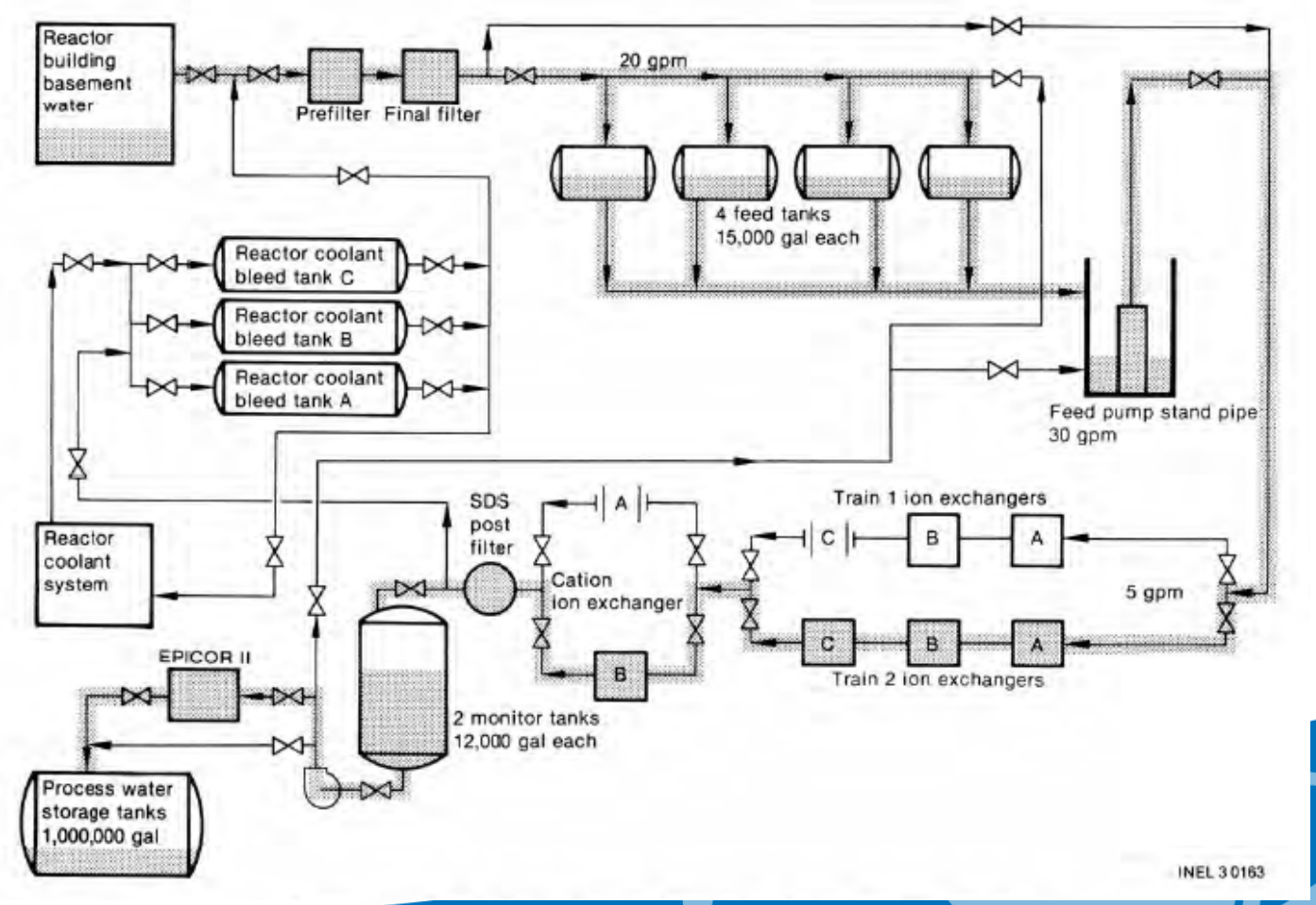

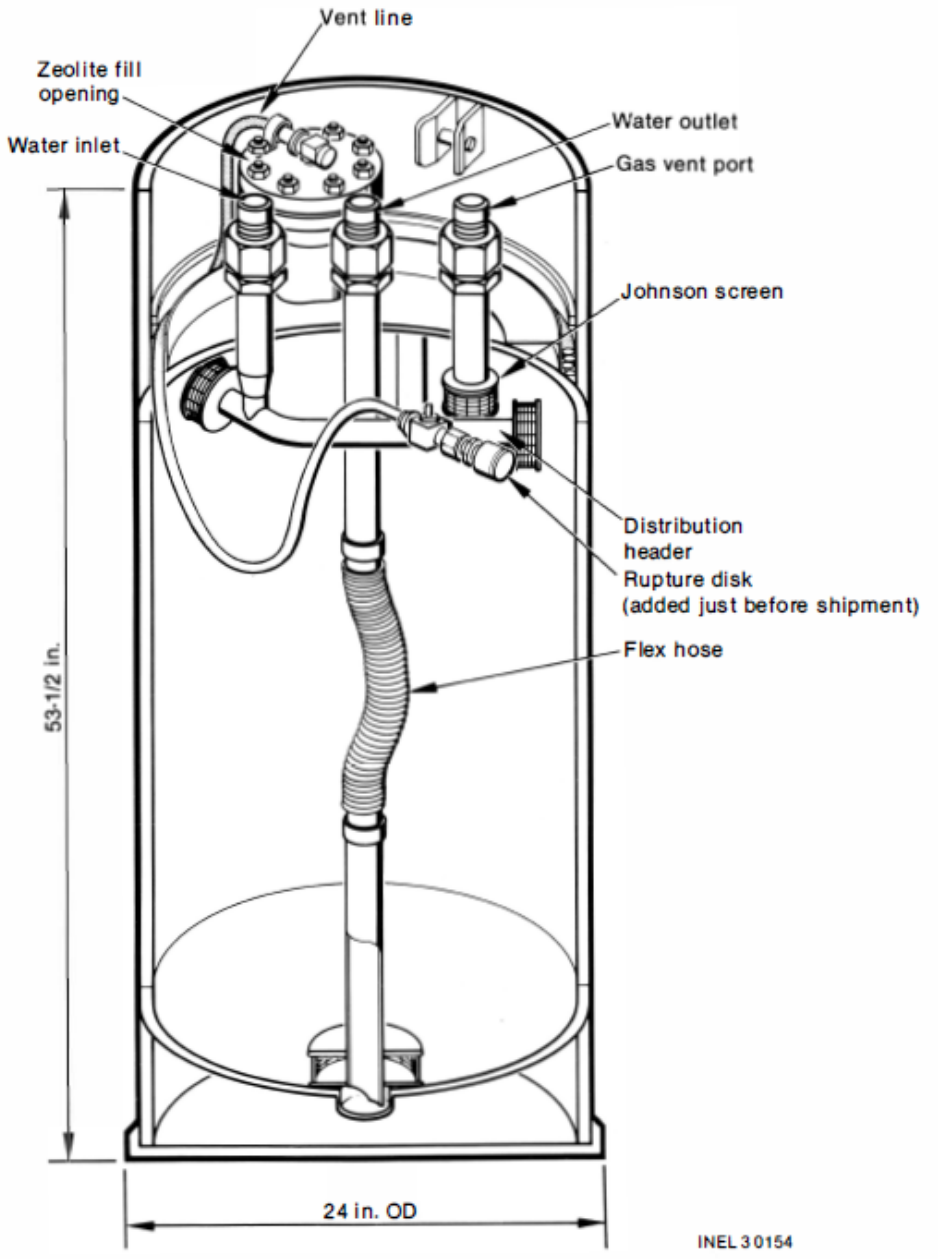

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Typical Submerged Demineralizer System Liner

(Cross-Section View, GEND-031B)

Processed Water Storage Tanks

(Each 370,000 Gallons, Epoxy-Coated Carbon Steel)

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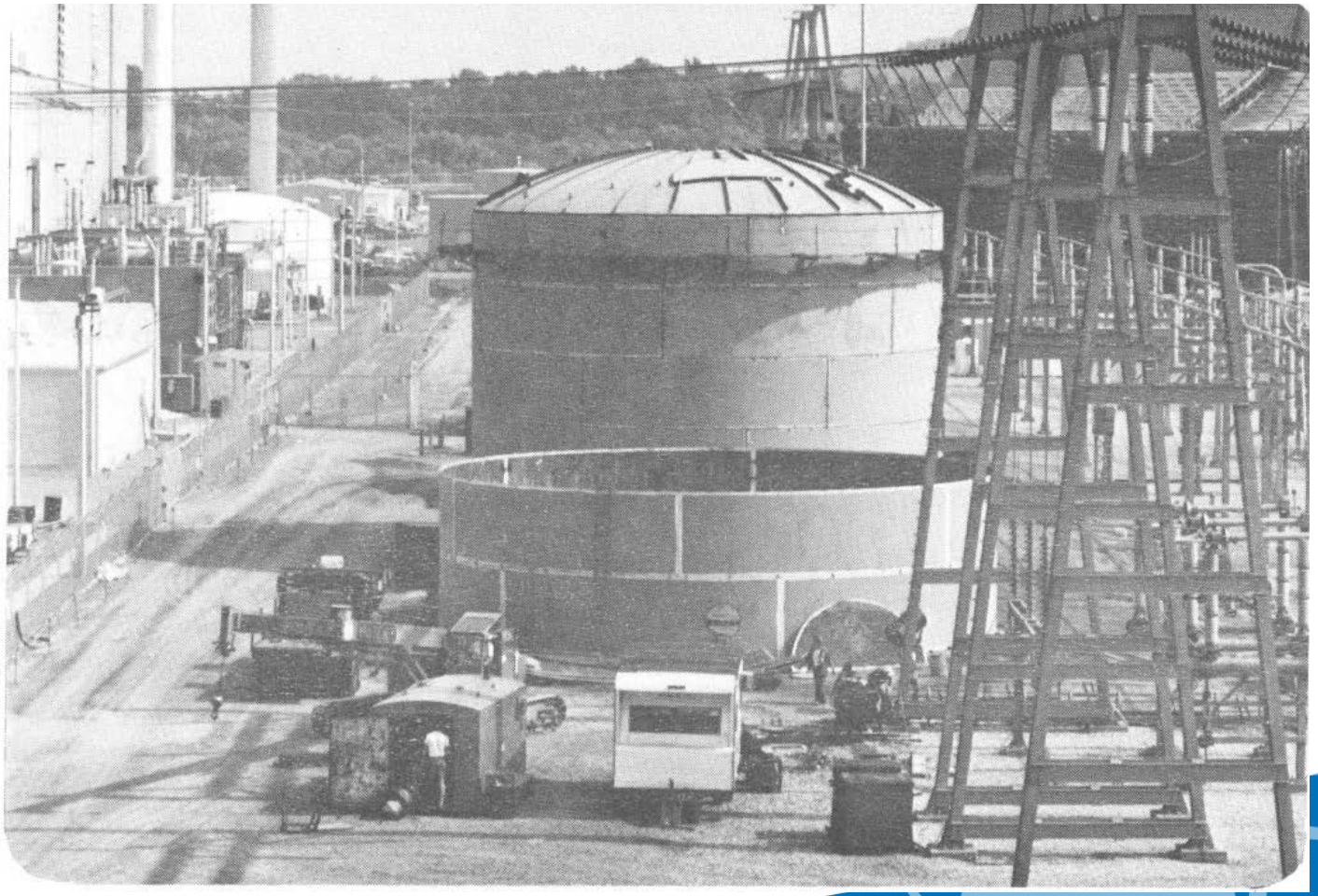

Loading Spent SDS Liner into Empty Shipping Cask

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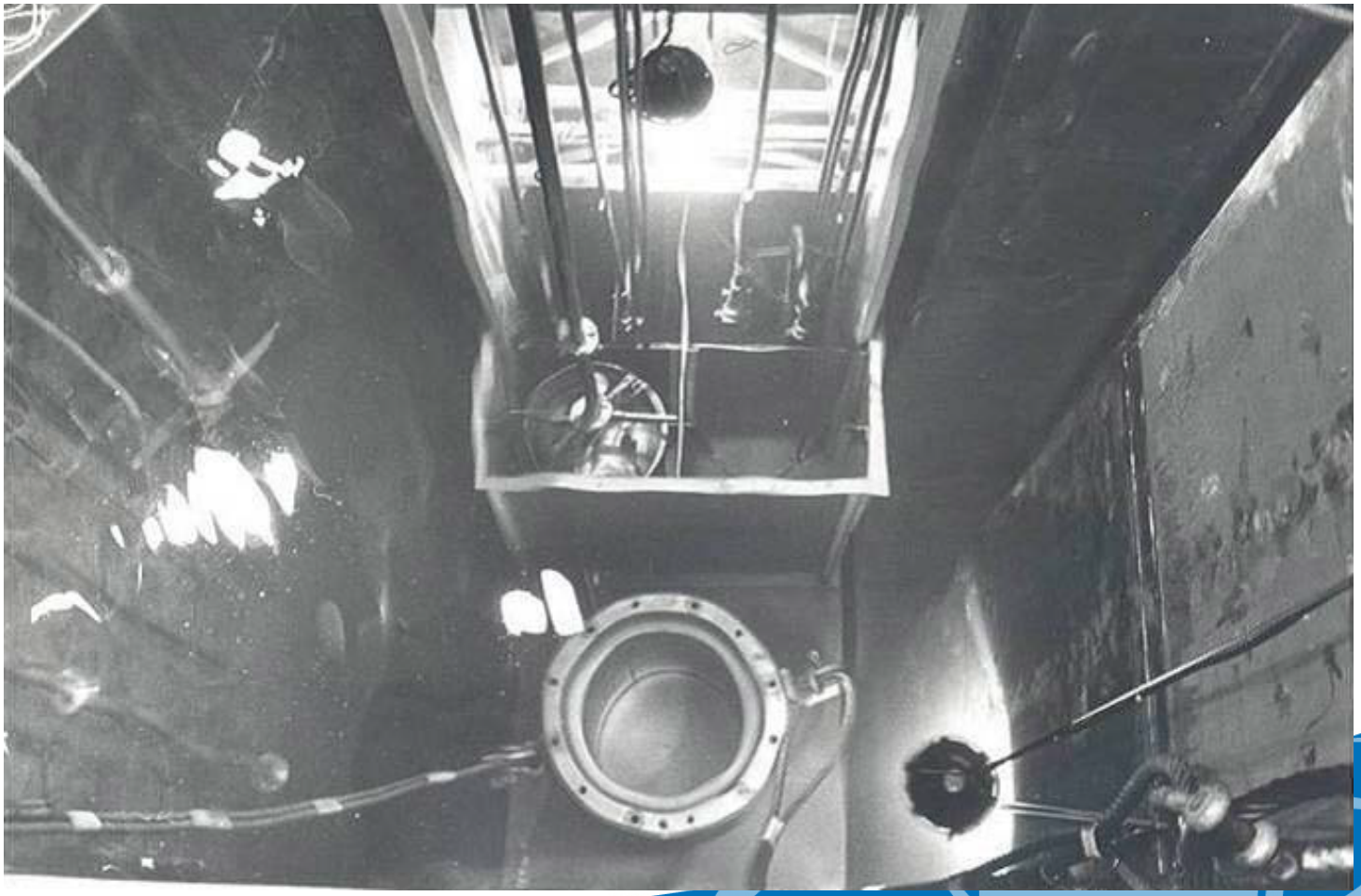

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View Inside Reactor Core Cavity

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

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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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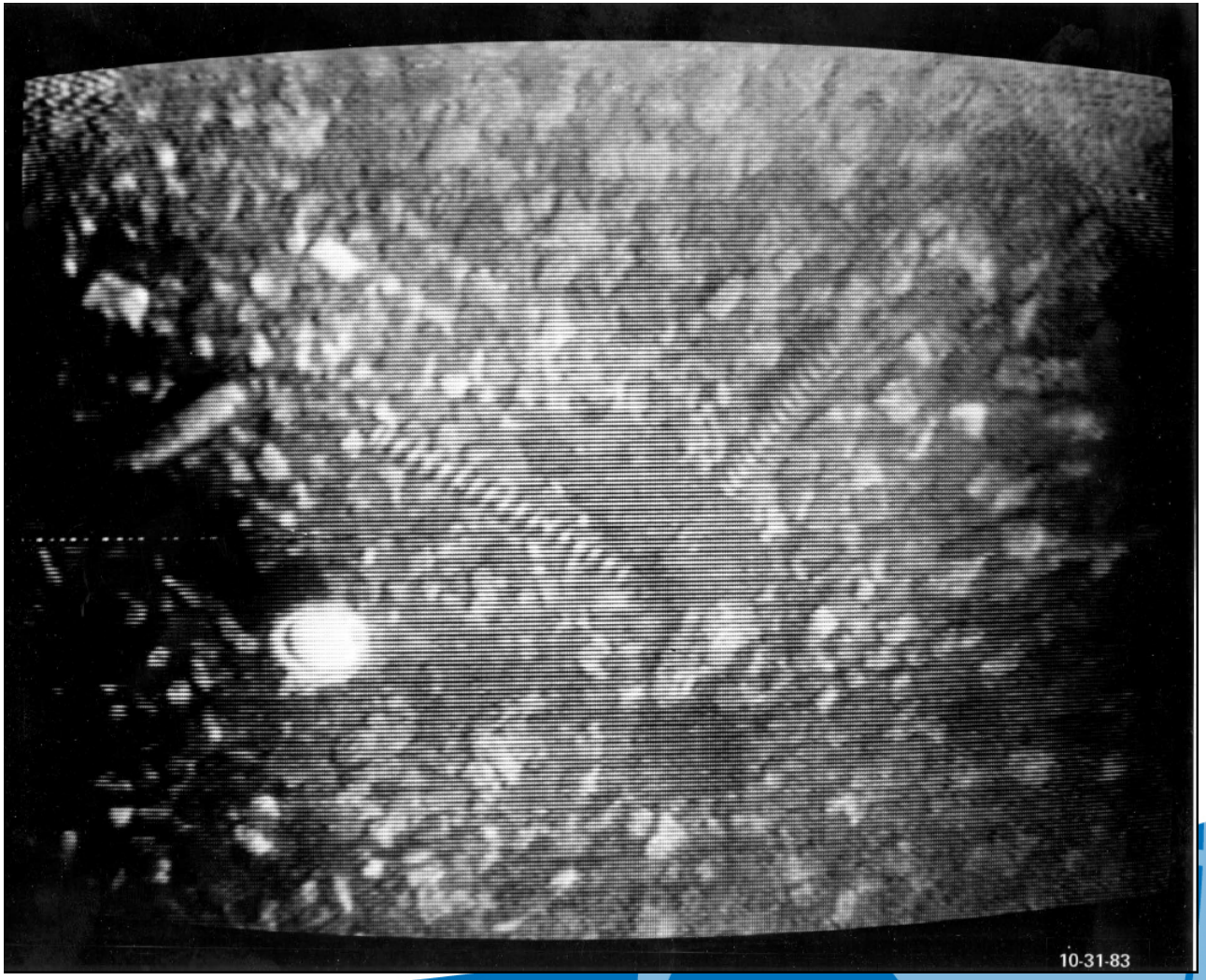

Inside Reactor Building, Polar Crane Inspection (1981)

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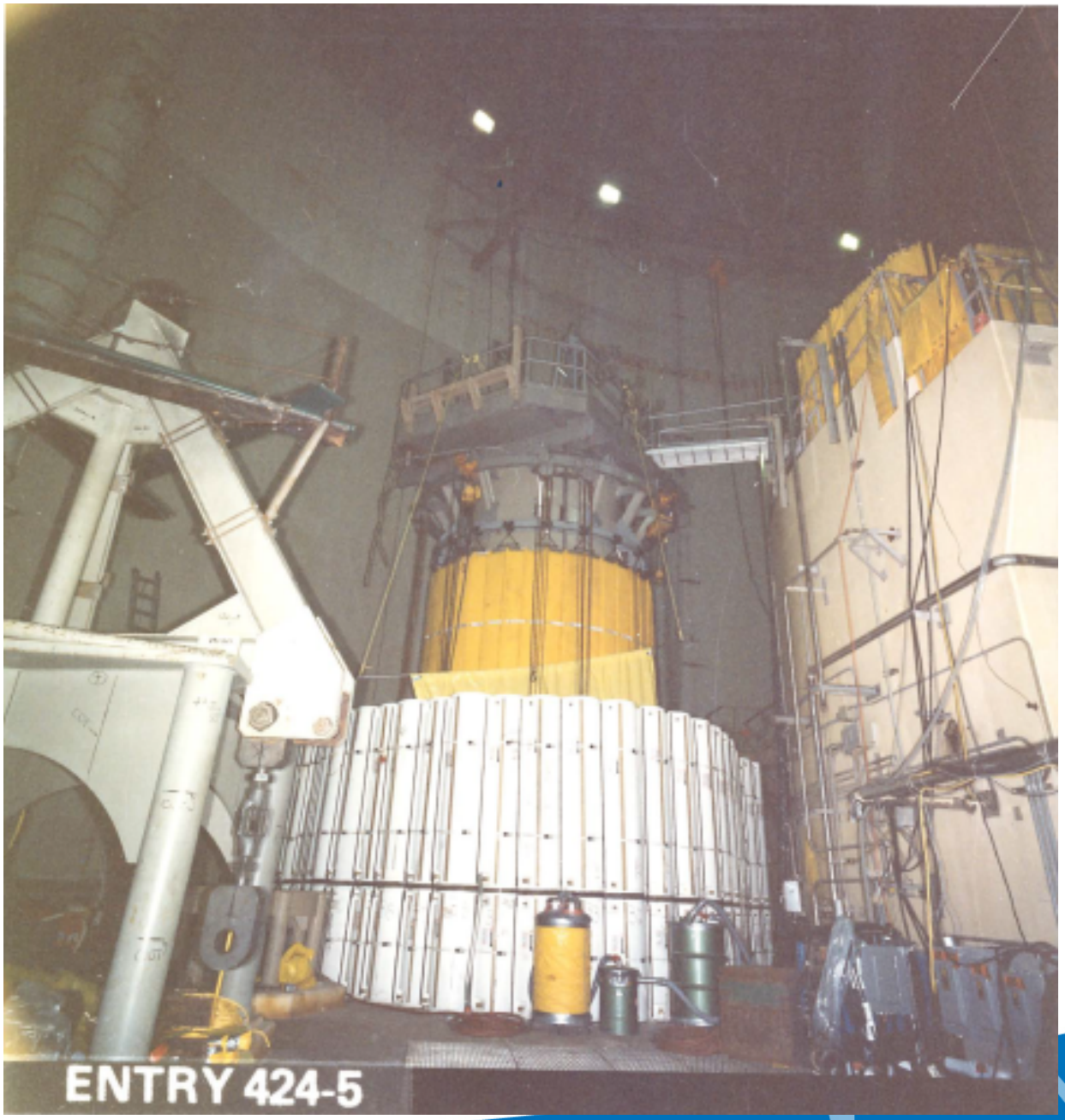

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Reactor Vessel Head and Service Structure

(Removed from Reactor Vessel, Placed on Stand with Sand-filled Curtain Shield)

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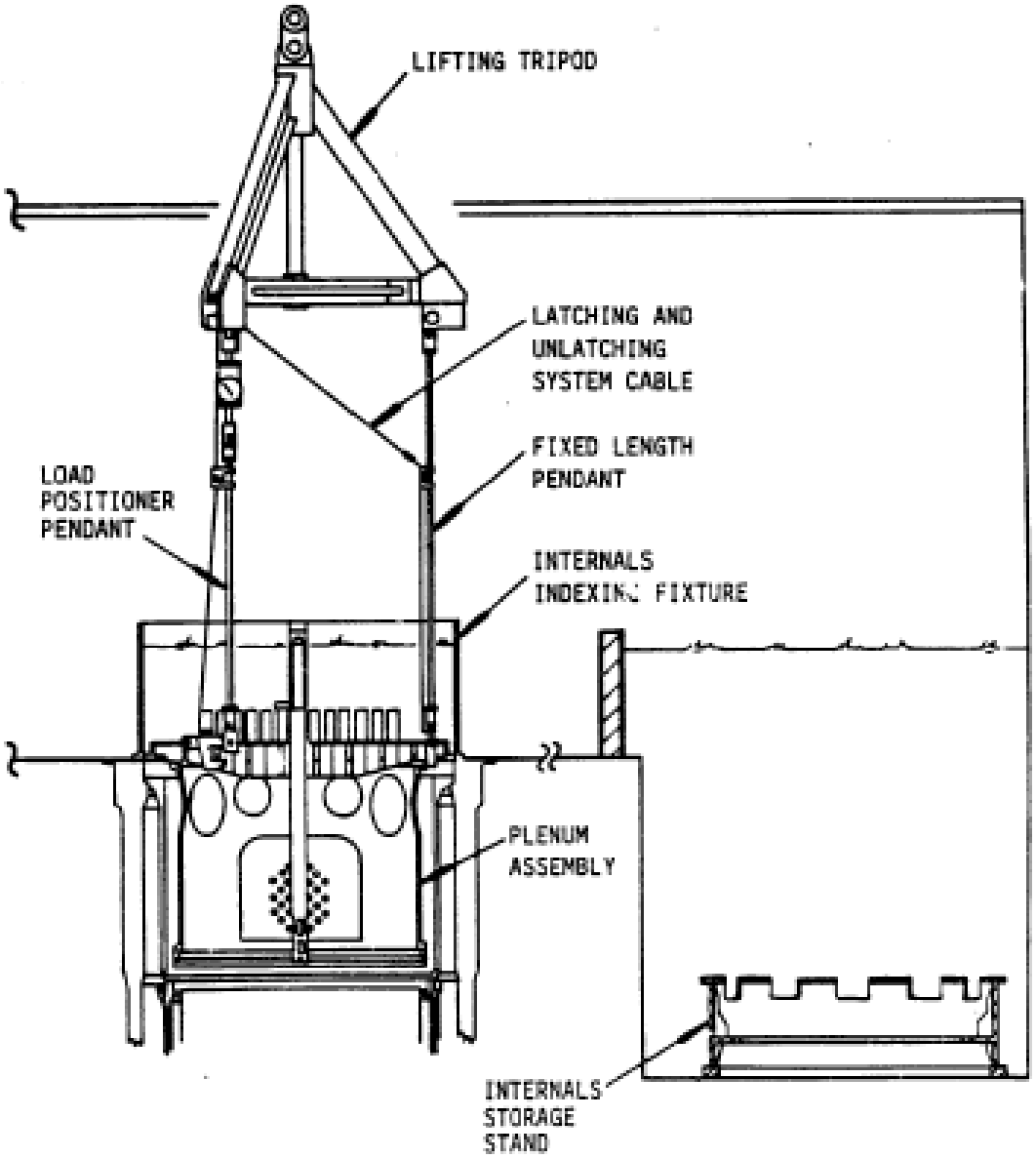
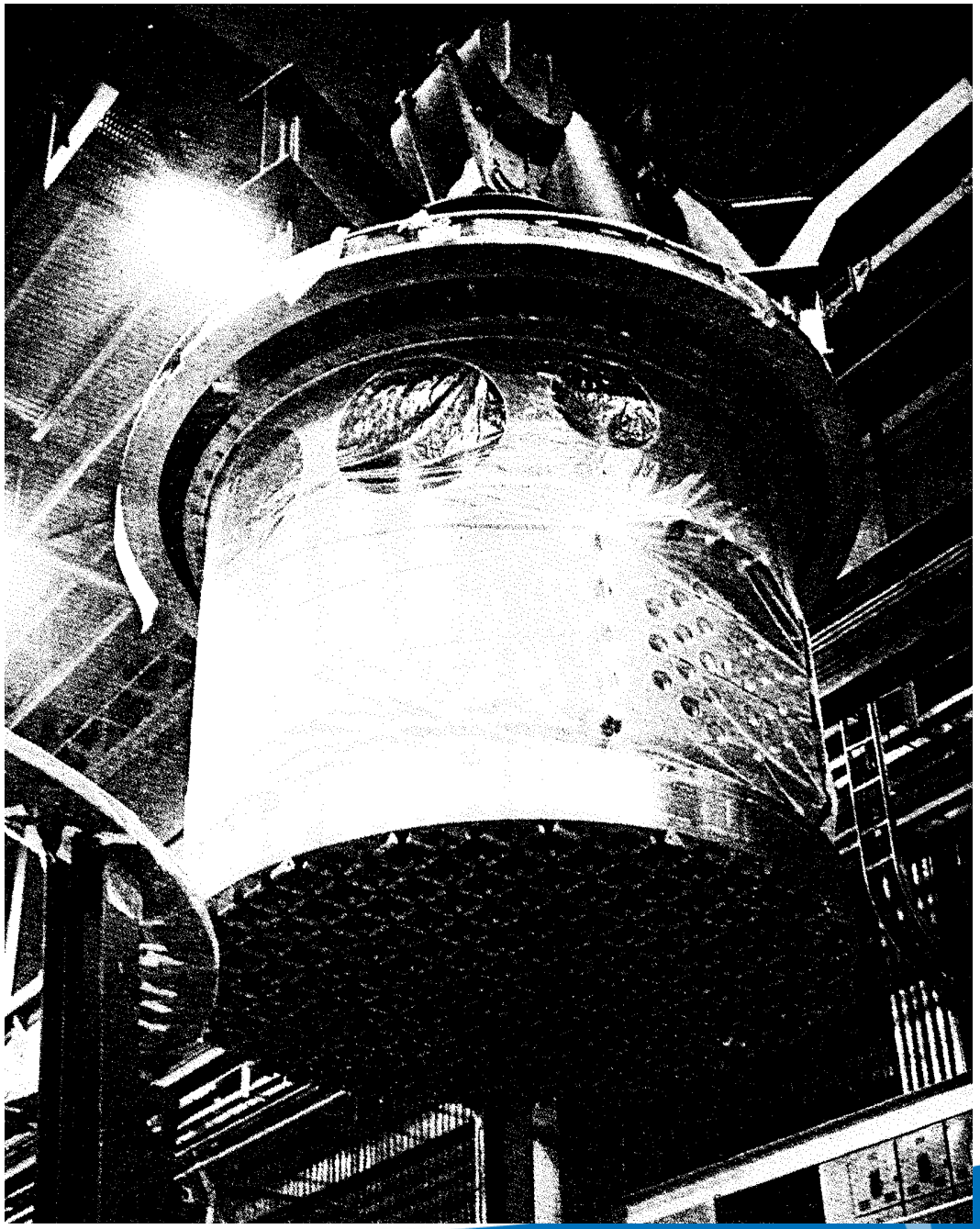
Plenum Assembly Lift Schematic
(GEND-054)





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Typical Fabricated Plenum Assembly in Preparation for Shipment

Upper Plenum Assembly Inside TMI-2 Reactor Vessel

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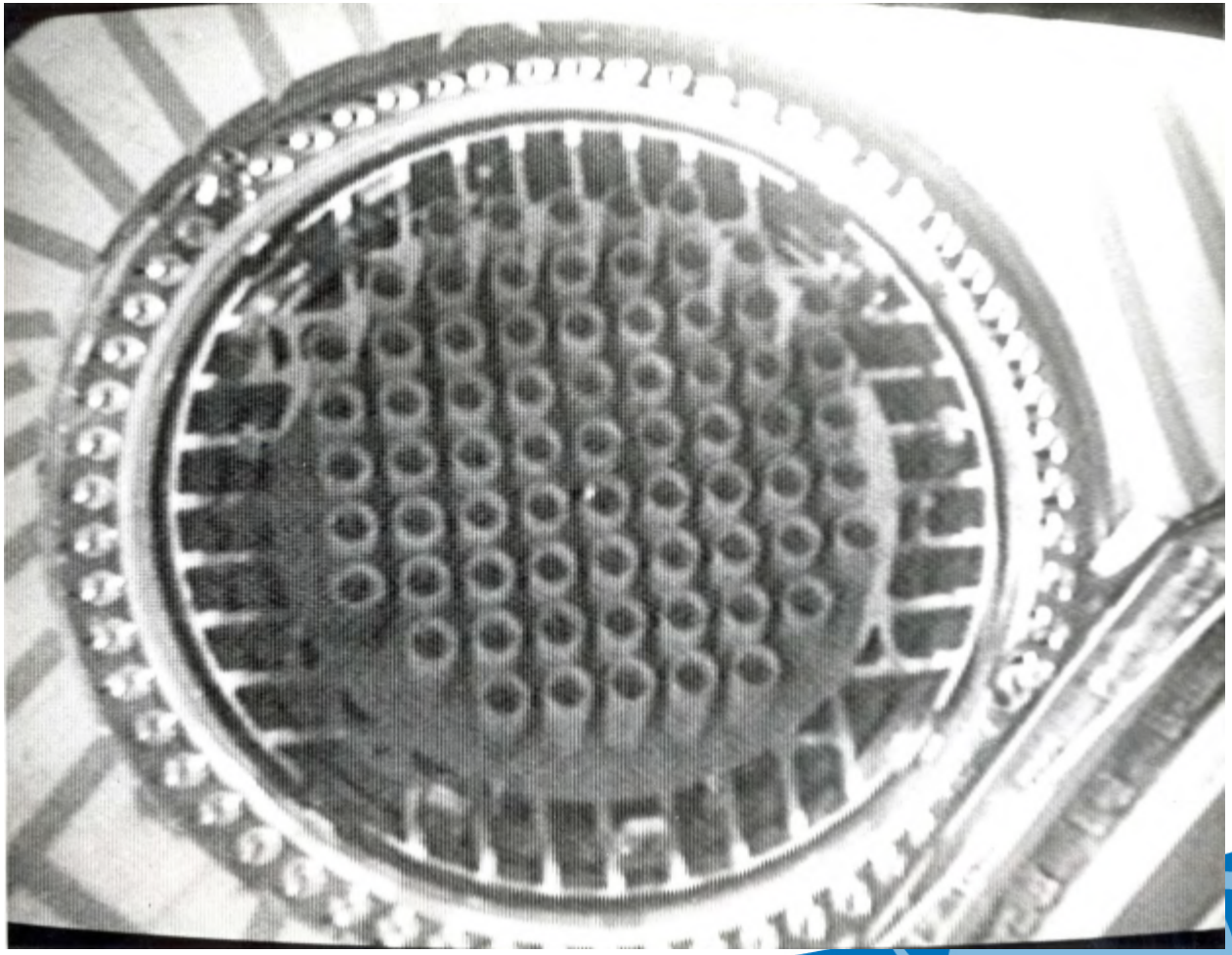

Upper Plenum Assembly Inside TMI-2 Reactor Vessel (Close-up)

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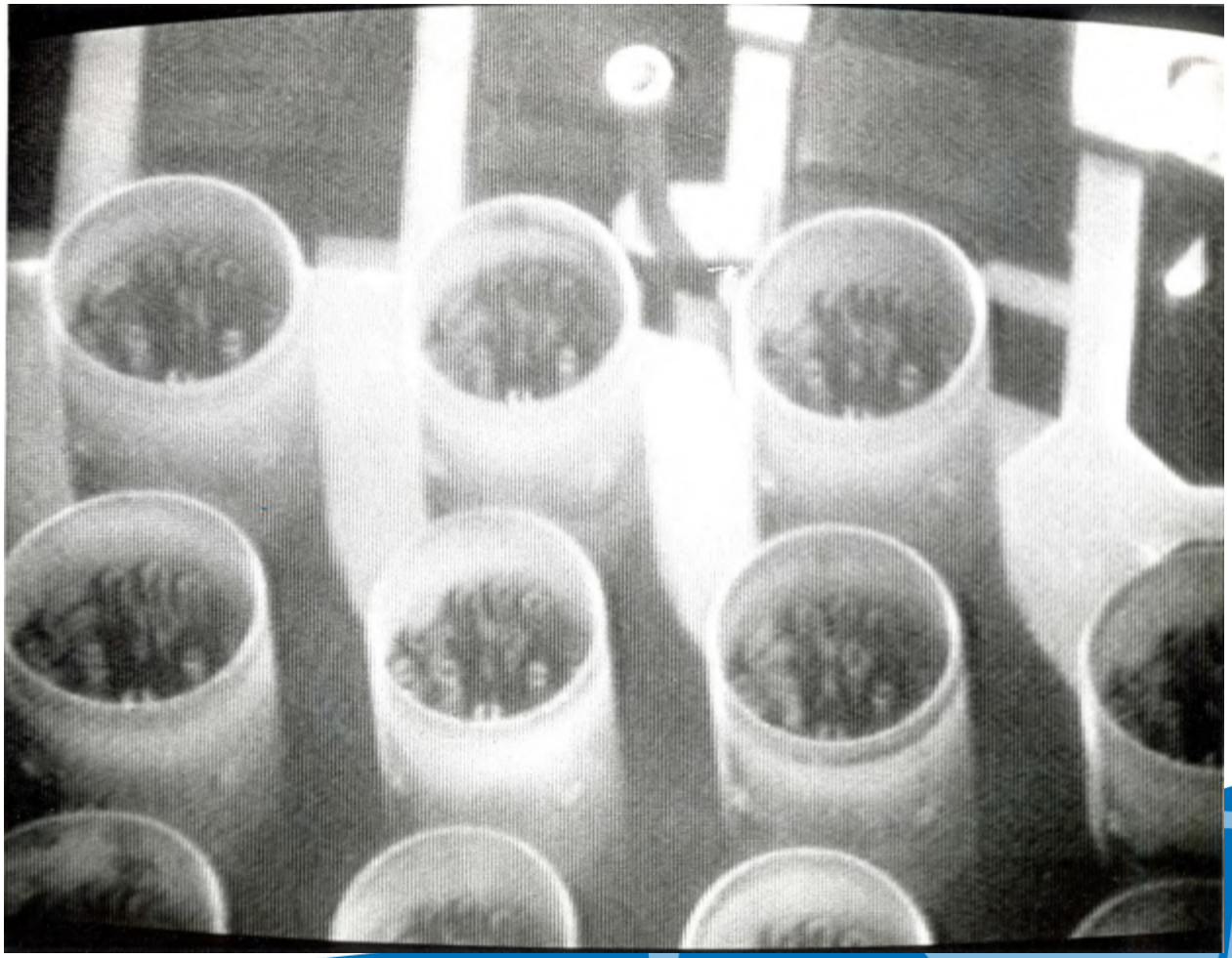

Bottom Side of Typical Upper Grid Rib Section Being Fabricated

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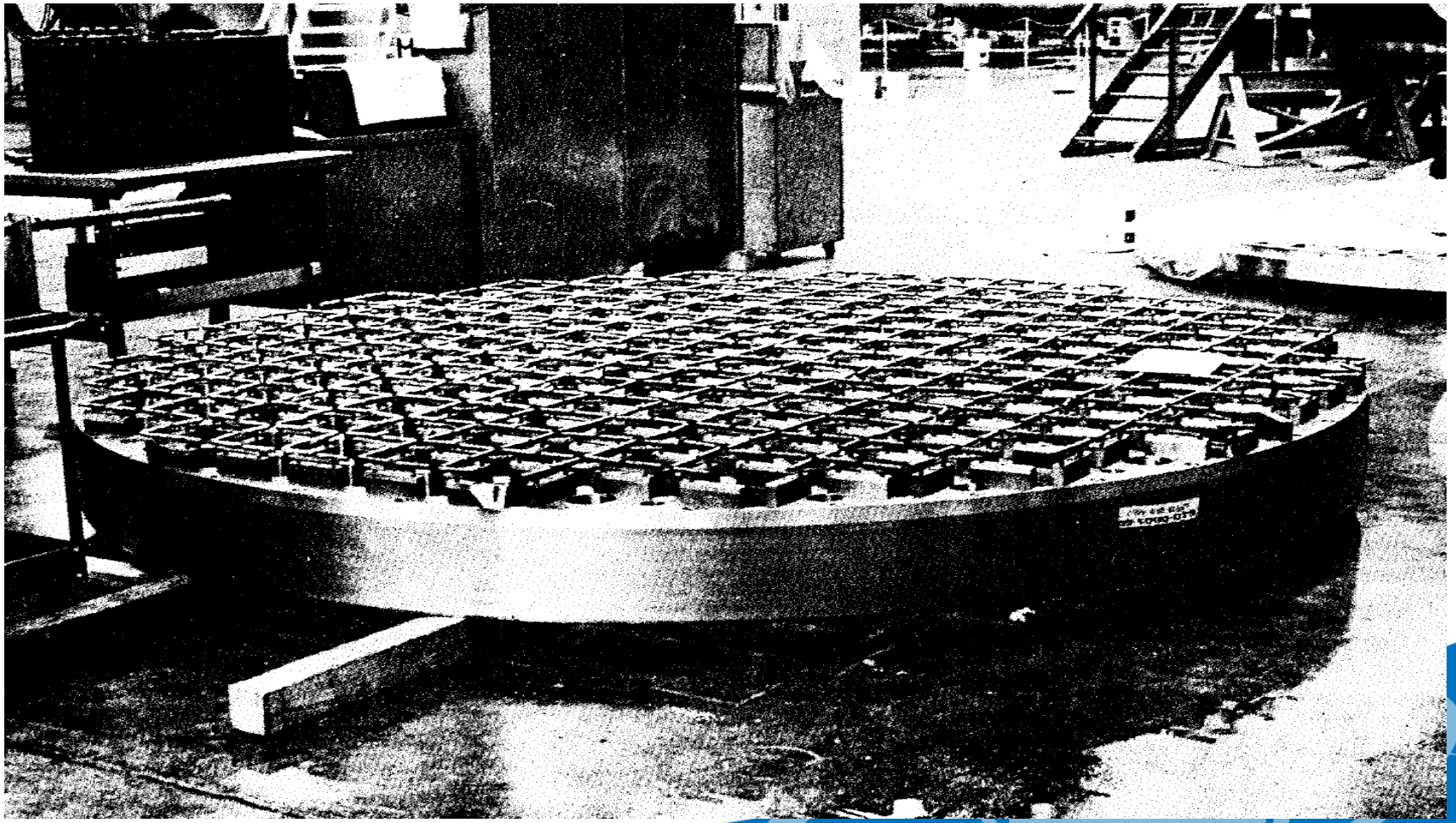

Upper Grid Damage at TMI-2

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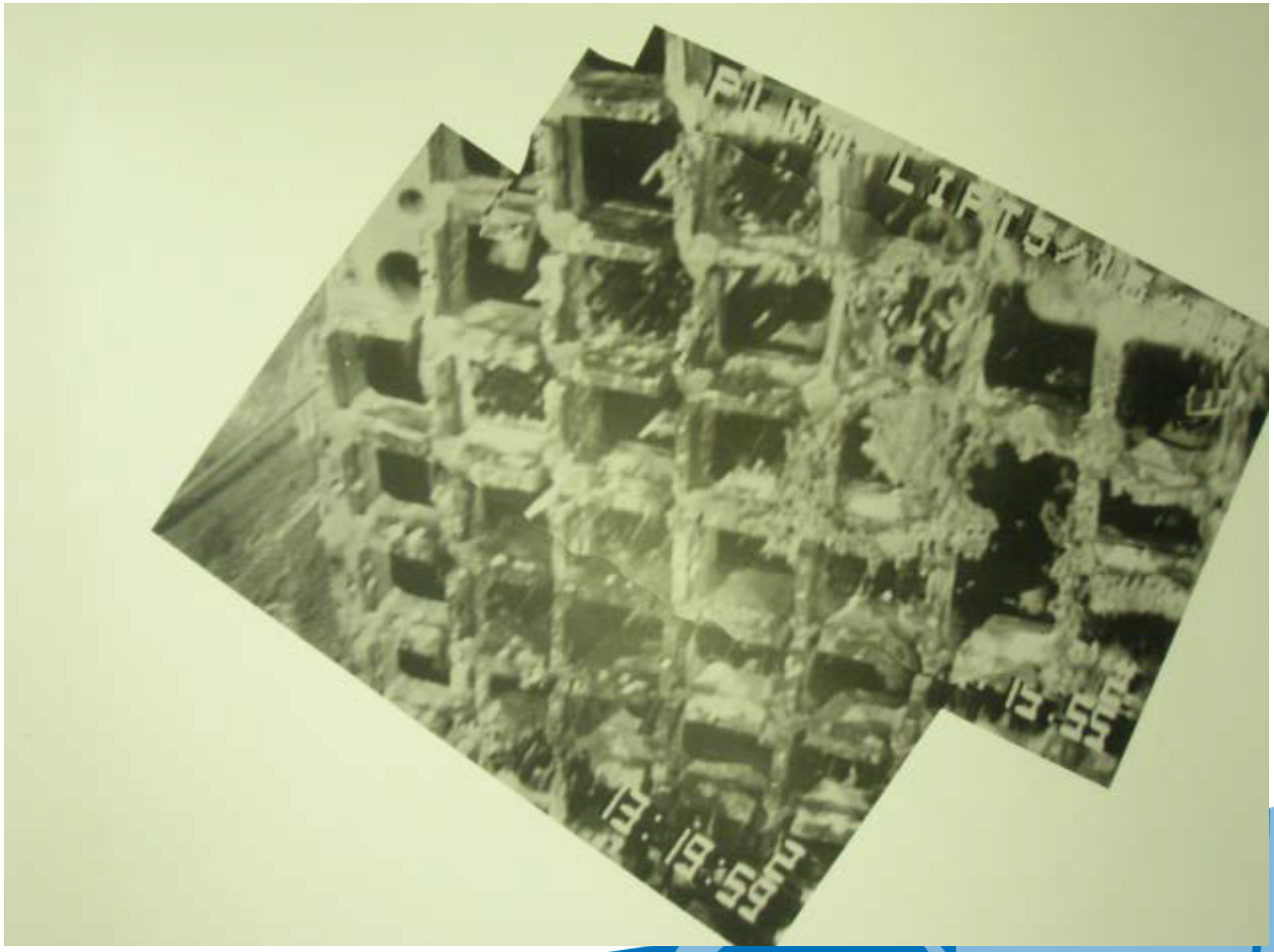

Upper Grid Damage at TMI-2

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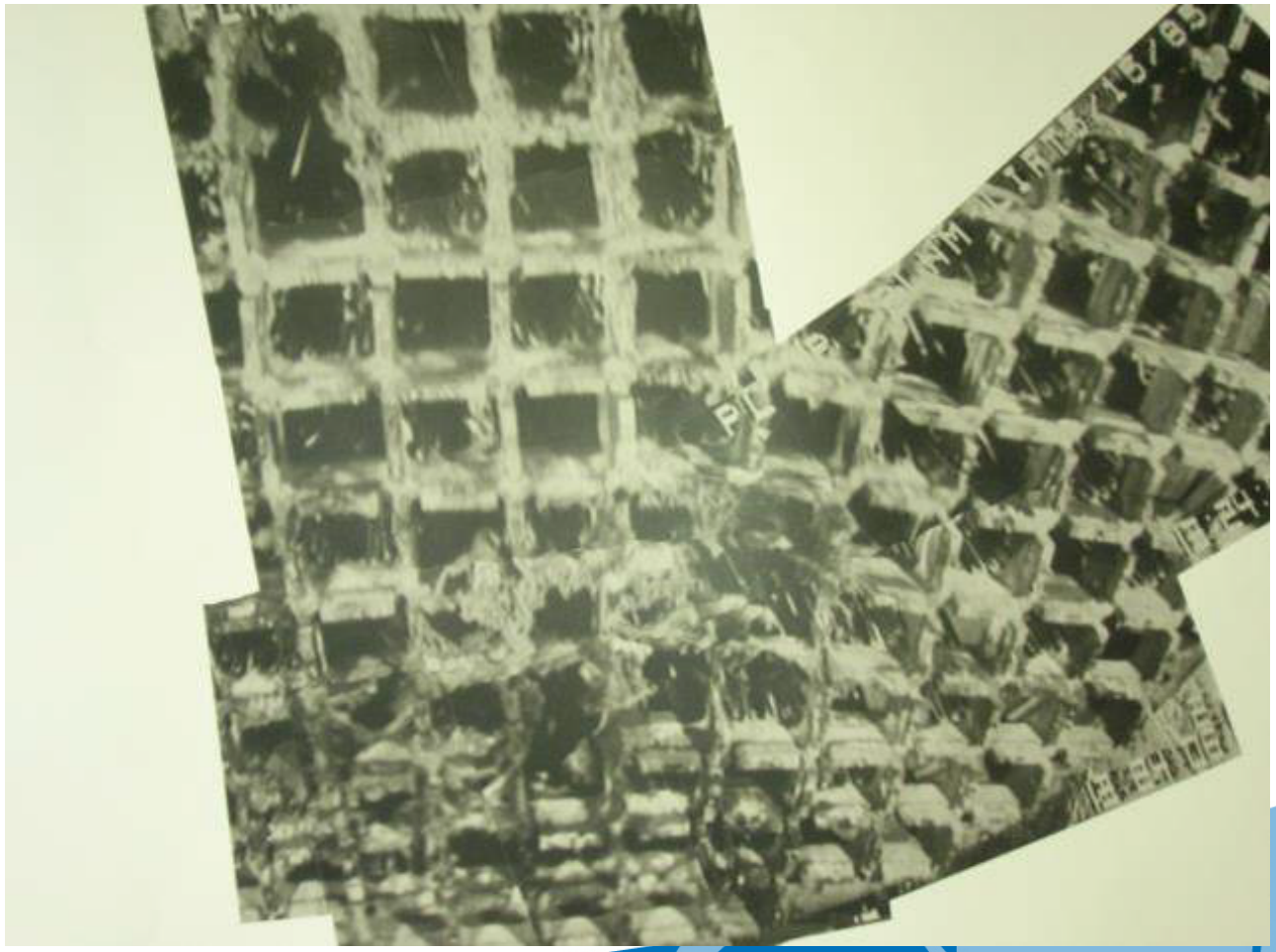

Upper Grid Damage at TMI-2

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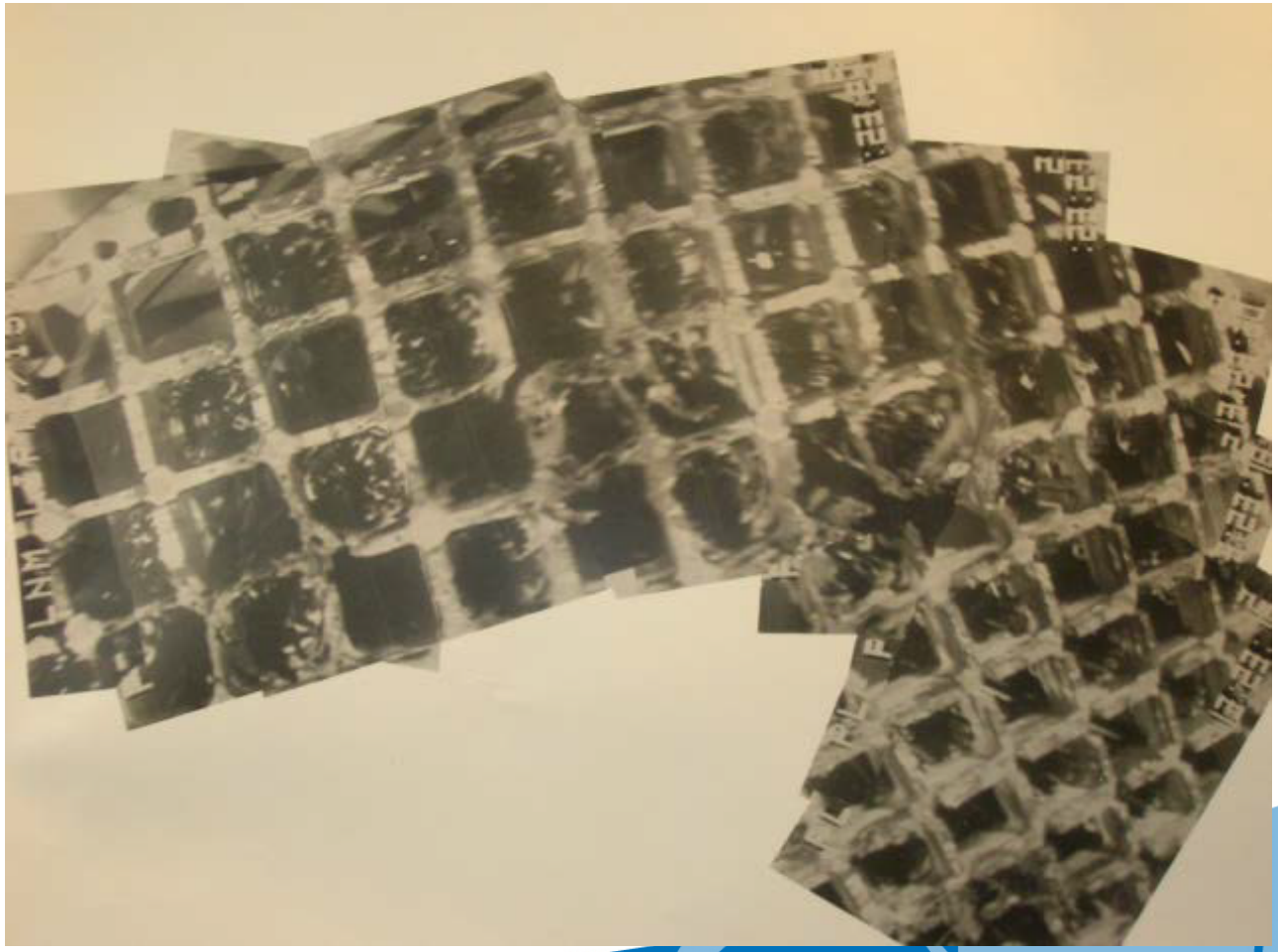

View of Lower Reactor Vessel Head (1985)

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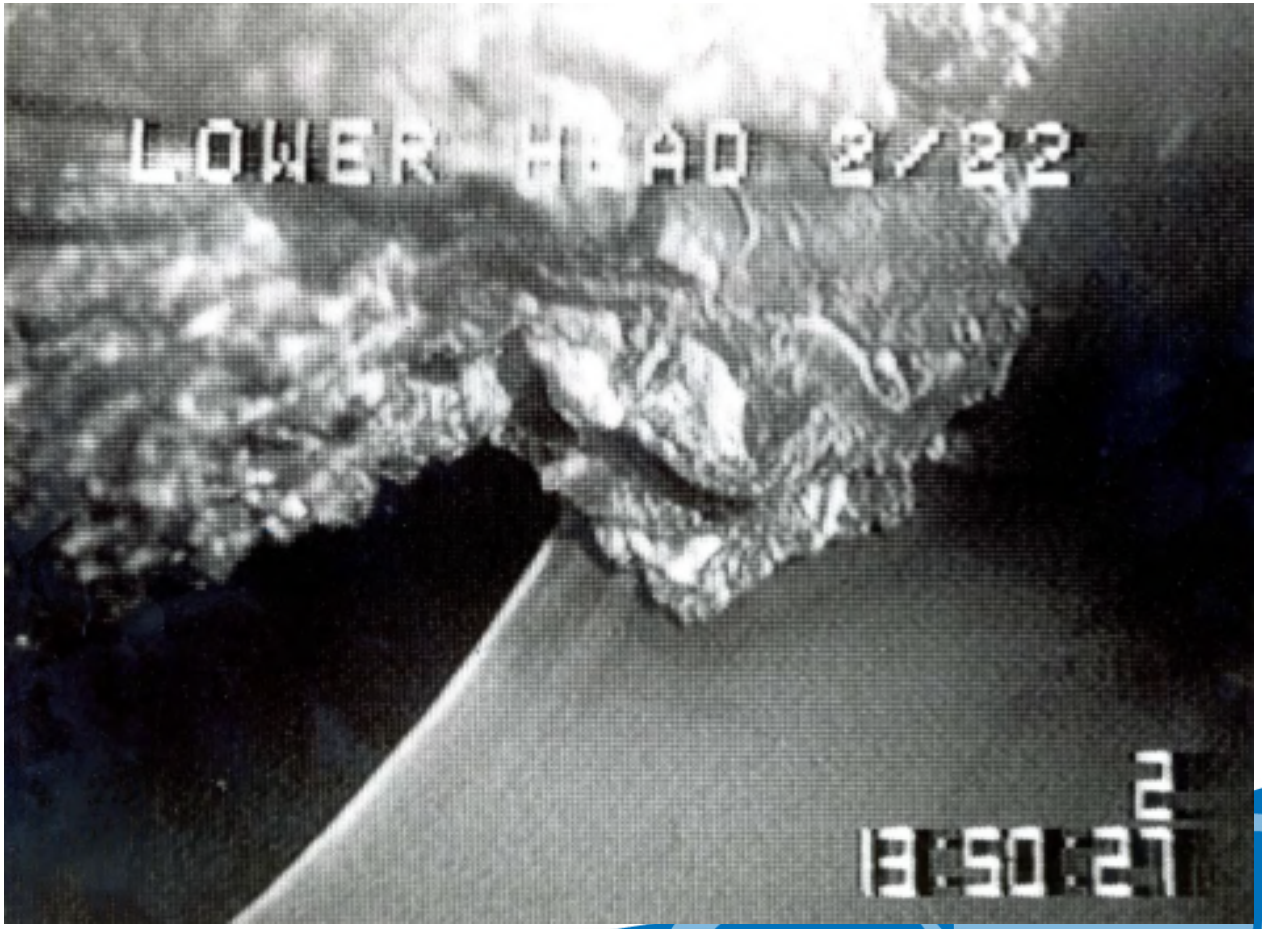

Lower Reactor Vessel Head Look

(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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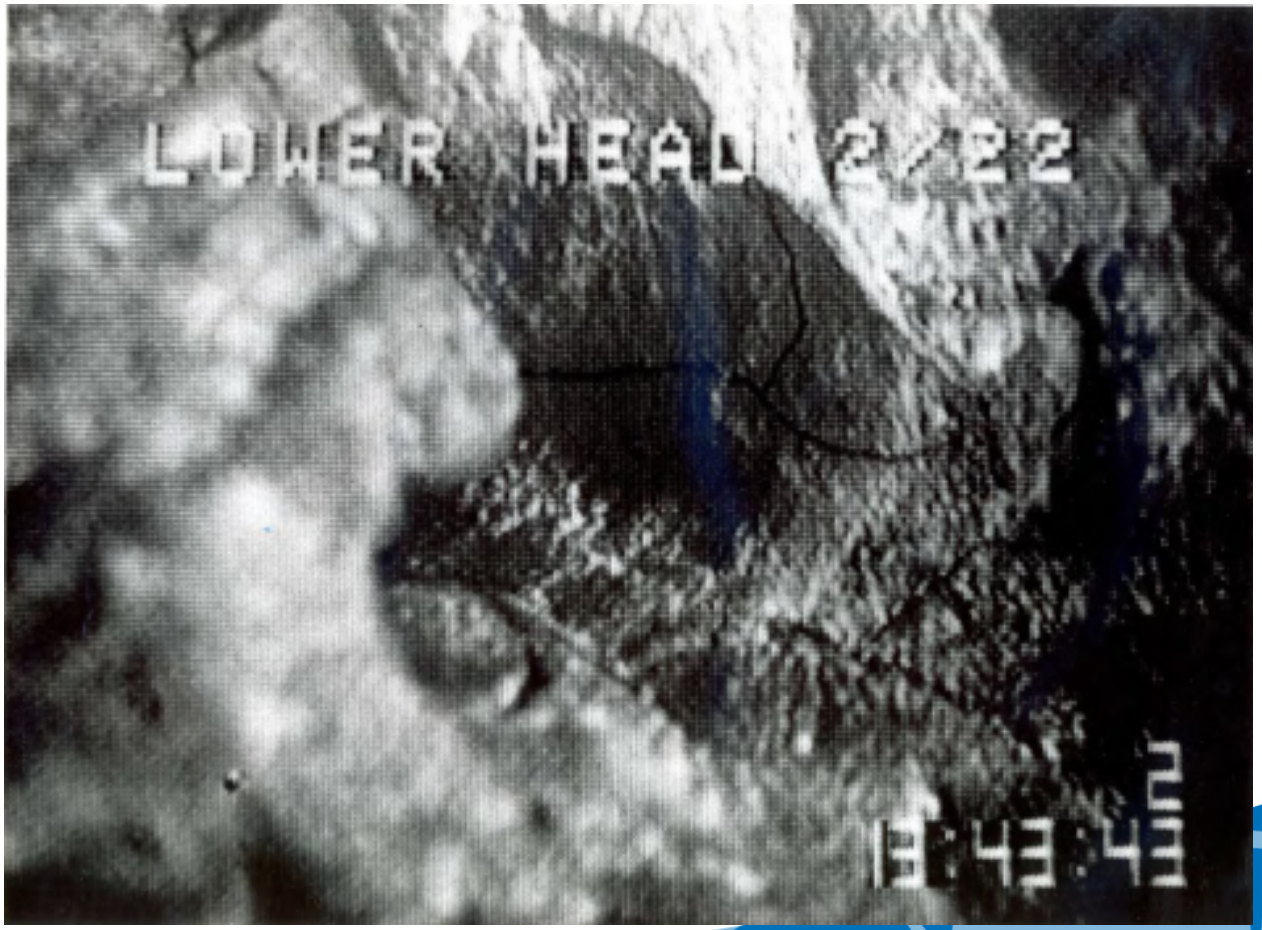

Bulk Defueling System
(Cross-Section View)

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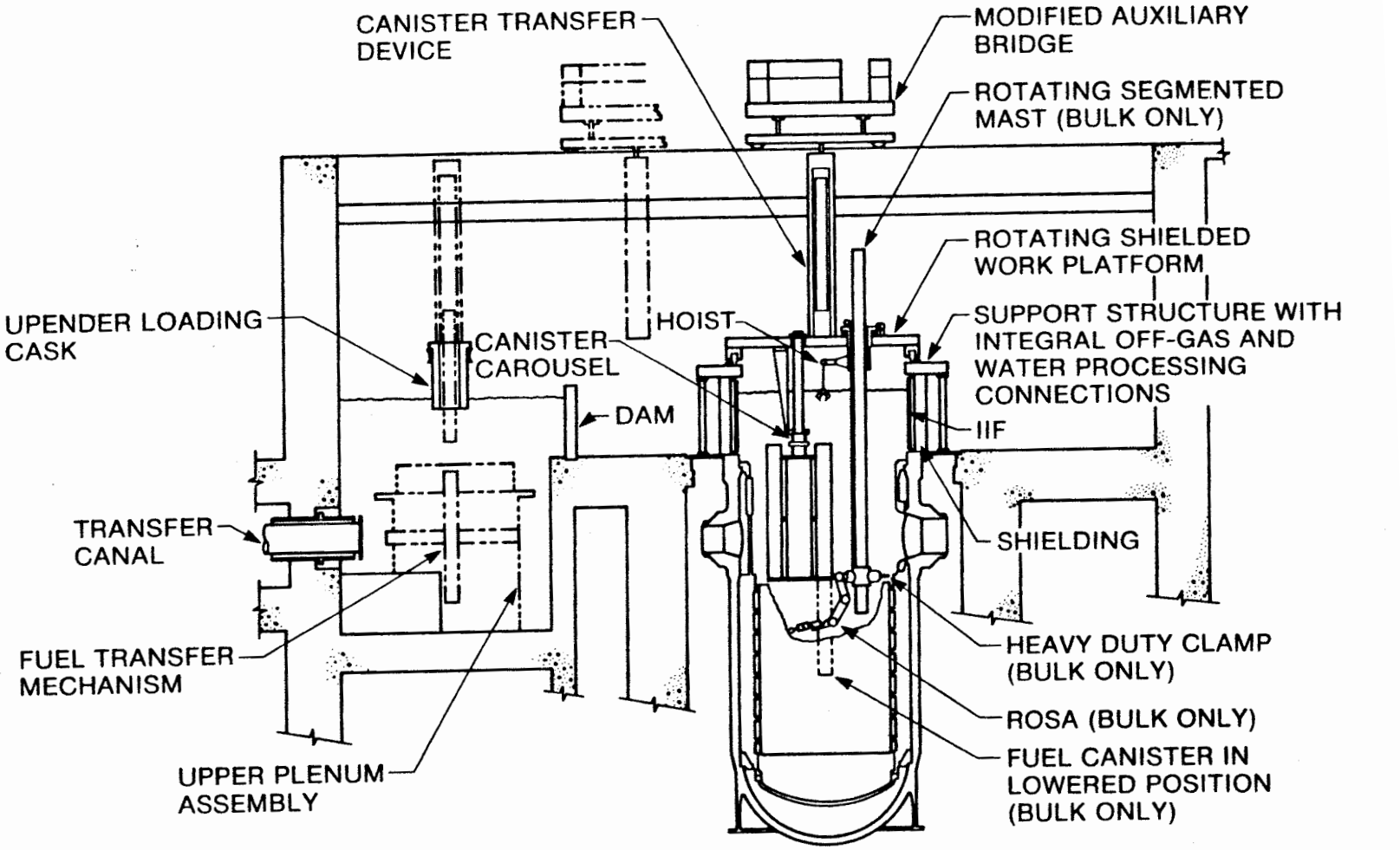

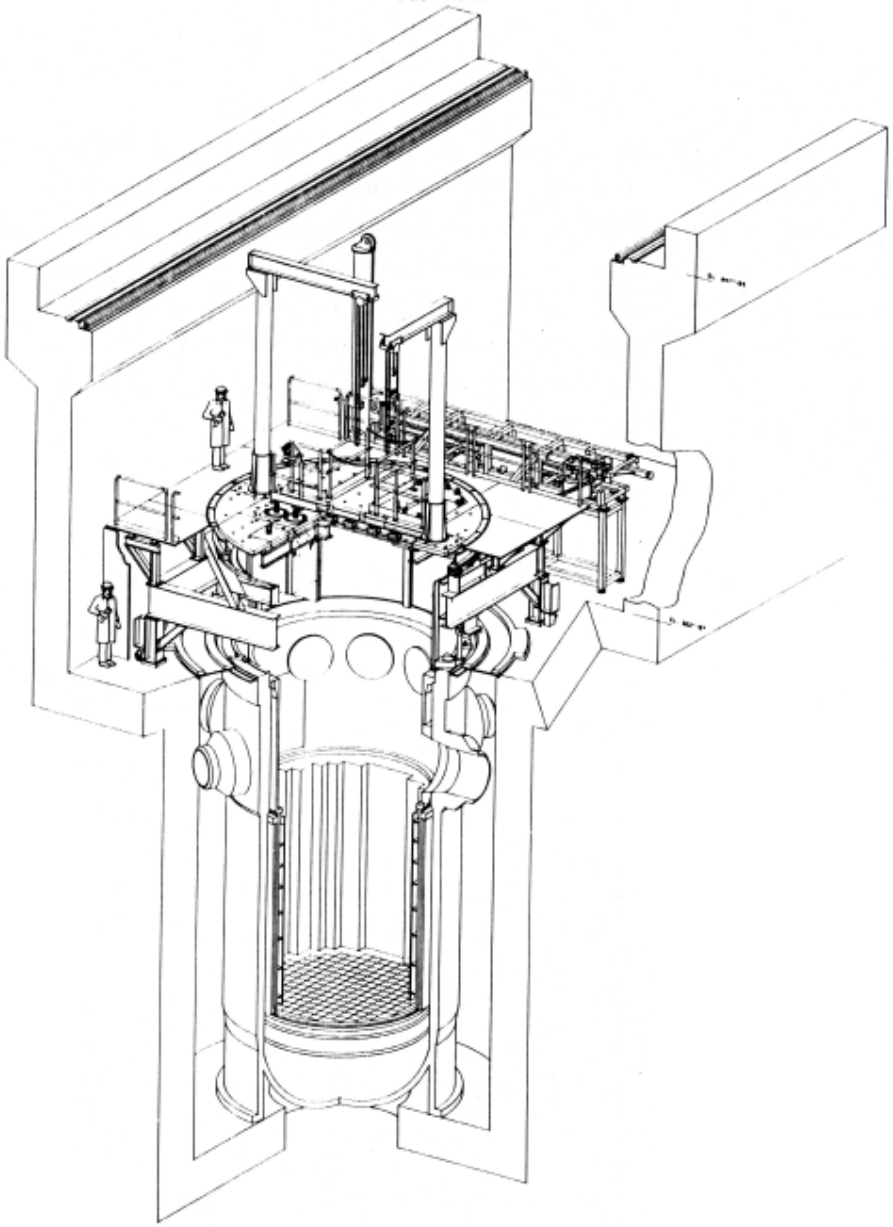

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Defueling Work Platform

(GEND-IN-65)

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

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Defueling Work Platform

(Installed Over Reactor Vessel)

Defueling, Removal of Fuel Debris Using Long-Handled Tools

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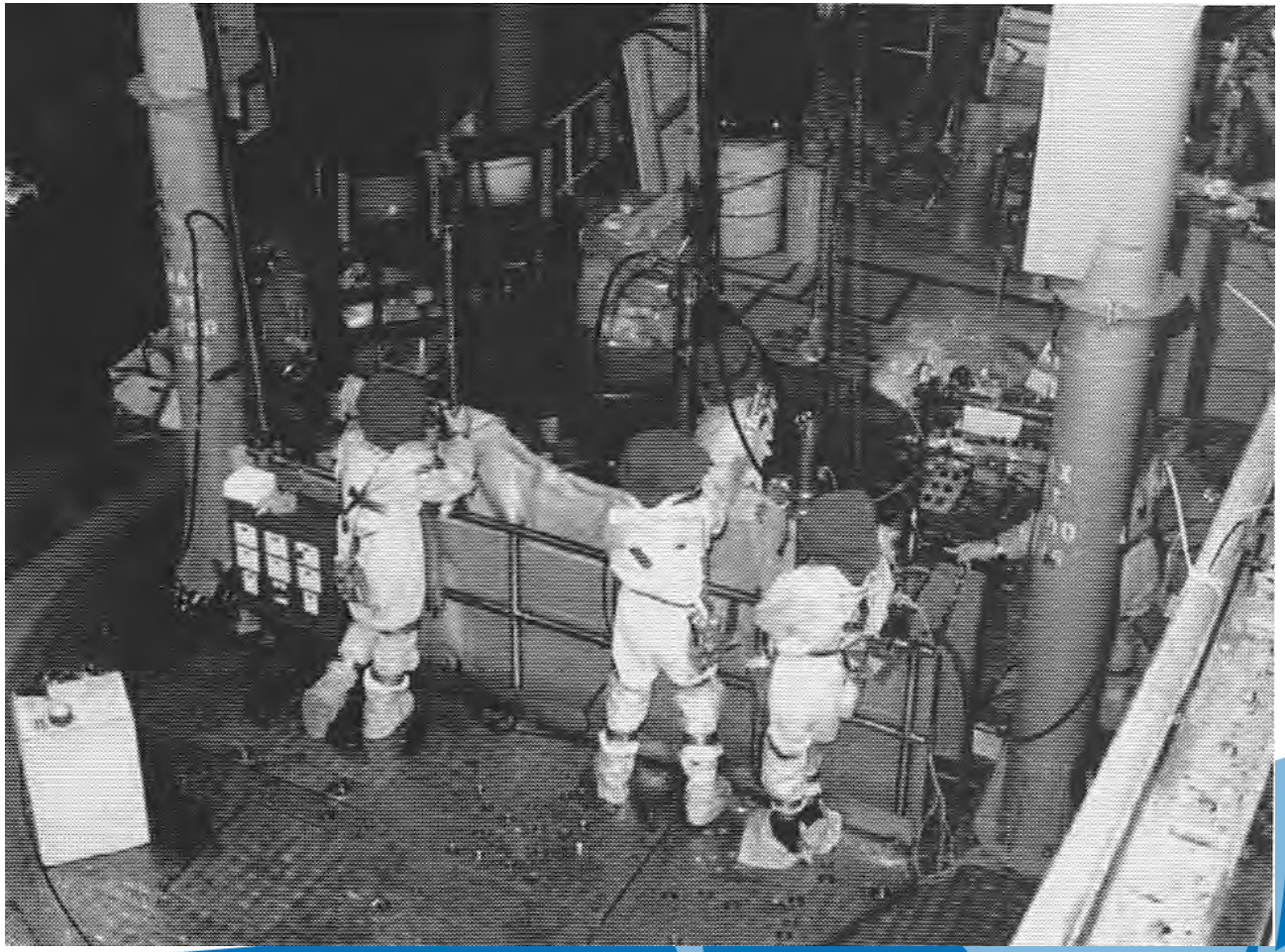

Defueling, Removal of Fuel Debris Using Long-Handled Tools

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

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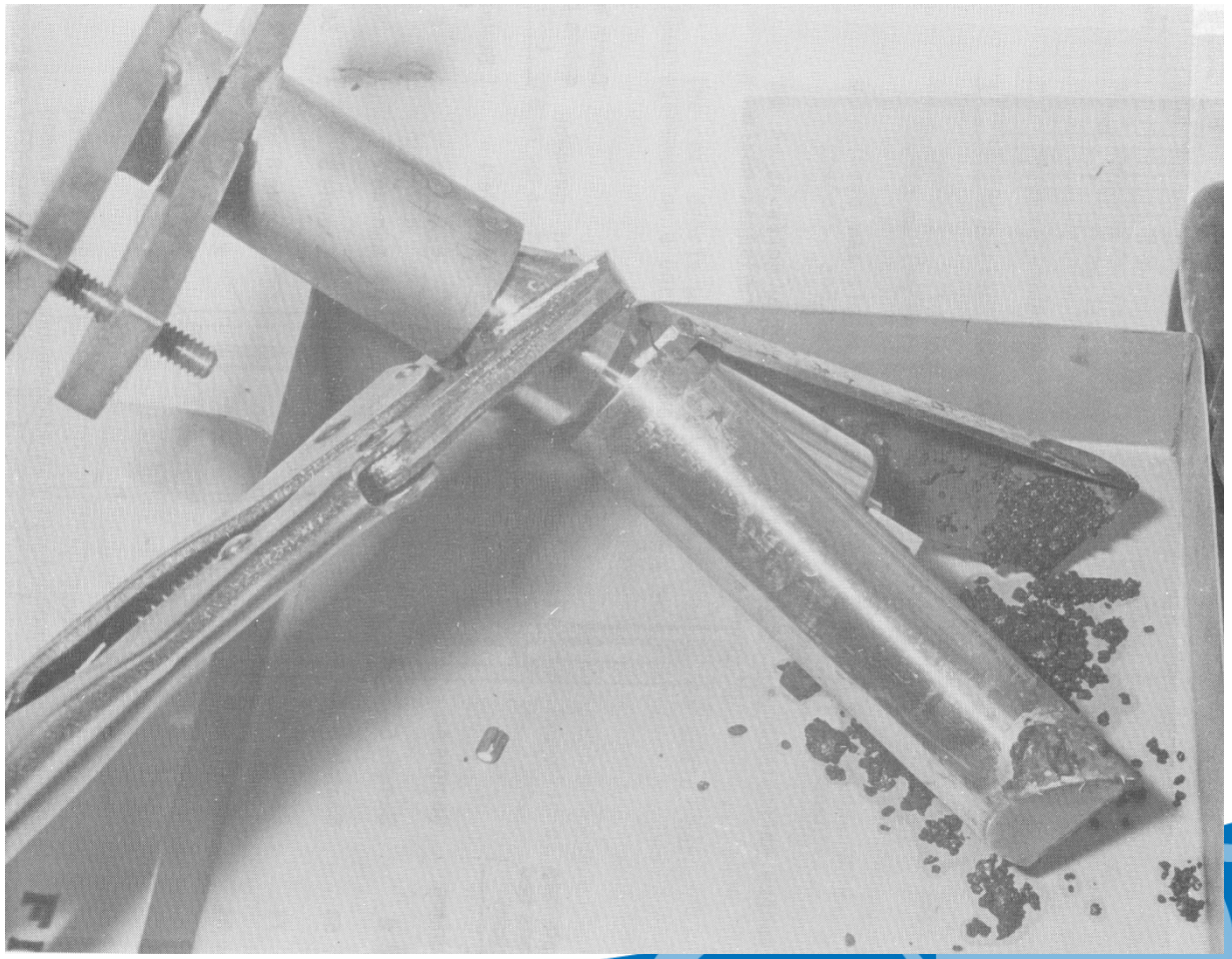

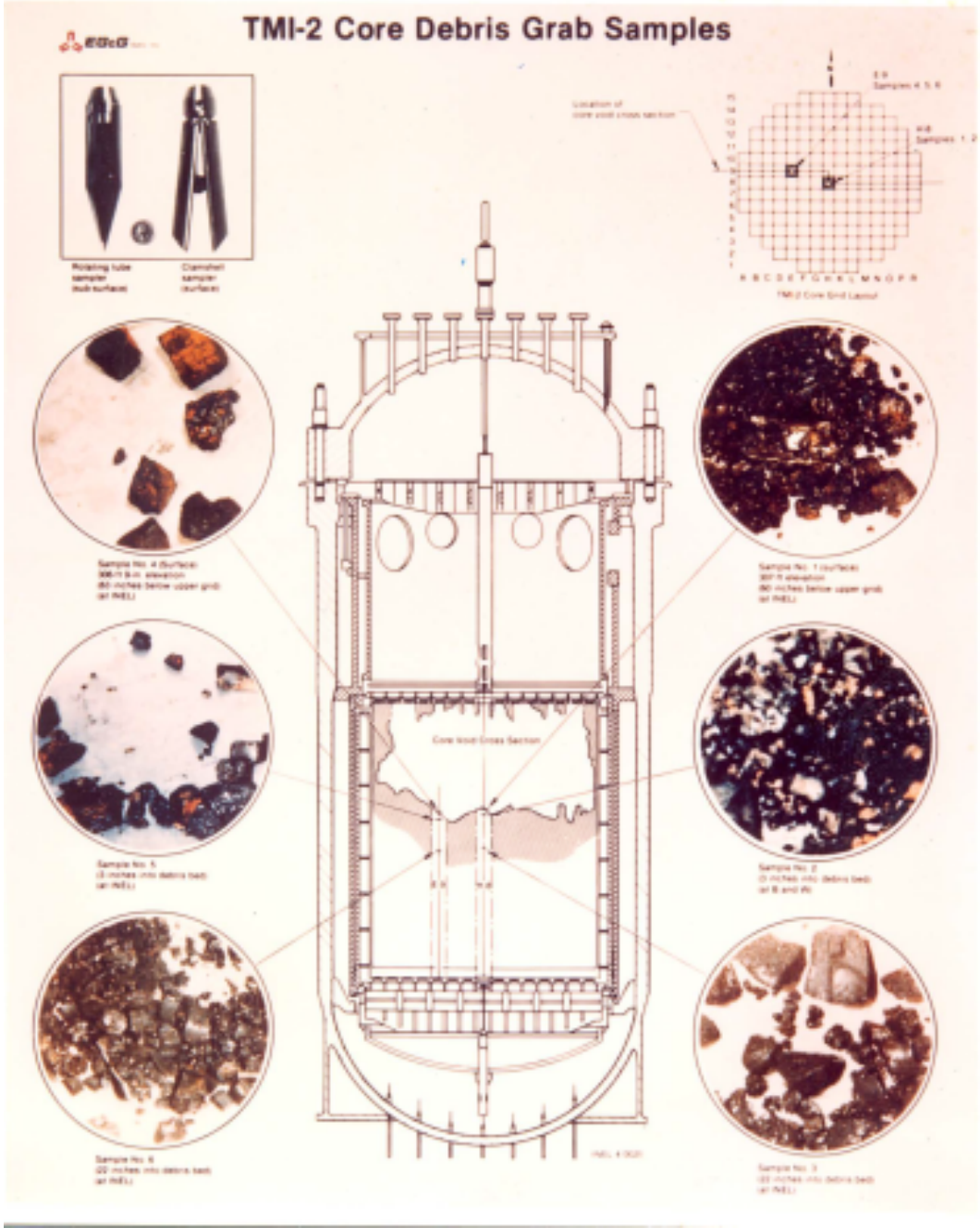

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TMI-2 Core Grab Samples Obtained in 1983

(GEND-INF-060)

The Evening News (Chernobyl)

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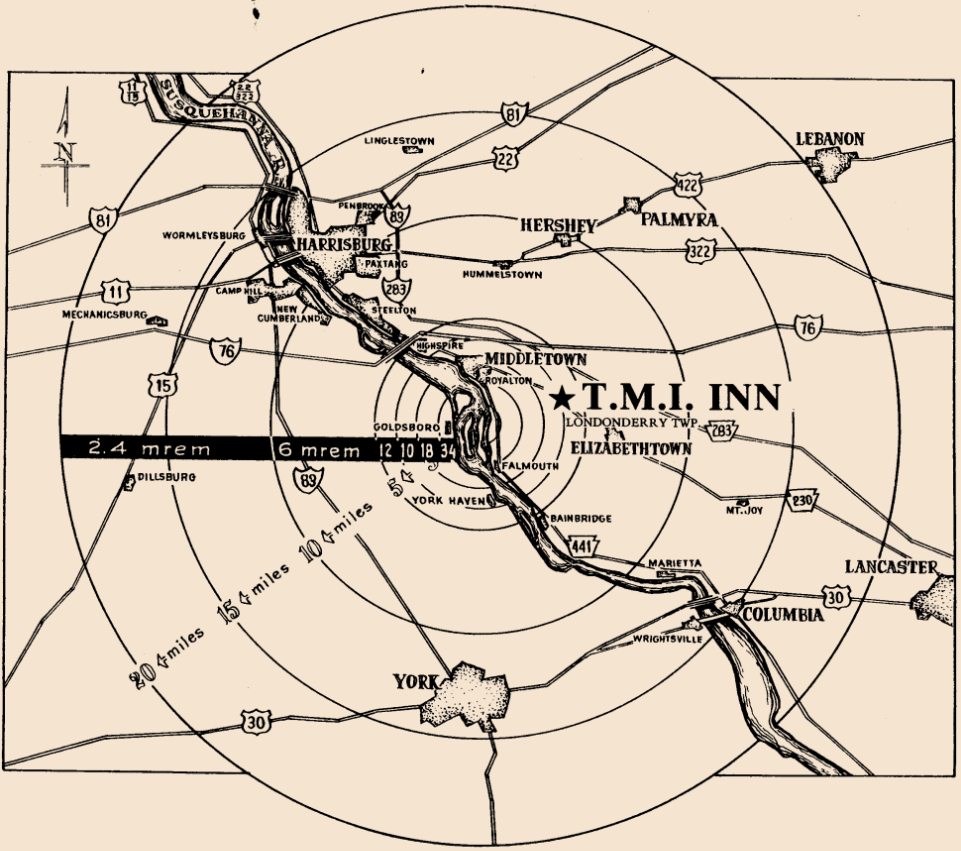
T.M.I. INN



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

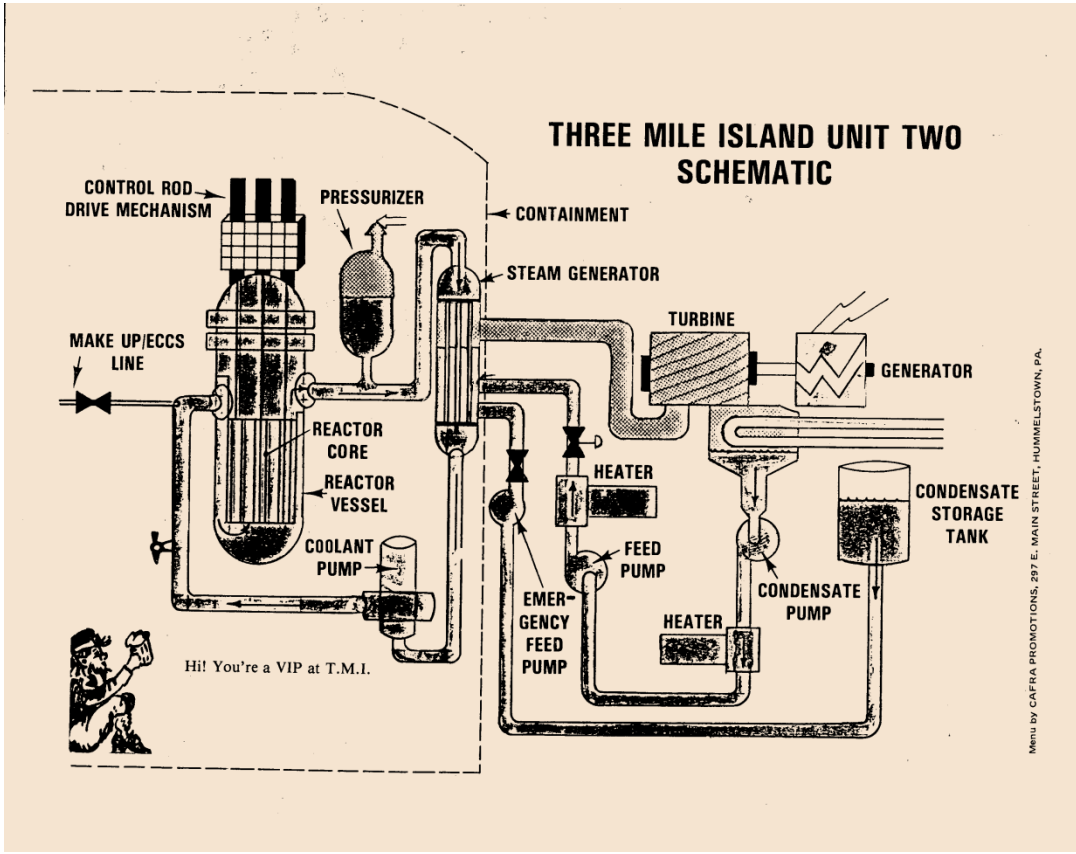
Includes lettuce, tomato, mayonnaise, bacon strips and three slices of bread.

PROTRON $2.75
Roast Beef & Swiss

NUETRON $2.50
Ham & Swiss

ELECTRON $2.50
Turkey & Provolone

PHOTON $2.50
Tuna & Provolone



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

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TMI Reactor Run-By

Carp

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Tiger Muskellunge

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Lessons (12) I learned from those 7 years

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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)

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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)

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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.

Thank You for Attending

Questions?

Regions: Please email your questions to David.Aird@nrc.gov

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