Browns Ferry Fire

DRP Heritage Discussion

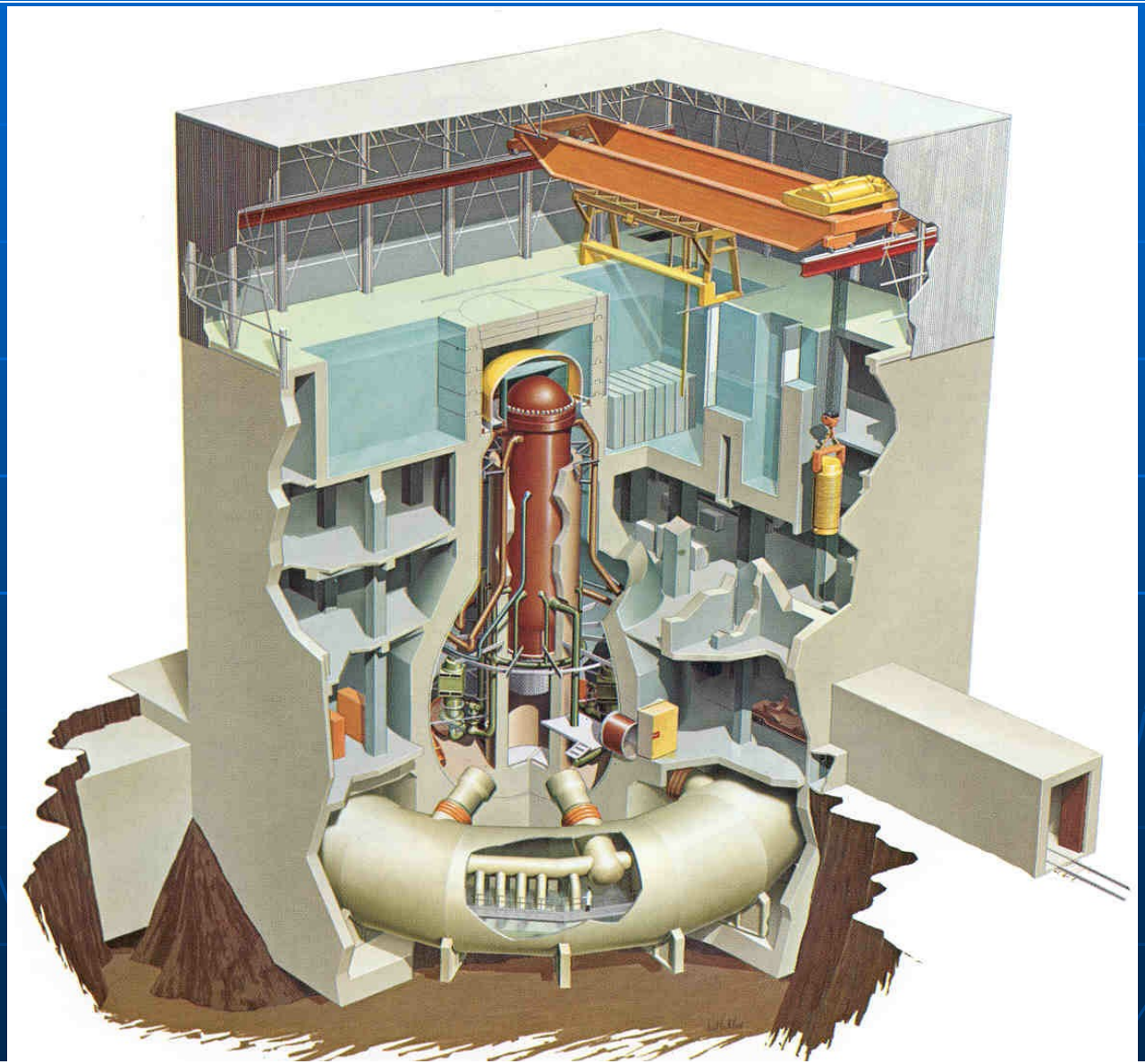
March 22, 1975

Presented by RPB6

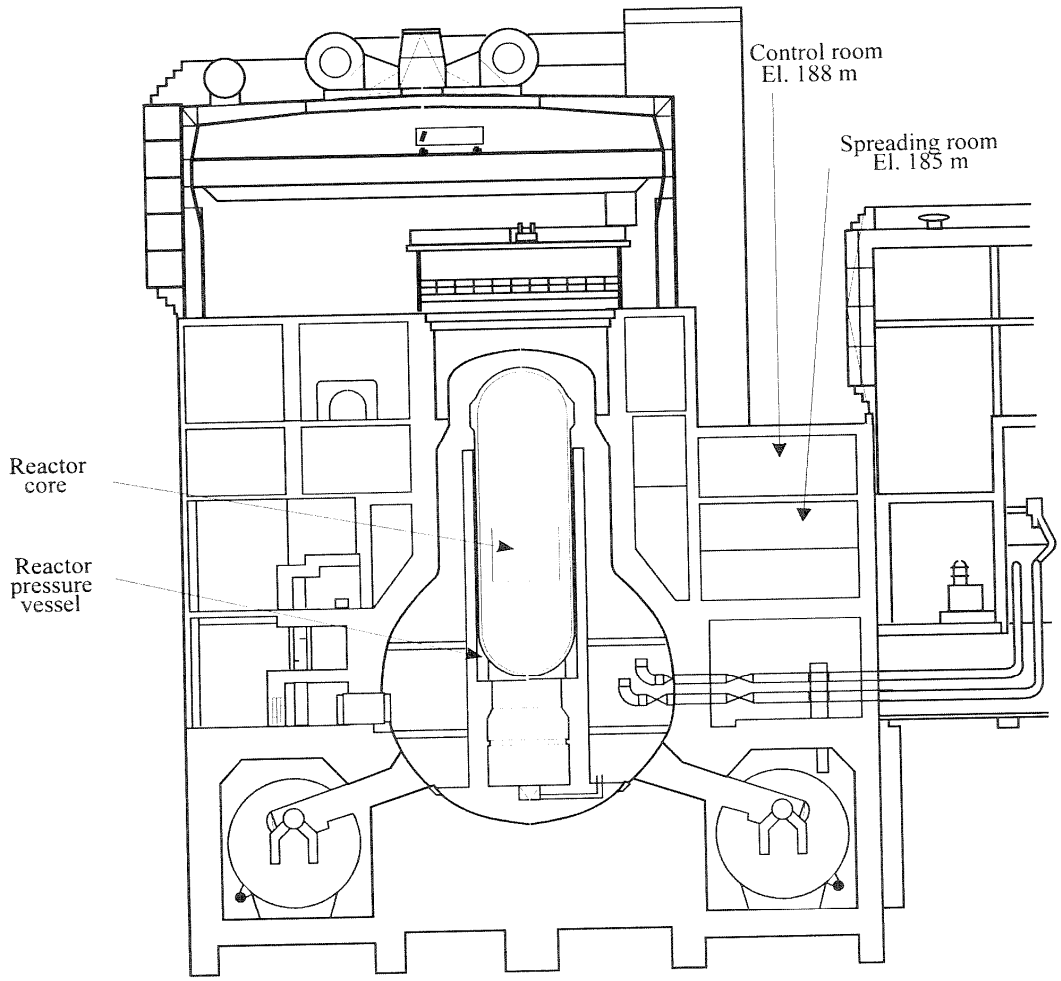
Agenda

- Introduction to Browns Ferry design and layout
- Plant conditions
- Sequence of events
- Lessons learned
- PRA insights

Browns Ferry Design and Layout



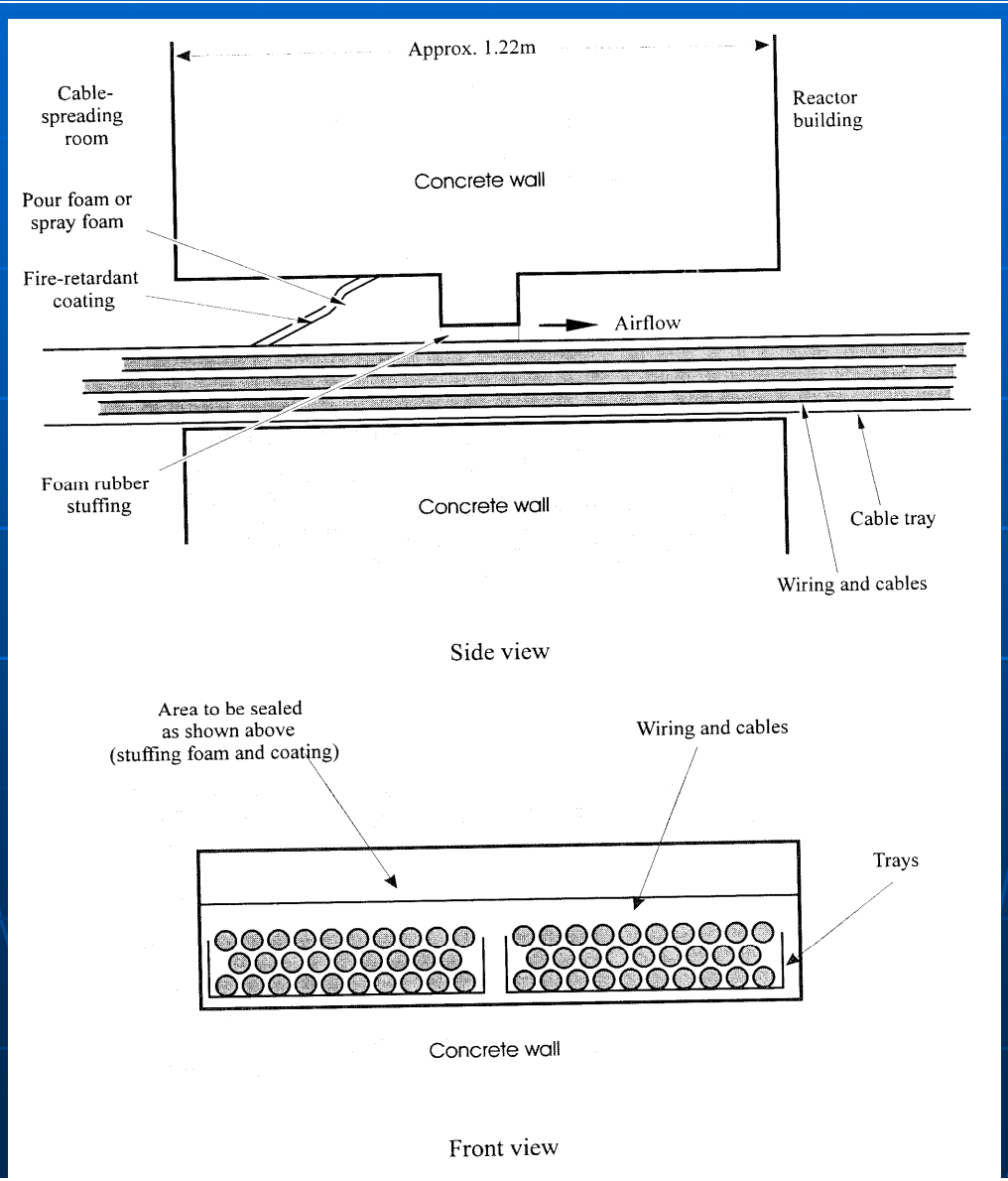
Browns Ferry Design and Layout



BWR/4 Design

- The reactor building is maintained at a negative pressure with respect to the exterior of the walls in order to ensure any airflow is always into the reactor building.
- The cable tray penetrations through the wall of the reactor building are sealed to minimize air leakage.
- The penetrations are filled with a polyurethane foam to form the seal, then a flame-proofing compound is applied over the foam and over the cables on both sides of the penetration to form a fire barrier.

Cable Tray Penetration



Cable Tray Penetration

Plant Conditions

- BFN 1 and 2 were operating at 100% power
- BFN 3 was under construction

Condition

- Leakage tests had been performed on the reactor building that indicated that air in-leakage should be reduced.
- At about 12:15 p.m., an engineering aide observed a hole about 2 to 4 inches wide in a cable-tray penetration through the wall.

Action

- The aide passed a lit candle by the hole and the flame blew horizontally into the hole, indicating a significant leakage path into the reactor building.
- The aide tried to stuff two pieces of sheet polyurethane foam into the hole (this type was far more flammable than the original design).
- He then re-lit the candle and rechecked the penetration.

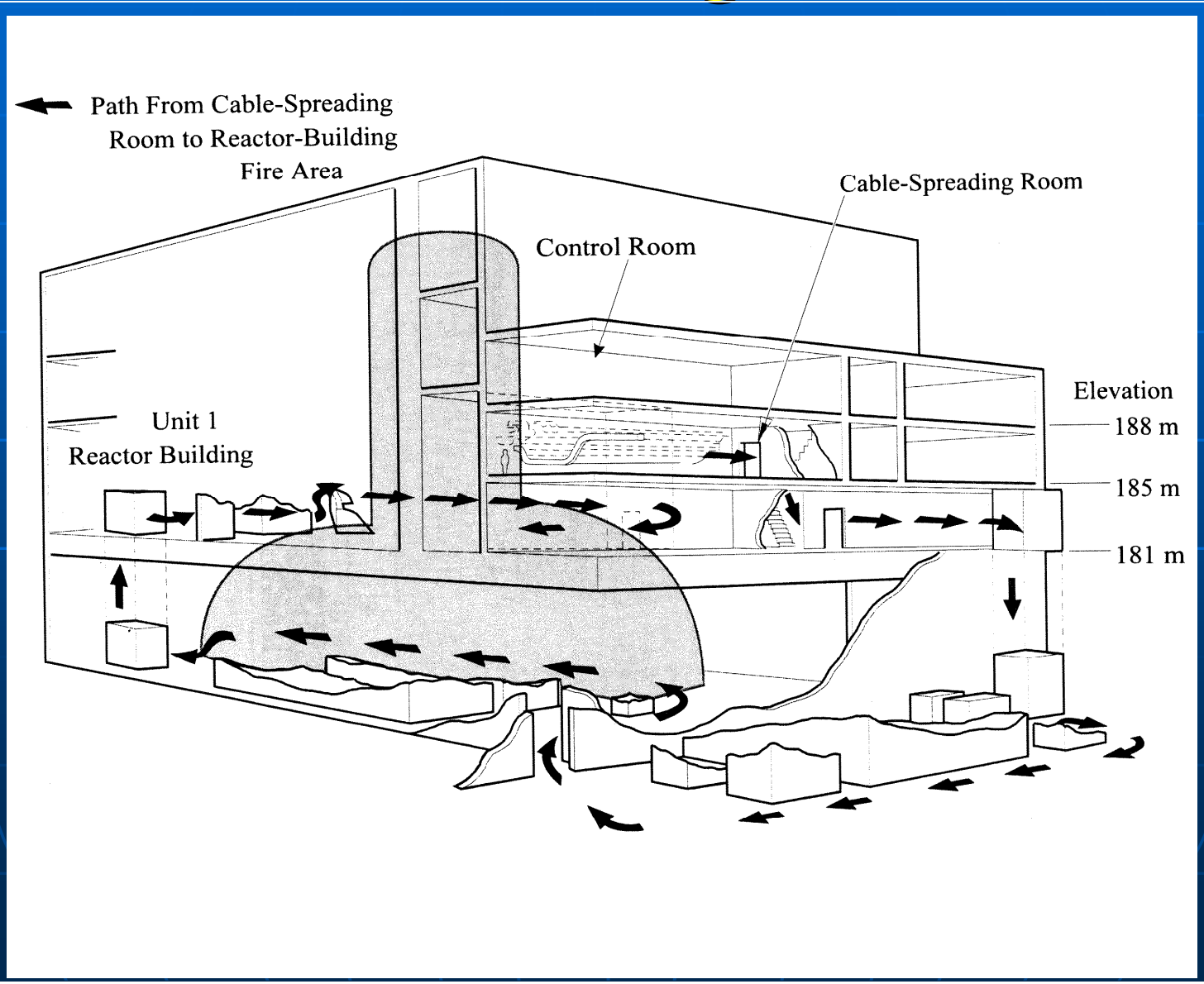
Result

- The flame was again pulled horizontally and apparently ignited the foam at this time ~1220.
- Attempts by the aide to extinguish the fire were unsuccessful … beat with flashlight, use of CO_2 and two dry-chemical fire extinguishers.
- Now there were two fires to contend with – one in the cable spreading room and one in the reactor building.

Timeline

- 1235: A fire was reported in the unit 1 reactor building. Plant personnel were informed of fire location. The fire brigade began fire fighting activities.
- 1240: Some ECCS annunciators alarmed and all diesel generators started despite normal vessel water level, steam pressure, and drywell pressure.
- 1242: The RHR System aligned itself in LPCI mode with all four pumps running. All four Core Spray System pumps aligned and started. The unit operator manually secured all eight pumps but couldn’t reset annunciators.

Path from Cable Spreading Room to Reactor Building Fire Area



Path from Cable Spreading Room to Reactor Building Fire Area

Timeline

- 1244: The RHR and CS pumps restarted for no apparent reason. The unit operator was unable to stop the pumps from the control panels.
- 1248: The unit operator was able to stop RHR and CS pumps from the control panels. Both recirculation pumps ran back for no apparent reason causing unit power to go from 1100 MWe to 700 MWe. Electrical boards started losing power. Half of RPS was lost. Remote manual control of seven SRVs was lost. Numerous annunciators alarmed on several control panels.
- 1251: The unit operator started lowering recirculation pump speed. Both recirculation pumps tripped for no apparent reason at >20% loading. The unit operator manually scrammed the reactor.

Timeline

- 1253: The unit operator confirmed that all rods were fully inserted. The unit operator tripped all but one RFP, secured extra condensate and condensate booster pumps, and manually started RCIC as a backup.
- 1254: The assistant shift engineer (ASE) tripped the turbine, opened the generator field breaker, and opened the motor operated disconnects. HPCI initiated automatically although the MSIV's did not close. Vessel water level increased to the normal range. Operators secured both HPCI and RCIC.
- 1255: 120VAC unit preferred power was lost. Among other things, control rod position indication and all neutron monitoring indication was lost.

Timeline

- 1256: Numerous electrical boards were lost:
  - 250 VDC Reactor MOV Board 1A
  - 250 VDC Reactor MOV Board lB
  - 480 VAC Reactor MOV Board 1A (CS, RHR, HPCI, RHRSW valves, RPS A)
  - 480VAC Reactor MOV Board lB (CS, RHR, RHRSW, RCIC, EECW valves, RPS B)
  - 480 VAC Reactor MOV Board 1C (EECW, RHR valves)
  - 480 VAC Shutdown Board 1A
  - 480 VAC Shutdown Board lB
- At this point the MSIVs closed placing the unit in isolation from the main condenser and securing steam to the RFP turbine. Also all ECCS was lost with the exception of four SRV's which could be operated from panel 9-3.

Timeline

- 1258: Reactor pressure rapidly increased; SRVs began opening and closing to maintain pressure between 1080 and 1100 psig. An unsuccessful attempt was made to open MSIV's from the backup control center. The unit operator manually opened SRVs for which he had control and reclosed them after pressure had decreased to *<850* psig. Pressure began increasing immediately.
- 1259: Reactor water level was decreasing due to almost constant SRV's blowdown to the torus.
- HPCI and RCIC were both inoperable due to the previous loss of valve controls. Torus cooling became vital due to heat added as a result of SRVs blowdown; but the RHR system was not available as a result of electrical board losses.

Timeline

- 1300: 4kV shutdown bus 2 lost power. This caused shutdown boards C and D to transfer to D/G's C and D.
- 1320: 4kV shutdown bus 1 lost power. This caused shutdown boards A and B to transfer to D/Gs A and B.
- 1321: The process computer was lost.
- 1330: The decision was made to depressurize the reactor by SRV blowdown. The unit operator manually opened four SRVs. Reactor pressure and water level began decreasing. At this time a condensate booster pump was running and the RFP bypass valve was open.
- Athens Fire Dept. first arrived at BF and soon after recommended the use of water to fight the fire; however, this action was declined due to OPS management fear of short circuit faults.
- 1334: 4kV shutdown bus 2 was energized from unit 2.

Timeline

- 1345: Unit preferred power was restored from Unit 2. Reactor pressure had decreased to 350 psig allowing the condensate booster pump to start injecting. Reactor water level had dropped from a normal 201 inches above the top of the active fuel to 43 inches above the top of the active fuel. Reactor water level began to increase.
- 1355: Reactor water level was approaching normal but the operator lost the ability to control the RFP bypass valve.
- 1357: An operator was able to manually close the RFP bypass valve.
- 1400: The unit operator was maintaining reactor pressure at <200 psig using SRVs and vessel level about normal using the CRD hydraulic pump and a condensate booster pump. 480VAC shutdown boards A and B were restored.

Timeline

- 1500: Attempts were made to align one RHR system for torus cooling and the other for shutdown cooling.
- 1600: RHR System I was aligned for torus cooling; but the decision was made not to start the RHR pumps in this condition since it was not established that the system was charged with water.
- 1630: 480 VAC reactor MOV board 1A was re-energized. This allowed placing the main turbine on the turning gear, restoring power to ECCS valves fed from that board, and energizing RPS A which restored half of the process monitoring.
- 1800: Use of water to combat the fire was again recommended by the Athens Fire Chief, but not used. SRVs previously operable from the CR became inoperable due to loss of instrument and control power to a solenoid in the air supply to a diaphragm valve in the air header to the primary containment. The drywell air compressor was started but its isolated discharge prevented air flow to the primary containment.

Timeline

- 1900: Based on the reactors now being in a more stable condition, OPS Management agreed to the use of water to fight the fire. Power was restored to the main steam line drain valves.
- 1945: The fire was reported out.
- 2008: High torus level was reached due to SRV blowdown. The assistant unit operator aligned and started the RHR drain pump to the main condenser hotwell.
- 2040: Drywell venting via SBGTS was started with 2.5 psig drywell pressure.
- 2150: A control air supply to primary containment equipment was established making four SRVs operable from the control room. The operator began lowering reactor pressure again starting from 580 psig.

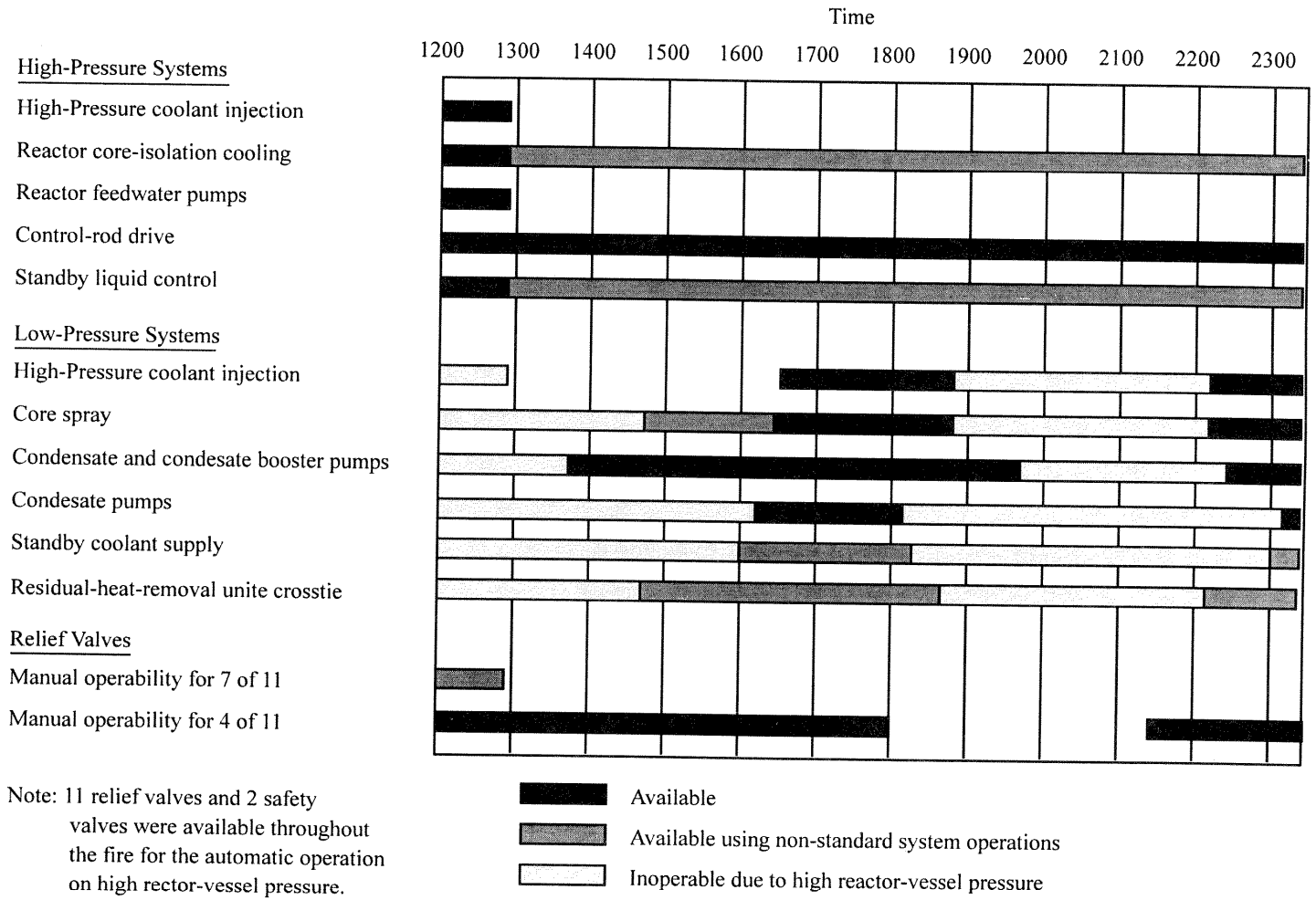
Timeline

- 2200: Reactor pressure was 340 psig and decreasing slowly.
- 2250: Secondary containment was established. Reactor pressure was 200 psig with vessel water level being controlled at 36” by a condensate booster pump.
- 0000: The need existed to flush RHR System II prior to placing it in shutdown cooling. A temporary flushing procedure had to be developed since the existing procedure couldn’t be used.
- 0100: Two source range monitors were placed in temporary service on the reactor side of the fire. This established the capability to monitor the core with 10 cps indicated on each SRM.
- 0130: Torus cooling was initiated using RHR System I.

Timeline

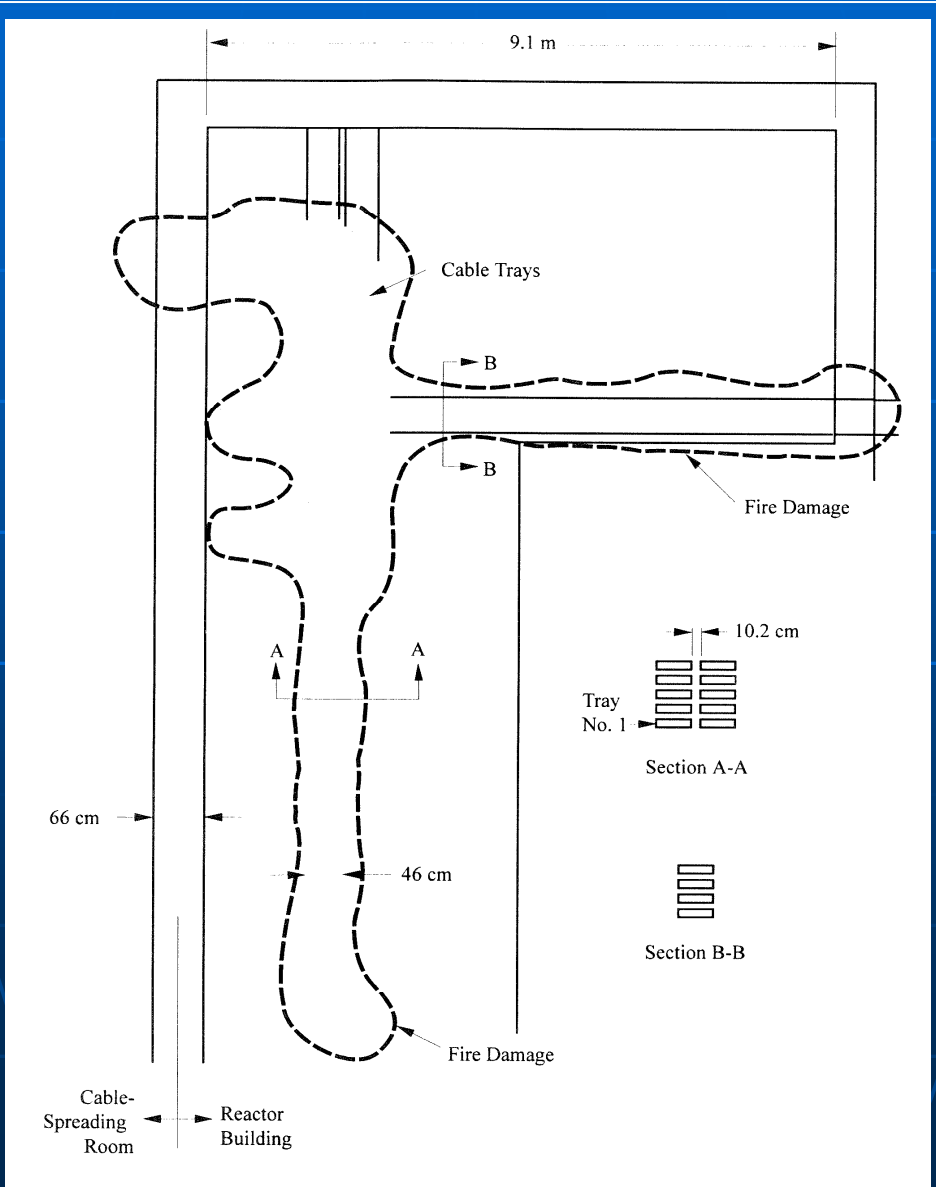
- 0245: Restoration of equipment had progressed to the point that core spray pumps A and C were operable from the control room.
- 0410: Shutdown cooling was established using RHR System II.
- 0930: The unit reached the cold, shutdown condition. Drywell temperature was 120 F. Torus temperature was 130 F and level +4”.

Equipment Availability During the Fire

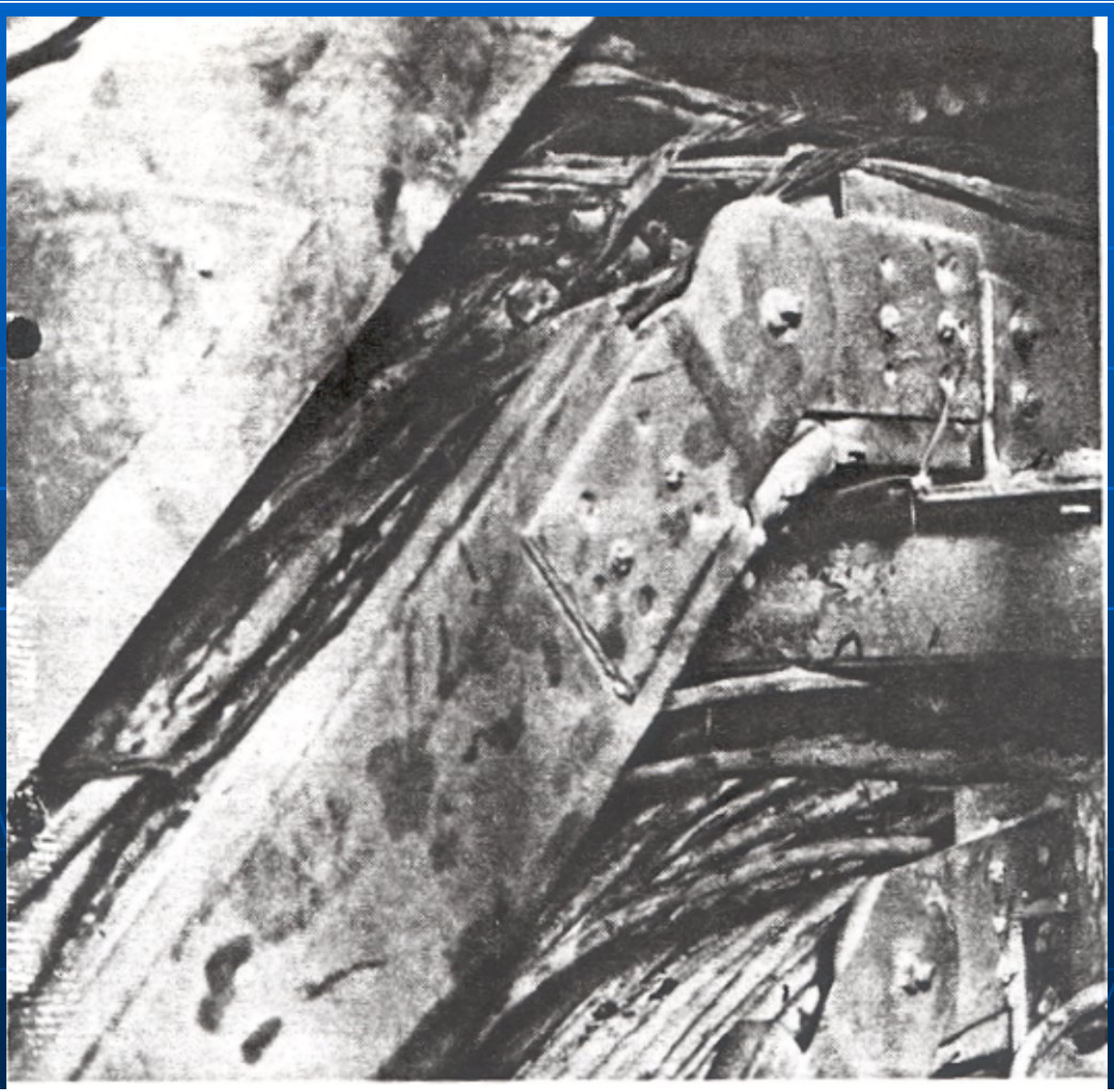


Note: 11 relief valves and 2 safety valves were available throughout the fire for the automatic operation on high rector-vessel pressure.

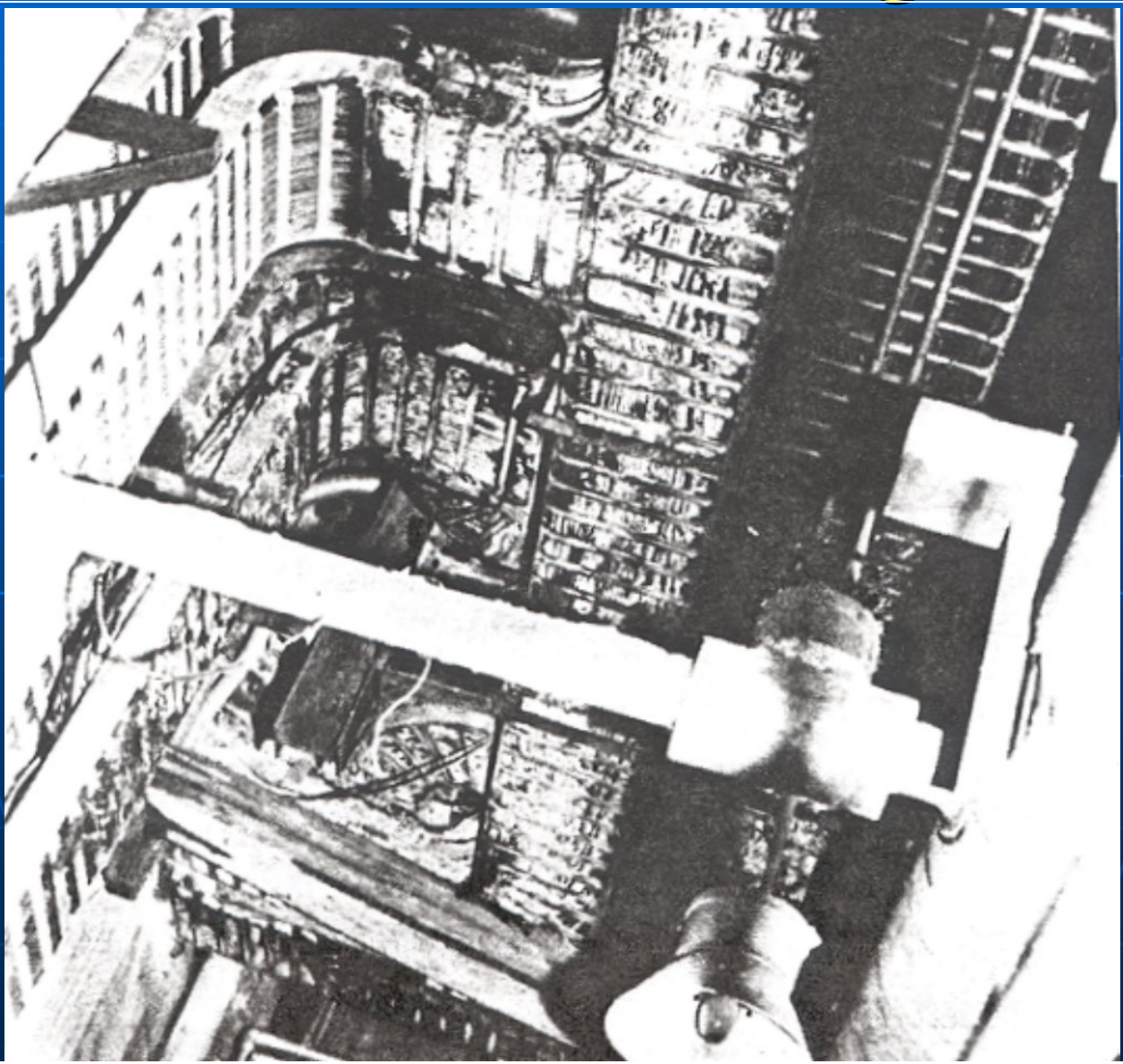
Fire Damage Area



Damage in Cable Spreading Room



Damage to Overhead Cables in the Reactor Building



Effect of Fire on Unit 2

- Much less pronounced impact
- Several minutes following Unit 1 first impacts, Unit 2 experienced decreasing power, alarms, and loss of some indicating lights. U2 shutdown at 1:00 p.m.
- 3 minutes later, MSIVs closed automatically and HP cooling initiated
- Following depressurization, LP pumps utilized for core cooling

Lessons Learned

- Improve method for air leakage test
- Provide better fire protection systems, equipment, and establish equipment storage areas
- Establish fire protection procedures
- Establish fire watch procedures
- Establish better Q/A and documentation of cable arrangement
- Provide better power supply separation
- Establish procedures to delineate the person in charge of control room and fire fighting
- Establish better regulations concerning fire protection and prevention (the birth of Appendix R)
- Standardize fire protection equipment

PRA Insights

- Really, Really, Really close!
- Approaching a 2.00E-1 event.
- SRA perspective may be a little more accurate.

ASP Summary

- Fire initiated/Reactor Scram
- Electric boards supplying power to systems used to cool core lost
- MSIVs auto closed resulting in loss of condenser to remove heat and loss of FW pump turbine (eliminated HP coolant injection
- Operable pressure relief valves manually opened, depressurized reactor to the point where cond. Booster pumps could be used
- Relief valves later failed. Only CR drive pumps left operable (limited capacity)
- Relief valves restored, Cond Booster supplied cooling restored. Normal shutdown cooling later established.