

Important Historical Nuclear Events



- **SL-1**
- **Browns Ferry Fire**
- **Three Mile Island**
- **Davis-Besse**

Accident Sequence Precursors

Significant Precursors

* Sorted by event date.

	Date	Plant	Title	LER	ΔCDP/ CCDP	Description
1	02/27/02	Davis-Besse	Multiple conditions coincident with RPV head degradation	346/02-002	6.E-03	The analysis included multiple degraded conditions discovered on various dates. These conditions included cracking of CRDM nozzles and RPV head degradation, potential clogging of the emergency sump, and potential degradation of the high-pressure injection pumps during recirculation.
2	02/06/96	Catawba 2	LOOP with an EDG unavailable	414/96-001	2.E-03	When the reactor was at hot shutdown, a transformer in the switchyard shorted out during a storm, causing breakers to open and resulting in a LOOP event. Although both EDGs started, the output breaker of EDG 1B, to essential bus 1B failed to close on demand, leaving bus 1B without AC power. After 2 hours and 25 minutes, operators successfully closed the EDG 1B output breaker.
3	09/17/94	Wolf Creek 1	Reactor coolant system blowdown to RWST	482/94-013	3.E-03	When the plant was in cold shutdown, operators implemented two unpermitted simultaneous evolutions which resulted in the transfer of 9,200 gallons (34,825 liters) of RCS inventory to the RWST. Operators immediately diagnosed the problem and terminated the event by closing the residual heat removal cross-connect motor-operated valve. The temperature of the RCS increased by 7 °F (4 °C) as a result of this event.
4	04/03/91	Harris 1	HPI unavailability for one refueling cycle	400/91-008	6.E-03	A degraded condition resulted from relief valve and drain line failures in the alternative minimum flow systems for the charging/safety injection pumps, which would have diverted a significant amount of safety injection flow away from the reactor coolant system. The root cause of the degradation is believed to have been water hammer, as a result of air left in the alternative minimum flow system following system maintenance and test activities.
5	12/27/86	Turkey Point 3	Turbine load loss with trip; CRD auto insert fails; manual reactor trip; PORV sticks open	250/86-039	1.E-03	The reactor was tripped manually following a loss of turbine governor oil system pressure and the subsequent rapid electrical load decrease. Control rods failed to insert automatically because of two cold solder joints in the power mismatch circuit. During the transient, a PORV opened but failed to close (the block valve had to be closed). The loss of governor oil pressure was the result of a cleared orifice blockage and the auxiliary governor dumping control oil.
6	06/13/86	Catawba 1	CVCS system leak (130 gpm) from the CCW/CVCS heat exchanger joint (i.e., small-break LOCA)	413/86-031	3.E-03	A weld break on the letdown piping, near the CCW/CVCS heat exchanger caused excessive RCS leakage. A loss of motor control center power caused the variable letdown orifice to fail open. The weld on the 1-inch (2.54-cm) outlet flange on the variable letdown orifice failed as a result of excessive cavitation-induced vibration. This event was a small-break LOCA.
7	06/09/85	Davis-Besse	Loss of feedwater; scram; operator error fails AFW; PORV fails open	346/85-013	1.E-02	While at 90-percent power, the reactor tripped with MFW pump 1 tripped and MFW pump 2 unavailable. Operators made an error in initiating the steam and feedwater rupture control system and isolated EFW to both steam generators. The PORV actuated three times and did not reseal at the proper RCS pressure. Operators closed the PORV block valves, recovered EFW locally, and used HPI pump 1 to reduce RCS pressure.
8	05/15/85	Hatch 1	HVAC water shorts panel; SRV fails open; HPCI fails; RCIC unavailable	321/85-018	2.E-03	Water from an HVAC vent fell onto an analog transmitter trip system panel in the control room (the water was from the control room HVAC filter deluge system which had been inadvertently activated as a result of unrelated maintenance activities). This resulted in the lifting of the SRV four times. The SRV stuck open on the fourth cycle, initiating a transient. Moisture also energized the HPCI trip solenoid making HPCI inoperable. RCIC was unavailable due to maintenance.
9	09/21/84	LaSalle 1	Operator error causes scram; RCIC unavailable; RHR unavailable	373/84-054	2.E-03	While at 23-percent power, an operator error caused a reactor scram and MSIV closure. RCIC was found to be unavailable during testing (one RCIC pump was isolated, and the other pump tripped during the test). RHR was found to be unavailable during testing because of an inboard suction isolation valve failing to open on demand. Both RHR and RCIC may have been unavailable after the reactor scram.
10	02/25/83	Salem 1	Trip with automatic reactor trip capability failed	272/83-011	5.E-03	When the reactor was at 25-percent power, both reactor trip breakers failed to open on demand of a low-low SG level trip signal. A manual trip was initiated approximately 3 seconds after the automatic trip breaker failed to open, and was successful. The same event occurred 3 days later, at 12-percent power. Mechanical binding of the latch mechanism in the breaker under-voltage trip attachment failed both breakers in both events.
11	06/24/81	Davis-Besse	Loss of vital bus; failure of an EFW pump; MSSV lifted and failed to reseal	346/81-037	2.E-03	With the plant at 74-percent power, the loss of bus E2 occurred because of a maintenance error during CRDM breaker logic testing. A reactor trip occurred, due to loss of CRDM power (bus E2), and instrumentation power was also lost (bus E2 and a defective logic card on the alternate source). During the recovery, EFW pump 2 failed to start because of a maladjusted governor slip clutch and bent low speed stop pin. A main steam safety valve lifted, and failed to reseal (valve was then gagged).

SL-1 Accident

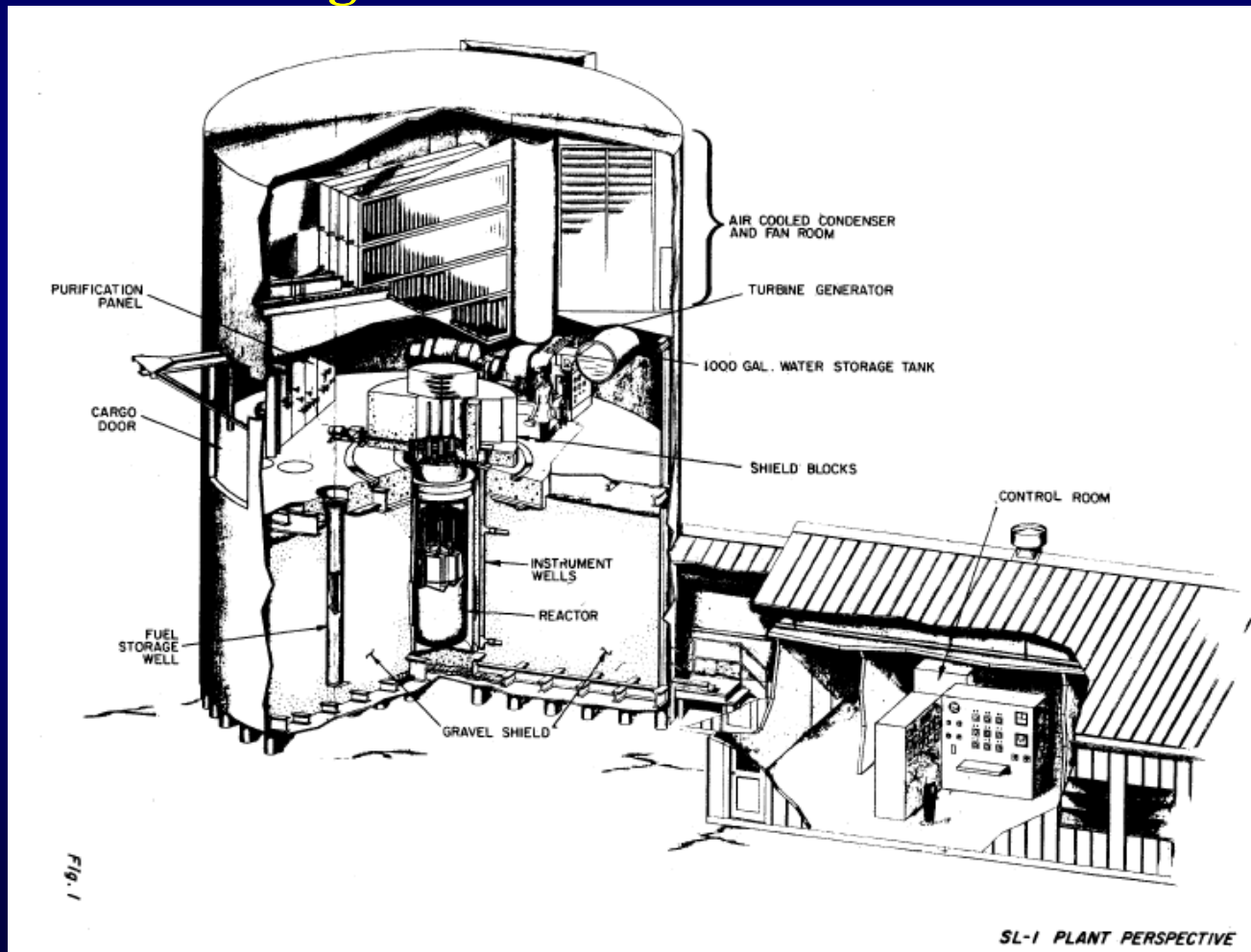
Stationary Low Power Reactor 1 (SL-1)

- Small (3 Mw_{th}) BWR
- Designed at INEL Idaho 1955-56
- Initial Criticality 1958
- Intended to power Army radar installations in tundra



SL-1 Accident

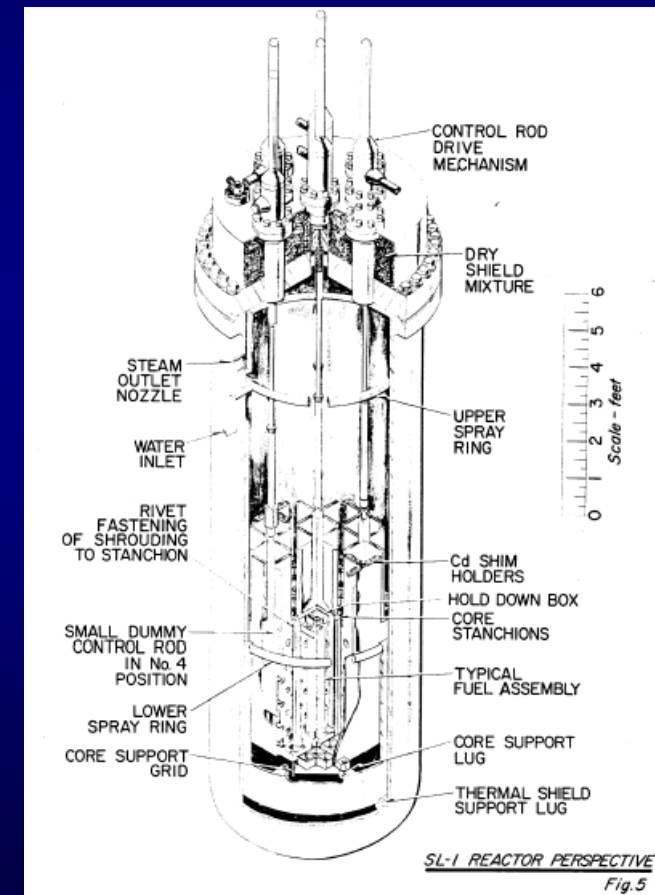
Plant Arrangement



SL-1 Accident

Reactor Design

- 40 Fuel Assemblies
- 5 Control Rods
- Designed for 3 year fuel cycle



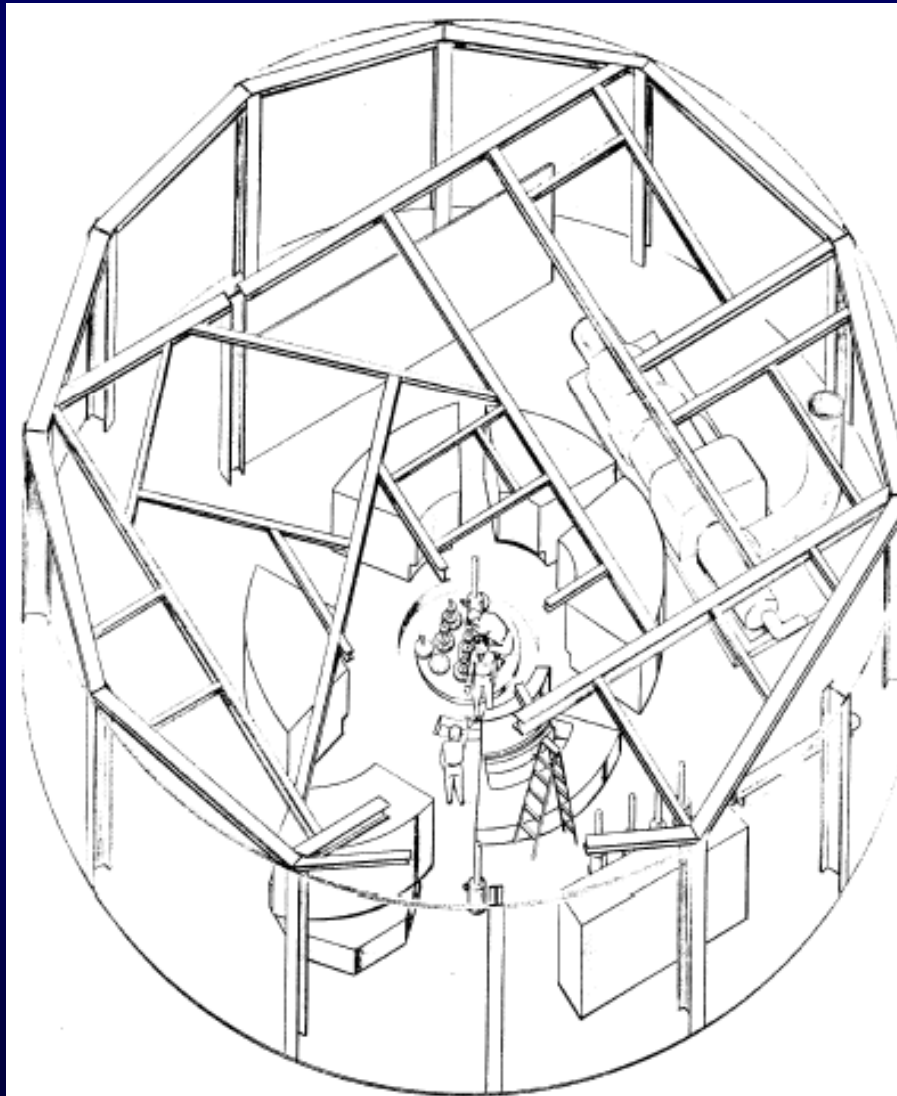
SL-1 Accident

January 3, 1961

- Reactor had been shut down since before Christmas, 1960
- Maintenance was being performed on Control Rod Drives
- Three operators working in the reactor building
- “Something” happened 9:01 p.m.

SL-1 Accident

BEFORE...



SL-1 Accident

**An operator manually
withdrew a control rod**

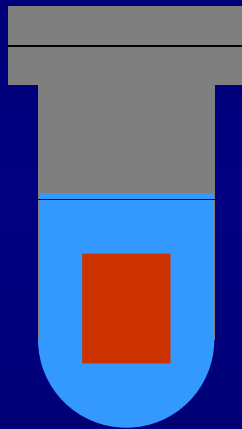
CRDMs had been removed

16" would cause criticality

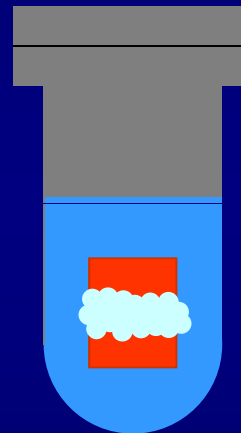
20" to Prompt Crit



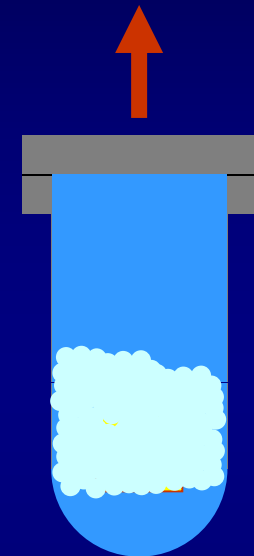
SL-1 Accident



**9:01 - REACTOR
BECOMES
PROMPT
CRITICAL**



**.004 SECONDS
LATER -
POWER PULSES
TO 20,000 Mw_{th},
STEAM VOIDS
BLANKET CORE**



**.034 SEC LATER
STEAM VOID
CAUSES WATER
ABOVE IT TO
“HAMMER”
VESSEL HEAD AT
160FT/SEC.
VESSEL TAKES
FLIGHT
25-Mar-10 - slide 9**

SL-1 Accident

Peak power was 20,000 Mw

- Equivalent to accelerating a 2000 lb car 0-60 in .0005 sec

Total Energy released was 140 Mw - sec

- Equivalent to a 2000 lb car traveling 219 mph
- 10 Pounds of TNT

Some of the fuel reached its vaporization temperature (3740 F)

- 20 % of fuel released

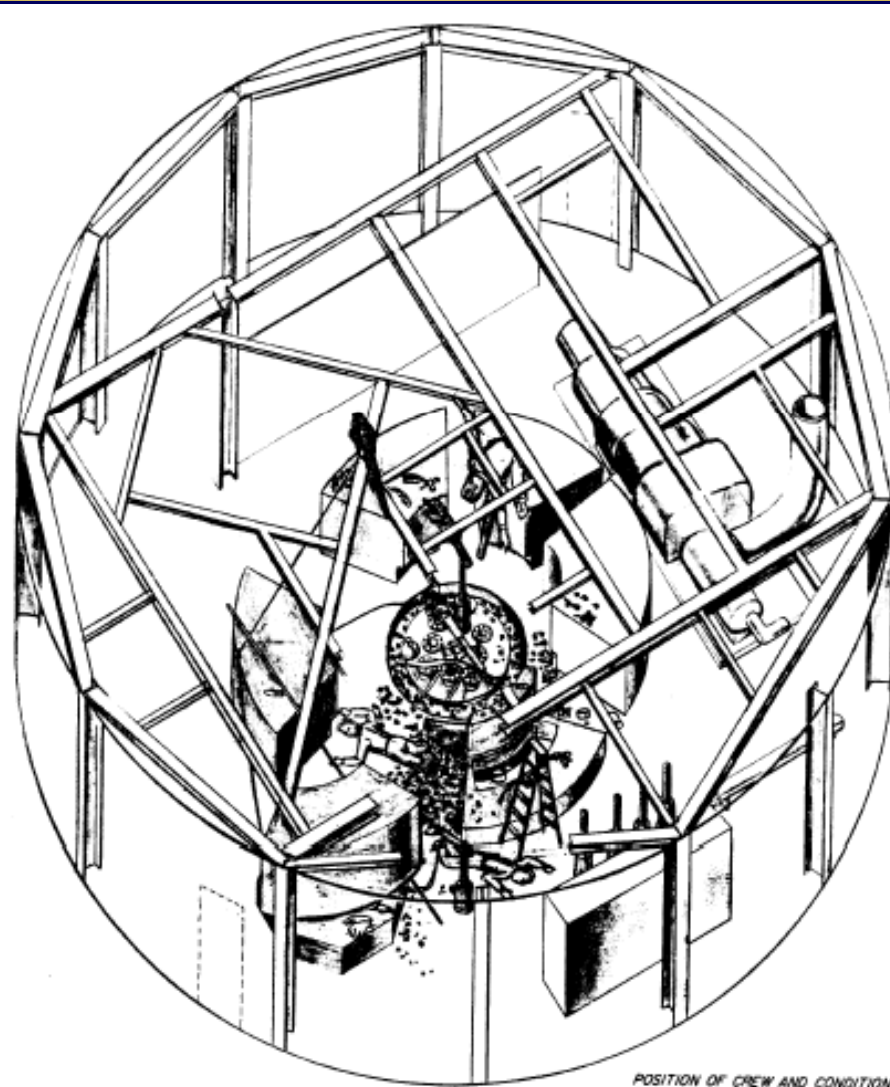
Steam pressure caused vessel to bulge from 14' to 15' in diameter

Explosion killed the 3 operators

- 2 immediately, 1 after being evacuated

SL-1 Accident

After...



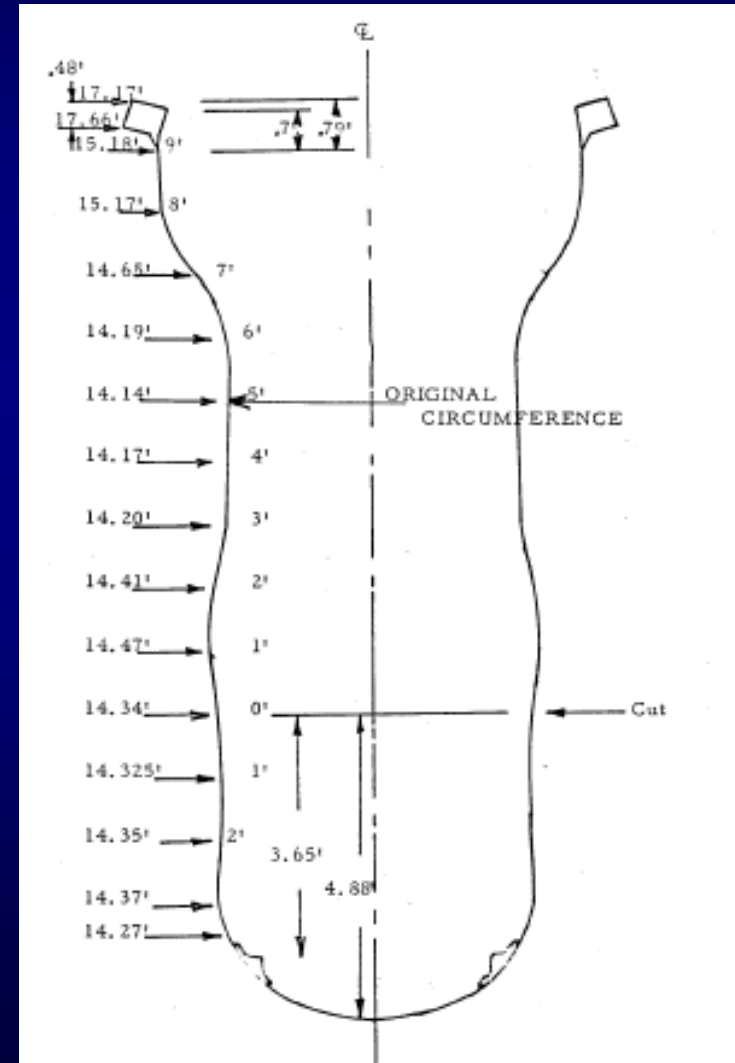
POSITION OF CREW AND CONDITION OF
REACTOR HEAD JUST AFTER INCIDENT
Fig. 56

SL-1 Accident



SL-1 Accident

Effects of Reactor Vessel



SL-1 Accident

Operators killed by force of the explosion, however...

When vessel rose out of shielding, operators exposed to significant radiation (activated operators) and much radioactivity released

- **Evacuee read 100-400 rem/hr**
 - **Attending Nurse received substantial exposure**
- **During the recovery of bodies,**
 - **13 workers received in excess of 3 rem**
 - **3 workers received in excess of 25 rem**
- **Releases from Core**
 - **10 curies became airborne by early morning 1/4**
 - **20 curies by the morning of the 5th**
 - **A total of 50 more curies 1/6 - 30/61**



SL-1 Accident



Killed in the only fatal U.S. nuclear plant accident in 1961 (Idaho), he is buried in a lead-lined casket which was then sealed in concrete and placed in a metal vault.

"Victim of nuclear accident. Body is contaminated with long-life radio-active isotopes. Under no circumstances will the body be moved from this location without prior approval of the Atomic Energy Commission in consultation with this headquarters." - *from the decedent's records,*

Arlington National Cemetery



Radiationworks.com

Browns Ferry Fire



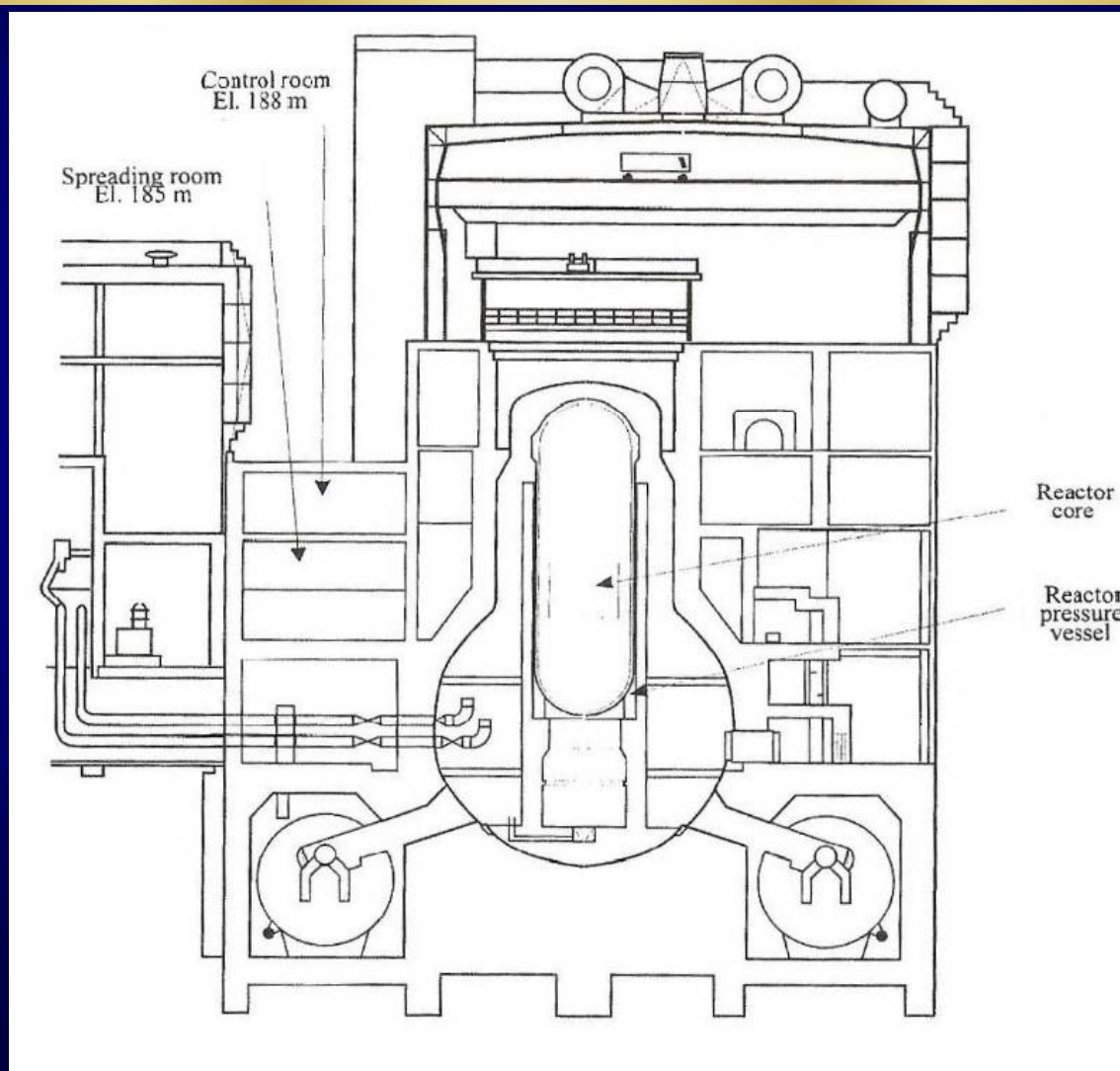
Browns Ferry Fire

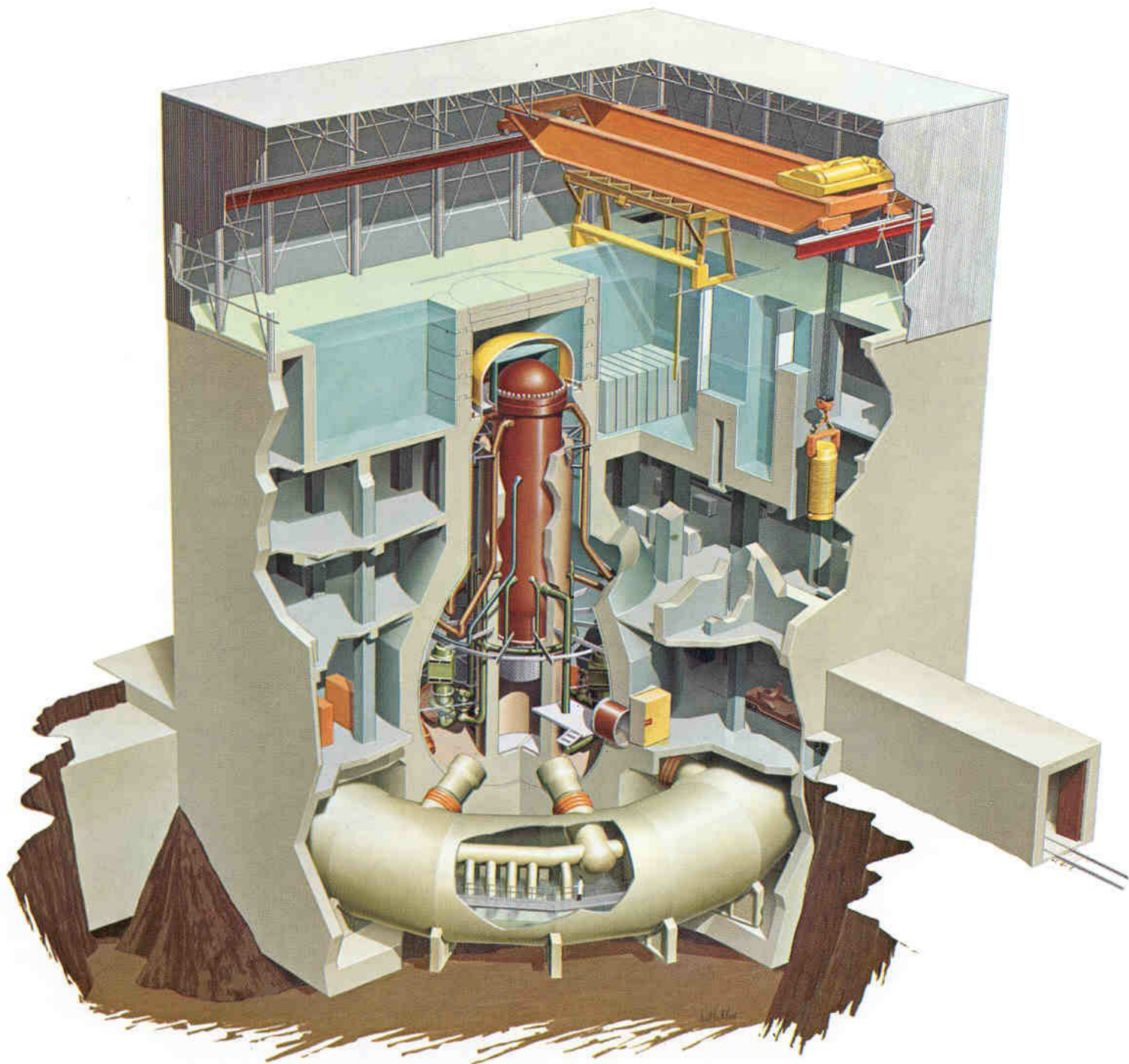
- Browns Ferry had three GE BWR/4 reactors
- Units 1 & 2 were operating at 100% power
- Unit 3 still under construction
- At 12:35 on March 22, 1975, a fire in the Unit 1 cable spread room was reported to the control room

Browns Ferry Fire

- Two workers were installing polyurethane foam insulation in the cable spreading room
- To check for air leaks, the workers were using a candle to see how air flow would affect the flame
- The candle was held too closely, and the foam caught fire at 12:20
- Rapid airflow through the opening caused the flames to spread

Browns Ferry Fire





Browns Ferry Fire



Browns Ferry Fire



Browns Ferry Fire

- Three fire extinguishers were used, but to no avail
- The incorrect fire reporting number was used, which delayed the response
- At 1240, all the ECCS pumps had started

Browns Ferry Fire

- Equipment indications in the control room were sporadic - - lights dimmed, glowed brightly, and showed spurious other equipment starting
- At 1250, the operators decided to shut down the reactor – after power had dropped inexplicably

Browns Ferry Fire

- At 1255, the only flow left into the reactor was the CRDs:
 - Normal feedwater gone
 - Core Spray was gone
 - RCIC was gone
 - Other ECCS systems were gone
 - Most of the Control Room instrumentation was gone

Browns Ferry Fire

- At 1330, the Unit 1 operator saw the core was about to be uncovered
- The operator depressurized the core, and used the Condensate Booster Pumps to add water
- At 1300, Unit 2 power began decreasing, and the reactor was scrammed
- At 1320, Unit 2 ECCS were lost
- Finally, at 1415, Unit 2 was depressurized and control was gained over the unit

Browns Ferry Fire

- Other issues:
 - A significant portion of the control room indicators were gone
 - An EDG failed at 1443
 - At 1400 the onsite telephone system failed
 - Torus level and temperature indications were gone

Browns Ferry Fire

- Fire fighting issues:
 - The Cardox system for that area had been disabled
 - Once finally activated, it drove smoke and fumes into the Control Room
 - The Cable Spread Room visibility was inches
 - Fire fighting equipment and SCBAs were broken or nonexistent

Browns Ferry Fire

- Although the professional fire fighting team from Athens arrived at 1300, the onsite crews battled the blaze for another six hours
- The Athens Chief recommended using water, but that was denied because of electrical hazards
- When water was finally used, the fire was out in 20 minutes

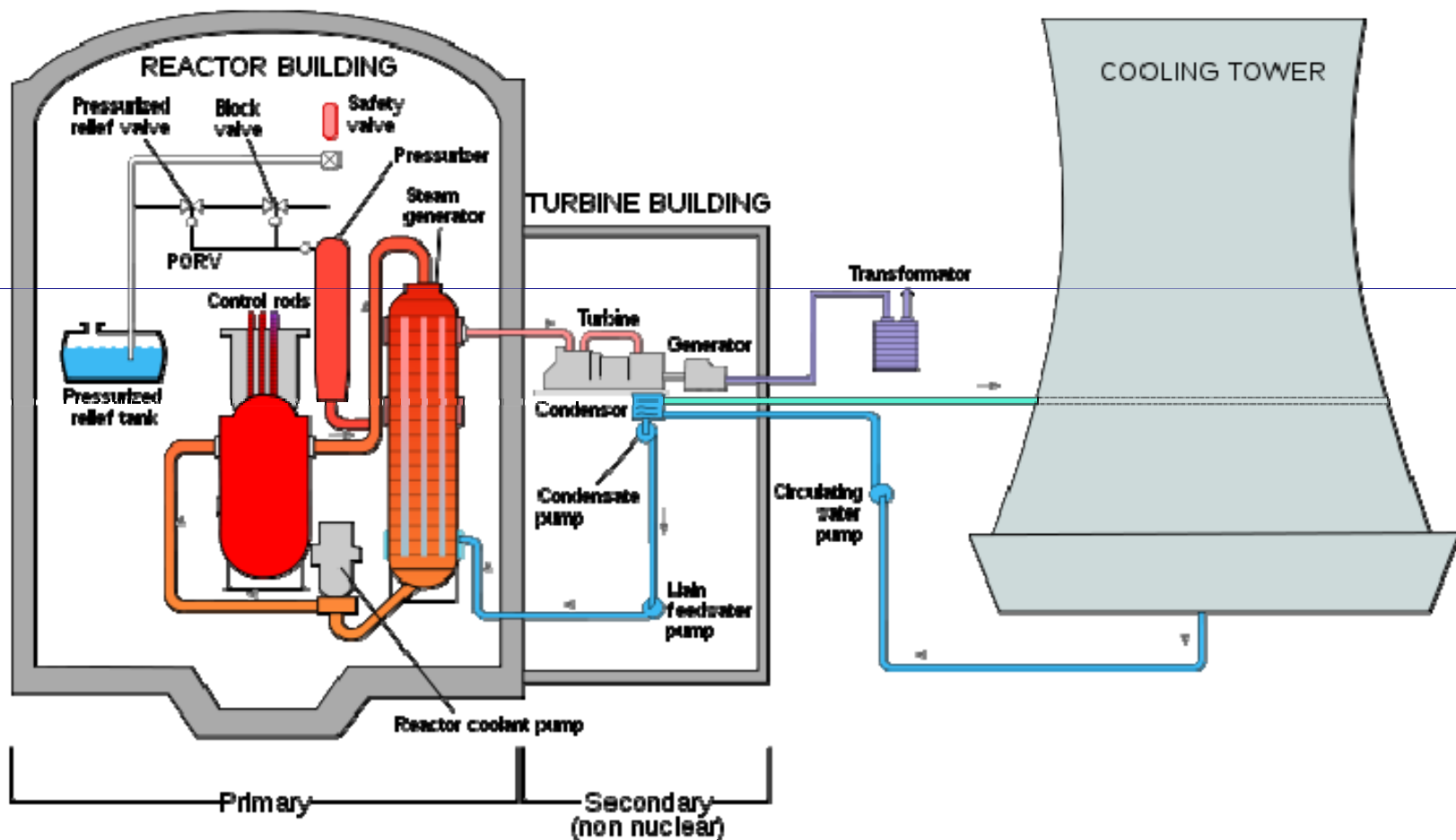
Three Mile Island - 2

March 28, 1979

Unit 2 experiences a loss of feedwater event



Three Mile Island - 2



Three Mile Island - 2

Sequence of Events

0 sec

The main feedwater pumps shut down automatically, due to a slight malfunction.

1 sec

Alarms sound within the control room.

2 sec

Because heat is no longer being transferred to the secondary loop, water pressure and water temperature in the primary loop rise. This is normal and no cause for concern.

3 sec

The PORV (pressure relief valve) opens automatically, releasing steam into a holding tank.

Three Mile Island - 2

4 sec

Auxiliary feedwater pumps automatically turn on: However, these pumps are isolated from the system by valves. Operators assume that the pumps are doing what they're supposed to do.

9 sec

The control rods, made of boron and silver, drop into the core, shutting down the chain reaction. Heat is still generated, though. In this state, the core produces enough energy to light 18,000 homes. The PORV light goes out, indicating that the valve is now closed. The valve is actually still open. Steam and water continues to be released through the PORV, creating a LOCA (loss of coolant accident).

Three Mile Island - 2

2 min

The EIW (emergency injection water) is activated, and water flows into the primary loop. This is a safety device, designed to keep the water at a safe level in the event of a LOCA.

4.5 min

Operators observe that the water level in the pressurizer is rising and that the pressure is decreasing. They turn off the EIW. The water level still appears to be rising. Reactor coolant inventory is actually dropping. The water, along with the steam, is now being released through the PORV.

8 min

An operator notices that the valves for the auxiliary feedwater pumps in the secondary loop are closed. He opens the valves. The steam generators are now being fed.

Three Mile Island - 2

15 min

By this time approximately 3,000 gallons have escaped from the primary loop.

45 min

Reactor coolant inventory continues to drop. Pressurizer level continues to increase.

1 hr 20 min

The reactor coolant pumps begin to shake violently. This is caused by the steam passing through the pumps. Two of the four pumps are turned off.

1 hr 40 min

The other two reactor coolant pumps are turned off.

Three Mile Island - 2

2 hr 15 min

Water no longer covers the top of the core. The control rods react to the superheated steam environment and begin to release hydrogen and radioactive gases. These are also released through the PORV.

2 hr 20 min

An operator from the next shift comes on duty and notices that the PORV discharge temperature is abnormally high. He stops the leak by shutting the PORV's block valve. More than a quarter of a million gallons of radioactive cooling water has been discharged since the PORV first opened.

Operators still don't realize that the water level in the primary loop is low. The water within the loop continues to boil away, which causes more damage to the core, more heat, and more radioactivity. 2 hr 30 min The operators receive the first indication that radiation levels are going up.

Three Mile Island - 2

2 hr 45 min

Radiation alarms sound. A site emergency is declared. Half of the core is now uncovered, and the radioactivity of the water in the primary loop is 350 times its normal level.

3 hr

Even higher radiation levels prompt the declaration of a general emergency. High temperatures in the core lead some to believe that the core is uncovered; others do not trust the temperature readings.

7 hr 30 min

Even after operators pump water into the primary loop, pressure is still high. The 'PORV' backup valve is opened to lower the pressure.

Three Mile Island - 2

9 hr

Hydrogen explodes within the containment structure, causing a pressure spike on the control room gauges and an audible thud. The spikes are believed to be caused by an electrical malfunction; the thud is thought, at least by some, to be just a ventilator damper.

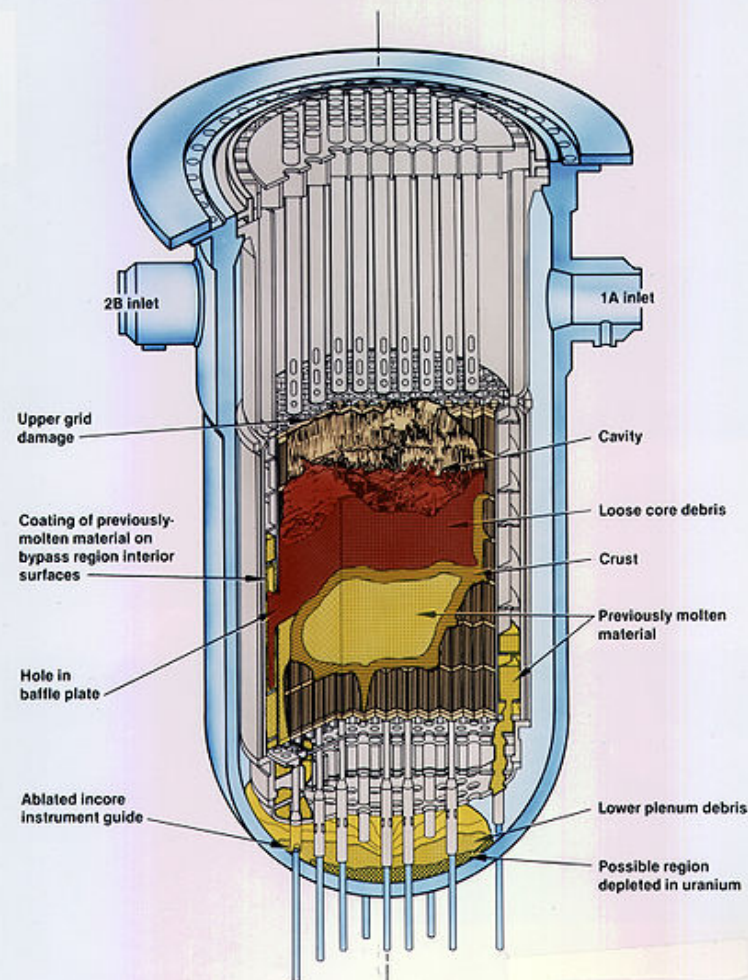
15 hr 50 min

The primary loop's pumps are turned on, which circulate water around the core. The core's temperature is finally under control, although half of it is melted and part of it has disintegrated. Also, there's still hydrogen in the primary loop.

Three Mile Island - 2

The end result:

TMI-2 Core End-State Configuration



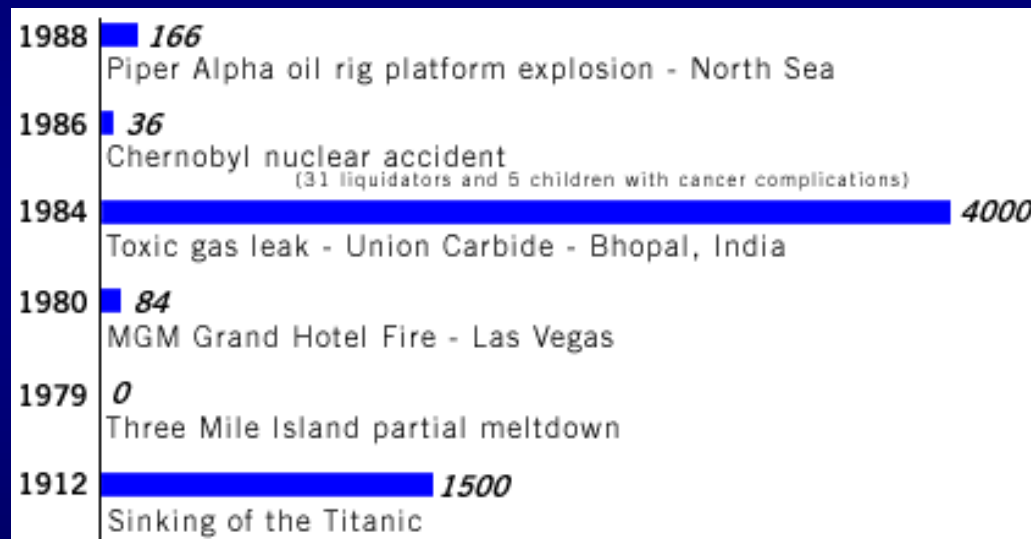
Three Mile Island - 2

The aftermath:



Three Mile Island - 2

But in perspective:

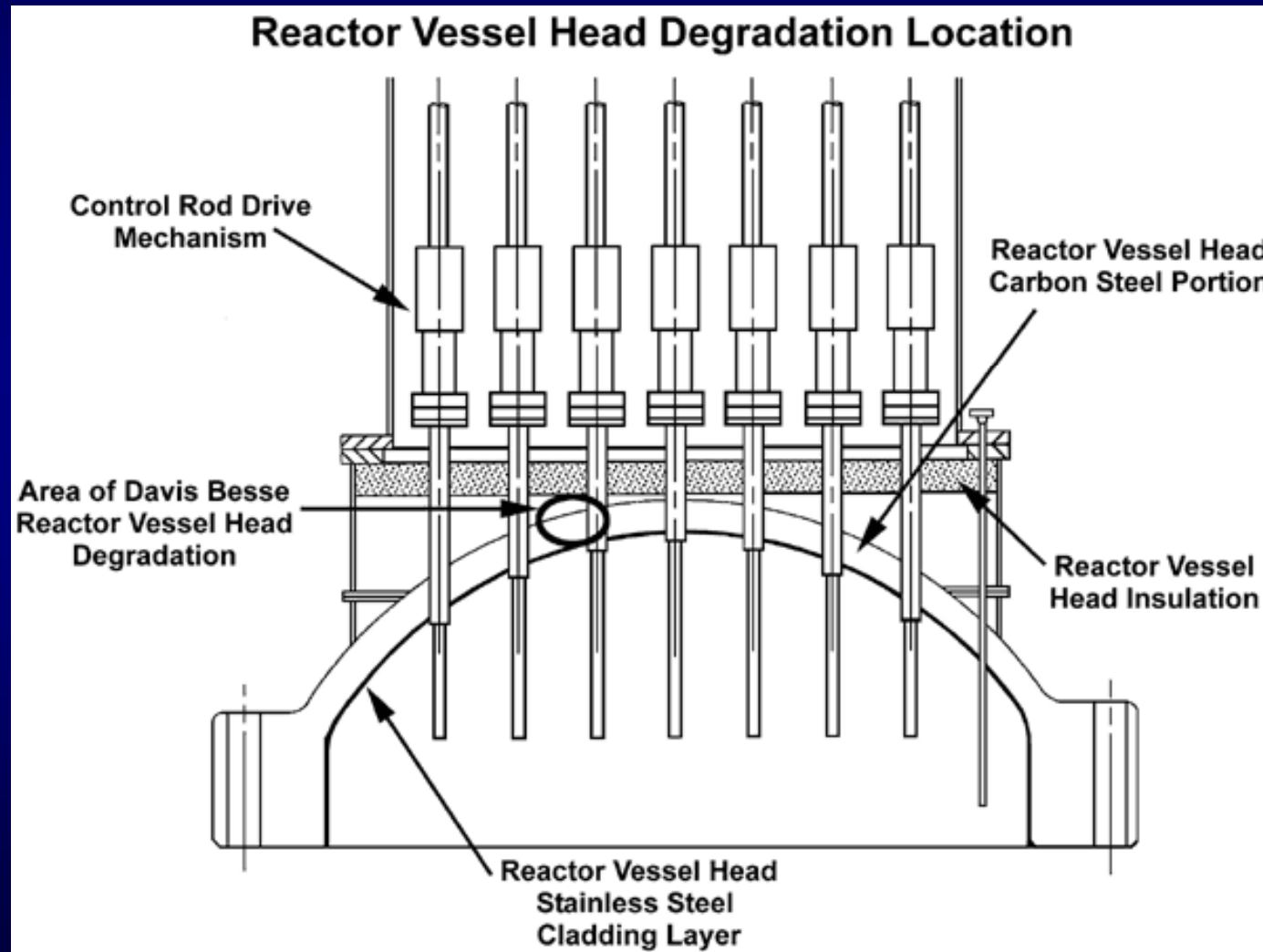


Fatality Comparison Statistics

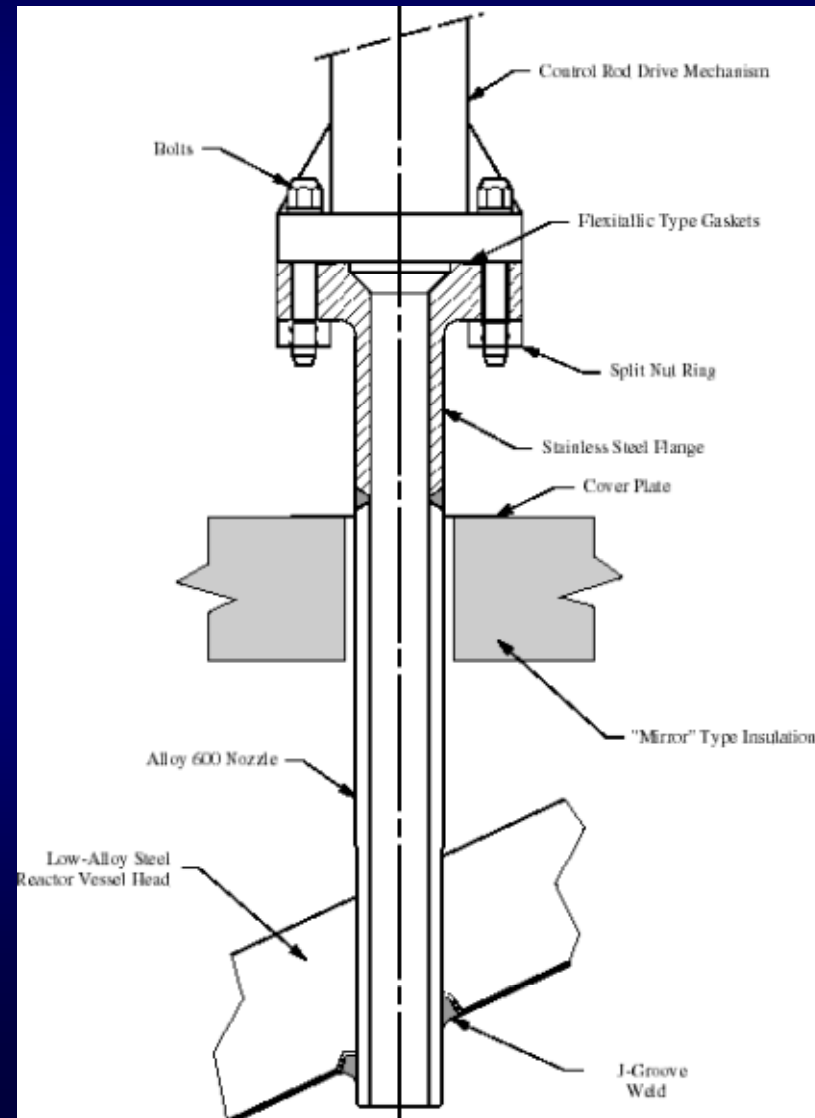
US Coal Mining 1931-1995 33,134
 Oil / Gas Industry 1992-1995 719
 Chemical Manufacturing 1992-1995 201
 US Automobile 1899-1995 2,903,036
 Smoking per year 419,000
 US Civil Aviation 1938-present +54,000
 US NRC Nuclear Power Historical 0

- The China Syndrome had been released 12 days earlier
- This unit was only operated for 4 days before the accident

Davis-Besse Head Event

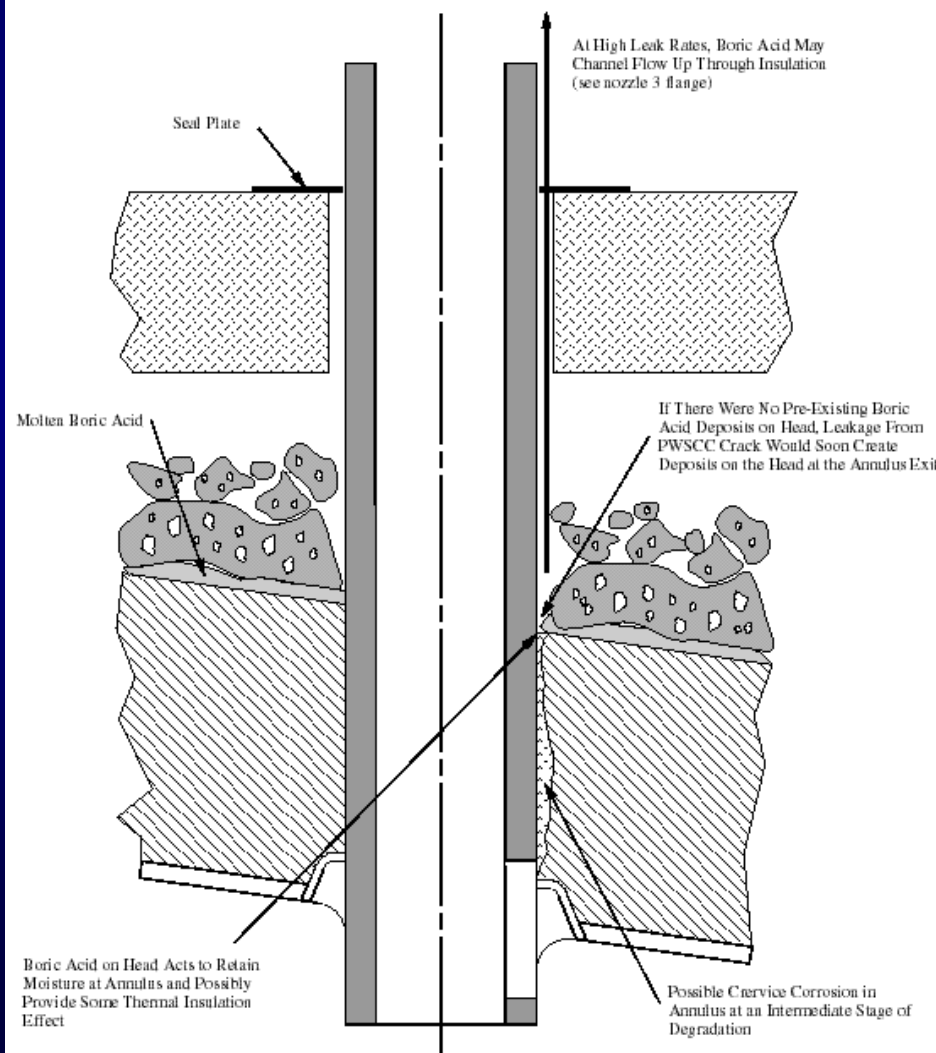


Davis-Besse Head Event

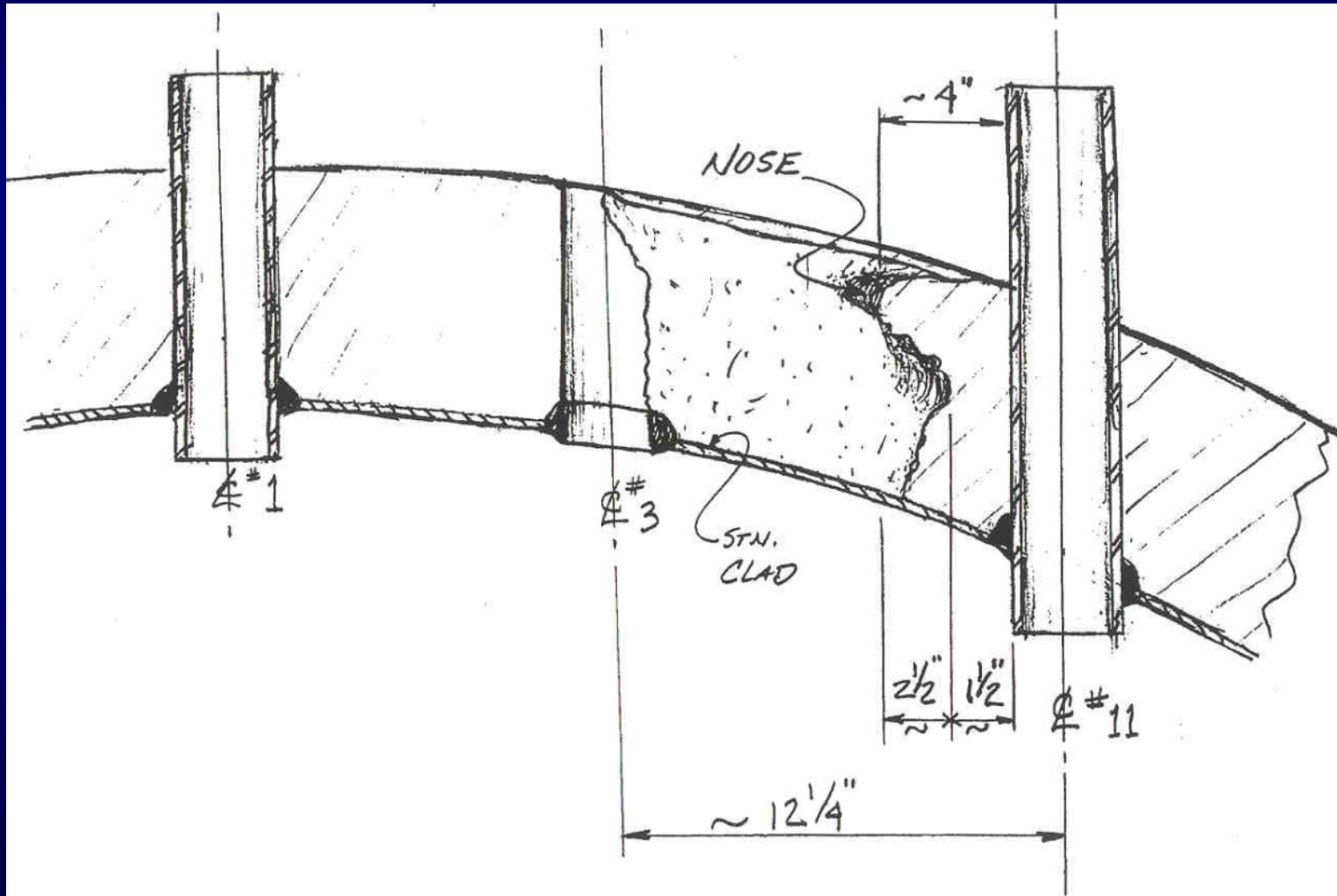


Davis-Besse Head Event

Source: EPR/DEI



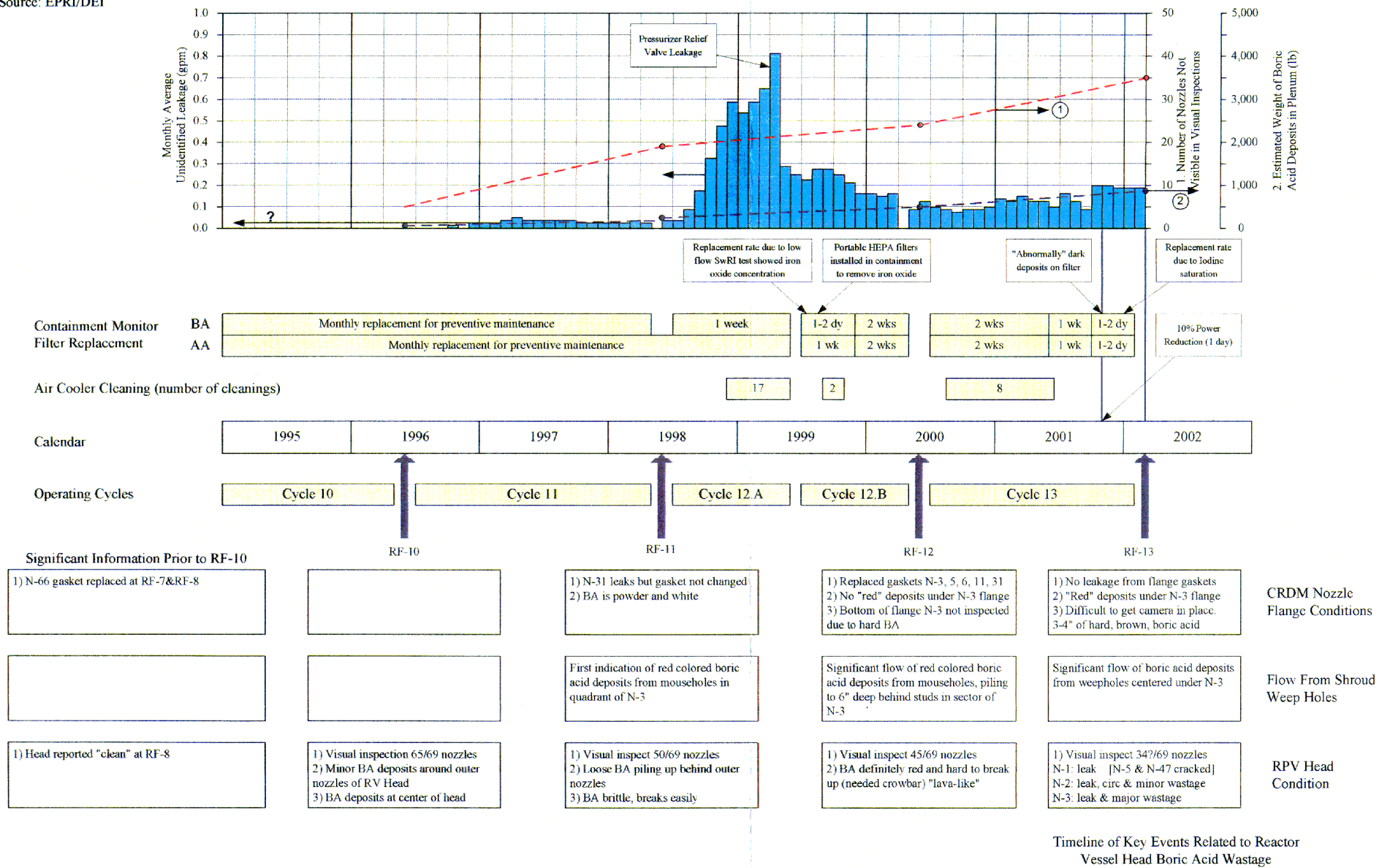
Davis-Besse Head Event



Davis-Besse Head Event



Source: EPRI/DEI



Davis-Besse Head Event

- End Result:
 - 2 Convictions in Federal Court
 - \$5.45M in NRC Fines
 - \$23.7M in DOJ fines
 - \$4.3M in other fines
 - Over \$700M in outage costs

Questions?