Three Mile Island Unit 2 Defueling- Safety & Risk Reduction Process Experience: Core Drilling Machine Evolution

Fukushima Forum

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Three Mile Island Experience

- **Light Water Power Reactor Core Melt Accident**
  - **1979: 38 Years ago**
  - **14 Year $1B Decontamination/Defueling Project**
- **Similar & Different Than Fukushima Daiichi (1F)**
  - **TMI Major but Less Technically Severe Accident**
  - **Similar Technical/Management/Social-Political Challenges**
- **Many Lessons Are Applicable**
- **TMI Was Safely Accomplished & 1F Can Be Also**

Three Mile Island Units 1 &2

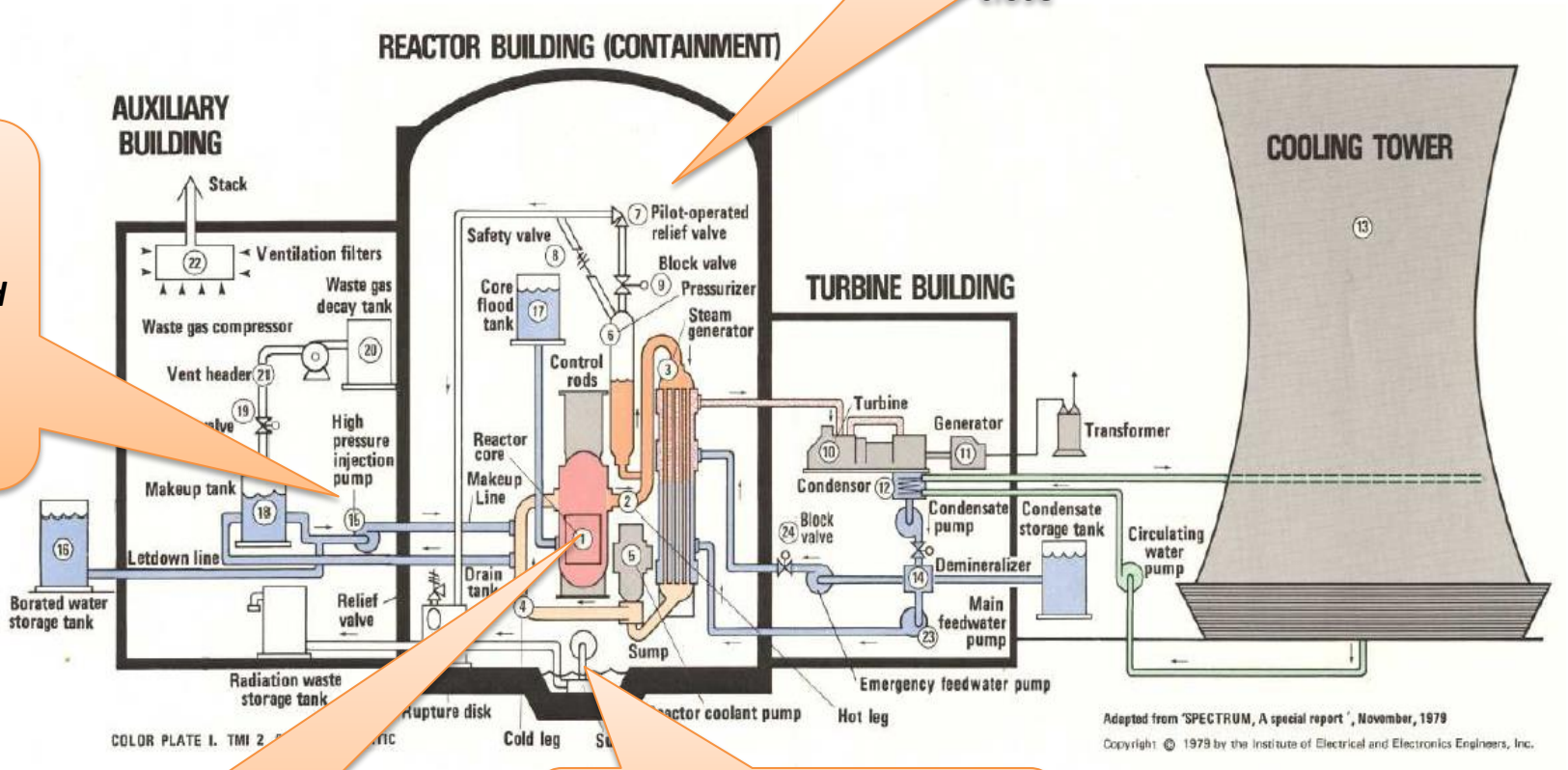
March 28, 1979

Three Mile Island Unit-2 Accident

March 28, 1979

04:00 Relief Valve fails to close

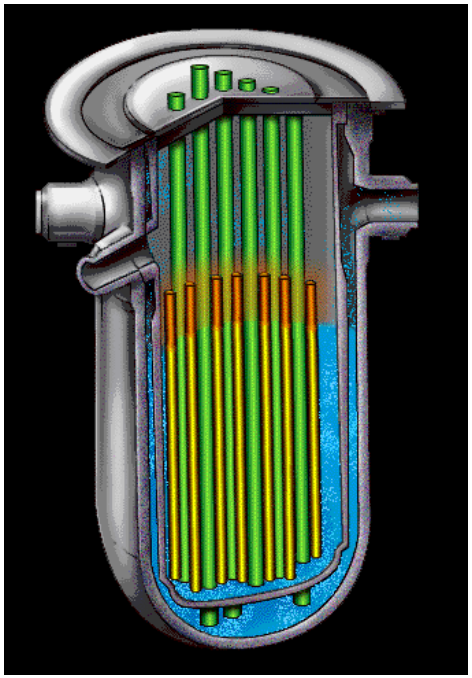
Operators Believe Reactor Overfilled and Turn Off Injection Pumps



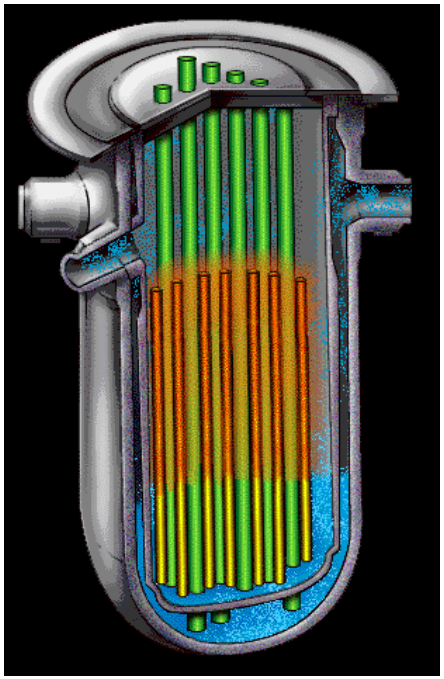
Core is uncovered Fuel overheats/fails/~50% Melt

650,000 gallons of highly radioactive water collects

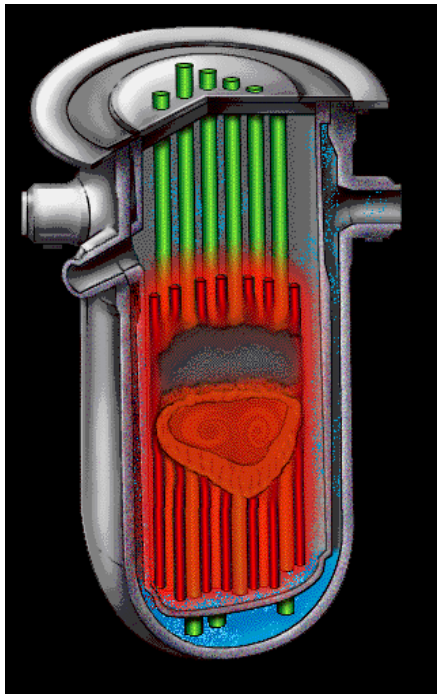
TMI Core Damage Sequence



~120 Min Core Uncovers-Damage Starts 800C Burst (~06:00)



~150Min Core Cladding Oxidize ~1800C (~06:30)



~226 Min Core Melted ~2700C (~07:30)

TMI Decontamination and Decommissioning (D&D) Approach

- **Prompt Safe & Cost Effective Cleanup**
  - **Control, Contain, Reduce Risks, Stabilize**
- **Clear End State Focus: Defuel Damaged Core**
- **Expect Surprises**
  - **Monitor, Self-Learn, Adapt, Succeed**
- **Keep Simple**
  - **Adapt Proven Technologies As Much As Possible**
- **Work Safely From Outside In**
  - **Step-wise with Constant Feedback Evolution**
- **Always: Think, Learn, Create, Improve**

TMI D&D Organizations

- General Pubic Utilities Nuclear (GPUN)-Owner/Licensee-Responsible for D&D Work
- US Nuclear Regulatory Commission
  - Delegated Authority to New TMI Program Office (TMIPO)
- US Department of Energy (DOE)
  - Provided Federal R&D Assistance (GEND) to:
  - Allowed DOE Laboratories to Independently Support NRC on Specific NRC Tasks, e.g.
- Nuclear Industry
  - Supported GPUN
  - EPRI Technical Support
  - Nuclear Contractors
    - Bechtel National and Others
      - Bechtel and GPUN Organizations Integrated Together
  - US Navy & Academic Advisors for Review and Assistance Groups

Safety-Risk Reduction Focus

- **Safe Prompt Defueling to Place Damaged Fuel/Radioactive Materials Into Safe Engineered Containers**
  - **Time at Risk In Un-Designed Post Accident Condition Was Important Risk Reduction Factor**
  - **Control & Containment of Radioactive Material**
- **High Activity Waste Container Safety**
  - **New Safety Issues, e.g. Hydrogen Generation**

Safety Review Process

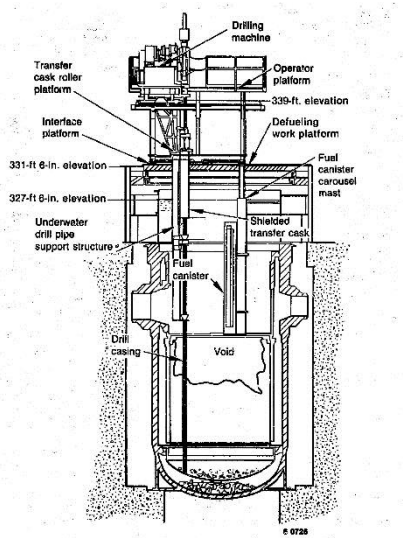
- **Stepwise Evolutionary Process**
  - **GPUN Safety Evaluation For Each Major D&D Step**
    - **DOE Safety Support to GPUN**
  - **USNRC Review/Approval**
    - **Risk Informed On Site Reviews**
    - **Within Bounds of NRC Programmatic Environmental Impact Statement**
    - **Safety Analysis for D&D Operations Within Bounds of Normal Reactor Accident Risk**

Core Drilling Machine Evolution

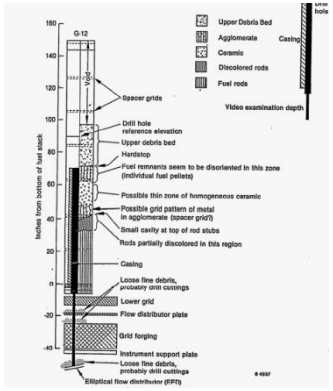
- **Beginning- Phase 1: Data Recovery R&D Core Stratification Sampling Machine Tool**
  - **1980-86**
  - **DOE/INL Lead & GPUN Support**
- **Phase 2: Core Mass Breakup Machine Tool**
  - **1986**
  - **GPUN Lead & DOE/INL Support**
- **Phase 3: Steel Structure Cutting Machine Tool**
  - **GPUN Lead & DOE/INL Support**
  - **1987-1988**

Drilling Machine Evolution

Core Sampling For Analysis/ Learning

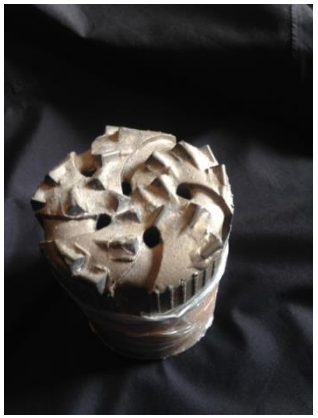


Core Boring Sampling



Analysis Results

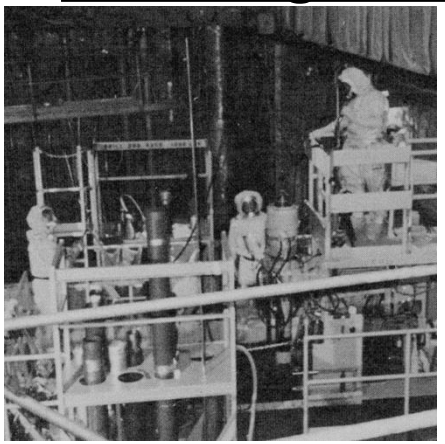
Core Mass Breaking Defueling



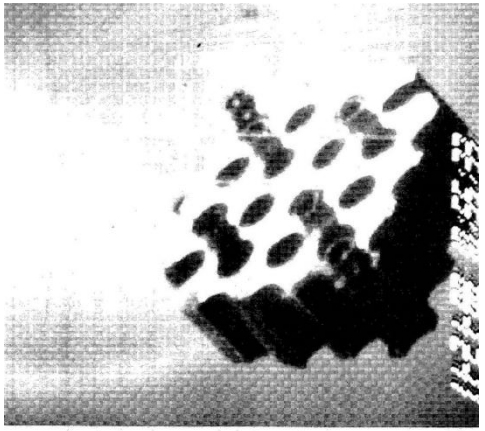
Core Breaking Bit

Broken Core Center Fragment

Core Support Structure Removal for Lower Defueling Access



Drilling Operation



Core Plate Segment

Phase 1 Core Bore Sample Evolution

- **1980-82: Developing Sampling Needs Discussions**
- **1981-83: DOE/INEL Evaluates Adapting Geologic Core Sampling Drilling Technology**
- **1984: Core Sampling Via Core Drilling Safety Discussions (GPUN, DOE, NRC)**
- **1985-August: GPUN Safety Submittal to NRC**
- **1986-June: NRC/TMIPO Approval SER**
- **1986-July: NRC Procedure Approvals & Operations**

Safety Issues Evaluated

- Release of radioactivity,
- Criticality,
- Boron dilution,
- Hydrogen evolution,
- Pyrophoricity,
- Fire protection,
- Decay heat removal,
- Reactor vessel integrity,
- Instrumentation interference,
- Heavy load drops,
- Ability to maintain control even if there was a reactor vessel leak,
- Occupational exposures
- There not being an Unreviewed Safety Question

Phase 2: Core Mass Breakup Drilling Evolution

- **1985-86: GPUN Adopted the Drilling Machine as a defueling tool to break up core mass based on positive team experience. Safety Discussions with all.**
  - **NRC Safety concerns regarding drilling forces on Reactor Vessel Instrument Guide Tube Integrity**
- **1986-July: GPUN Safety Submittal to NRC**
- **1986-July:NRC/TMIPO Approval SER**
  - **With Vessel Integrity Location Limitations**

Phase 2: Defueling Core Mass Breakup Tool-2

1986-September: GPUN Provides Safety Analysis for Guide Tube Safety

1986-October: NRC Approves Drilling over Wider Area

1986-October: NRC Approves Procedures and Drilling Began.

1986-November: 409 Drill holes Breaks Up Central Core Mass Successfully.

Phase 3: Lower Core Structure Cutting Tool Evolution

- **1986-1987: With Good Experience With Drilling Machine, GPUN/EG&G adapts it and discusses with NRC for cutting steel structures for lower fuel access.**
- **1987-October: GPUN Safety Submittal for Cutting LCSA.**
- **1988-January: NRC approves with dimensional controls**
- **1988 January: NRC approved procedures and GPUN cutting begins sequentially and successfully**

Summary of Safety Lessons

- Constant Onsite Risk Informed Focus
- Adaptive Learning with Safety Hold Points
- Sequential GPUN and NRC Safety Evaluations Built on Previous Experiences
- Early Safety Design Basis Criteria Was Important
- Constant Effective Communications Between:
  - Scientists/Developers
  - Licensee Engineers/Operators
  - Regulators