Three Mile Island Unit 2 Radiological Dose Management: Lessons Learned Applicable to Fukushima Daiichi

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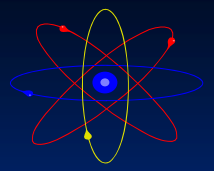
RELEVENT BACKGROUND

- Former Director of Radiation Protection (RP), Three Mile Island Nuclear Plant (post-accident)
- First RP Director of both TMI-1 *and* TMI-2
  - Radiation Field Operations, Radiological Engineering, Radiation Health, Radiation Instrumentation, Radiation Dosimetry
- Directed the TMI-2 Radiological Controls Program from 1988 to the final shipment of damaged fuel to the DOE Idaho National Laboratory, and achievement of Post-Defueling Monitored Storage in 1993

Three Mile Island Unit 2

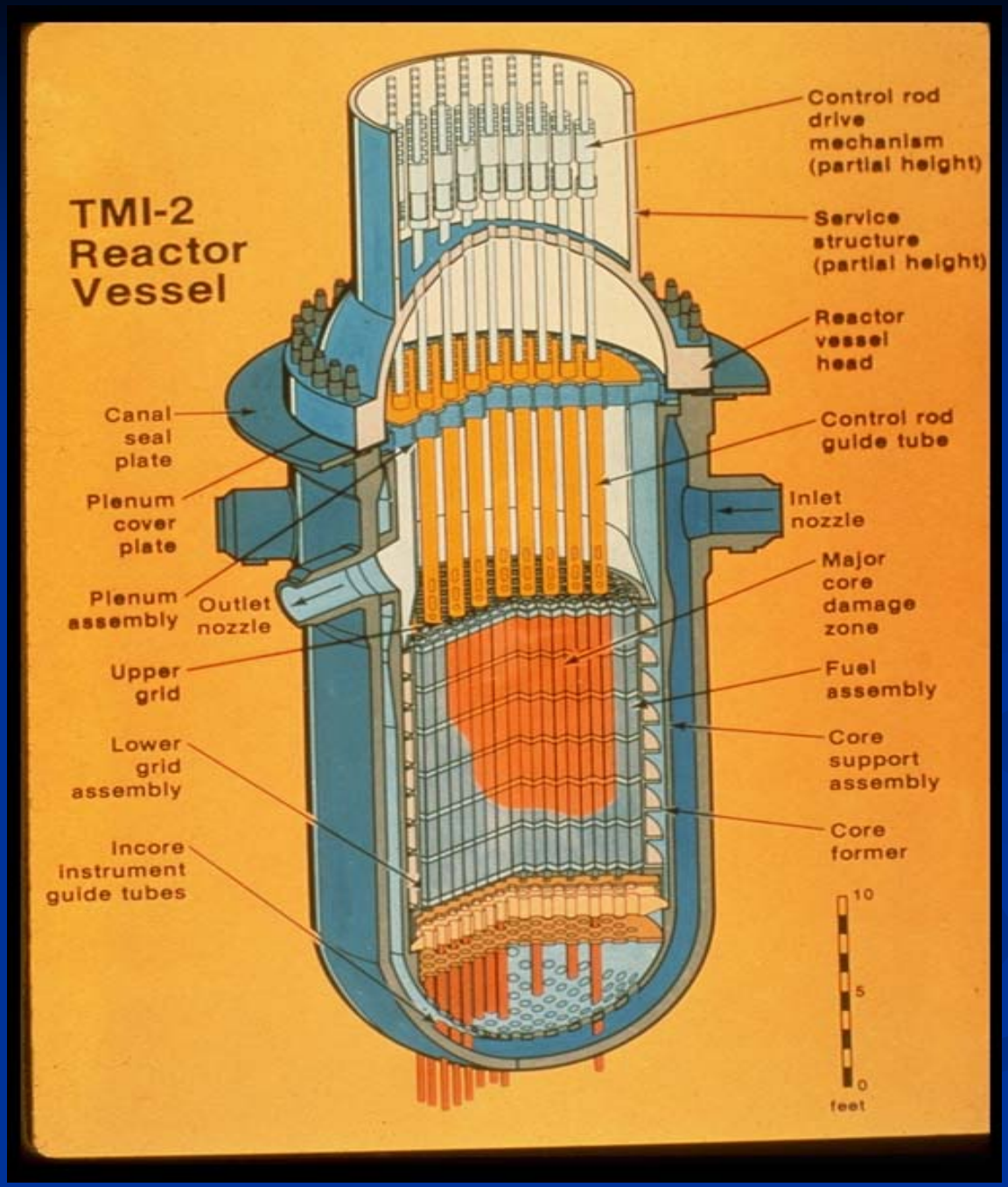


- Pressurized Water Reactor (PWR)
- NSSS: Babcock & Wilcox (B&W) – 880 MWe
- Initial Criticality: 28 March 1978
- Commercial Operation: 30 October 1978
- Accident: 28 March 1979
- Effective Full Power Days (EFPD) – <100 !

Three Mile Island – Site Layout

TMI-2 Accident Chronology

- 28 March 1979 – 32 years ago
- 16 March 1979 "China Syndrome" movie released and in theaters around TMI
- 23 July 1980 – 1st Reactor Building Entry
- July 1984 – Reactor Vessel Head removed
- October 1985 – Defueling began
- July 1986 – 1st off-site shipment of reactor core debris
- January 1990 – Defueling completed
- 28 December 1993 - PDMS Approved by NRC
- Spent Fuel in Dry Storage at Idaho National Lab


TMI-2
Reactor
Vessel
Control rod drive mechanism (partial height)
Service structure (partial height)
Reactor vessel head
Control rod guide tube
Inlet nozzle
Major core damage zone
Fuel assembly
Core support assembly
Core former
Canal seal plate
Plenum cover plate
Plenum assembly
Outlet nozzle
Upper grid
Lower grid assembly
Incore instrument guide tubes
10
5
0
feet

Major Considerations between TMI-2 & Fukushima Daiichi Accidents

- Obvious – PWR vs. BWR
- Single Unit vs. Multiple Units
- Primary Containment Remained Intact
- Reactor Vessel Not breached
- Effluent Releases via Auxiliary Bldg (except Kr-85)
- Spent Fuel Pool - not damaged and played no role
- No real site damage (except core damage)
- Hydrogen 'burn' but no hydrogen explosion
- No offsite power loss (or SBO)
- No extensive detectable offsite contamination
- No required evacuation of general public

Exemplary Leadership

- Strong Safety Culture – Before NRC Required
- Strong Senior Leadership
- President/Vice-President worked directly for Admiral Rickover – Father of U.S. Nuclear Navy
- Several Nuclear Navy Admirals served as Directors
- For extended time – >20 NRC Inspectors onsite
- State of Pennsylvania oversight
- Improved public outreach following poor start
  - Local Physicians trained after some abortions inappropriately recommended
  - Whole Body Counts offered to general public

Exceptional Radiological Controls

- Strong work management
- Exceptionally qualified staff hired
- High priority from Senior Management
  - Radiation Protection Policy
  - Radiation Protection Plan
  - Radiation Procedures – verbatim compliance
  - ALARA Committee
  - Mockups
  - Advanced Radiation Worker Training
  - Stop Work Authority at Radiation Technician Level
  - Pre- and post-job briefings
- Committed to Excellence

Innovation with Radiological Controls

- Digital Reading Dosimeters (DRD)
- Breathing Zone Air (lapel) Samplers
- Powered Air Purifying Respirators (PAPR)
- Whole Body Contamination Monitors
- Ice vests and Vortex suits for worker cooling
- Hydration for high heat area entries
- Completely assisted PPE donning and removal for all Reactor Building (RB) entries – rescue crews
- Multiple dosimeter packs where needed (up to ~10 dosimeters due to radiation stratification
- Command & Control Room for RB entries

Summary Technical Plan for Decontamination and Decommissioning December 1980

The major objectives of the TMI-2 decontamination and defueling plan:

- o Maintain the reactor in a safe state,
- o Decontaminate the plant,
- o Process and immobilize dispersed fission products,
- o Remove and dispose of the reactor core, and do so with maximum assurance of public health and safety

TMI-2 PDMS Requirements

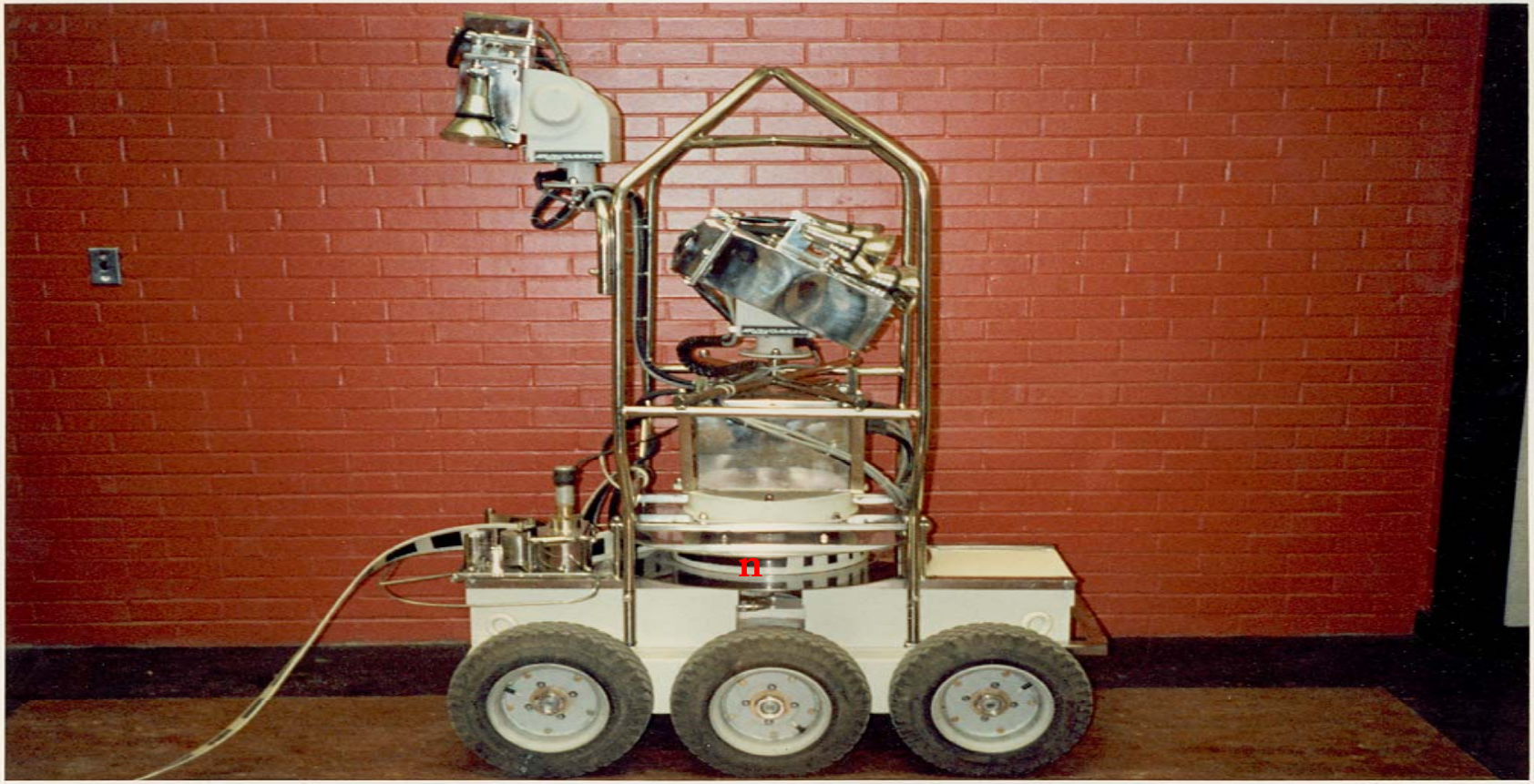
- **<1% Failed Fuel remaining**
- **No real potential for liquid or airborne effluents**

  Reactor Building – "Breather" system with passive ventilation system – maintained at atmospheric pressure

  Liquids sampled for any groundwater intrusion/effluent
- **No fire damage potential**
- **All accident generated water (AGW) processed**
- **Long-term radiological surveillance program in place**
- **Decommissioning funds in escrow**
- **Unit-2 to be decommissioned when Unit-1 done**
- **Others**

Recovery and Defueling Issues

- Major engineering undertaking
- Extensive radiological controls challenge
- Performing tasks not performed before
- Plasma Arc Torch cutting of fuel and reactor internals
- Use of long handled tools
- Special design equipment
- Special contractors needed under utility guidance
- Major use of robotics…

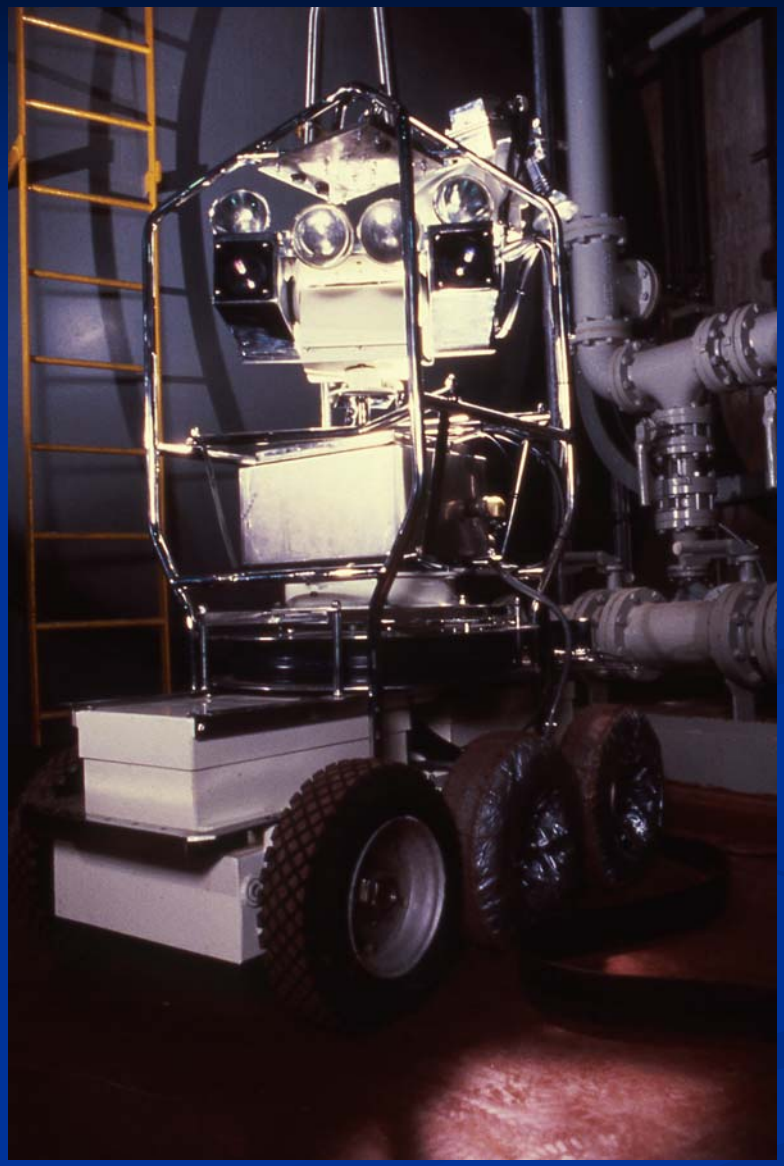


T.M.I. Rover

Designed for Use at Three Mile Island Nuclear Power Plant, Pittsburgh, Pennsylvania – Standard's six wheel, 570 lb. undercarriage was developed for use in contaminated areas for initial surveillance as part of the radioactive waste cleanup program for the power plant. The undercarriage measures 50" long x 29" wide x 19" high and operates electrically by remote control.

STANDARD MANUFACTURING CO., INC. DALLAS, TEXAS

Robotics Photos from Video

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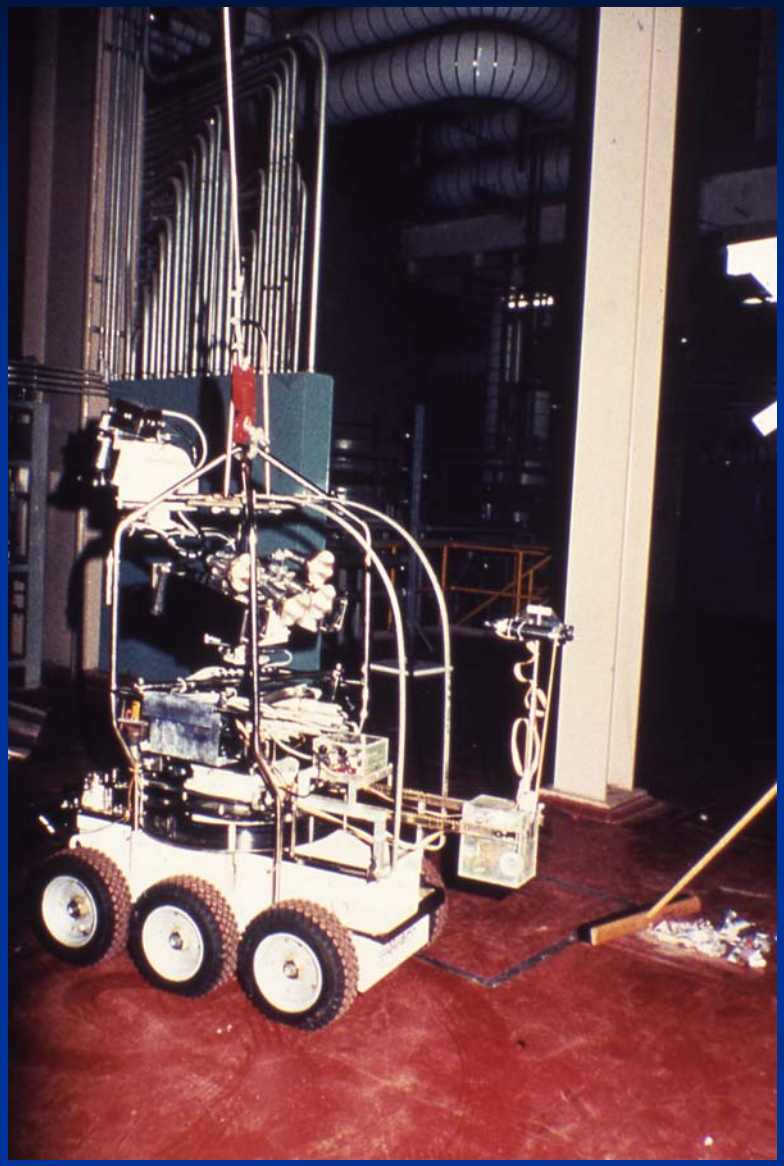


D&D Categories (U.S.)

DECON (Decontamination)

SAFSTOR (Safe Storage) – TMI-2 PDMS – Essentially meets SAFSTOR requirements

ENTOMB

Dose Estimates for Cleanup

TOTAL CUMULATIVE RADIATION WORKER DOSE

MINIMUM* – 2000 person-rem (20,000 person - mSv)

MAXIMUM* – 8000 person-rem (80,000 person - mSv)

***OTHER ESTIMATES* – AS HIGH AS >20,000 person-rem (>200,000 person - mSv)**

******NUREG-0683 – Estimated (1981)*

Worker Cumulative Dose

Estimated TOTAL
1979-1993 to reach PDMS

~6600 person-rem (66,000 mSv)

- ~62,500 person-mSv*
- ~3,500 person-mSv**

*GPU Nuclear TMI-2 Annual Dose Report
**USNRC NUREG-0713
NOTE: Total includes some TLD and some Self-Reading Dosimeter data

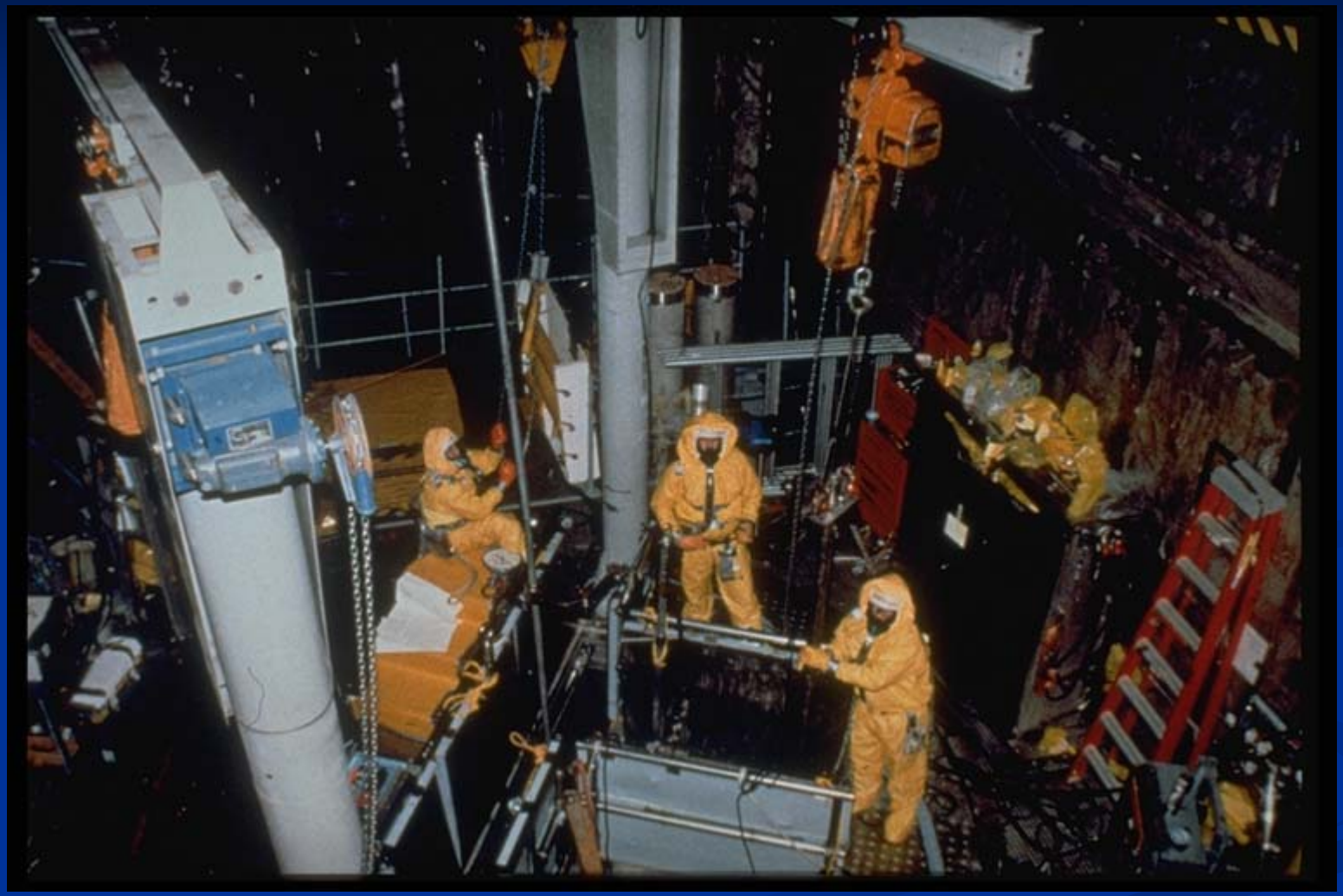
TMI-2 Worker Overexposures

- Twelve (12) *instances* during initial accident response
- Whole body doses from TMI-1 post accident sample
  4.1 rem (41 mSv) by 2 workers
  3.9 (39 mSv) rem by 1 worker
- One (1) additional in 1986 – handled a fuel chunk
- NO acute injuries
- Each individual received a medical evaluation
- Internal doses generally low – NO overexposures
- NO overexposures due to Discrete Radioactive Particles (DRPs or "hot particles")
- Total overexposures = 13

TMI-2 Worker Overexposures

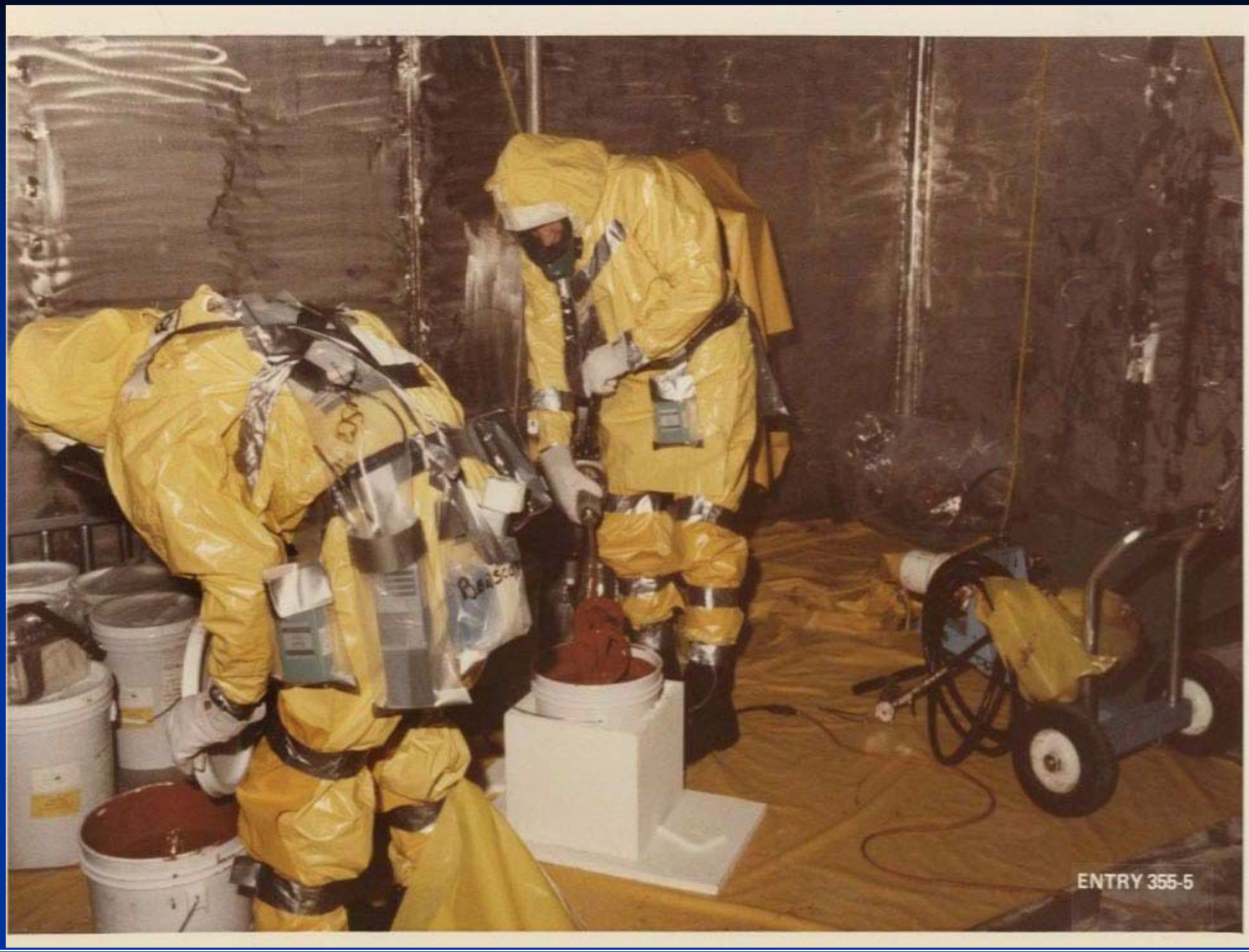
- Whole body doses (from TMI-1 post accident sample)
  - 4.1 rem (41 mSv) 2 instances
  - 3.9 (39 mSv) rem by 1 instances
- Skin
  - 12,000 – 166,000 mrem *partial* (120-1660 mSv) 9 instances
- Extremities
  - 20,000 to 64,000 mrem (200-640 mSv) 2 instances
  - 58,000 mrem (580 mSv) 1 instance to palm of hand (1986)

NOTE: All of the above occurred within a few days of the accident except for the 1986 handling of a fuel chunk



Remote Defueling Operation Over Reactor Vessel

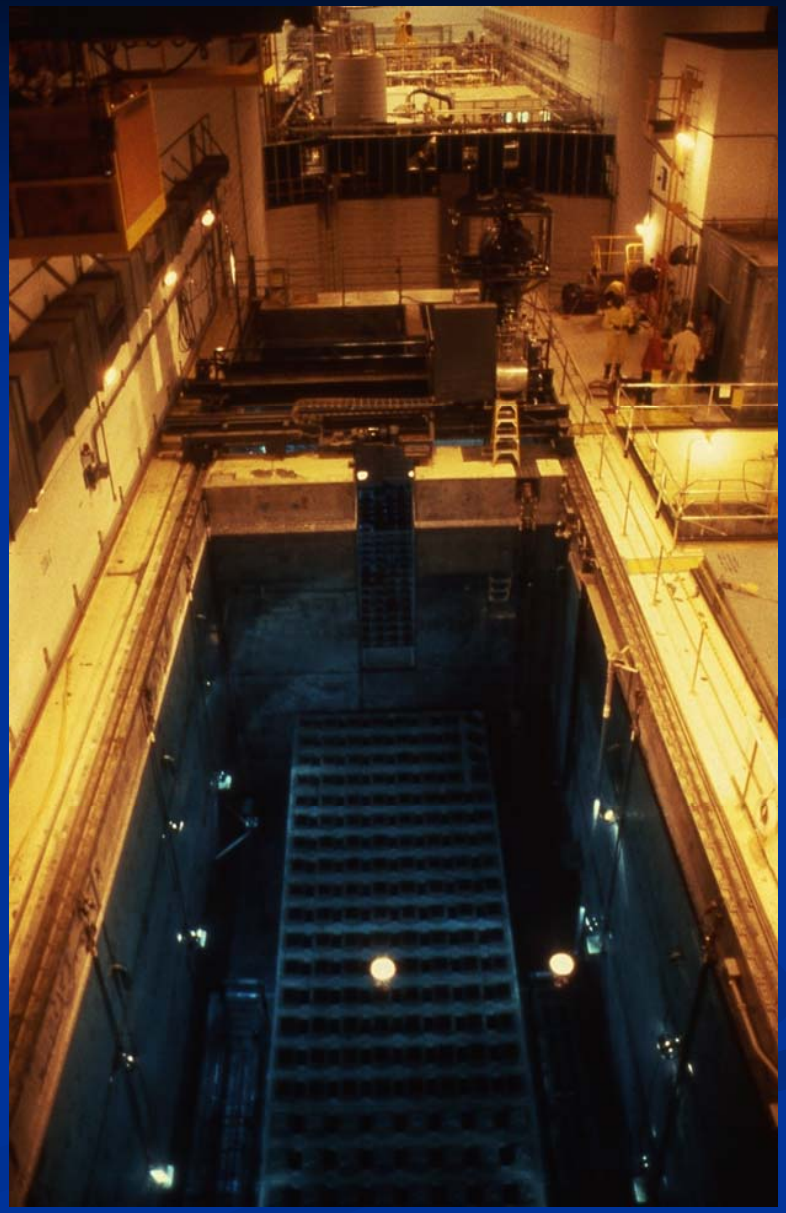
Personnel Protective Equipment for Platform Work

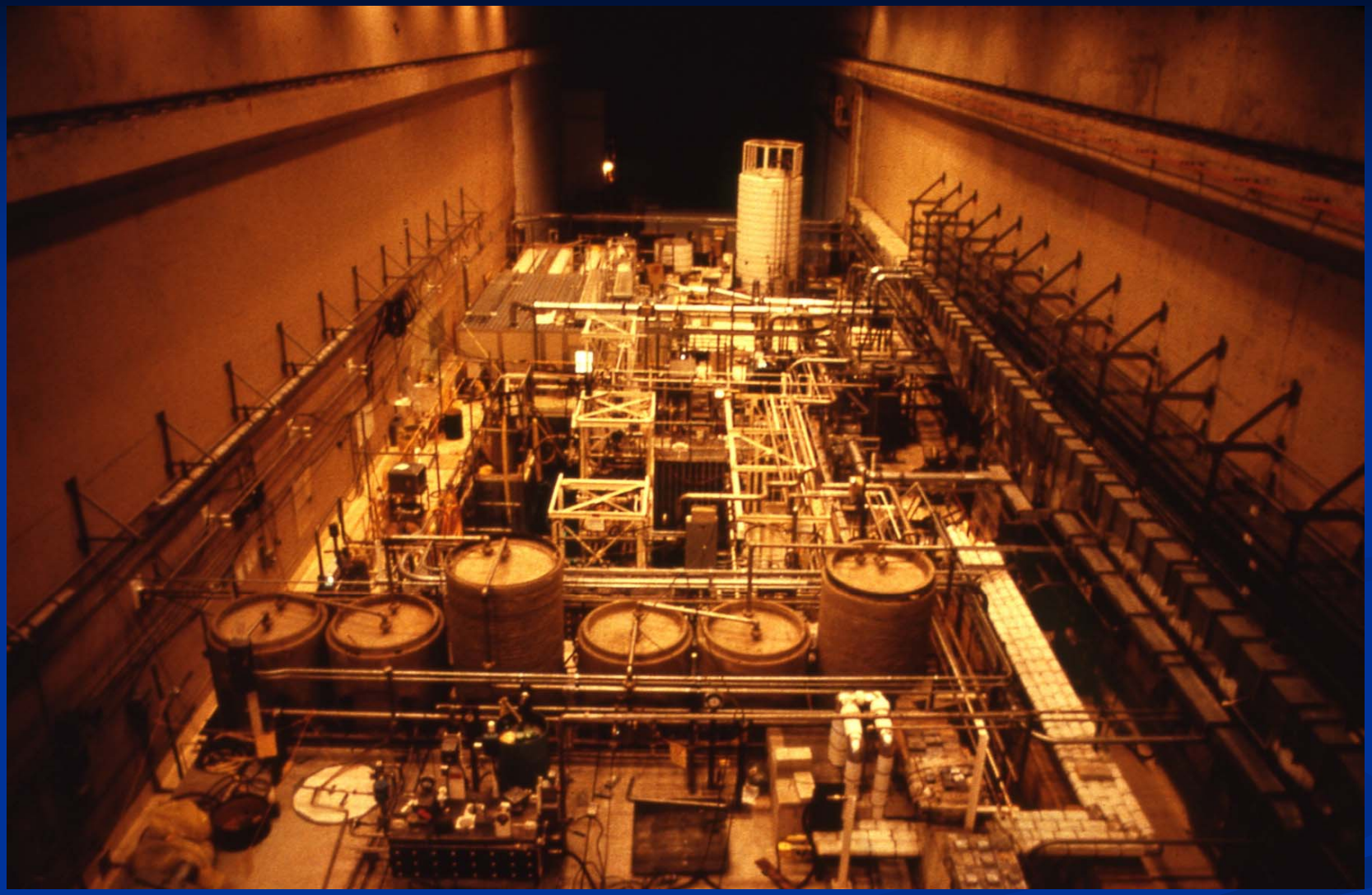

ENTRY 355-5

Spent Fuel Pool Bay for both Units

TMI-1 at bottom of photo with normal configuration

TMI-2 in top of photo with SDS

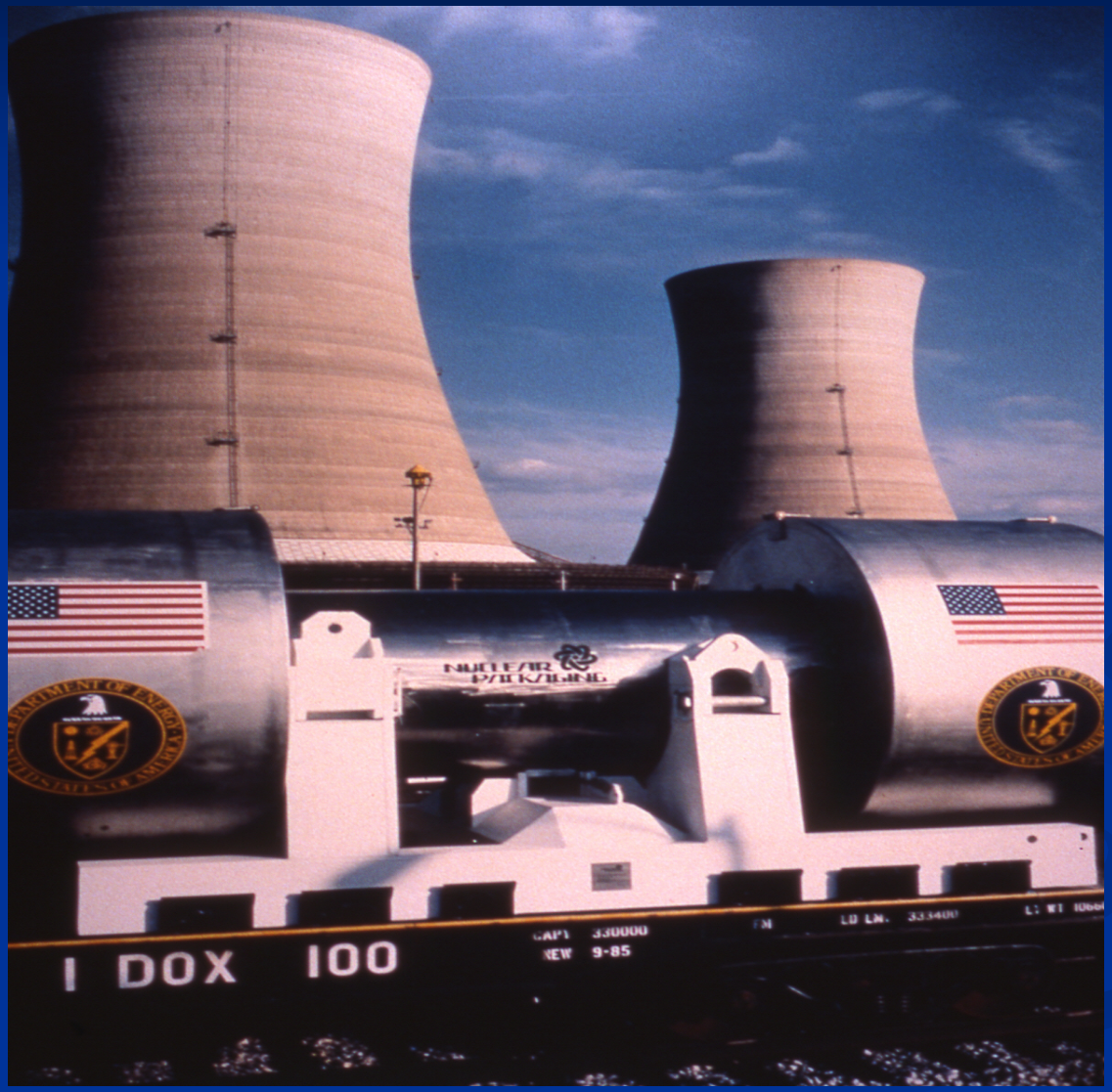




TMI-2 Spent Fuel Pool Submerged Demin System

Reactor Vessel Microorganism Turbidity Problem

USDOT Approved Rail Shipping - Spent Fuel



Some Key Points Given to 5 Japan Parliament Members in June 16 Meeting

- Simple conclusion could be that Daiichi was 3-4 times worse than TMI-2
- Not the case – may present ~8-12 times the magnitude of a challenge
- TMI-2 had no extensive plant damage
- No penetration through reactor vessel
- The task is enormous and will require incredible effort and cooperation
- National and International level of effort with the best minds and talent necessary

Some Key Points Given to 5 Japan Parliament Members in June 16 Meeting

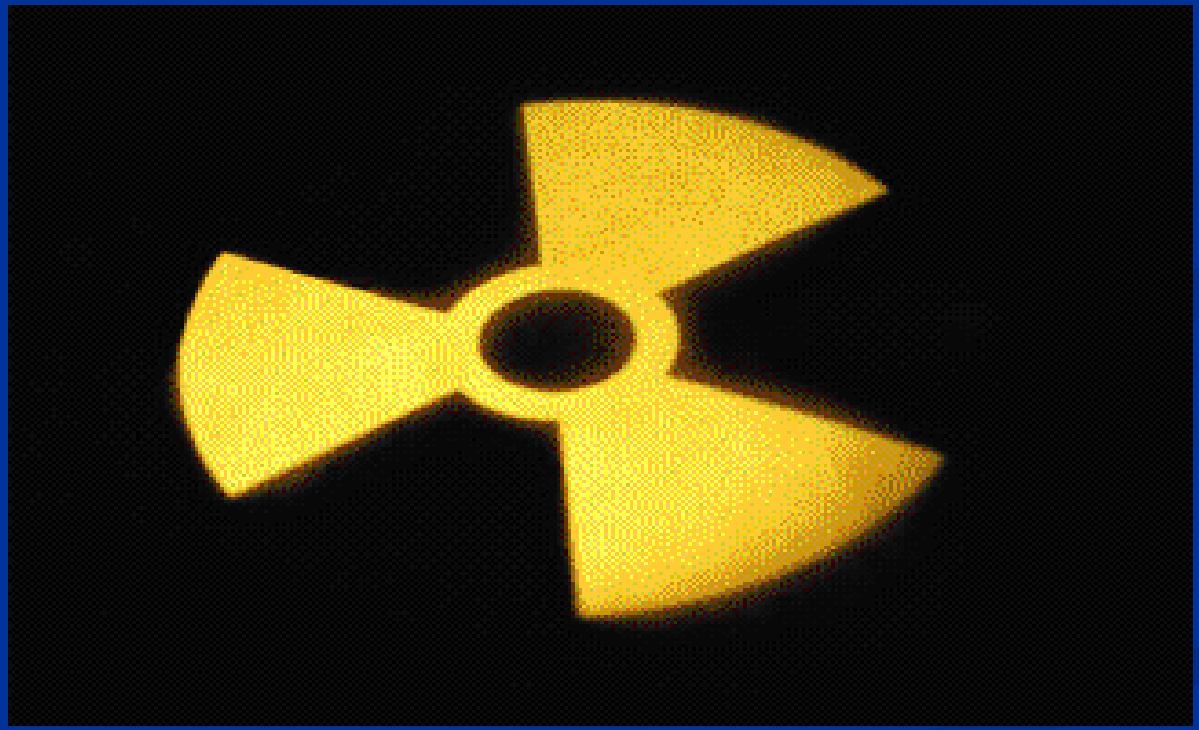
- Major Hot Spots exist (throughout plants)
- Fuel Fragments (highly radioactive) - >10,000 mSv/hr
- Discrete Radioactive Particles - fuel, fission and activation products)
- These DRP's are invisible to the eye - can act like 'fleas' due to electrostatic charge
- Plutonium (strong public reaction expected)
- Tritium – radioactive 'water' – cannot remove like particles (problematic effluent)

Some Key Points Given to 5 Japan Parliament Members in June 16 Meeting

- Build airplane type hanger structure to contain each Daiichi units
- May need to adjust regulations for radiation worker Dose Limits such as 100 mSv in 5 years
- To clean to 95%, may require 50-100k trained radiation workers
- Radioactive waster processing and volume reduction is critical
- NO nuclear plant in the world has seen a 15 meter tsunami and 9.0 earthquake

And…

Thank You



CONTINGENCY SLIDES

TMI-2 Overexposures

HISTORY OF PERSONNEL EXPOSURES IN EXCESS OF REGULATORY LIMITS

YEAR	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NUMBER	12 (see below)	None	None	None	None	None	None	None	None	None	1 (see below)

DETAILS OF EXPOSURES

YEAR	TYPE OF EXPOSURE	NUMBER OF INSTANCES	RESULTING DOSE IN 1 QUARTER
1979	• Whole Body	1	• 4100 millirem
1979	• Whole Body and Skin	1	• Whole body dose: 3900 millirem Skin dose: 26,100 millirem
1979	• Skin Only	8	• Doses ranged from 12,000 millirem to 166,000 millirem to portions of the skin. In one case, most of the skin received a dose of 13,200 millirem.
1979	• Whole Body and Extremity	1	• Whole body dose: 4100 millirem Extremity dose: 64,000 millirem.
1979	• Extremities Only	1	• Dose of 20,000 millirem to fingers.
1989	• Extremities Only	1	• Dose of 57,198 millirem to palm of hand.

Major PDMS Activities

TMI-2 WORKER DOSE FOR MAJOR ACTIVITIES

1986 - 1989

ACTIVITY	PERSON-REM
Defueling Operations (reactor vessel only)	698
Defueling Support (tool repairs, water cleanup)	1058
Reactor Building Miscellaneous (robotics, crane ops, radwaste, etc.)	765
Decontamination (outside the reactor building)	424
Routine Operations (ops, chemistry, rad con outside reactor building)	277
Ex-Vessel Defueling (pressurizer, OTSG, etc.)	216
TOTAL	3438

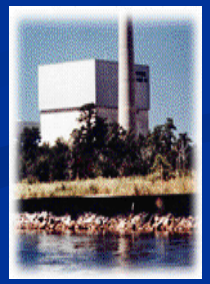
Experience Utilized to Decommission Saxton Experimental Reactor

PPE Issues Played a Major Role

Reactor Building Entrance Airlock

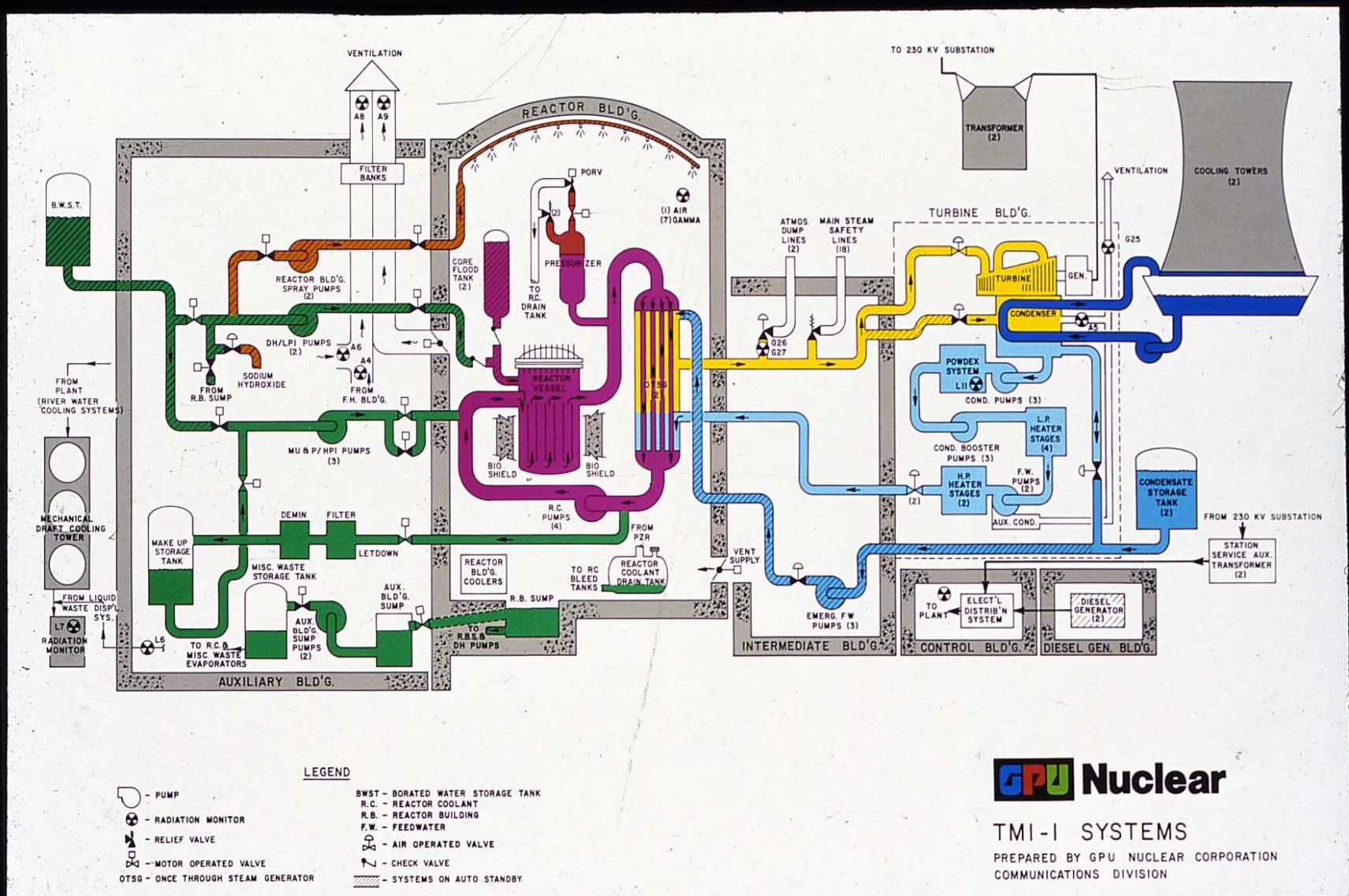
RELATIVE BACKGROUND

- Director of the Radiological Controls & Occupational Safety Program at the Oyster Creek Nuclear Plant (1993-1997)



- BWR-2 commercial operation 1969

  ~ 'sister' plant to Fukushima Daiichi Units 1-4



GPU Nuclear

TMI-1 SYSTEMS

PREPARED BY GPU NUCLEAR CORPORATION
COMMUNICATIONS DIVISION

Three Mile Island – Both Units Operating