Challenges Encountered at TMI 2 Defueling - Possibly applicable to 1F as Lessons learned

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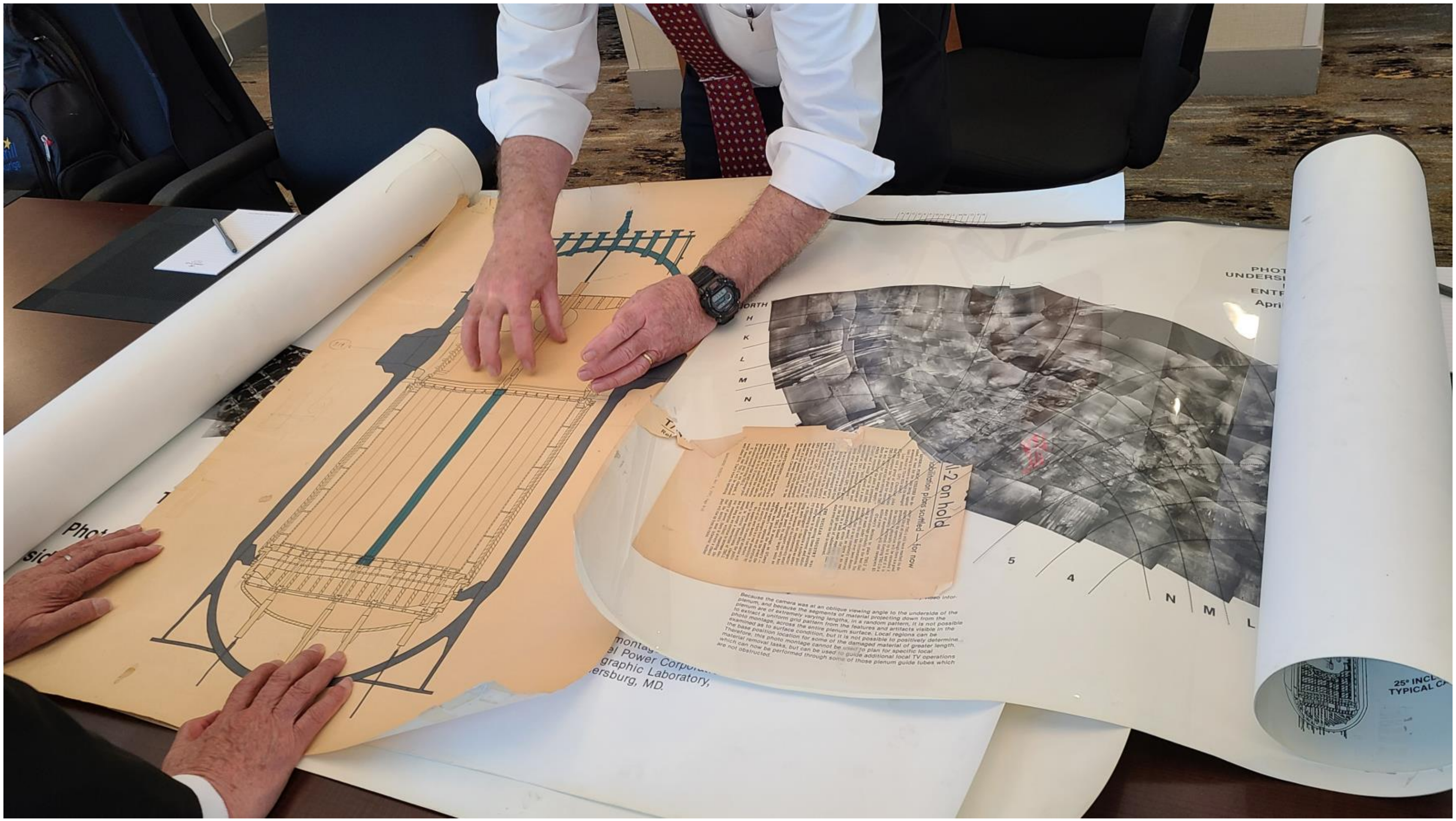
Presented to NDF's 7th International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station

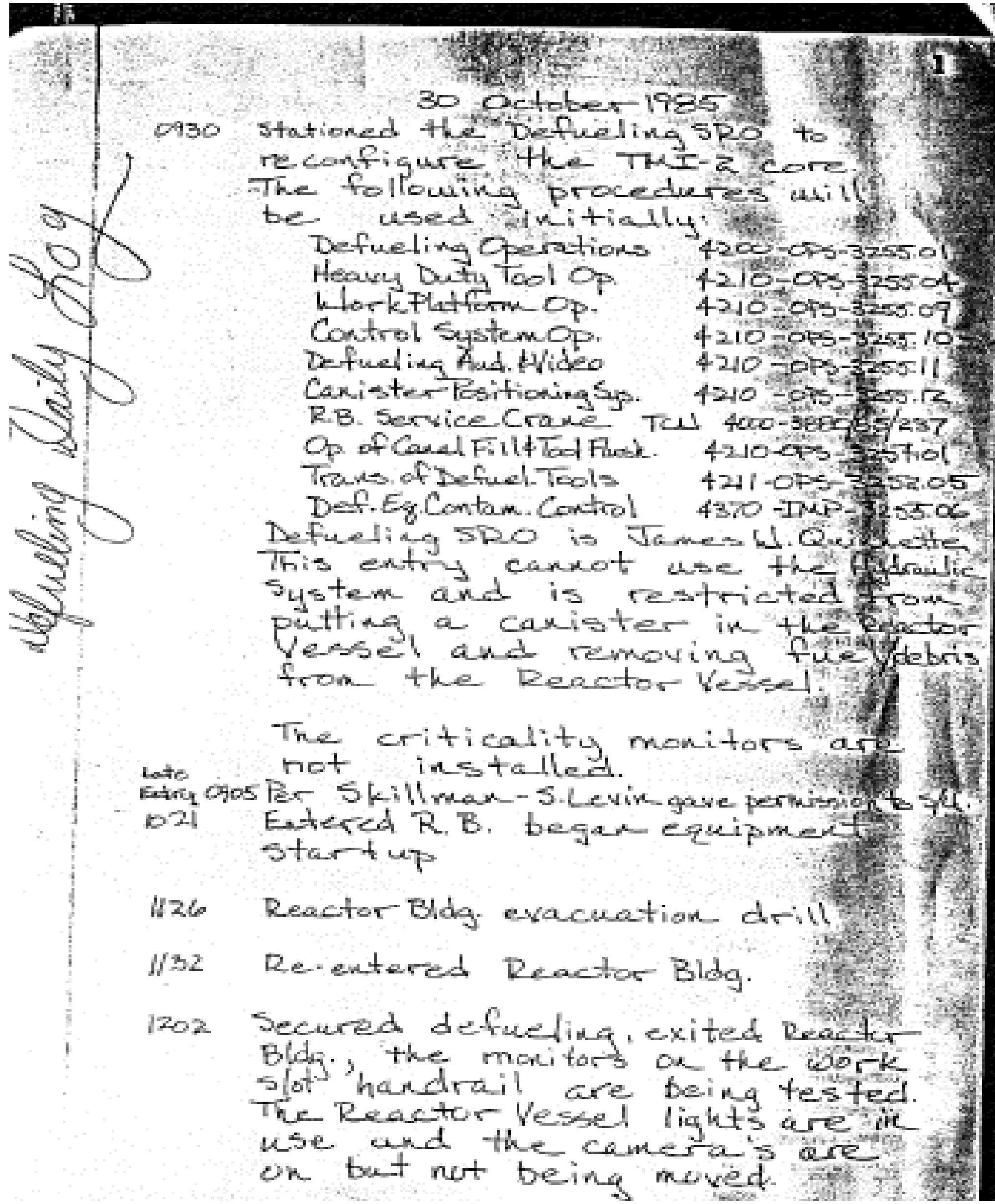
August 28, 2023

This Presentation was created from the personal files of GR Skillman, files from the NRC's Knowledge Management (KM) Digest, and files from colleagues of GR Skillman



Page 1 of TMI 2 Defueling Log

October 30, 1985



Defueling Daily Log

1

30 October 1985

0930 Stationed the Defueling SRO to reconfigure the TMI-2 core. The following procedures will be used initially:

Defueling Operations	4200-OPS-3255.01
Heavy Duty Tool Op.	4210-OPS-3255.04
Work Platform Op.	4210-OPS-3255.09
Control System Op.	4210-OPS-3255.10
Defueling Aud. & Video	4210-OPS-3255.11
Canister Positioning Sys.	4210-OPS-3255.12
R.B. Service Crane TCN	4000-3880-85/237
Op. of Canal Fill & Tool Flush.	4210-OPS-3257.01
Trans. of Defuel. Tools	4211-OPS-3252.05
Def. Eq. Contam. Control	4370-IMP-3255.06

Defueling SRO is James W. Quinnette. This entry cannot use the hydraulic system and is restricted from putting a canister in the Reactor Vessel and removing fuel/debris from the Reactor Vessel.

The criticality monitors are not installed.

Late Entry 0905 Per Skillman - S. Levin gave permission to SU.

1021 Entered R.B. began equipment start up

1126 Reactor Bldg. evacuation drill

1132 Re-entered Reactor Bldg.

1202 Secured defueling, exited Reactor Bldg., the monitors on the work slot handrail are being tested. The Reactor Vessel lights are in use and the camera's are on but not being moved.

Three Mile Island Nuclear Plant

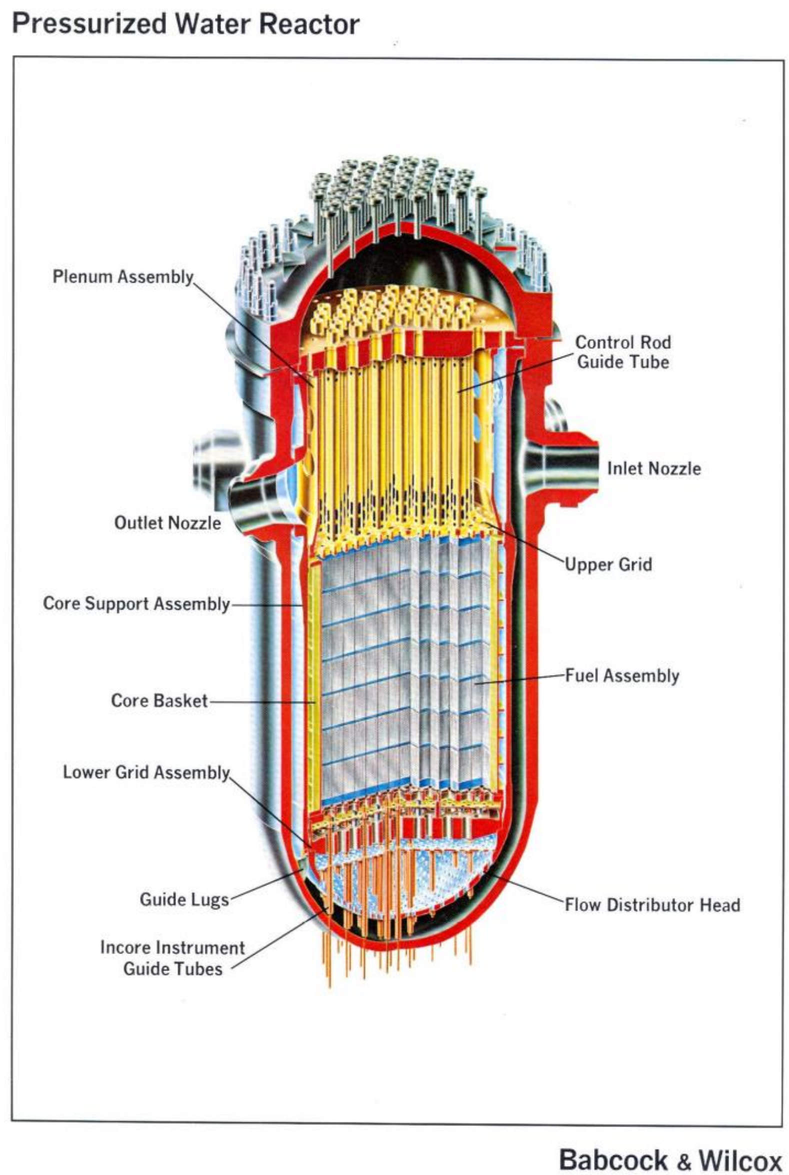
Three Mile Island is in the middle of the Susquehanna River, Aerial View (from Northwest to Southeast)

TMI-1 – B&W NSSS - 2568 MWt – Commercial 1975
TMI-2 – B&W NSSS - 2772 MWt – Commercial 1979

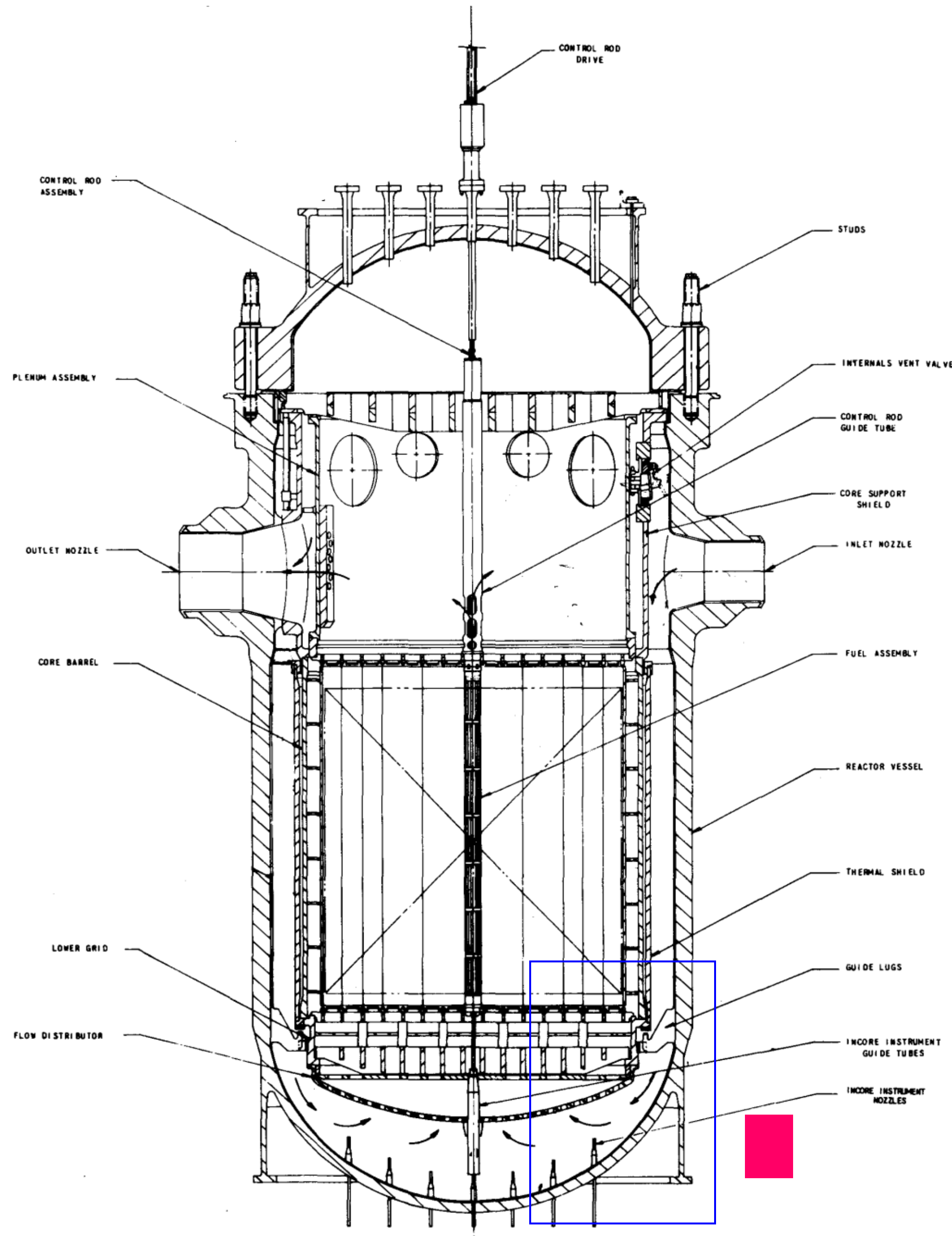
Susquehanna River – Any radioactive release to this river will be a national catastrophe

- The Susquehanna River is About 440 Miles (700 KM) Long
- It is the 16th largest river in the USA
- It provides drinking water source for multiple localities downstream
- It provides ~ 50% of the fresh water to Chesapeake Bay, the largest estuary in the United States
- There would be a very serious national consequences for any leak of radioactive water from the TMI 2 plant into the Susquehanna River

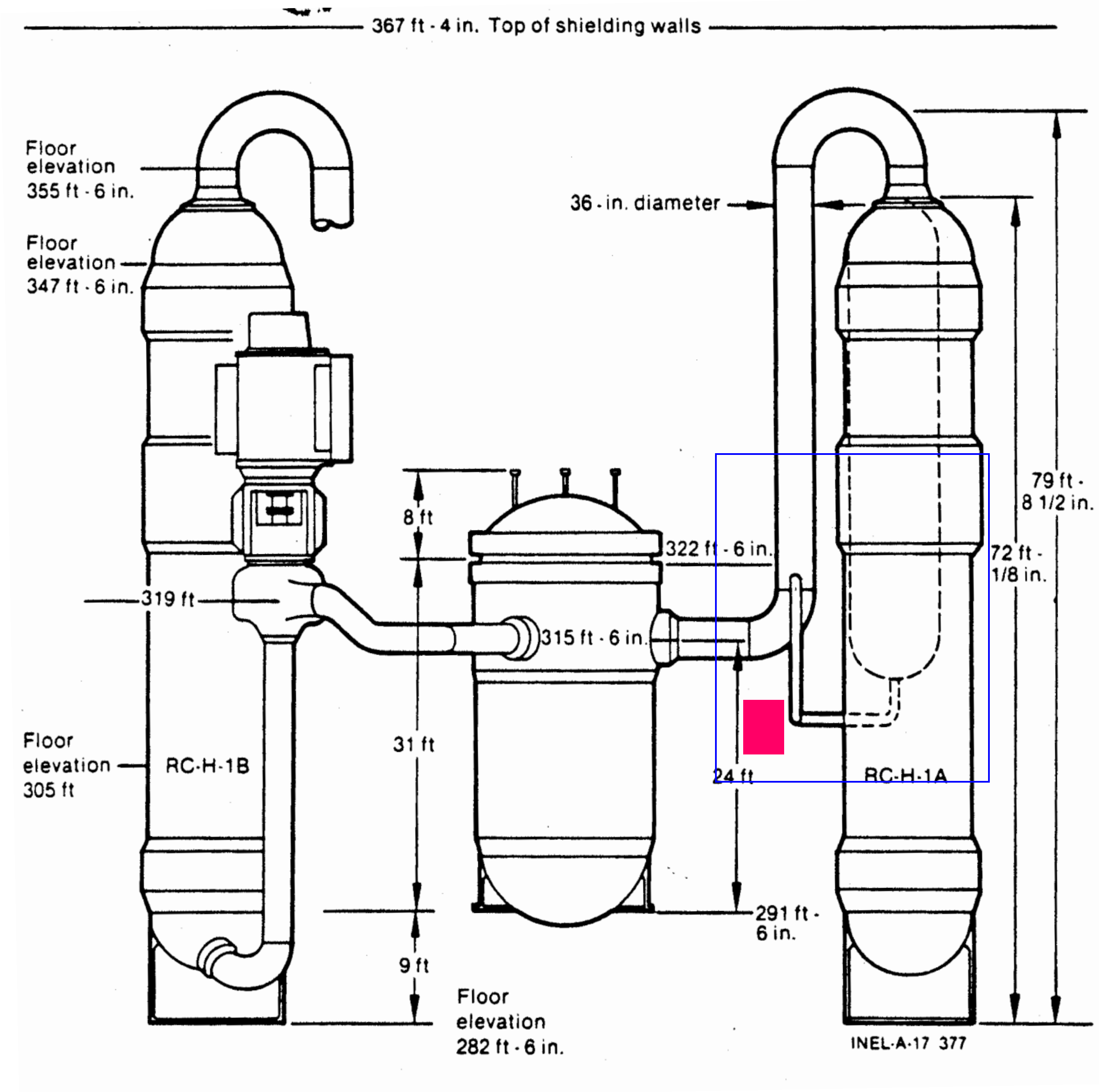
Typical B&W Reactor Vessel Cutaway View Showing Internals



TMI-2 Reactor Vessel Internals Diagram – See blue box / red box (complexity of core support structures)



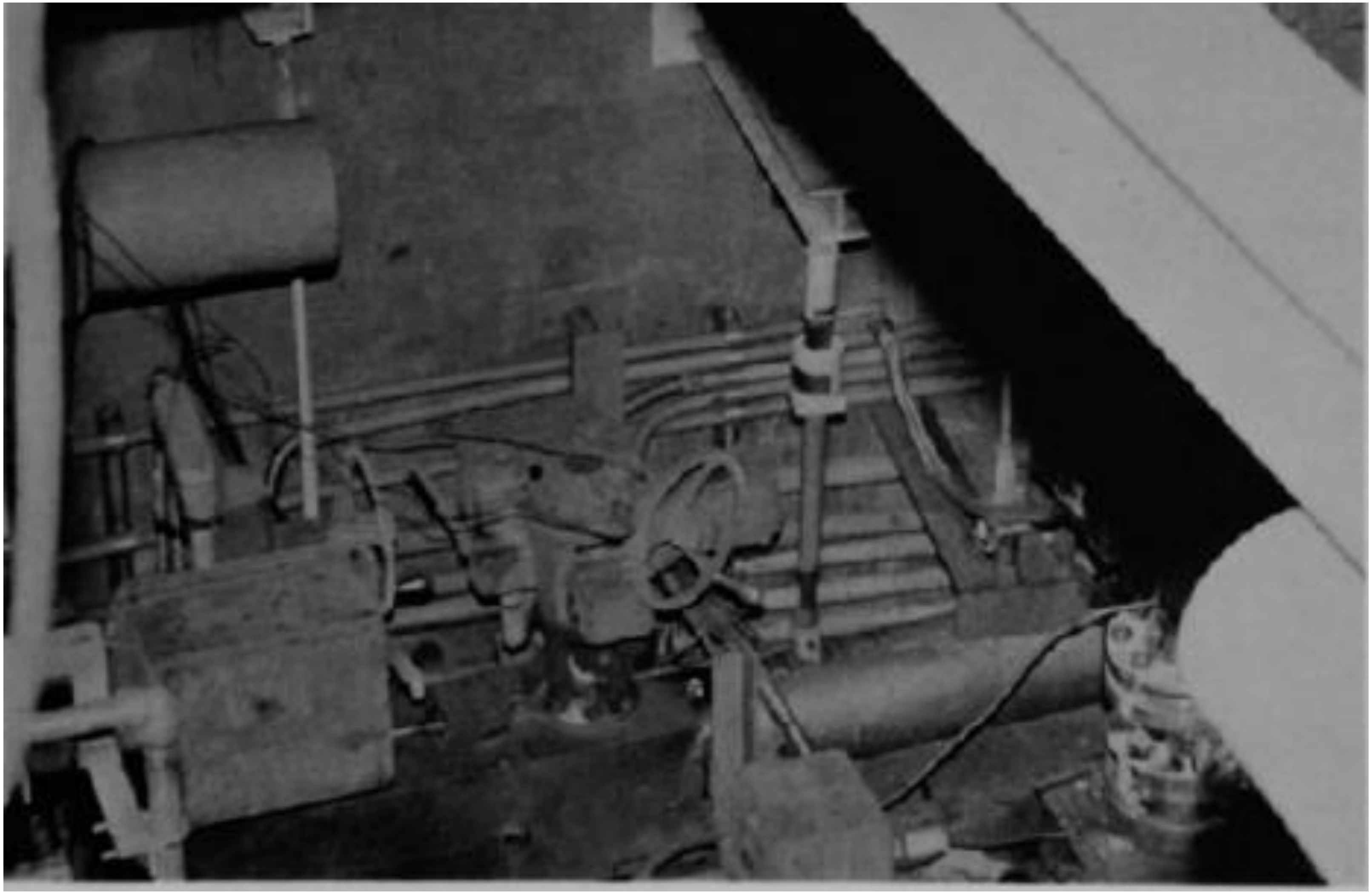
Typical B&W Reactor Coolant System Physical Arrangement with TMI 2 Floor Levels (See Surge Line, Pressurizer in Phantom at red box)



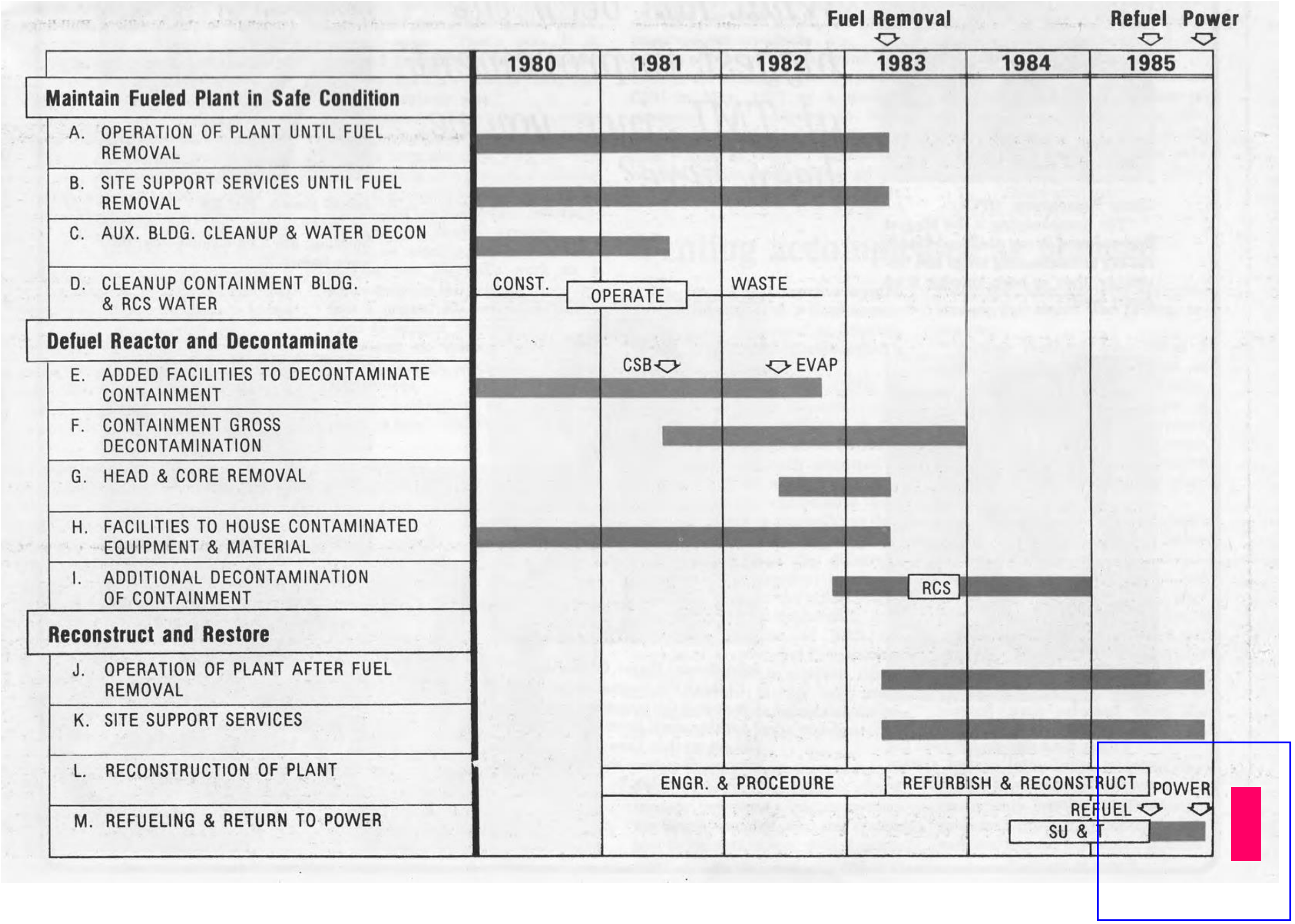
The Accident

- The Accident happened at 0400 on March 29, 1979
- The Susquehanna River was at full spring runoff, thereby containing farm field drainage from numerous agricultural properties from as far as 400 miles upstream. This water contained Coliform bacteria
- The Accident was the result of a small Reactor Coolant system leak that ultimately resulted in core damage. The Power Operated Relief Valve (PORV) opened as designed, but failed to close as designed. It remained open for 140 minutes resulting in void formation in the core, core melt, and several hundred thousands gallons of highly radioactive water leaking into the basement of the Reactor building
- Nearly all important areas of the plant became inaccessible due to never-before experienced radiation levels

Pressurizer Pressure-Operated Relief Valve (PORV)



Importance of Data Gathering - GPU Early Cleanup Schedule (Aug 1980) – Before Quick Look – Notice 'Return to Power' date at red box



TMI 2 Cleanup Timeline

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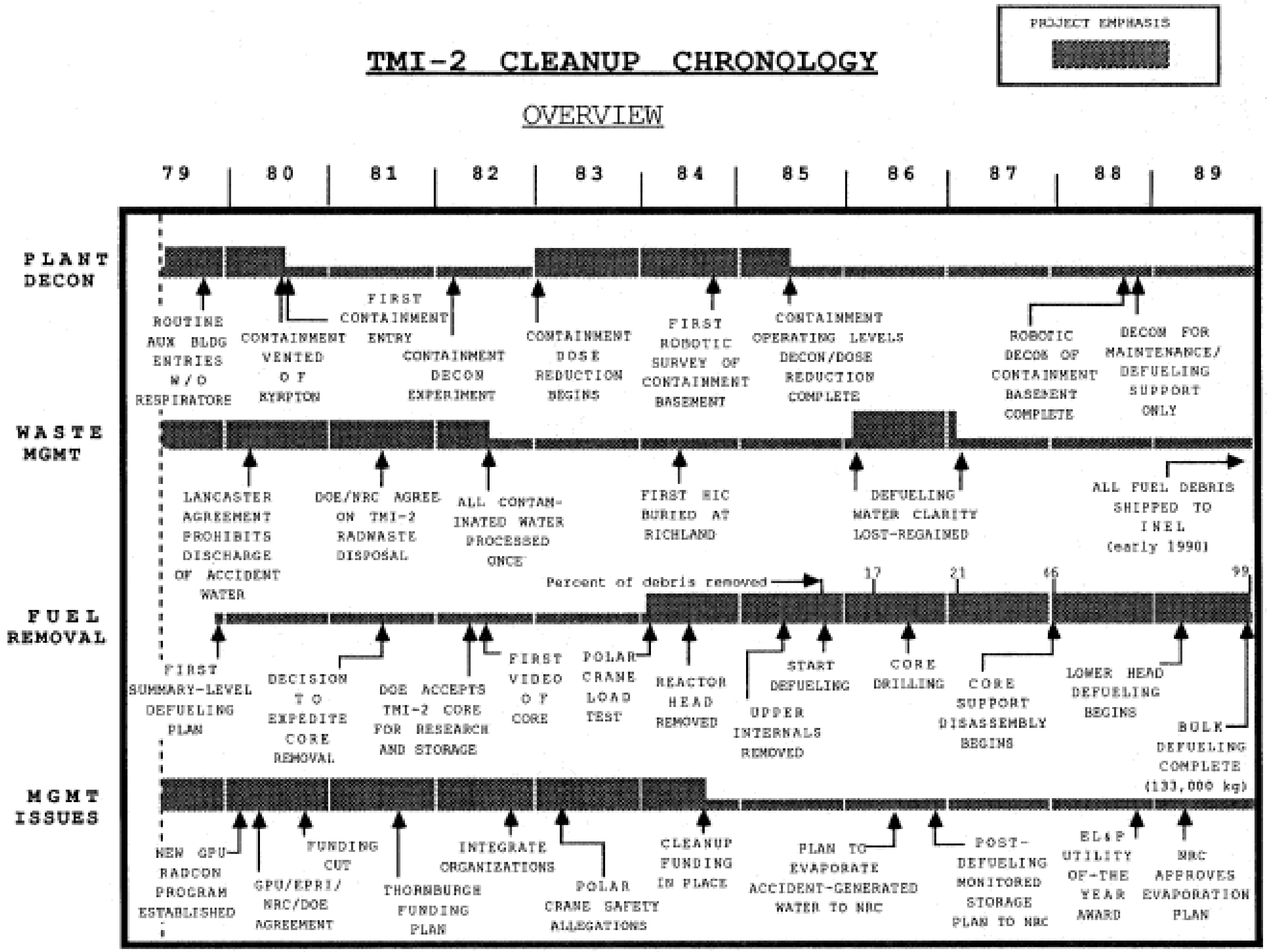
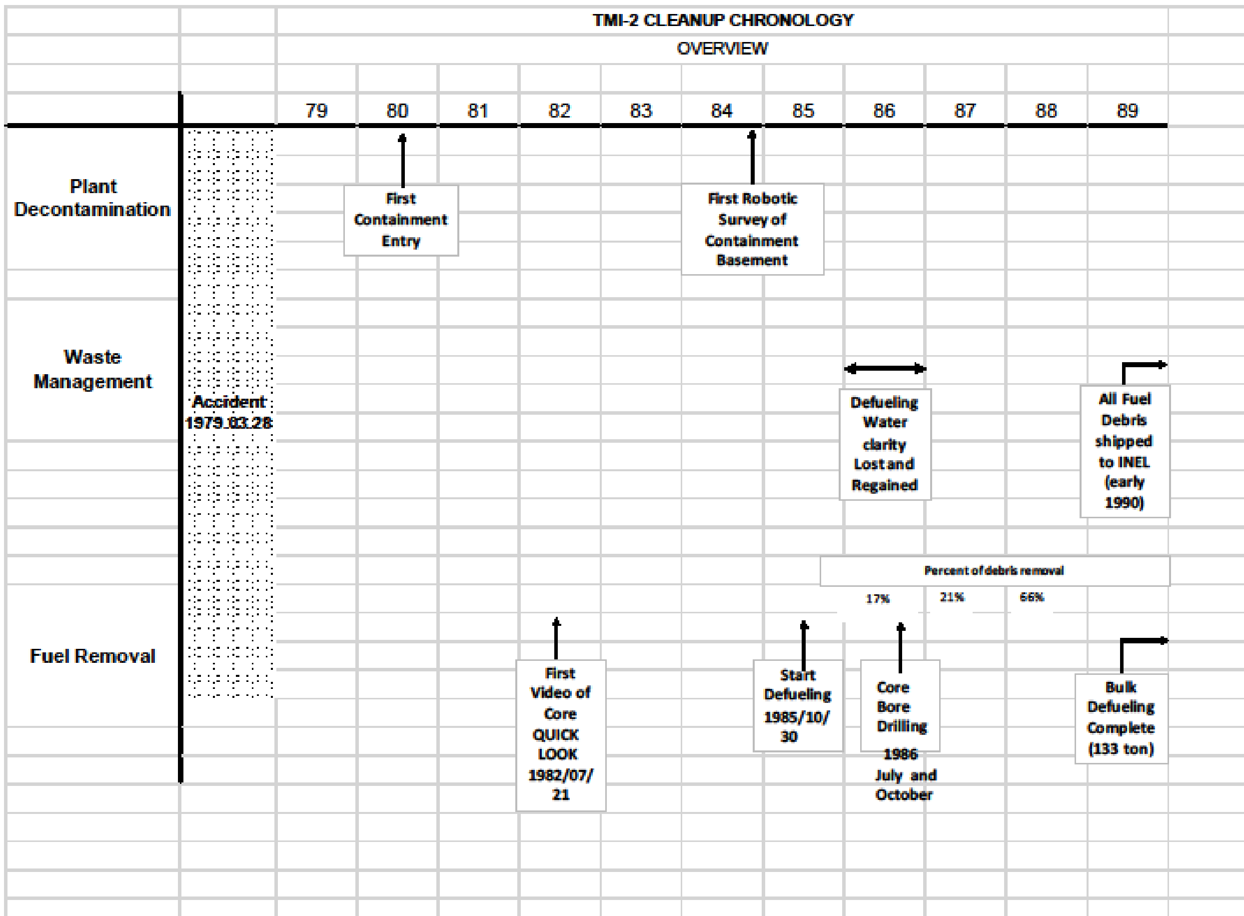


Figure 1-1. TMI-2 Timeline: Overview

Simplified Timeline – Main Events



Data Acquisition was critical for choosing next steps for Defueling Planning

- Data Acquisition was essential to enable the TMI 2 organization to move forward
- GPU leaders worked with several consultants to develop and execute a ‘Quick Look’ experiment simply to observe what, if anything, may be below the top of the core
- Until Quick Look there was no understanding of the core conditions, and no clear plan of action to access or remove the degraded core
- Following Quick Look, plans for Defueling and supporting clean up actions began to emerge. Consideration of ‘Restart’ ended
- Quick Look made clear the need for additional data gathering such as getting Core Debris Samples

Quick Look 7-21-1982 (GEND-030 Vol 1)

(Also repeated on 8/6 and 8/12, 1982)

- Three and a half years after the Accident
- Team Removed CRDM Leadscrew while standing on the Vessel Head Service Platform
- Accessed core by lowering a camera and companion light assembly through Leadscrew opening H-8, dead center of the Core
- Utilized 1.5” (~38mm) Diameter Camera
- Discovered upper 5.5 feet (~1.5 m) of core was missing

First Visual Access to Core - Quick Look on July 21, 1982 (Three Years after the Accident)

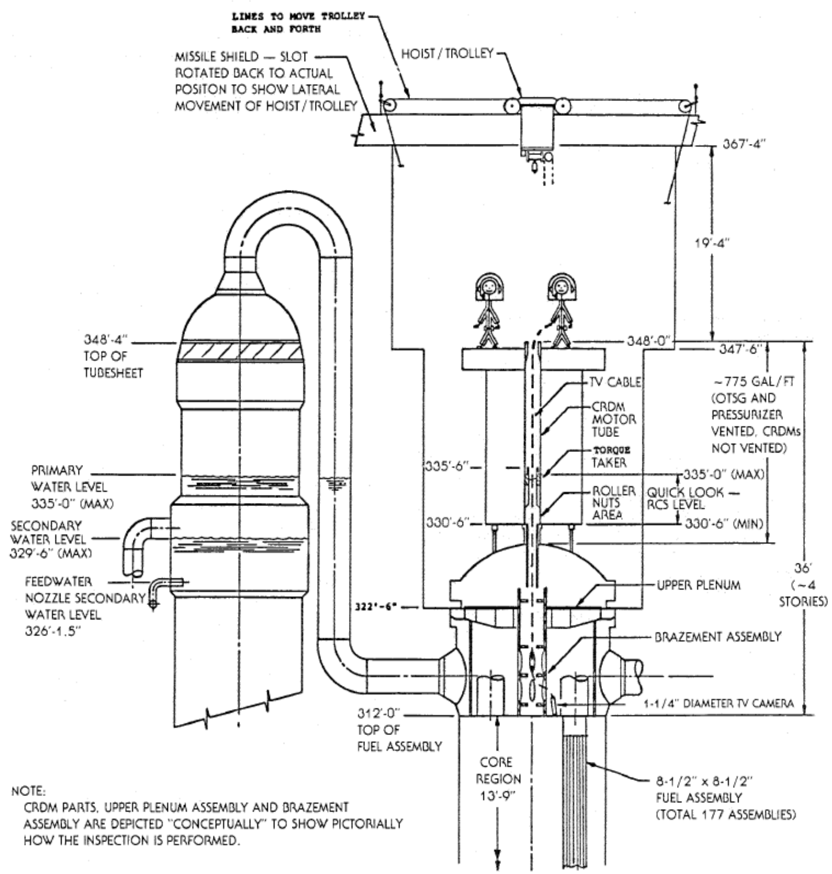
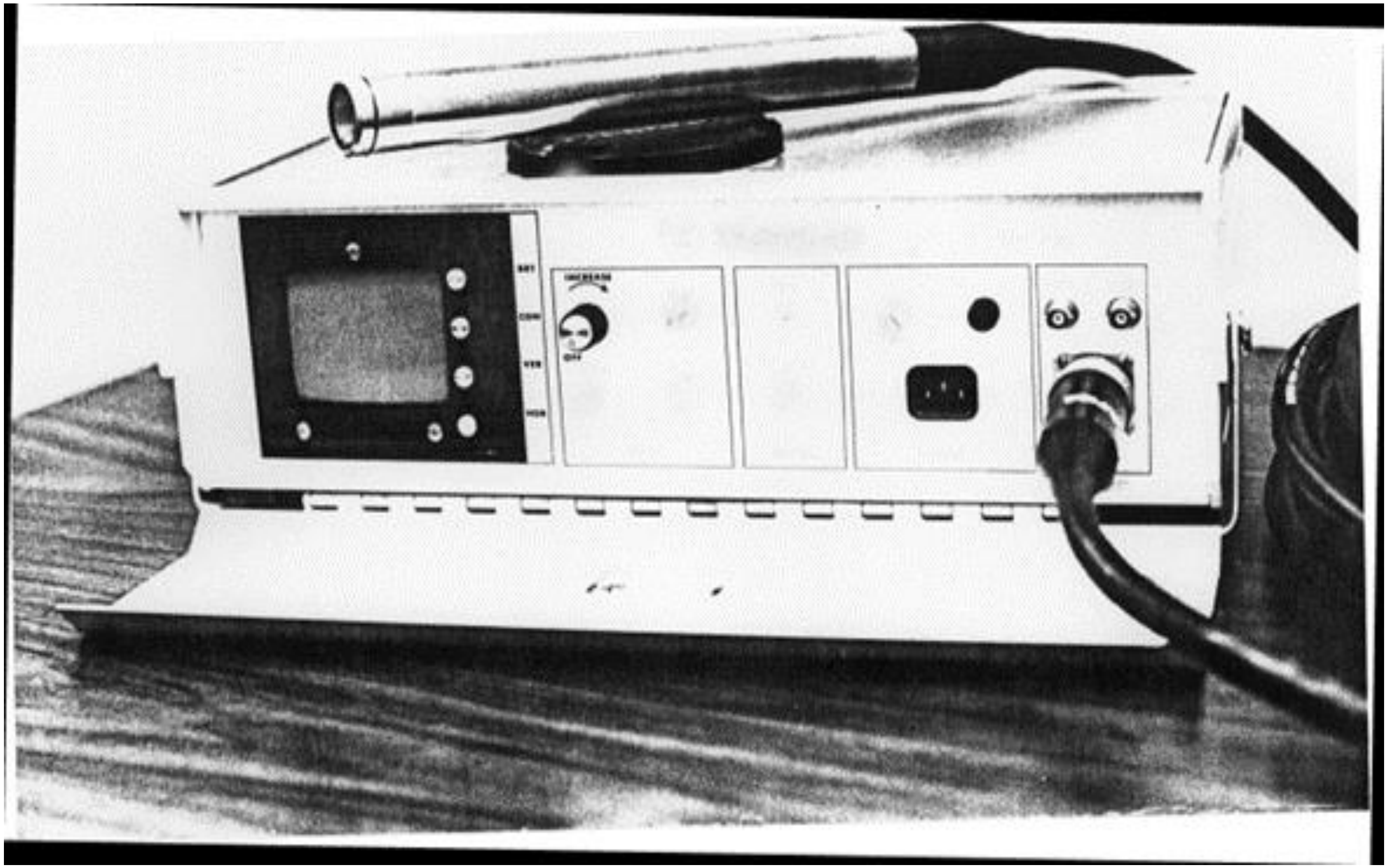


Figure 5-8. Conceptual Arrangement for TV "Quick Look" via Leadscrew Hole

5–14

Quick Look Camera and Electronics

(Data Report – Quick Look Inspection Results – TPO/TMI-026)



Quick Look Team handling Quick Look Camera July 21, 1982

(Penn State University TMI-2 video library)

Quick Look Team - Inserting Quick Look Camera into CRDM Opening July 21, 1982

(Penn State University TMI-2 video library)

Quick Look on 7-21-1982
Fuel Pins, Spacer Grid, Fuel Pin Upper Spring

Quick Look on 7-21-1982
Spacer Grid, Fuel Pins

Additional Quick Look Inspections

- There were three Quick Look Inspections

  Quick Look I - July 21, 1982

  Quick Look II - August 6, 1982

  Quick Look III - August 12, 1982

Each Inspection utilized the same basic approach of accessing the core from the Service Structure through a Leadscrew opening

- Each Inspection entered the damaged core from a different CRDM Leadscrew position effectively one or two fuel assemblies distant from the first Quick Look

Assumed Core Conditions after the Quick Look Inspections (NP-6931)

At this early stage of Data Retrieval we did not know what additional fuel damage we might discover as we began fuel removal

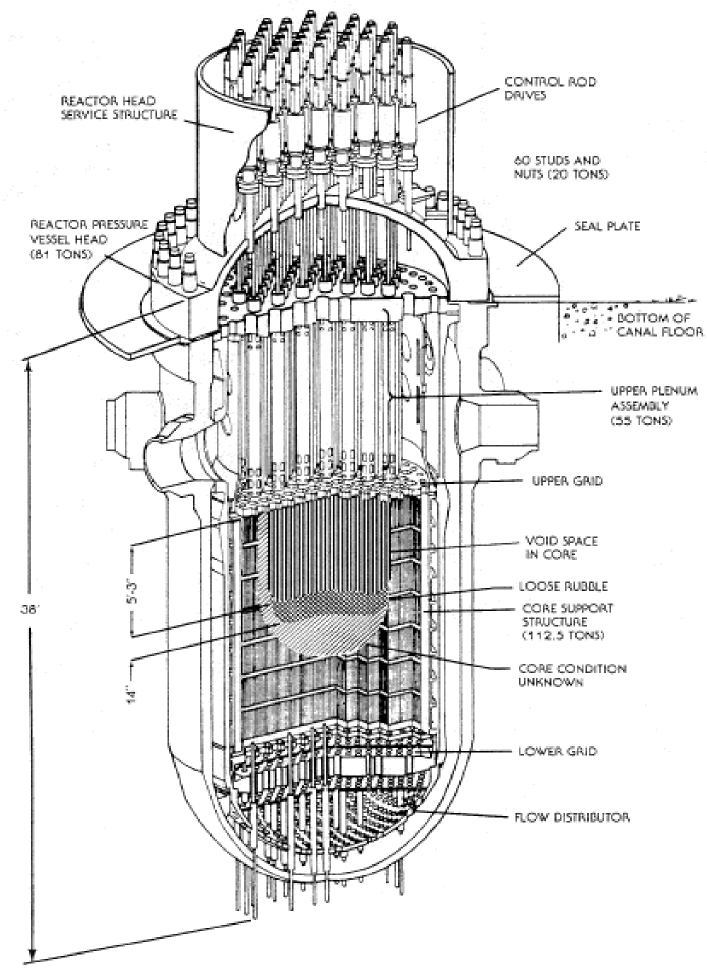
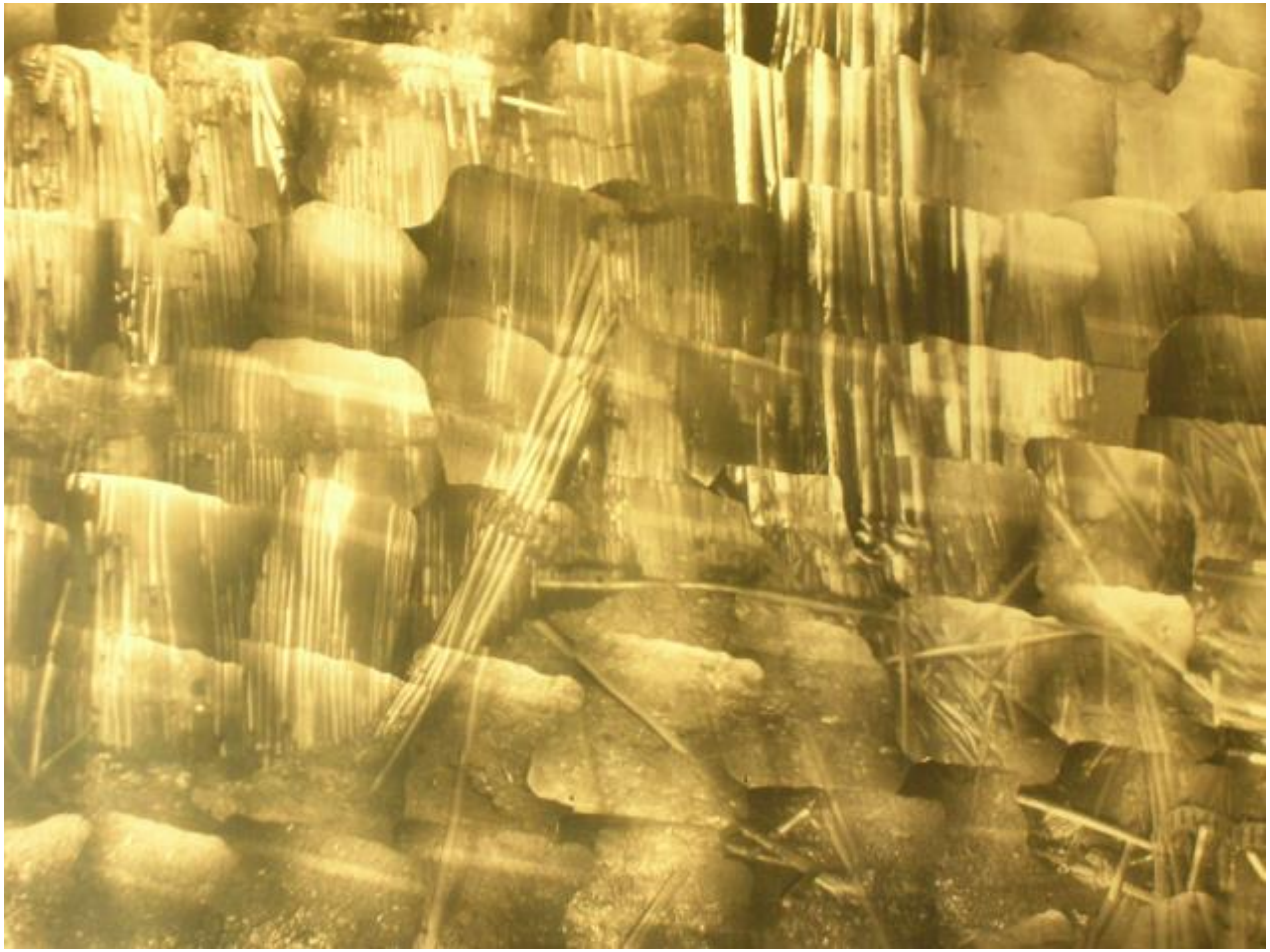


Figure 5-3. Known Post-Quick Look Core Conditions: 1982–1985

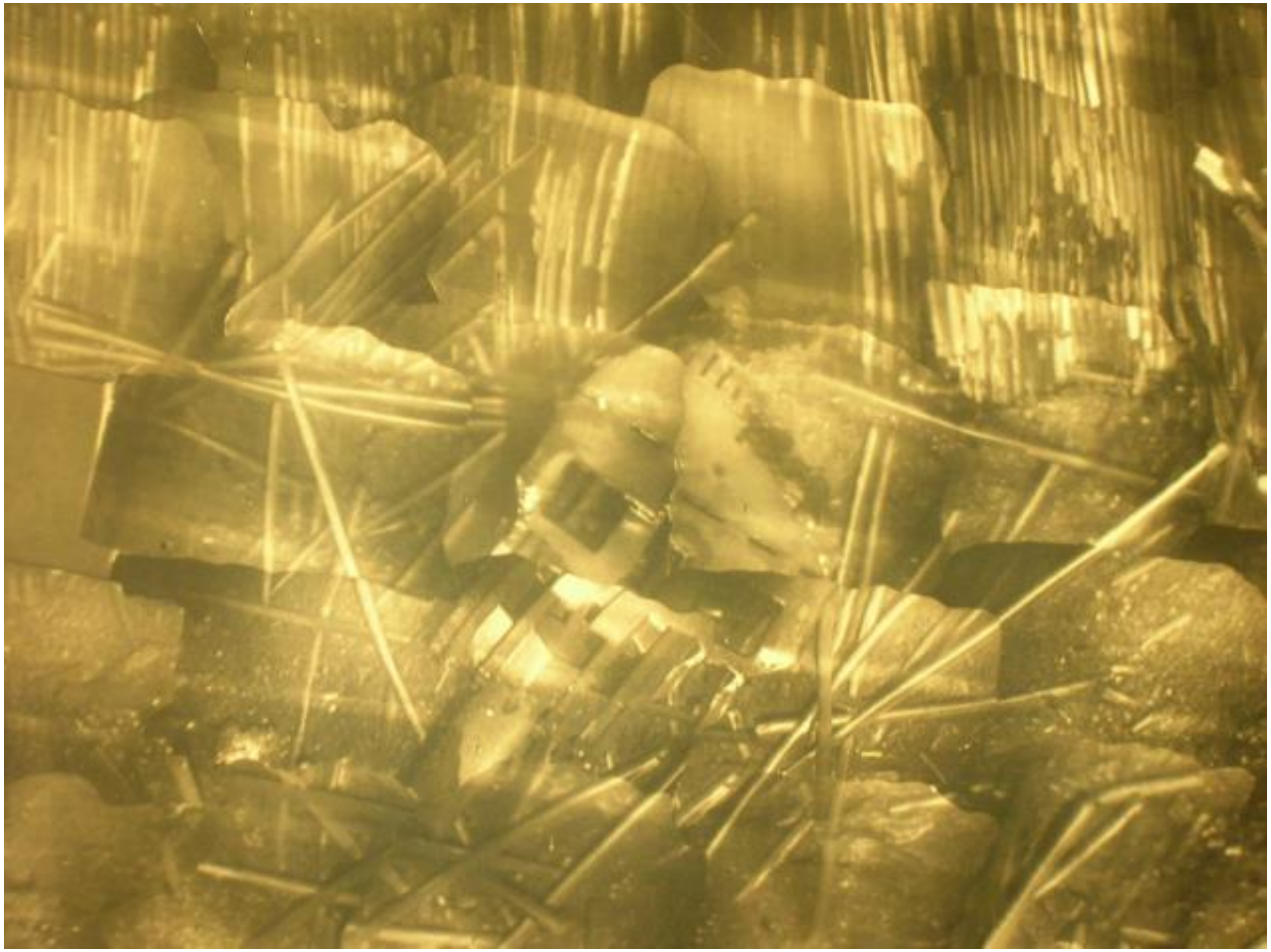
As the result of Quick Look campaign, GPU developed a comprehensive plan to approach Defueling

- Quick Look demonstrated the value of Data Acquisition and pointed to the benefit and value of additional Data gathering
- Quick Look showed the requirement for a comprehensive approach to Defueling that would include specialized tooling and procedures
- Prior plans, schedules and ideas regarding the plant's future (specifically, Restart) and core removal were discarded. New plans were developed based on the new data
- The Challenge became one of how to safely and comprehensively remove the damaged core while minimizing integrated dose, assuring worker safety and industrial safety

Conducted additional Camera Exams by using a rotating camera inserted into the ‘Quick Look’ opening to create a 360’ Panorama Image of the core void



Close-Up of core debris obtained during the 360' Panorama camera exam



Conducted Camera Inspection of Lower Region of Reactor Vessel - (Image shows Bolted Connection of outer shell of CSA to Elliptical Flow Distributor Plate)

Value of Data Gathering

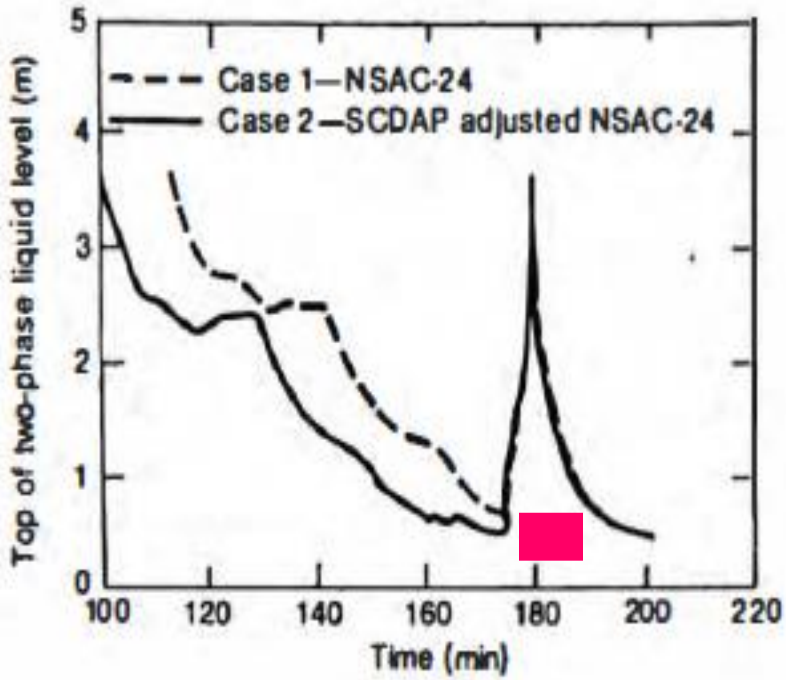
Correlating Core Damage after Quick Look (and other data) to Analyses

- From an important Analyses performed by the Nuclear Safety Analyses Center - (NSAC):

  – One set of temperature measurements made between 4 and 5.5 hours into the accident indicates some temperatures in the region of 2500° F, but others were below 700° F around the outer edge of the core. (From NSAC 80-1, Technical Description, Pages 9-10)

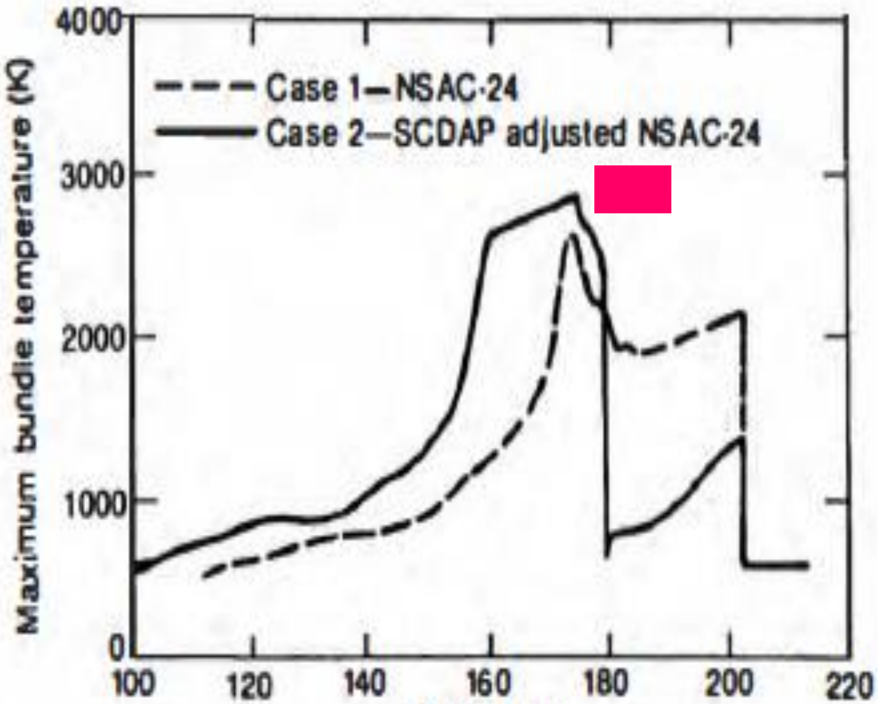
  – All temperatures above the core center remained above 700° F (scale) limit of the recording instrumentation) for about 8 hours into the accident, and some remained above 700° F for up to 30 hours. (From NSAC 80-1, Technical Description, Pages 9-10)

Top of two-phase Liquid Level / Time Correlation
TM l-2 ACCIDENT Evaluation PROGRAM, EG&G Idaho, February 1986, Page 42 (1 Of 2)
See core level continuously dropping for ~ 3 hours from 0400- to ~0700 3/29/1979) See next slide for maximum fuel bundle temperature.



Core Liquid Level

Maximum Bundle Temperature / Time Correlation TMl-2 ACCIDENT Evaluation PROGRAM, EG&G Idaho, February 1986, Page 42 (2 of 2) See 3000'K at ~175-180 min (~0655-0700 3/28/1979)

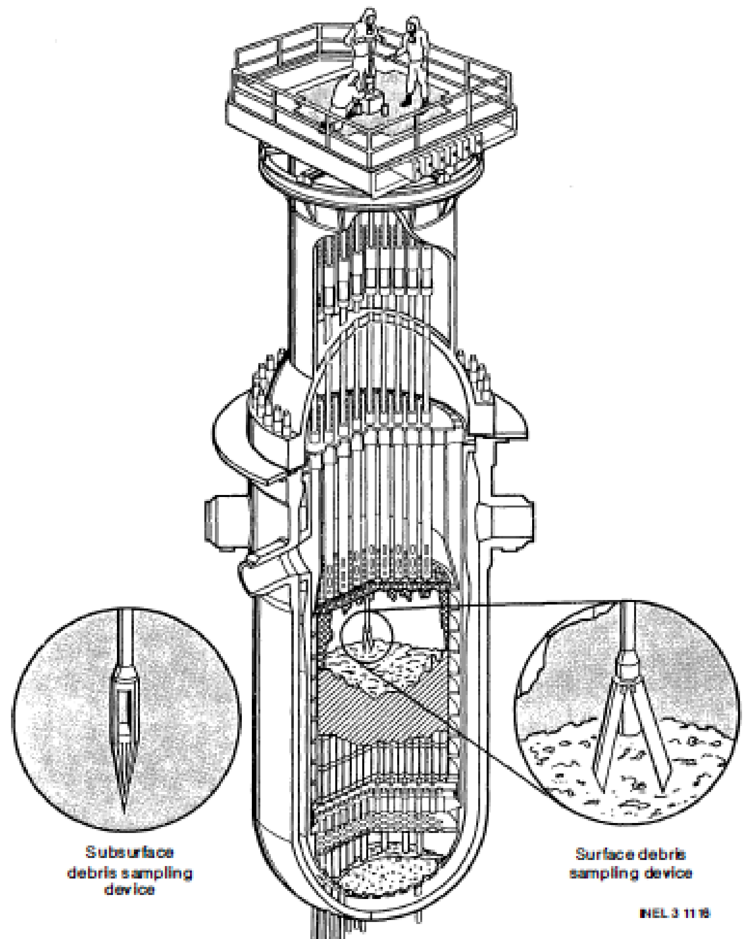


Core Peak Temperature

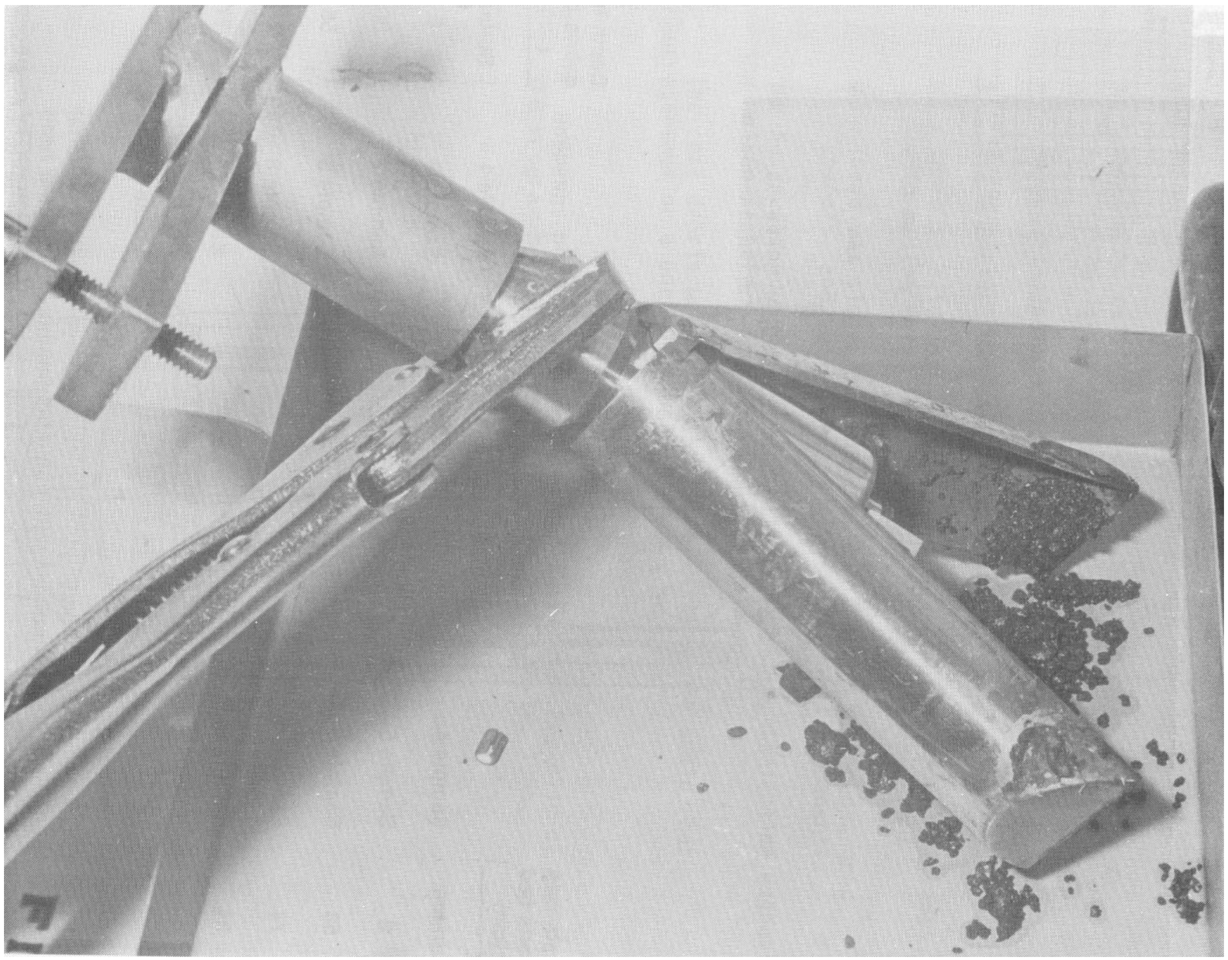
6 0494

TMI-2 Core Debris Sampling (GEND-57)

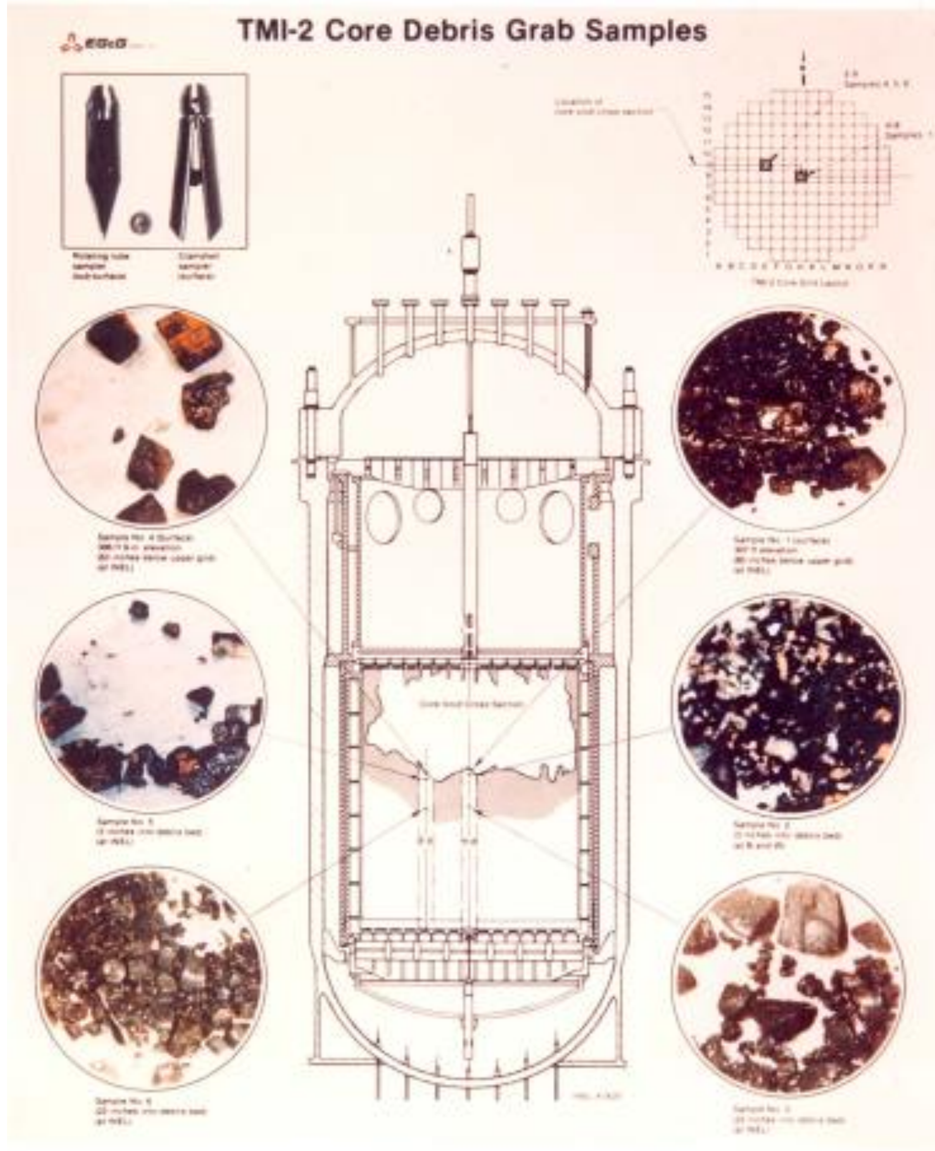
Work teams utilized same access path to the core as Quick Look, and used a ‘Clamshell tool’ to obtain multiple core samples (Grab Samples) from deep in the core debris bed



TMI-2 Core Debris Grab Sample tool ('Clamshell Tool') showing fuel debris

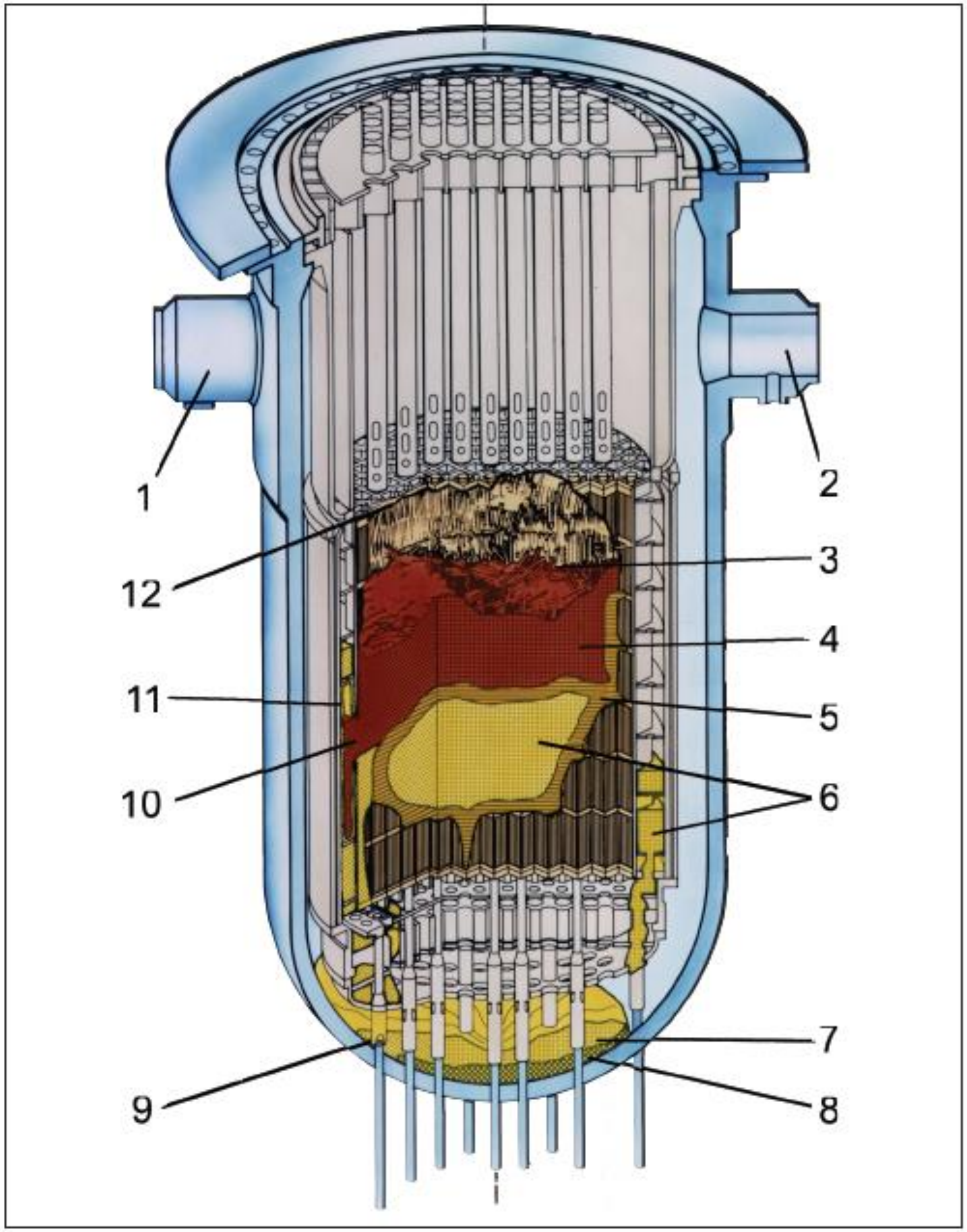


Examples of TMI 2 Core Debris Grab Samples obtained by 'Clamshell Tool' (EGG-6531, Page 7)

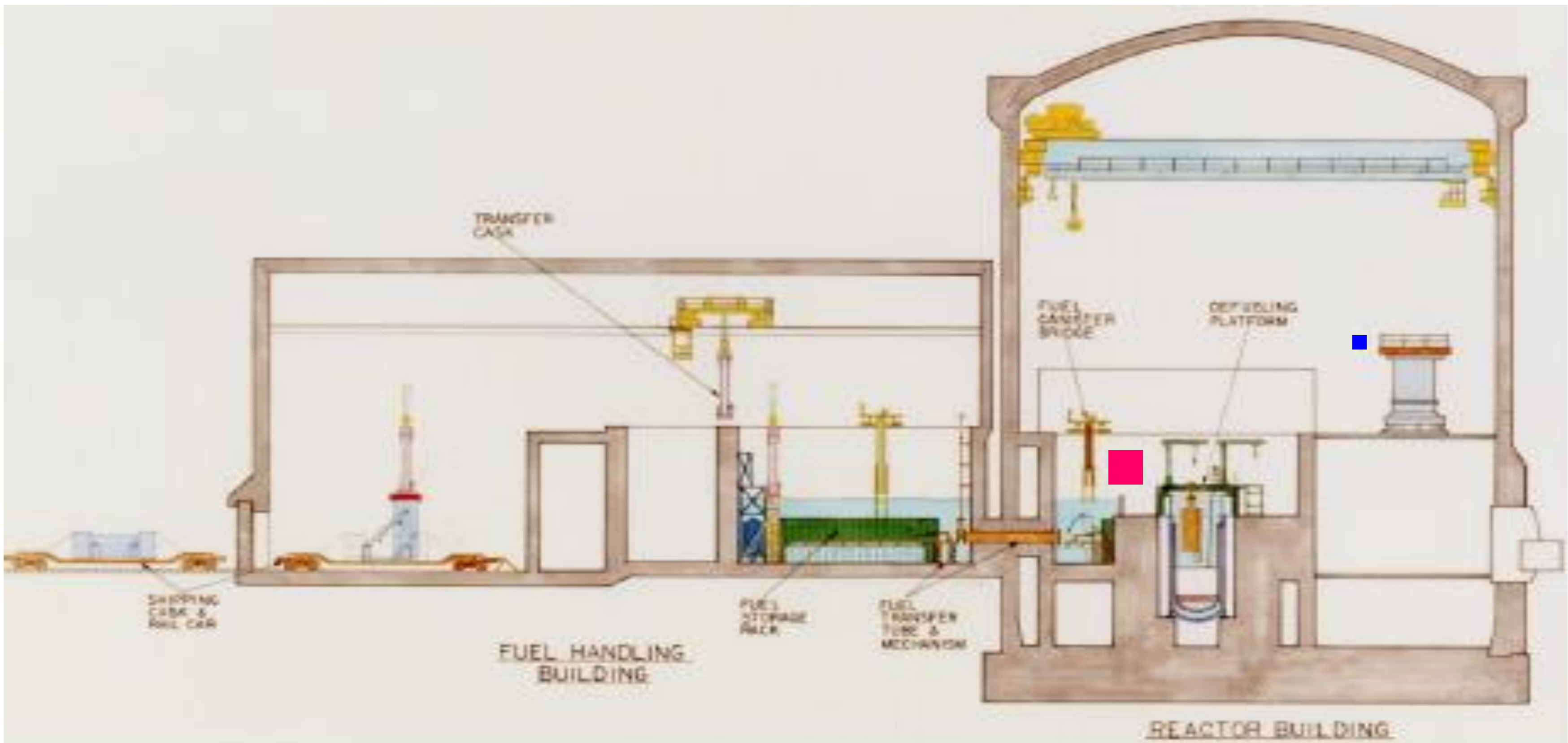


TMI-2 Core End-State Configuration

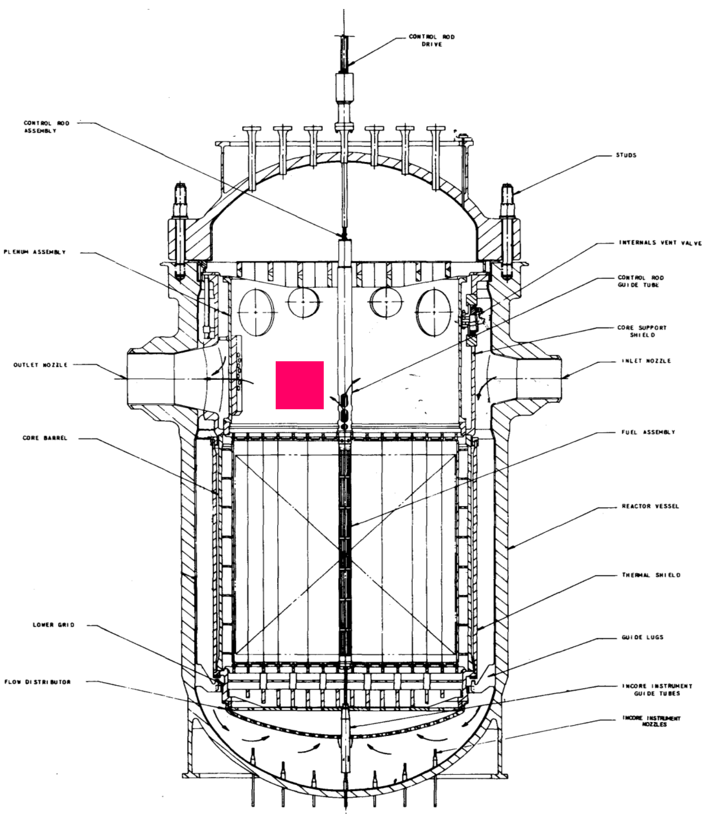
Notes (NUREG/CR-6042):
(1) Cold leg Loop 2B inlet
(2) Cold leg Loop 1A inlet
(3) Cavity
(4) Loose core debris
(5) Crust
(6) Resolidified molten material
(7) Lower plenum debris
(8) Hard layer debris
(9) Damaged in-core instrument guide
(10) Hole in baffle plate
(11) Coating of resolidified molten material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

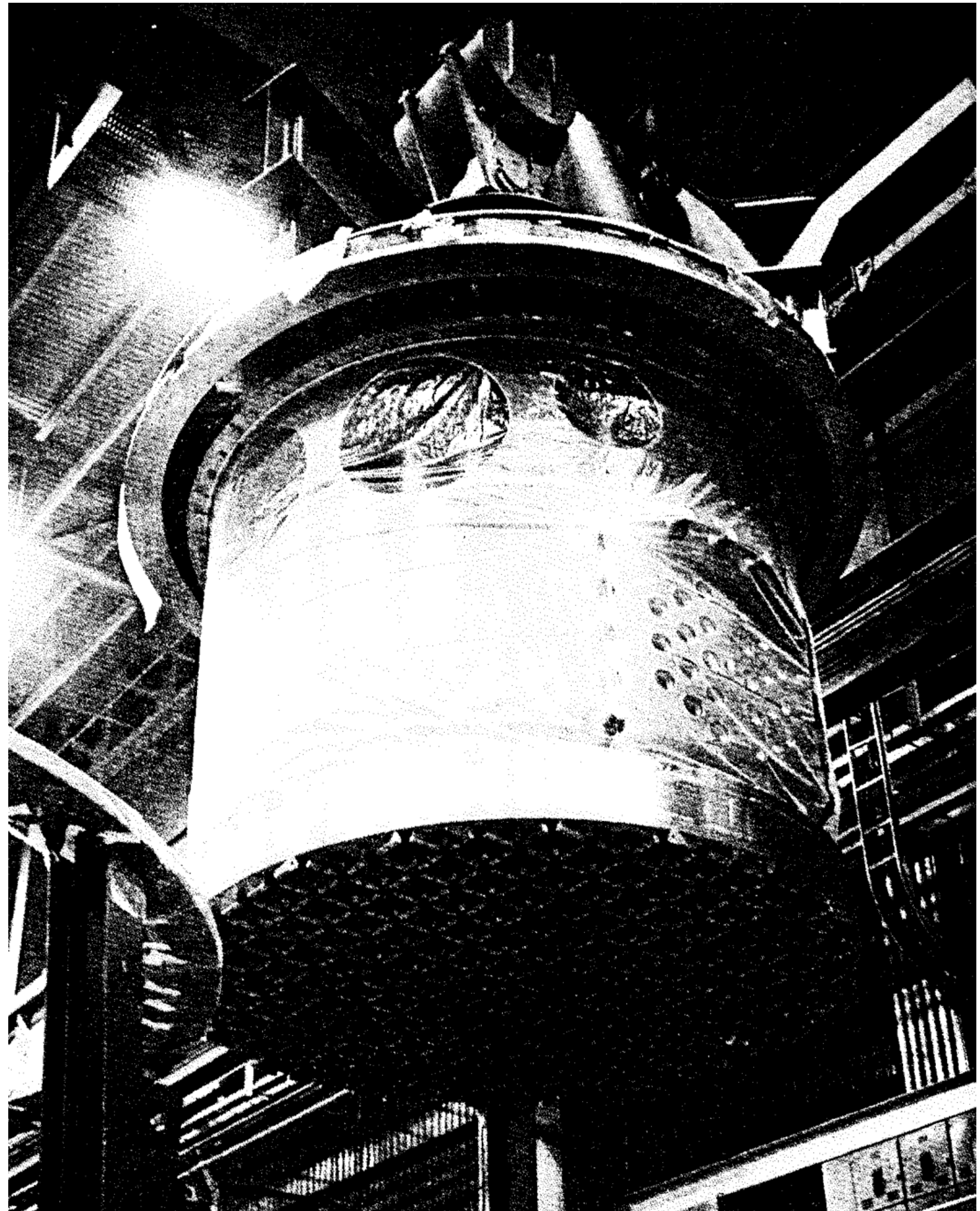


TMI 2 General Layout in Preparation for Defueling
(See Red Dot - Work Platform, Water Dam, Fuel Transfer Mechanism)

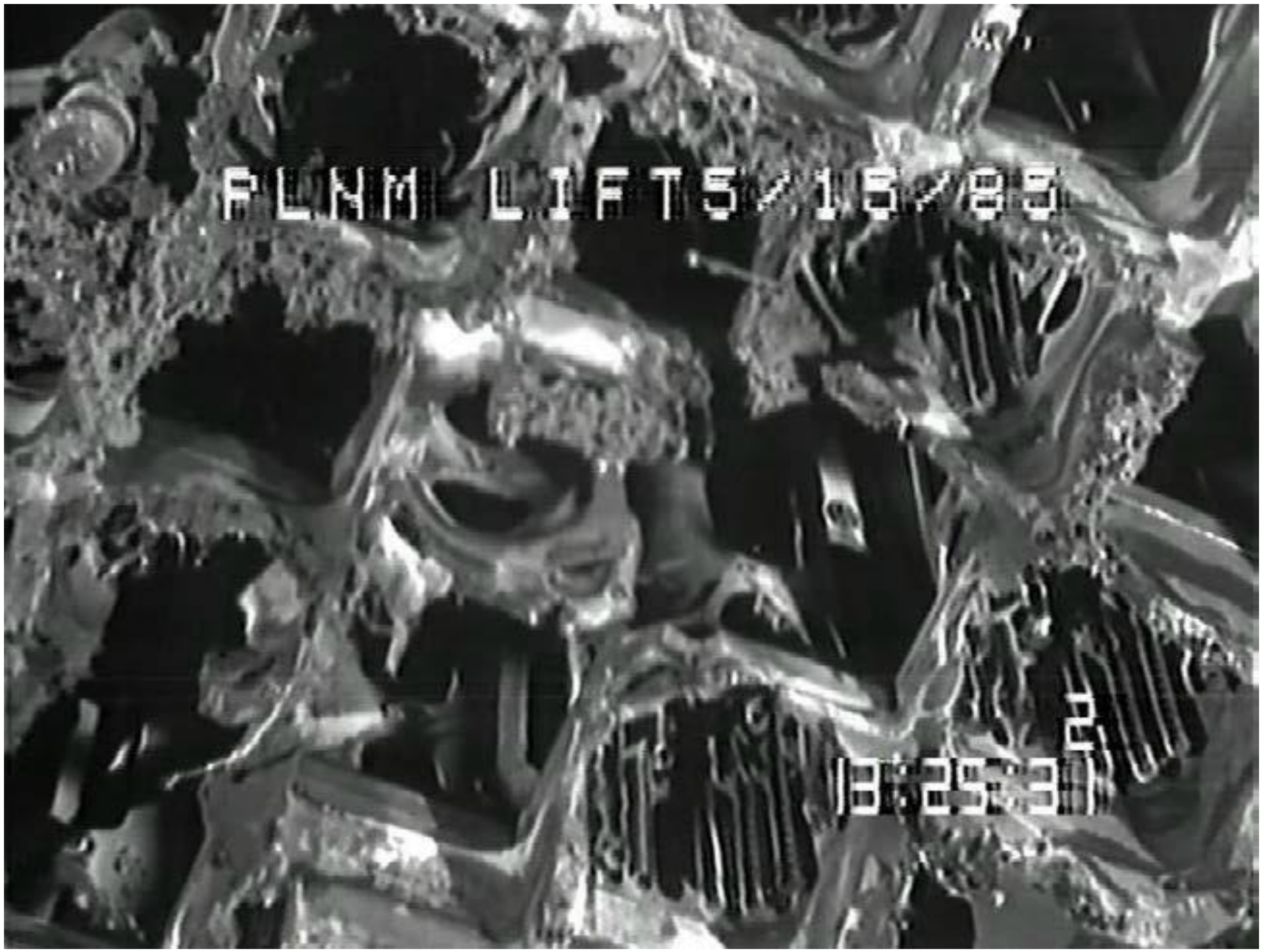


Location of image for next slide

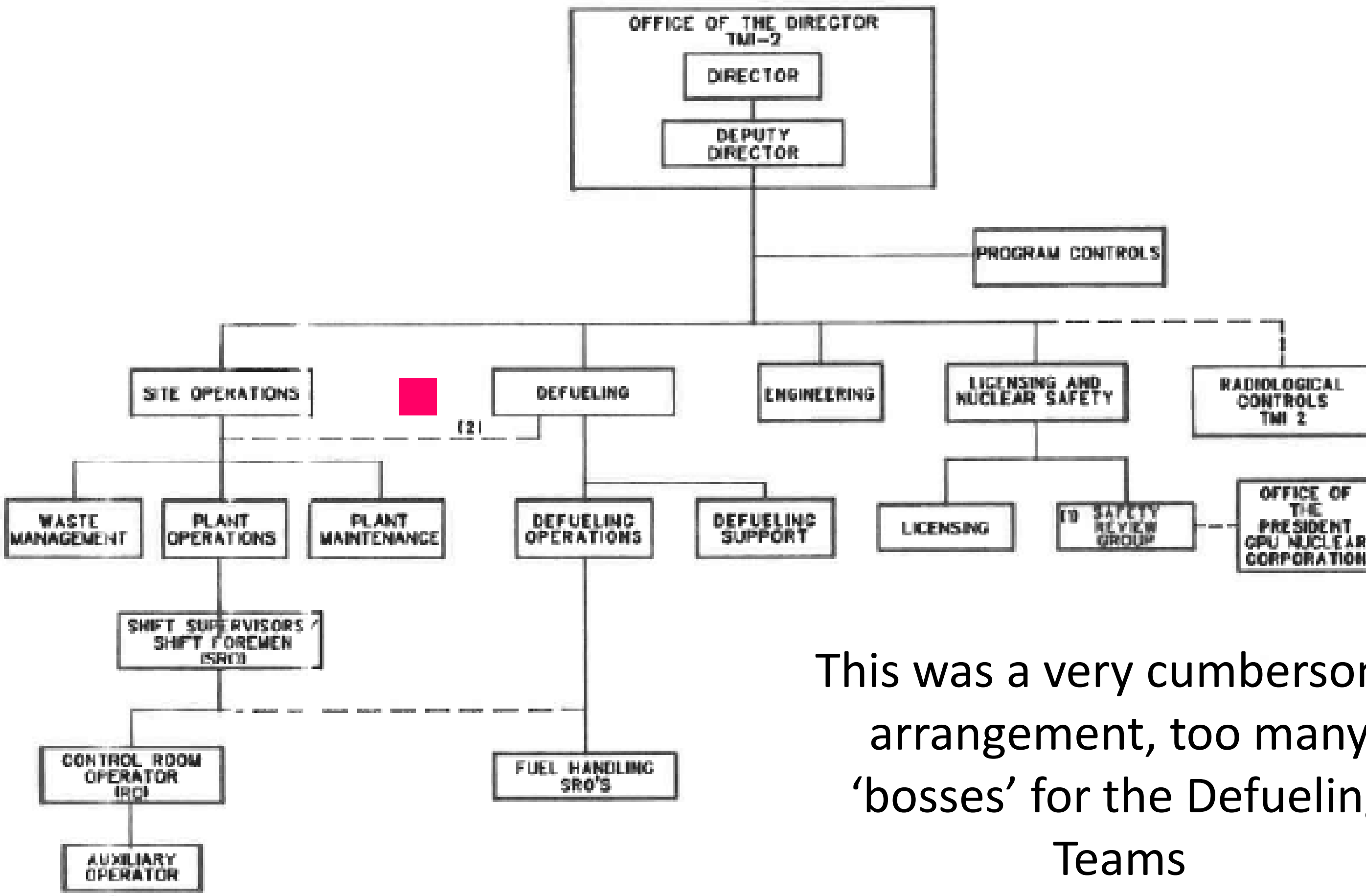




After removing the 55 ton Plenum – we observed this damage on the Upper Grid Plate



TMI 2 Defueling Organization at beginning of Defueling October 1985 (Red dot - See connection of Defueling to Site Operations)



This was a very cumbersome arrangement, too many 'bosses' for the Defueling Teams

Developed the Organization to conduct Defueling

- Trained 6 qualified operators to earn Fuel Handling Senior Reactor Operator Licenses (FHSRO) from the US NRC, to enable supervising fuel removal. The FHSRO was the Supervisor for the on-duty defueling team
- Utilized original, licensed trained GPU / Met Ed Operators
- Each defueling shift was authorized to perform defueling operations independently from other organizational distractions
- Constructed and used the Mockup in the Turbine building, an exact replica of the rotating Work Platform in the Reactor Building, to train the Operators to perform defueling tasks

Mock Up inside the TMI 2 Turbine Building - Identical to the Rotating Work Platform in the Reactor Building - Oversight Committee on Mock-Up

Defueling Operations

- The Defueling Team size in the original Organization Plan consisted of ~11 individuals
- Defueling Team workers were unionized TMI 1 and TMI 2 GPU employees. The employees were represented by a strong labor union. Both the union and the workers vigorously supported Defueling throughout the Defueling Campaign.

GPU Evaluated multiple Defueling System Options

- Concepts that were studied as front-runners.
  - Long Handled Tools - shallow water level
  - **Long Handled Tools - deep water level (Selected Option)**
  - Shredder - discharge pumped to Fuel Handling Building (FHB)
  - Shredder - discharge gravity fed to inside-Reactor Building (RB) canisters
  - WCSD (Westinghouse Consolidated System Design) – ROSA (Discarded)
  - MANFRED - (Discarded – underwater access, maintenance and decontamination challenges)
- **Selected Bulk Defueling System with Rotating Work Platform utilizing Long handled Tools**
- Built an identical Mockup of the Rotating Work Platform with tools enable worker training and proficiency

Robotic Defueling Concept - WCSD / ROSA

(Discarded – underwater access, maintenance and decontamination challenges)

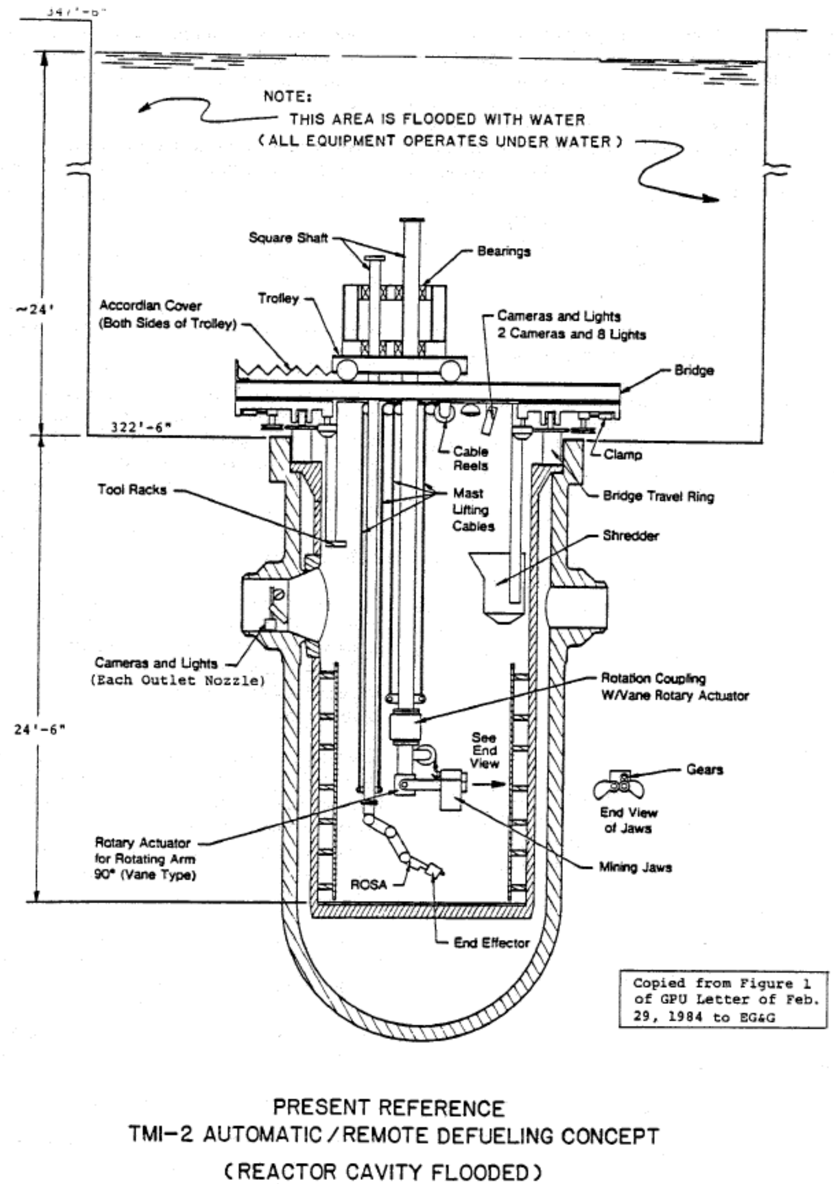


Figure 8-8. Automatic/Remote Defueling Concept

Remote Defueling Concept - MANFRED – (Discarded – underwater access, maintenance, decontamination challenges)

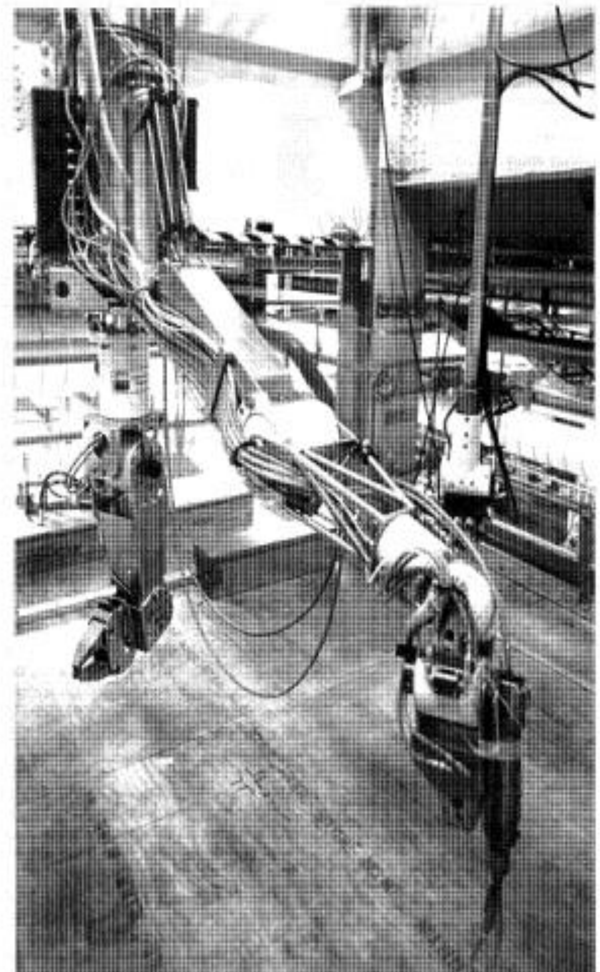
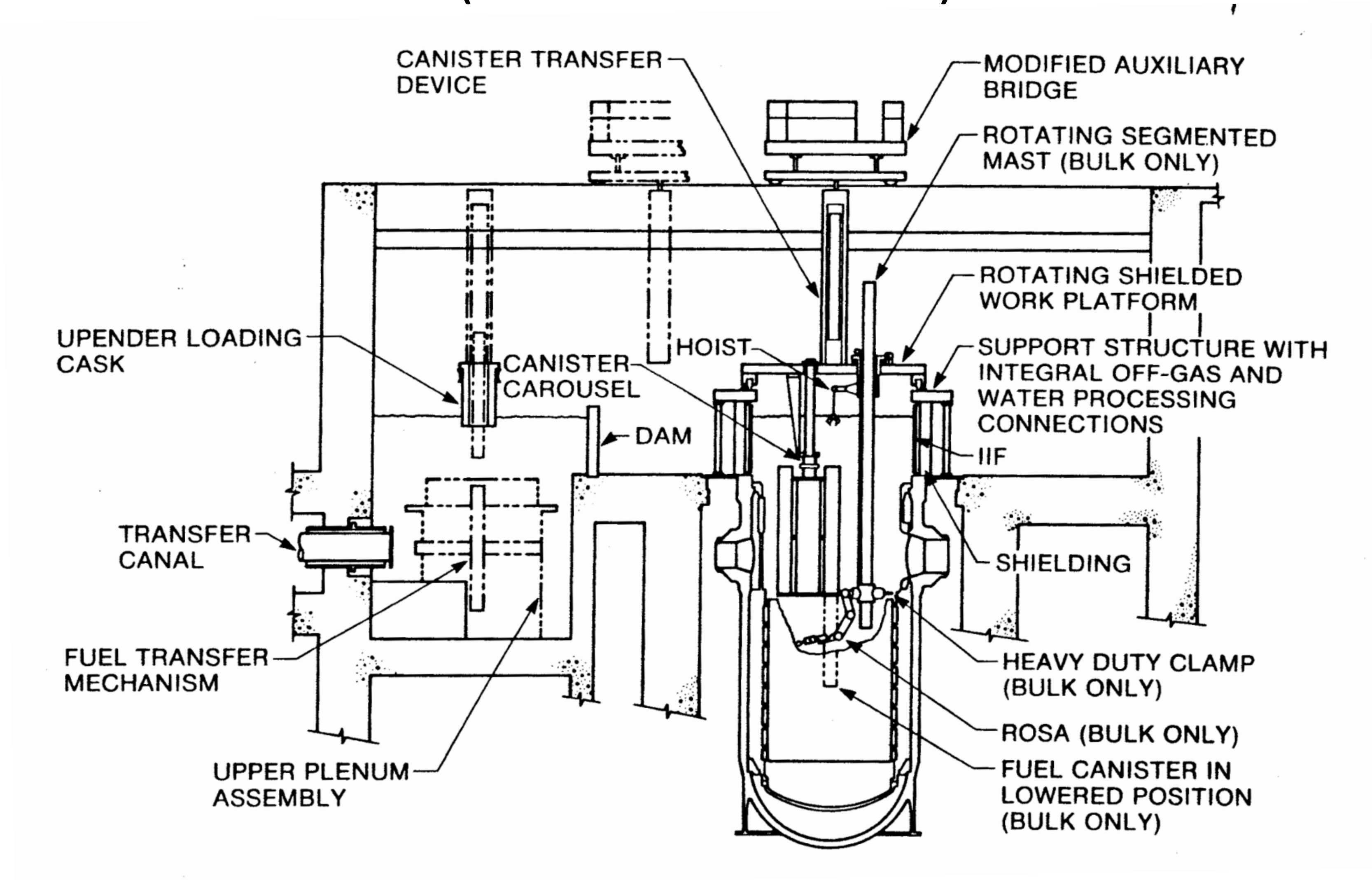


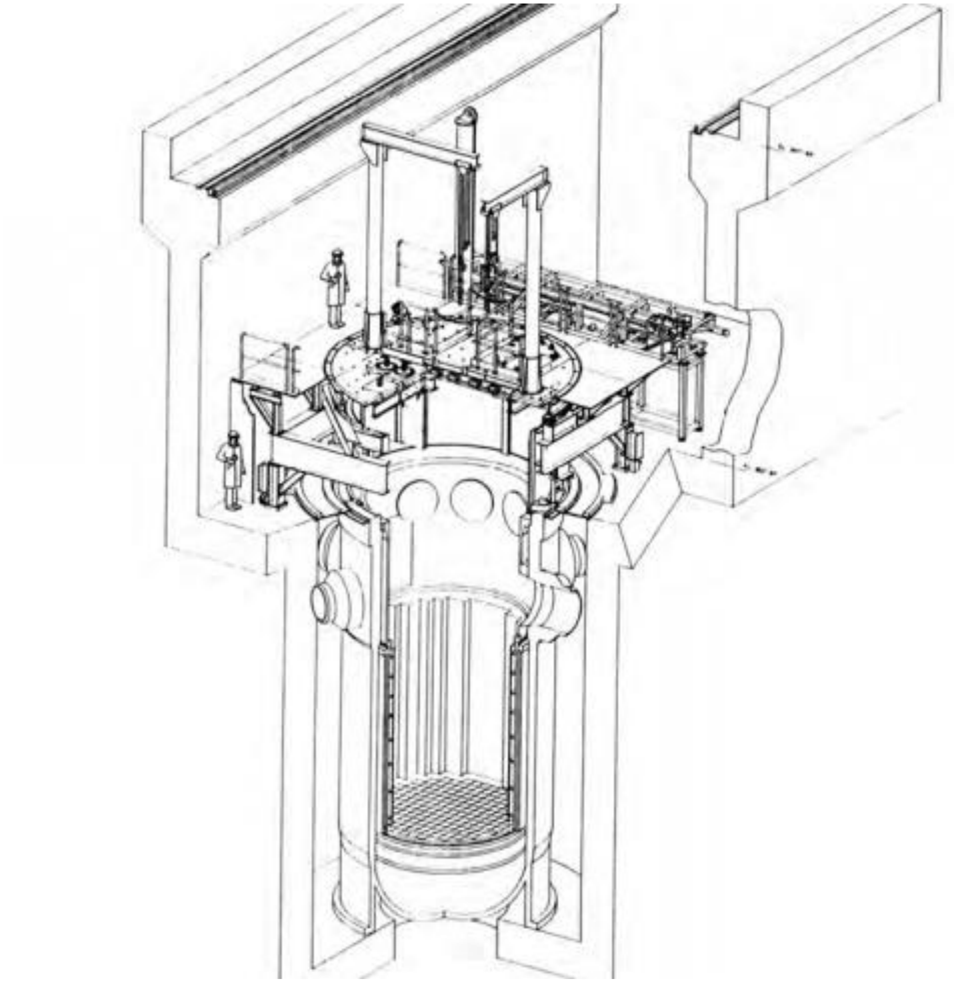
Photo 8-10. MANFRED

Early Concept of the Bulk Defueling System – Relatively simple, tooling accessible, more easily repaired – (ROSA not included)

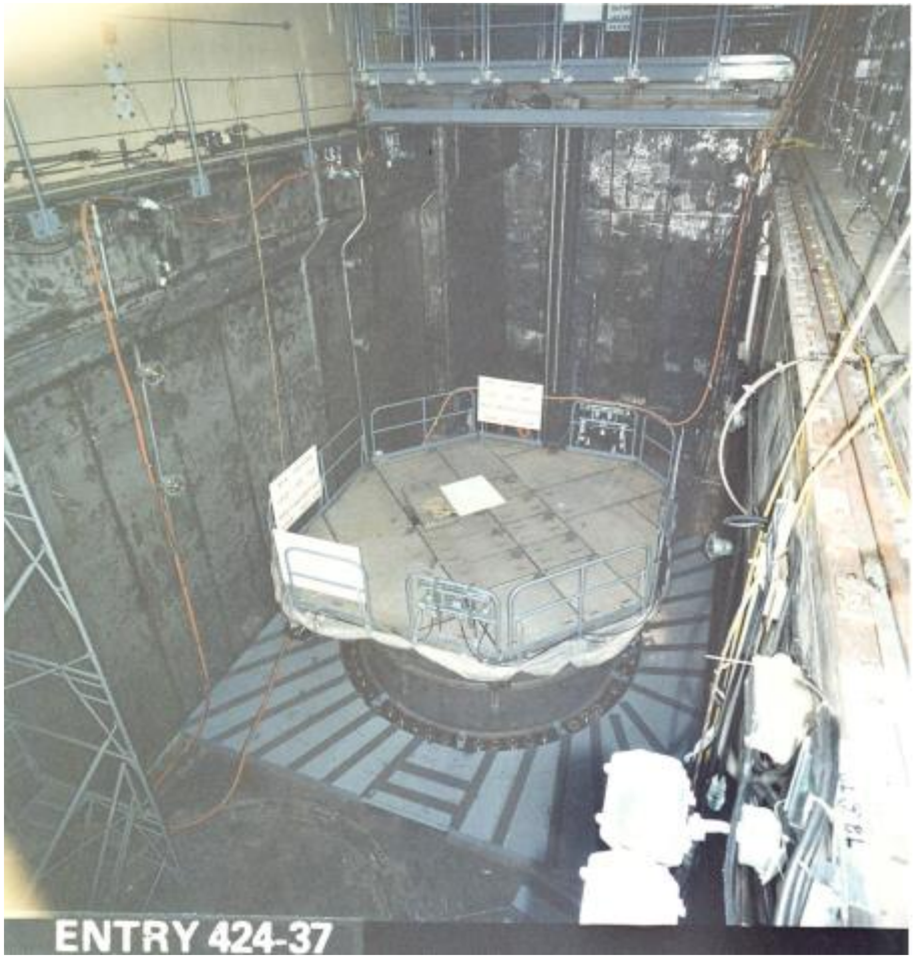


Defueling (Rotating) Work Platform

(GEND-INF-065)



Defueling Work Platform - under construction (Installed over TMI 2 Reactor Vessel)



Defueling Team working over ‘open slot’ in Rotating Work Platform

Defueling Team on rotating Work Platform over the TMI 2 Reactor Vessel

Defueling Team on Work Platform

Summary of Long Handled Tools

(NP-6931)

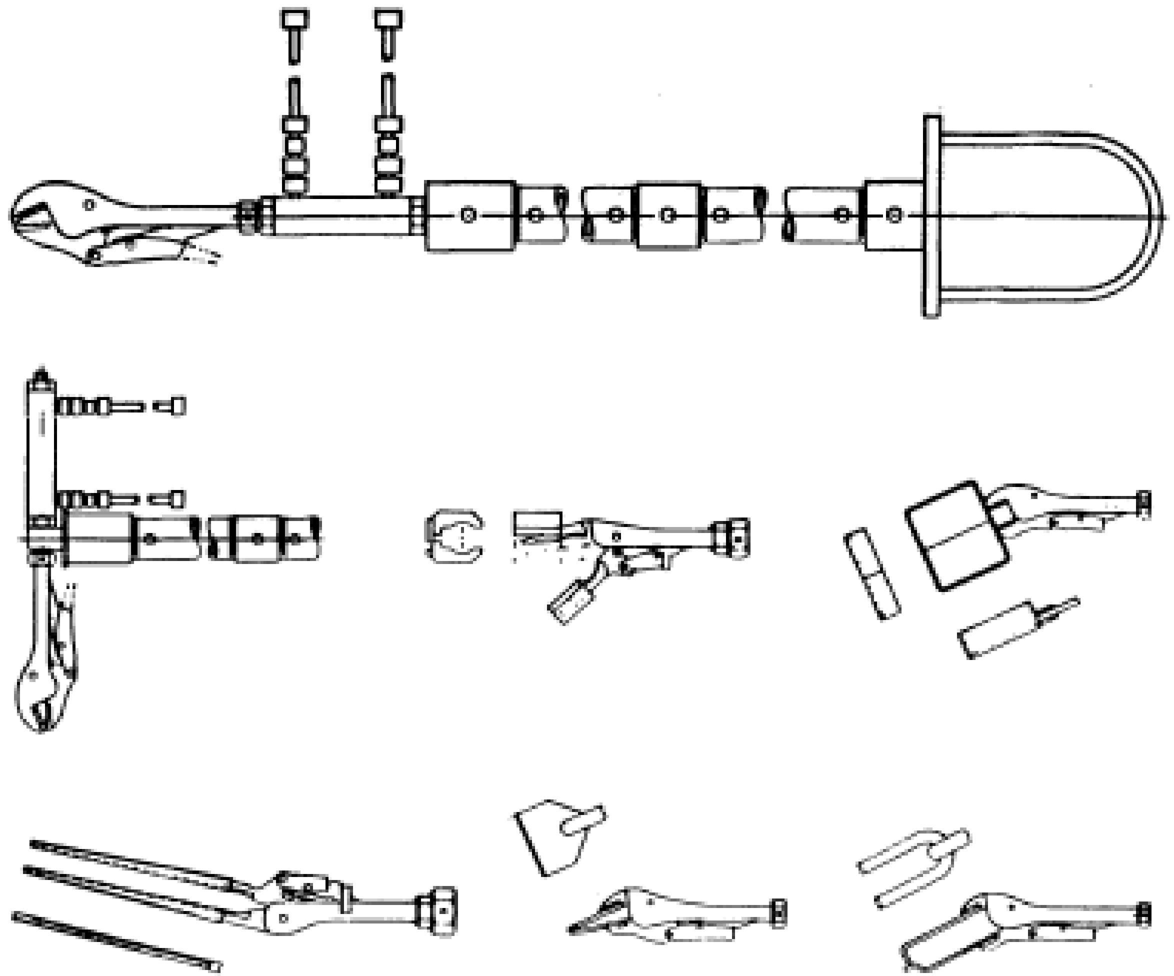
Table 8-3. Summary of Long-Handled Tools

Light-Duty	Heavy-Duty
Vise grips	End effector handling tool
Bolt cutters	Three-point gripper
Hook tools	Four-point gripper
Socket wrench	Grapple
Debris bucket handling tool	Single-rod shears
Partial fuel assembly tool	Parting wedge
Measuring probe	Heavy-duty tong tool
Light-duty tong tool	Spade bucket tool
End fitting loading tool	Clamshell tool
Banding tool	Heavy-duty shears

Powering the Tools

- Defueling Tools were designed with common “quick-disconnects”, simple hydraulic fittings used worldwide for connecting and disconnecting hydraulic tools
- When the Defueling Tools were changed, several drops of hydraulic fluid leaked into the Reactor Vessel water. The Reactor Vessel water was processed accident water.

Handheld Defueling Tools



Chisel Tool and Heavy Duty Shears (NP-6931)

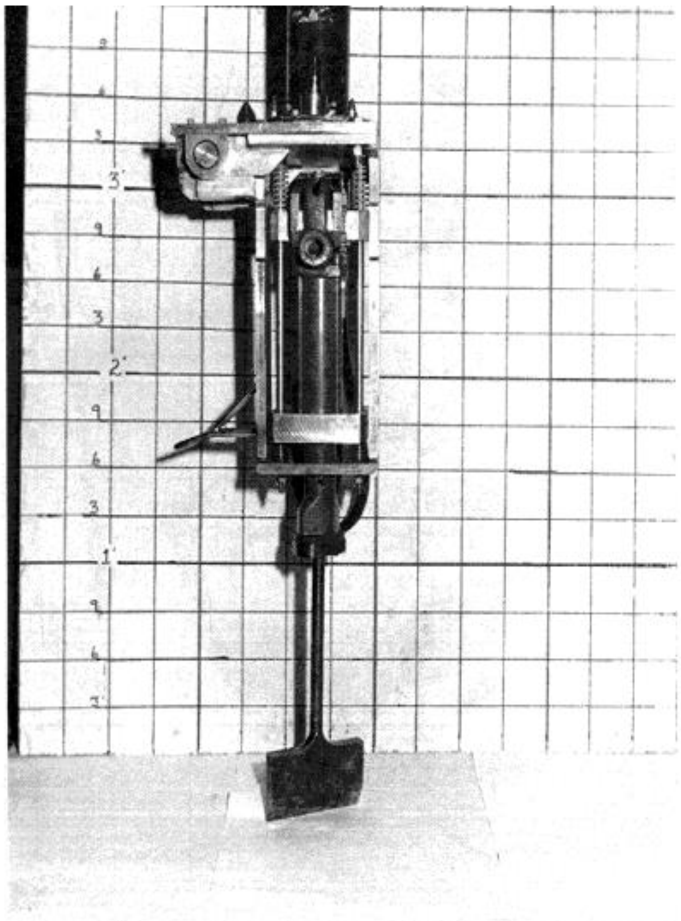


Photo 8-3. Chisel Tool

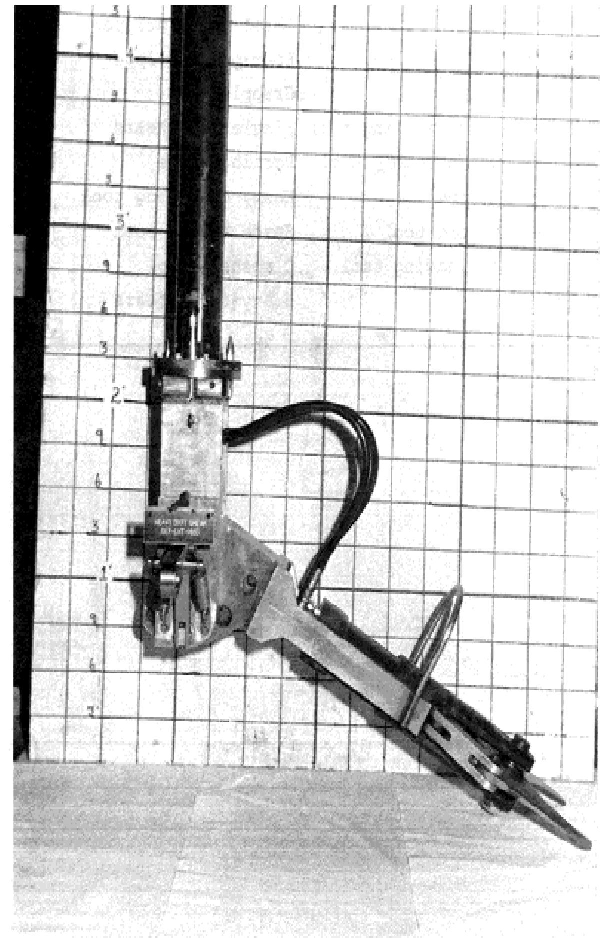
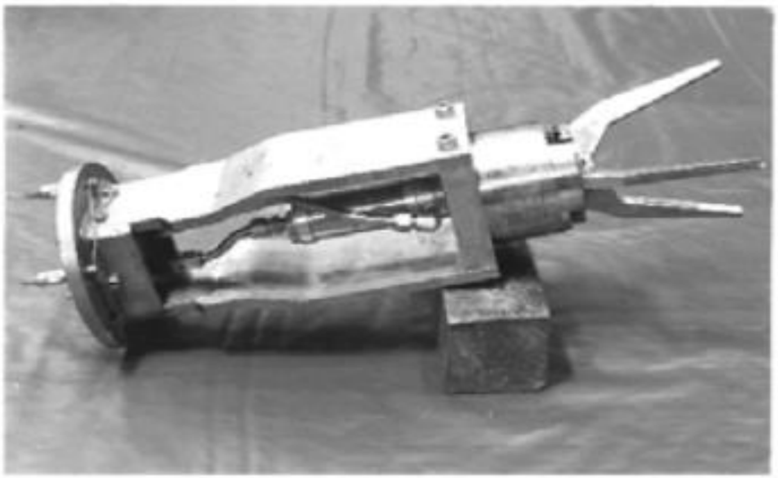


Photo 8-2. Heavy Duty Shears

Splitter and Shear Tools, Spade Bucket Tool

(NP-6931)



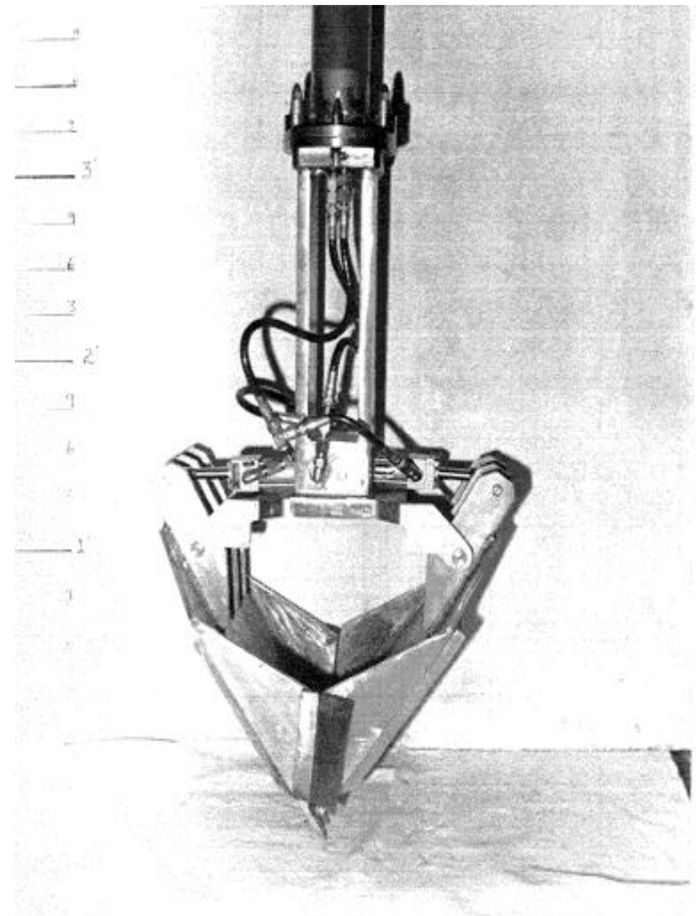


Photo 8-4. Spade Bucket Tool

Parting and Grab Tool, Small Clam Bucket Tool

Visibility and Lighting - Early 1986 - Visibility lost due to bio growth in the Reactor Vessel Water

- The tools were powered by common hydraulic fluid, a hydrocarbon fluid, similar to the power steering fluid in our automobiles. Miniscule amounts of leaked hydraulic fluid became ‘food’ (nutrition) for invisible biological contamination
- Bio growth resulted from invisible Coliform in the Reactor Vessel water (recycled accident water) feeding on the miniscule amounts of hydraulic fluid
- From the beginning of Defueling in October 1985 until Mid-December 1985 the Defueling Teams had good visibility
- Visibility was lost due to unchallenged Bio Growth
- Lighting was not capable of providing visual observation of fuel targets
- The Reactor Vessel water became opaque

Image of Bio Growth in Reactor Vessel Water
(Debris ‘clumps’ approximately ‘fingertip’ size)

As the result of loss of visibility, the Defueling Teams continued to remove material without direct observation of target debris (Defueling ‘blind’)

- Even with degraded visibility, the Defueling Teams continued to grasp and pull core remnants. Without clear visibility, the <u>Defueling Teams were defueling ‘blind’</u>
- Even while Defueling was being conducted in mid-1986, GPU and DOE agreed to initiate the ‘Core Bore – Data Retrieval’ Campaign (Core Stratification Sampling Program)
- The objective was to obtain physical core (Stratification) samples using the DOE-provided Core Bore Machine that would be mounted on the Rotating Work Platform

While using the Core Bore Machine as a Data Retrieval Tool, the Defueling teams discovered that the Core Bore Machine was a successful Defueling tool

- The Core Bore (Stratification Sampling) Program targeted 10 core locations (see Slide 61) and led to the discovery of a doughnut-like crust in the core
- The Core Bore Machine produced small debris chips (from the teeth of the cutting bit) that were removed by the Fuel Debris Vacuum System while boring was occurring. The Fuel Debris Vacuum System also removed small fuel particles. The Defueling Teams discovered that the combination of the Core Bore Machine and the Fuel Debris Vacuum System produced effective fuel removal
- The Core Bore Machine was later used as critical defueling tool making ~400 bores (“Swiss cheesing”) into the lower core. The Core Bore Machine later achieved prominence as an essential companion to the Plasma Arc Torch to access and Defuel the lower core regions

Core Bore Sample Locations (10)

GEND-INF-092-v1 TMI 2 Core Bore Examinations Volume 1 – Page 22 (PDF)

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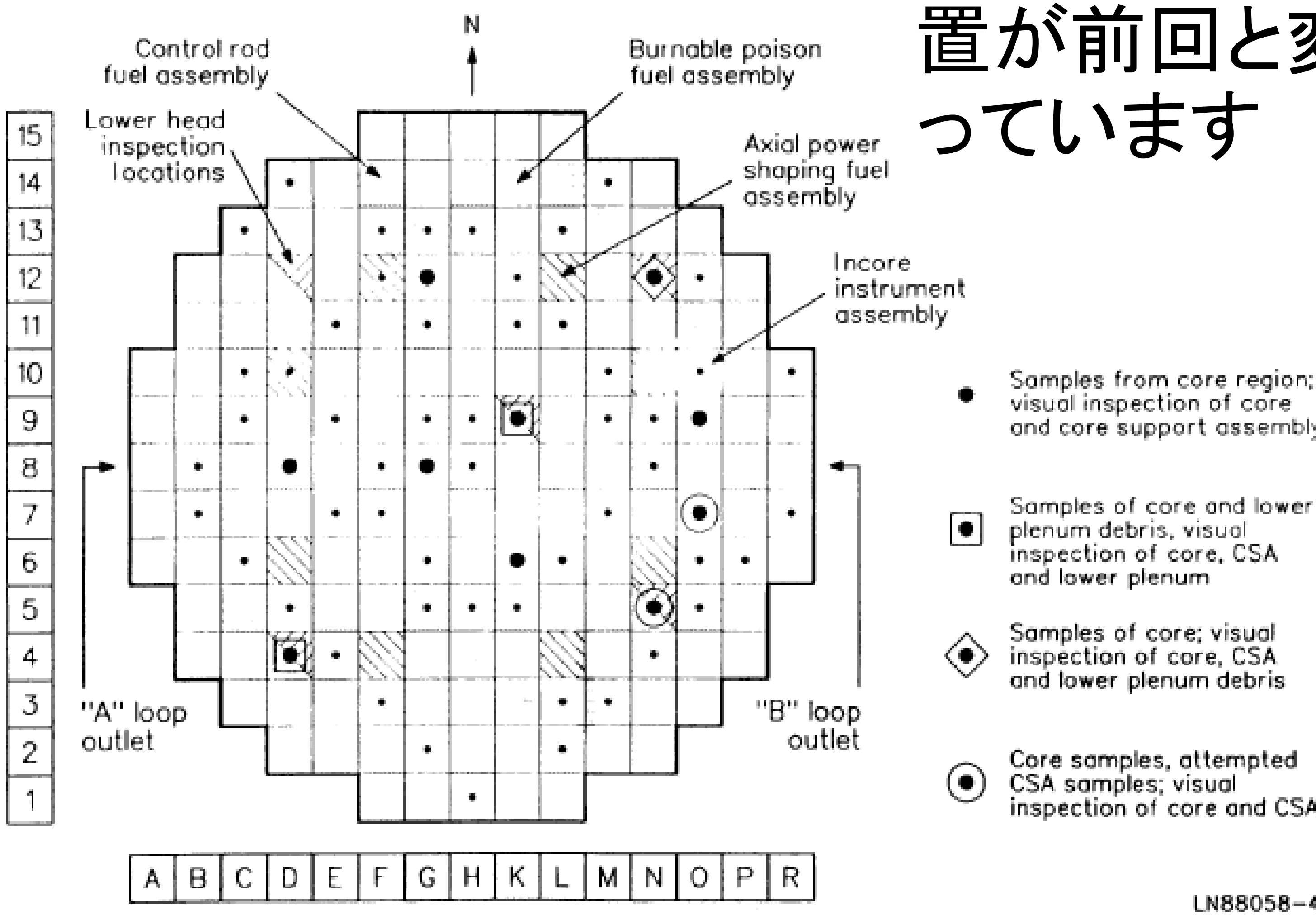
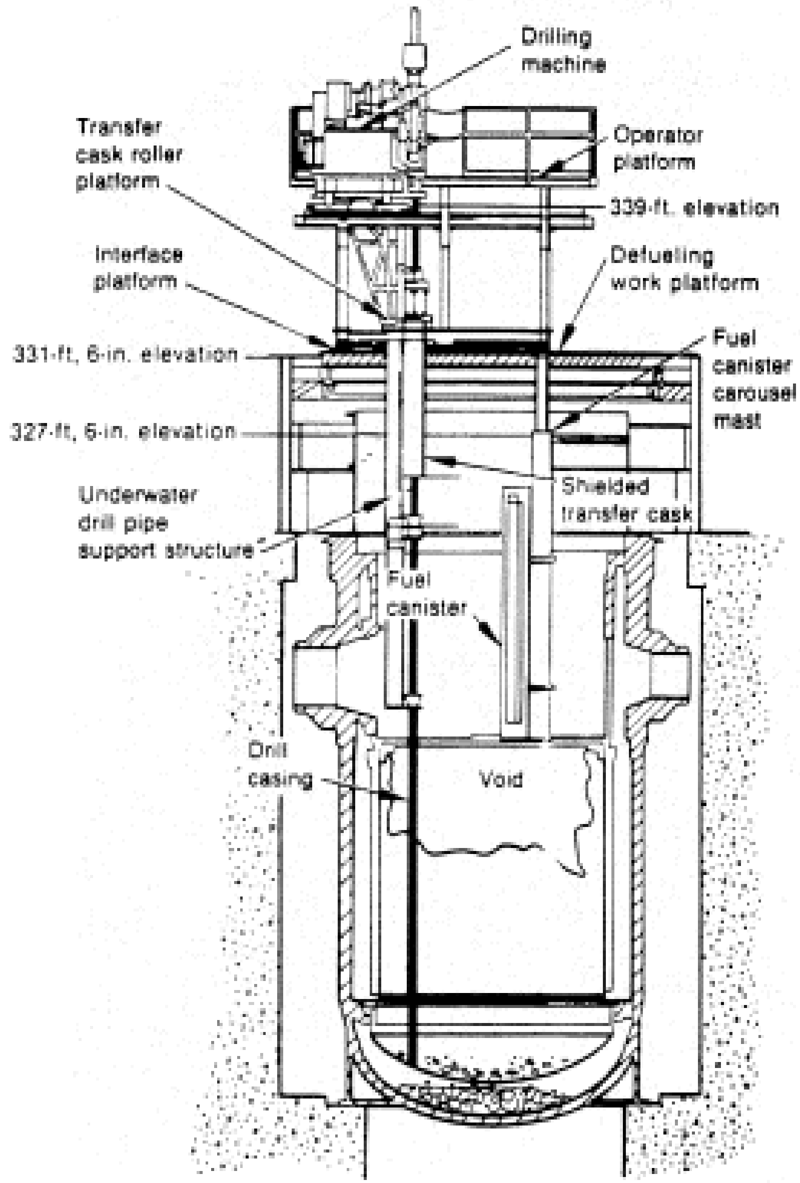


Figure 2. Core bore sampling locations.

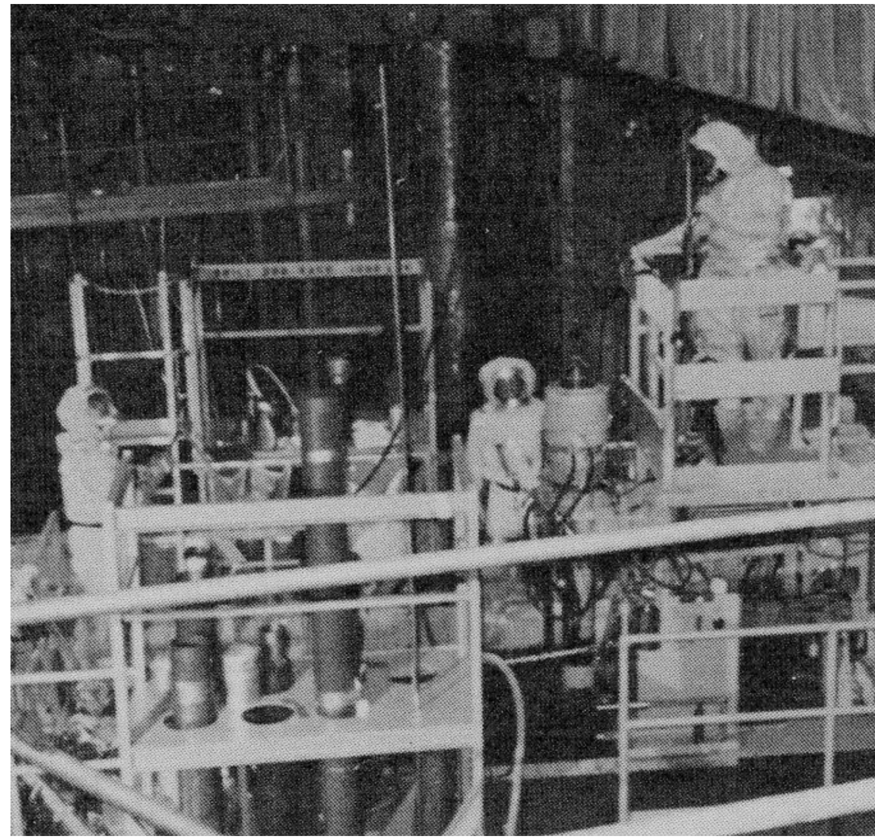
Core Boring Machine



Core Bore Drill Bit

The Core Bore Machine was installed on the Rotating Work Platform as a data acquisition tool. Its usefulness expanded to a key Defueling tool. It was not installed on the Mock-Up). It had been tested at INEL before shipment to TMI2

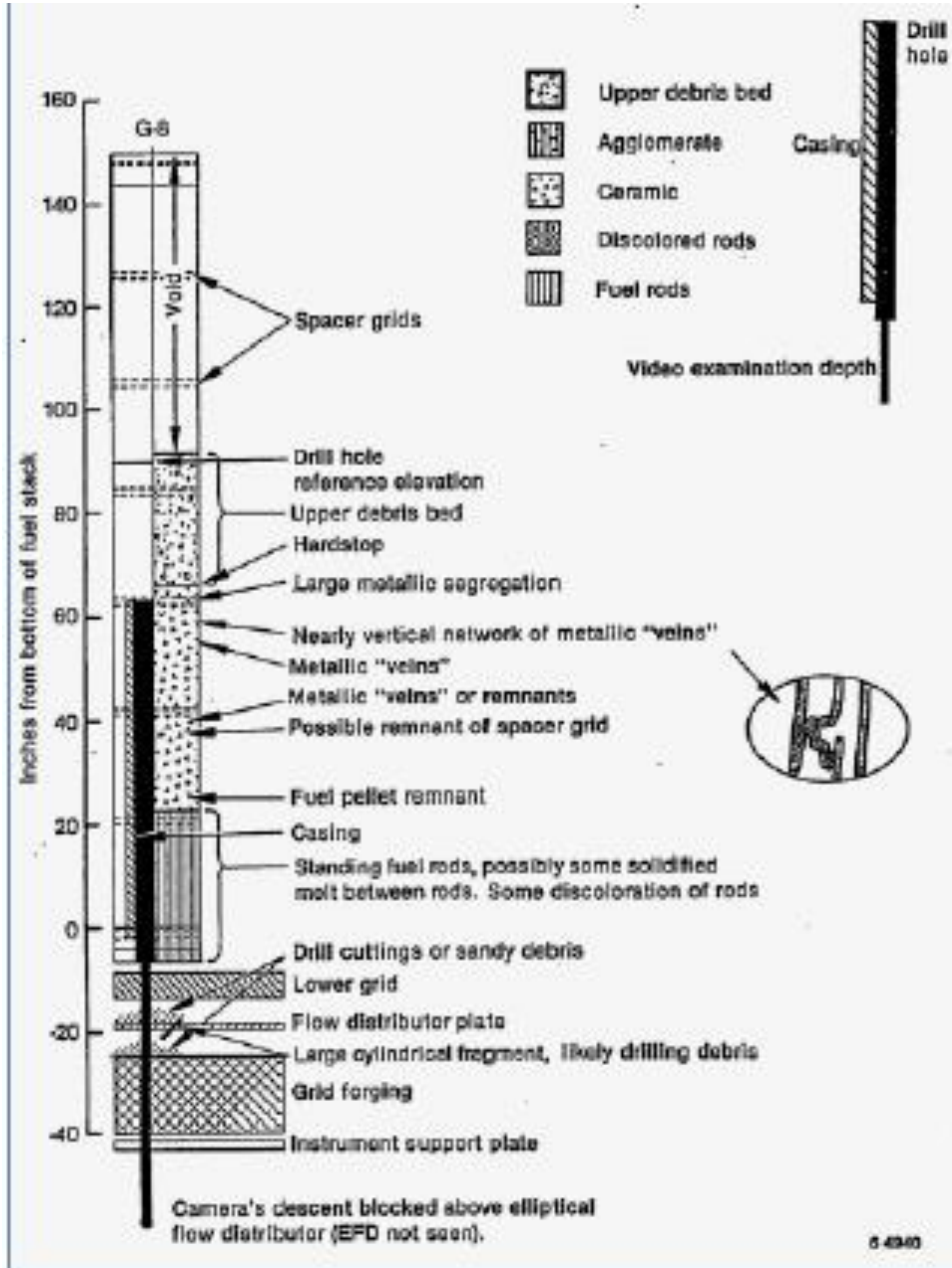
Core bore machine. The core bore machine, which was used to extract core stratification samples in 1986, was used during defueling to break up the solidified monolith (melted-together core materials) in the core region.   The machine was also used to drill through and cut portions of the lower core support assembly. NRC approved. (NUREG/KM-0001, Supplement 1). Safety Evaluations accompanied each phase of Core Bore use.



Core Bore Elevation Details

(KM Supplement 2 Page 51)

Elevation is above the bottom surface of the fuel pellet stack within the fuel pins



Fuel Debris Vacuum System

•Designed to remove small loose debris as large as the approximate size of a fuel pellet
•Supported from the underside of the defueling work platform and was controlled from the console on the work platform

•The vacuum pickup nozzle was connected to a canister by a flexible hose and was manipulated using a long-handled tool. Debris was picked up and passed first through a Knockout canister; any remaining debris larger than 0.5 microns was collected in a Filter canister

•Vacuum defueling began on December 31, 1985, in which about 300 pounds of debris was loaded into the Knockout canister

•Based on tests, the vacuum system, even with modifications, was ***not effective*** in debris removal, primarily as the result of ***excessive clogging***. Various airlift systems were later designed to perform this function

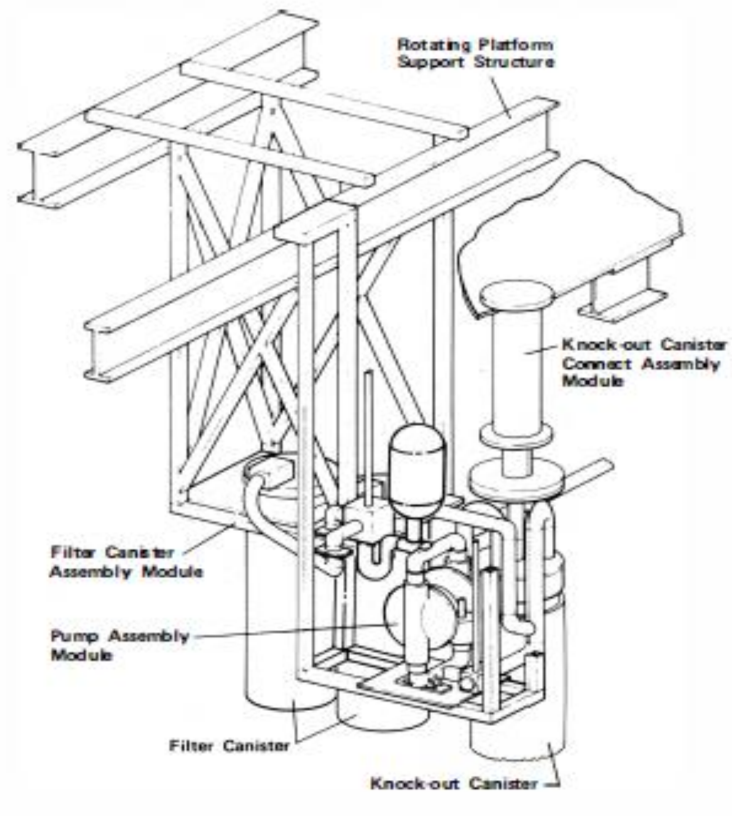
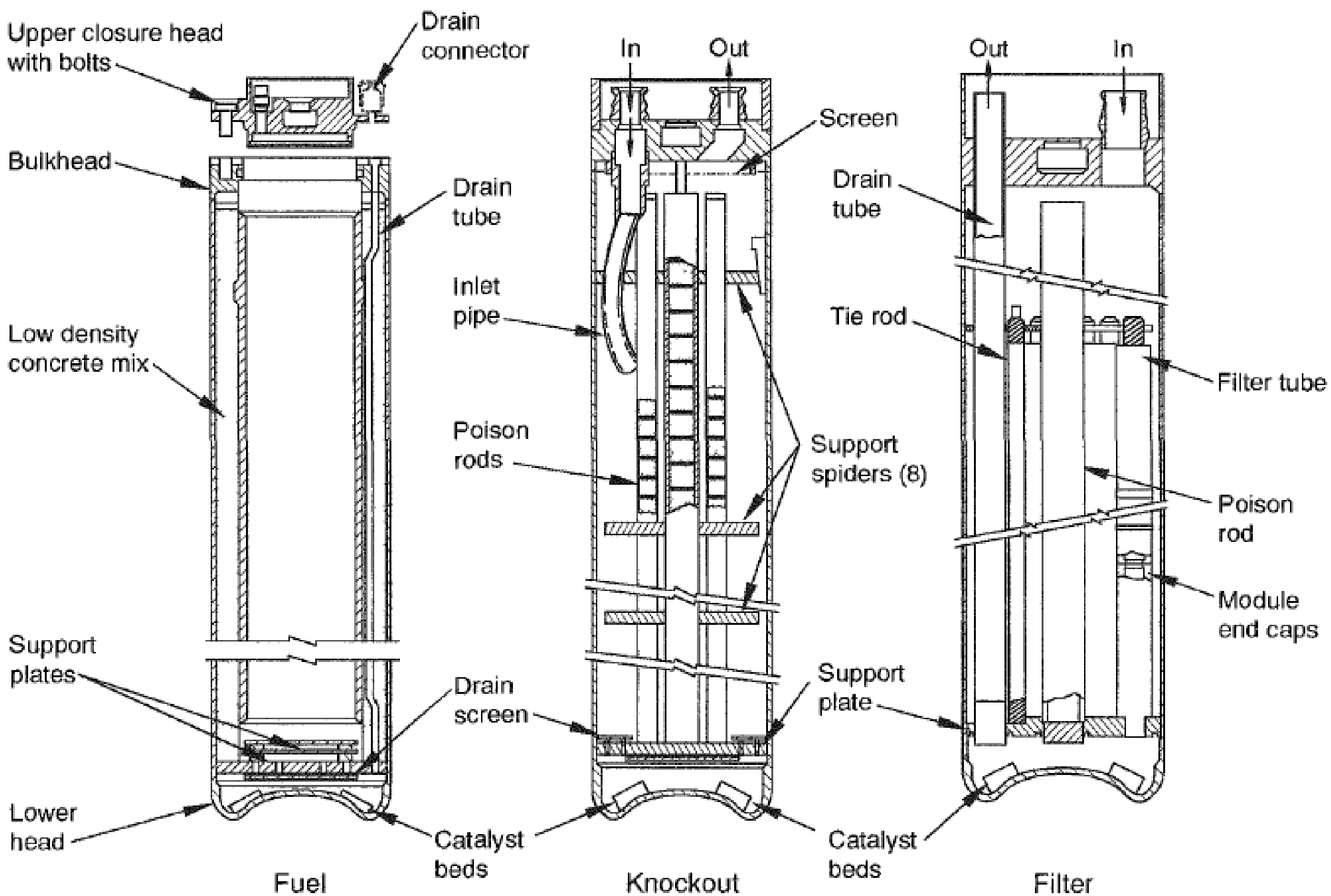


Figure 15. Vacuum system.

Three Different Canister Designs Used for TMI 2 Defueling – 342 Total
268 Fuel Canisters – Receptacle for Large Chunks
12 Knockout Canisters – Particles from ~140 Microns to Pellets
62 Filter Canisters – Core Debris smaller than ~140 microns



Defueling Below the original lower core boundary

- The Defueling Teams used the Core Bore Machine for precise vertical cuts into underlying structures
- The Defuelers used ACES (Plasma Arc Automated Cutting Equipment) System for precise horizontal cuts

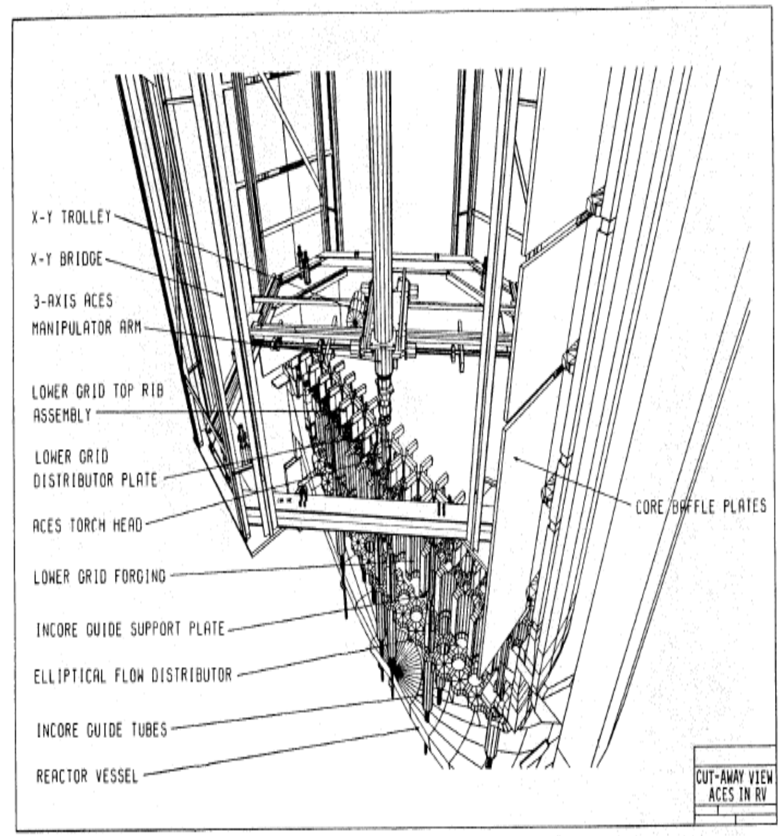
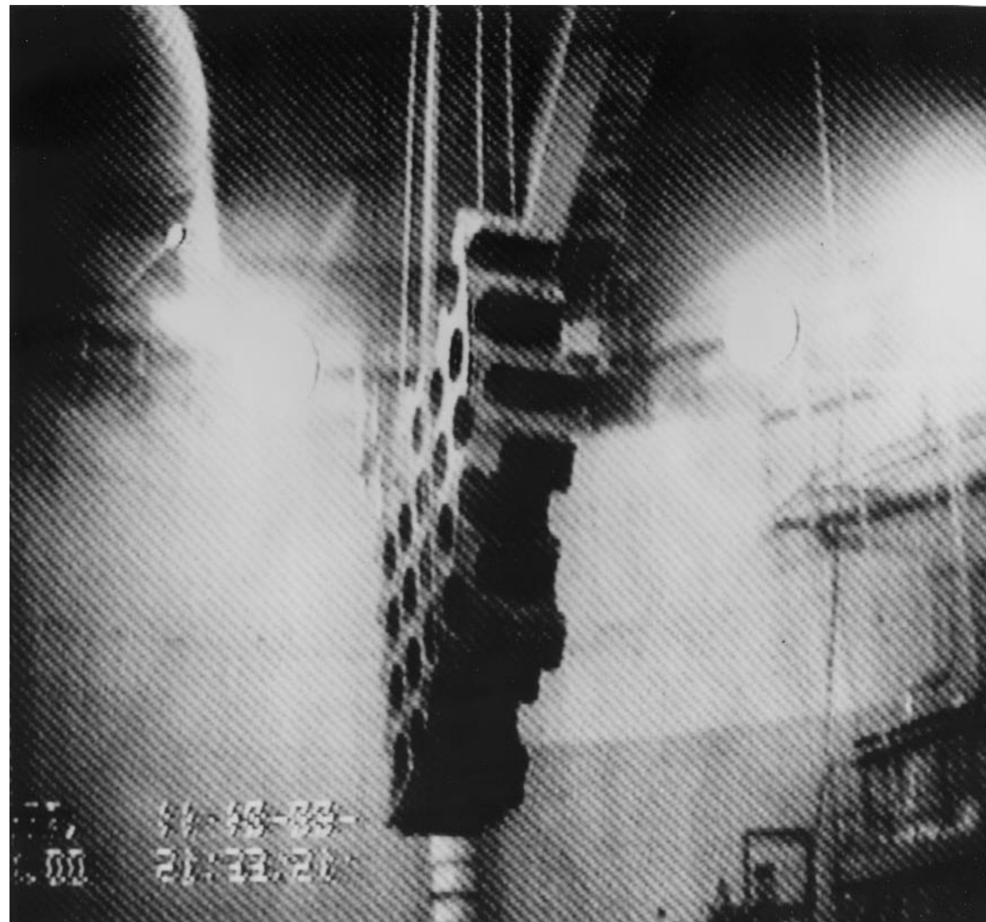


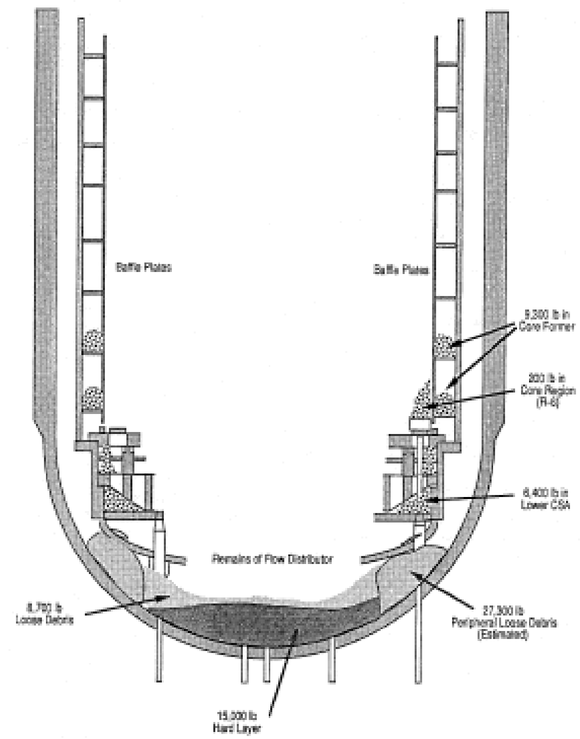
Figure 8-18. Computer View of ACES in the Reactor Vessel

See portion of Lower Grid Forging cut by Plasma Arc torch. This piece of the lower grid forging is being removed from the reactor vessel (KM Supplement 2).

Portions of lower core structures were removed to gain access to fuel below the Lower Core Support Assembly structures and to the bottom of Reactor Vessel



Fuel at Bottom of Reactor Vessel



TMI-2 MATERIAL AT THE BOTTOM OF THE REACTOR VESSEL

Figure 8-19. Lower Head Cross-section with LCSA Cut Out

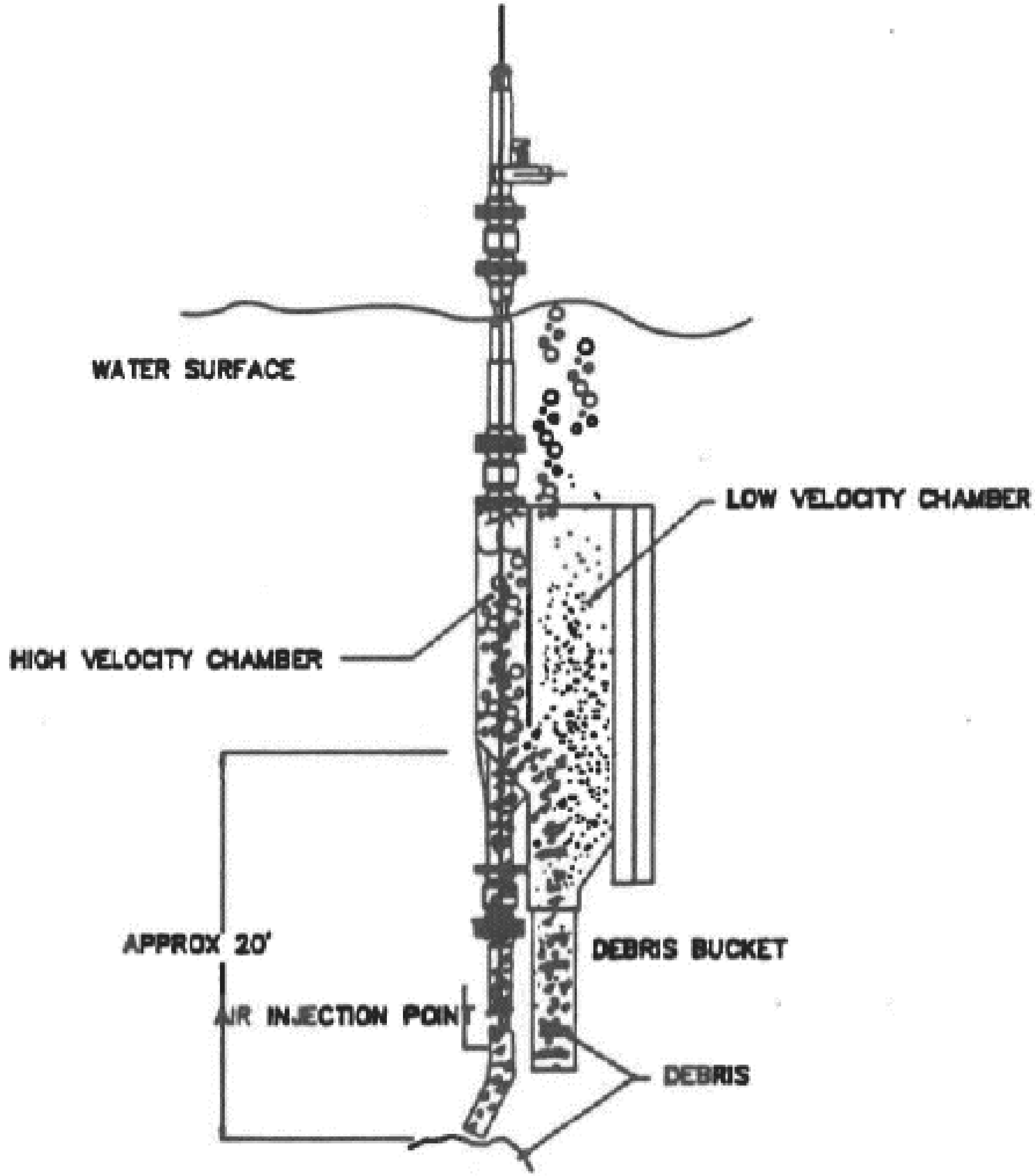
Removal of core debris from the reactor vessel's lower head

- Defueling preparations required the removal of the incore guide tubes and sections of the elliptical flow distributor head.
- Equipment used to remove loose debris on the lower head included:
  - An airlift
  - Long-handled tools
  - In-vessel vacuum system
- Cavitating (High Pressure – Pulsating) water jet and an impact hammer with a chisel point were used to break up the resolidified debris attached to the lower head
- The removal of about 30 tons of core debris from the lower head was completed in November 1989

A Heavy Duty Air Lift Vacuum System was installed and utilized

- This system lifted debris as large as 5 centimeters from the core region rubble bed and the lower head region of the reactor vessel.
- The system included an air compressor, airlift pipe, and a Fuel canister. Compressed air was injected at the bottom or suction end of the pipe to draw water into the pipe along with entrained fuel debris.
- Debris was deposited into a fuel canister located at the top of the airlift piping. The airlift increased packing efficiency in Fuel canisters already containing oddly shaped pieces of debris, such as partial fuel assemblies and end fittings

Air Lift Vacuum system (KM Supplement 2, Page 65)



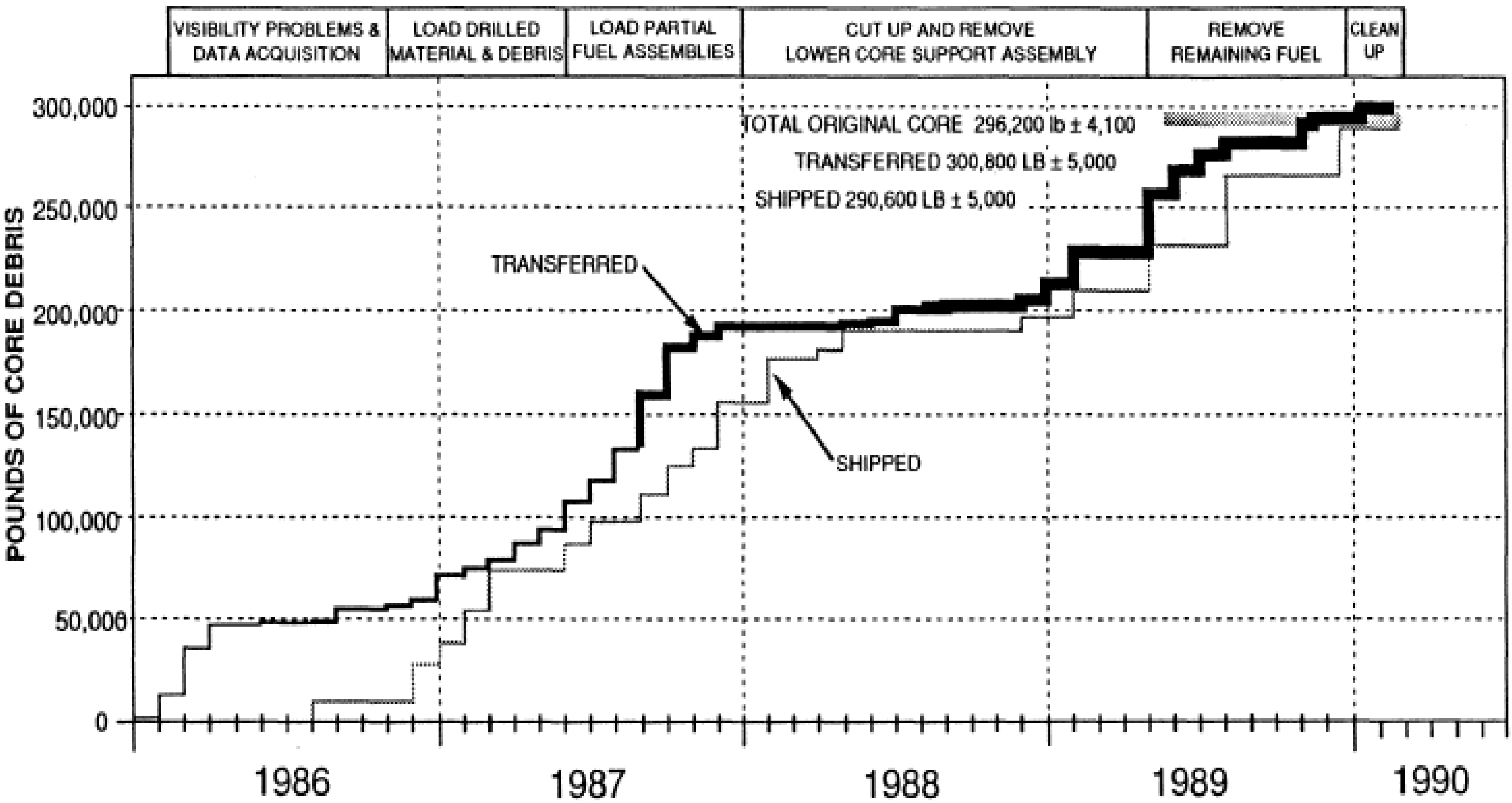
Important TMI 2 Defueling Incidents (KM - Supplement 2)

- Very few incidents, two injuries, and a few other relatively minor incidents were reported during defueling operations:

- *Dropped Canister*. On December 14, 1985, a load drop event occurred early in the defueling operations when a defueling canister and support sleeve fell into the reactor vessel.
- *Dislodged Defueling Tool*. On May 22, 1986, the trolley on the number one jib crane on the rotating work platform disengaged and fell into the reactor vessel.
- *Dislodged Defueling Tool*. On August 19, 1986, a worker on the defueling platform was injured when a long-handled tool in the reactor vessel was dislodged from its temporary storage location and fell onto the worker's right hand, pinning it between the tool and the tool rack.
- *Worker Slipped into Reactor Vessel*. On May 22, 1988, a worker on the defueling platform slipped and fell partway into the reactor vessel through an open access hatch. The individual worker was installing equipment in the reactor vessel in preparation for the reinstallation of the plasma arc cutting assembly. The worker had temporarily unhooked himself from a sling to accomplish the work.
- *Workers in Contact with Fuel Debris-1*. A small section of a fuel rod was unknowingly withdrawn from the reactor vessel when the defueling tool was removed from the reactor vessel, and the section of fuel rod fell on the work platform. The piece measured 10 roentgen per hour on contact and was picked up with a Peters tool (vice grip) and dropped back into the vessel.
- *Workers in Contact with Fuel Debris-2*. In another incident, in 1989, one worker received an overexposure of about 55 rem to the hand (which was in excess of regulatory limits) while unknowingly handling a piece of fuel debris in the TMI-2 containment building decontamination facility. A coworker received an unplanned exposure of about 13 rem to the skin on a hand.

TMI-2 Defueling Progress (Defueling Completion Report, GPU 1990)

Note: The first canisters of core debris were <u>Transferred</u> from the Reactor Building to Spent Fuel Pool "A" in January 1986 These canisters were subsequently <u>Shipped</u> to the Idaho National Engineering Laboratory for analysis and storage



General Technical Lessons Learned – Skillman

- If only one lesson is learned from my participation in this Forum, it will be worth the effort! It is this - and it is Most Important: Demonstrate Respect the Technology. Give full attention to the main characteristics of our technology that identify us - Nuclear Safety, Radiation Safety and Industrial Safety. Ensure that complete and thorough technical evaluations are conducted and challenged for Criticality, Pyrophoricity, Loss of cooling, Loss of shielding, unexpected radiological emergence, hydrogen and radioogas evolution, fall prevention, overhead protection from falling articles, respiratory protection, training and, where workers are over water, flotation (Drowning) protection.

- A critical lesson from the TMI 2 experience was the relationship between the Regulator (US NRC) and GPU. The NRC established a Field Office at TMI 2 and staffed it with highly qualified, experienced NRC personnel. The NRC Inspectors fulfilled their legally required obligation to Inspect and Enforce the nuclear regulations, and did so courteously, objectively, thoughtfully, and constructively, recognizing that TMI 2 was no longer operable, and that it was not going to restart. Both GPU and the NRC developed and maintained an 'arms-length' relationship that enabled us to work with each other and to fulfill our legal and professional accountabilities.

- Data Acquisition is critical for success. Thorough quantifying examinations, even small ones, and larger ones like Quick Look, and Core Bore, are critical in establishing plans for a safe and successful fuel removal campaign strategy. Each data-retrieval step creates opportunity for additional data acquisition. At TMI 2, each data acquisition event provided a more understandable path to the 'next step‘.

- Defueling system - choose a simple and basic Defueling Process. Choose a process that utilizes proven technologies that are simple to repair and that have available spare parts. Beware any concept that isolates the Defueling Team (licensed operator on the ‘work platform’) from the target fuel material (i.e., “remote”), except for providing abundant shielding and viewing access. In parallel, build a nearly-identical Mockup and train exhaustively on the mockup. Create and prove the procedures based on actual mockup experimentation.

- Water Quality - Water can be both a radiological source and radiological shield. This is particularly applicable to NDF's Option 2. Ensure the water is radiologically and biologically clean. Water, in any application around nuclear fuel, constitutes a nuclear moderator therefore requires treatment with poison, likely B10, to ensure criticality prevention. Water must be treated to eliminate biological species, ie. Coliform, that would threaten water clarity and biological risk. Some form of antiseptic treatment is recommended for all water used in and around the operators. Actions that create either turbulence (energetic water motion that results in fine particle release’) or opacity require treatment in some form.

- Visibility - Both Lighting and Visibility were a constant challenge during the TMI 2 defueling campaign. Any defueling option that requires direct visual observation requires both clear visibility to the target object and accompanying adequate electrical power and lighting. Consideration must be given to reduction of, or loss of, viewing capability because of shadows. Ensure adequate lighting and provide back-up where forward progress is essential.

General Organizational – Leadership Lessons Learned – - Skillman

- Defueling 1F will be a major challenge. Substantial resources will be committed to this extraordinary undertaking. Those chosen to be Leaders and that fully participate in Defueling deserve the greatest respect that the company can provide. Involvement in Defueling should be a career-enhancing assignment and those that are deeply involved should be rewarded for their commitment.
- Procedures - Creating procedures is wildly unpopular, laborious and painstaking. However procedures are necessary to ensure repeatability for routine tasks, and to ensure caution on non-routine tasks. Preparing (writing, refining) the defueling procedures, when prepared by those who own and who will use those same procedures, assures ownership and enhances compliance with those procedures.
- Before Launching the Defueling Campaign - Senior Management is well advised to clearly, earnestly and personally communicates the overall 1F Defueling Strategy and underlying Policy to the implementing personnel. If Senior Management and the Implementing Personnel are aligned, there is great probability of an excellent outcome.
- Decisions by Senior Management are most respected and supported when Senior Leaders fully participate in the Site's work culture. Also, the site will be slow to support Senior Leadership if Senior Leadership is too distant. Decisions from a distant office, where isolation and potential immunity from consequences prevent Senior Leadership from fully understanding the site's situation, can prevent organizational cohesion and success.
- Once the overall Defueling Strategy has been agreed upon, Senior Management is well advised to take action to achieve full agreement by <u>all levels</u> of accountable leadership, more specifically, those who sign the documents, and those who are responsible for success (or failure) of the Strategy.
- Beware Marketers masquerading as consultants. (Confirm that a 'consultant' that is advocating a specific product or course of action is not simply peddling a useless, unknown or unproven product or questionable course of action.)
- Senior Management is well advised to conduct regular, frequent, candid, two-way communication on agreed-upon Overarching Goals and Expectations that focus on successful outcomes and accomplishments of each major phase of the defueling Program, leaving daily site and defueling management to the site forces. If Senior Management focuses on disappointing daily equipment experiences or poor daily debris removal amounts without taking the time to understand the basis of that performance, the Defueling teams will quickly recognize that Senior Management is 'Out of Touch' with the site challenges. Let the Defueling teams work out their problems and let Senior Management provide abundant support.
- Quality Assurance - Senior Management is well advised to establish, early in the creation of the Defueling Strategy, the required Quality Level of tools and documentation. Some of these are very sensitive regarding nuclear safety, others are not. This early action by Senior Management is intended to provide clarity of Management Policy on the Quality Level of all Defueling activities. Some Defueling equipment and documentation may require significant nuclear-industry Quality Assurance (Fuel Canisters, Filter Canisters, Knockout Canisters, Fuel storage containers) where construction detail, prevention of criticality, and longevity, are essential. Virtually all Defueling Tooling is expendable, and often not commercially available. A Policy Decision to exclude all 'nuclear industry' quality requirements' except in specific nuclear safety applications (Criticality susceptible) and insistence on robust commercial quality elsewhere will greatly facilitate schedule and program success. This decision will most likely reduce staggering costs and eliminate organizational conflict.

Building the Defueling Organization Lessons Learned - Skillman

- Defueling will introduce constant challenges. The Defueling Organization is well advised to anticipate unexpected circumstances and be prepared to swiftly make changes when appropriate. Policy and procedures should anticipate this reality and ensure the overarching Guidance procedures enable swift adjustment without paralysis.
- The Defueling Organization is well advised to keep or retain those processes that are functioning well, monitor and adapt quickly where slight changes will yield additional success, be prepared to remove failing processes promptly, and replace them with fresh ideas. In brief, keep that which succeeds, modify where necessary and reasonable, replace when necessary. Attempt, in all cases, to keep the good.
- Characteristics for the types of people that will make the best fuel handlers will be individuals comfortable with manual and robotic operation of devices, who have instinctive understanding of tooling design, mechanical and hydraulic forces and function, who understand lighting and shadows, and who are adept at 'fixing things'.
- Characteristics for the types of people that will make good managers for Defueling include technically qualified individuals who have a deep respect for nuclear technology, who will make decisions promptly and effectively, who like people, who are compatible even when stressed, who enjoy being involved in complex work processes, who understand tool design and practical mechanical and hydraulic concepts, and who are quick and comfortable understanding mechanical and hydraulic forces, spatial geometry, shielding and source term.
- The most effective leaders through the TMI 2 experience were those individuals that had a thorough understanding of the specific technical discipline for which they were accountable, and more importantly had an unwavering respect for nuclear technology. They understood the dangers associated with the technology, and adjusted their commitment for progress and accomplishment with the recognition of the limits created by the radiological and practical circumstances that were being experienced. These effective leaders also understood reasonable human limitations in terms of work schedules, employee's personal challenges, and worker's capacity to work. The most effective leaders were competent, approachable and friendly, yet effective in setting goals and targets for work outcomes, and enforcing standards for conduct and discipline. Competent leaders at TMI 2 understood that tasks that were time sensitive or radiologically sensitive needed to be treated with special caution.