NUCL 402 Engineering of Nuclear Power Systems

Lecture 36: Three Mile island Accident

S. T. Revankar
School of Nuclear Engineering
Purdue University

Date Occurred: March 28, 1979

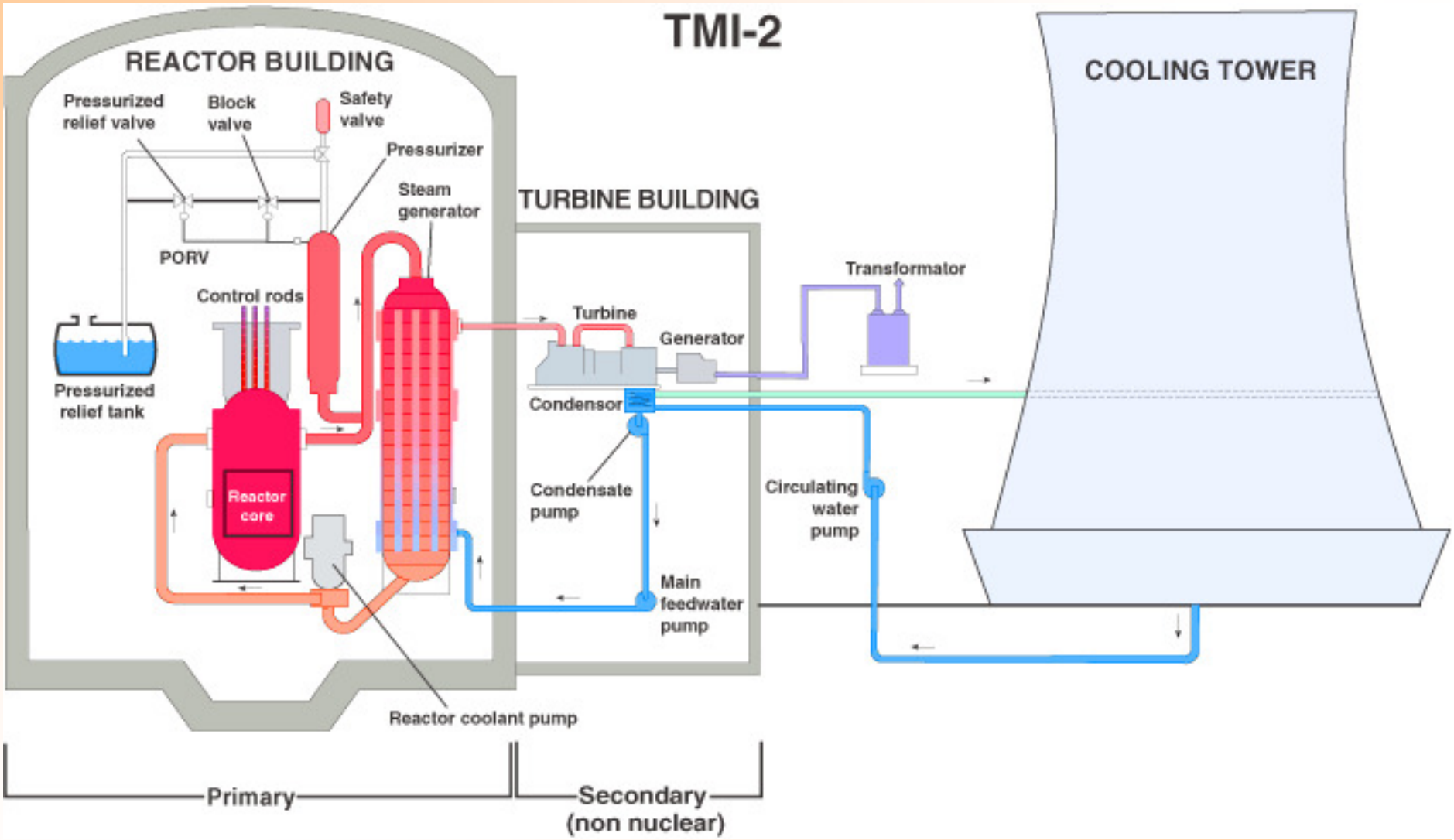
- TM1 in Susquehann River is about 10 miles South East of Harrisburg, PA. It is a PWR 900 MWe B& W Design
- Unit-2 Started on December 1978, (Unit 1 since 1974)

Features

2-Coolant Loops – "Once Through Steam Generator"
37,000 Fuel Steam Generator
Operating Pressure – 15.2 MPa
Pressurize - Power Operated Relief Valve (PORV)
Quench Tank – Rupture Disc (28 M^3)

ECCS – HPIS (11.4 MPa) Borated
CFS (4.1 MPa) Borated
LPIS (2.8 MPa) Borated
Containment Water Spray (+Diluted Sodium Hydroxide)

Auxiliary Feed To Secondary – 3 Separate Pumps, 2 – Electrically Driven, 1 – Steam Turbine



S. T. Revankar-36-3

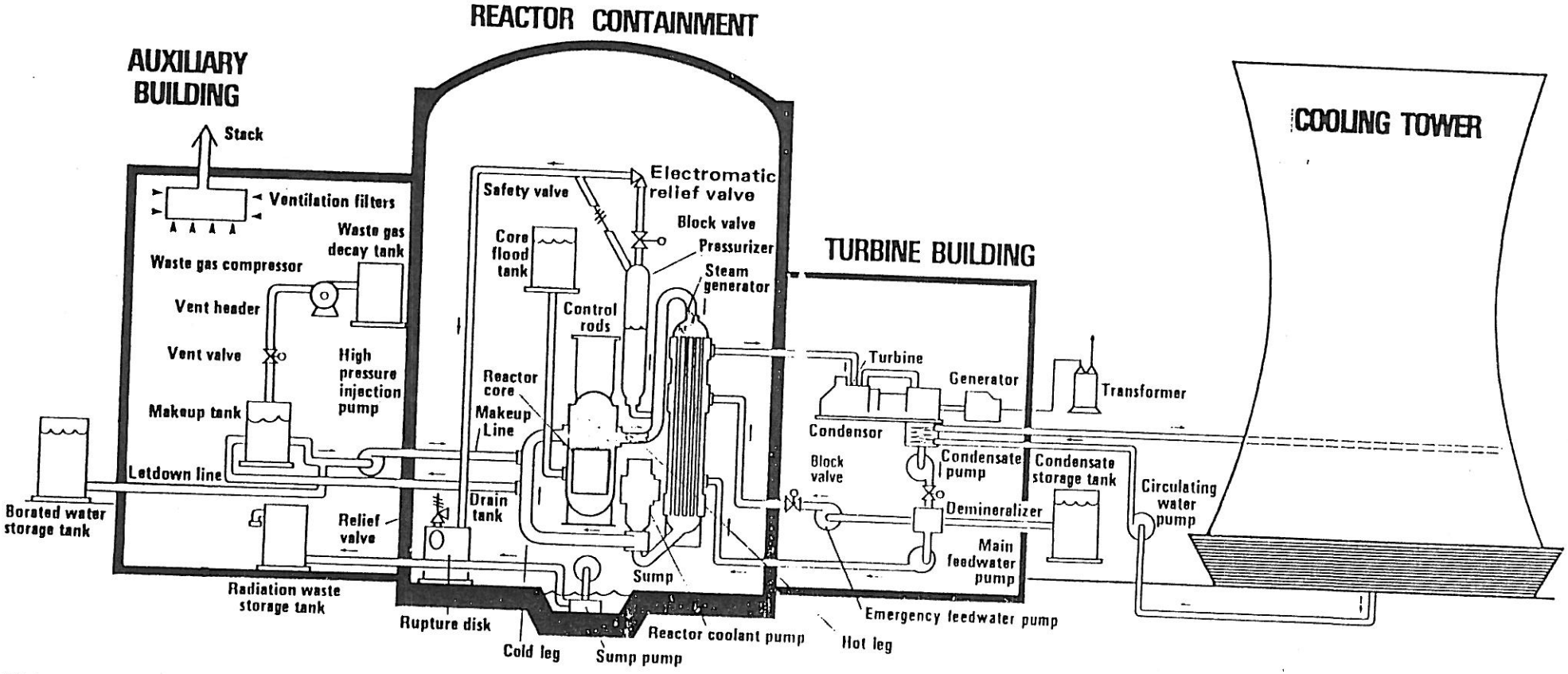
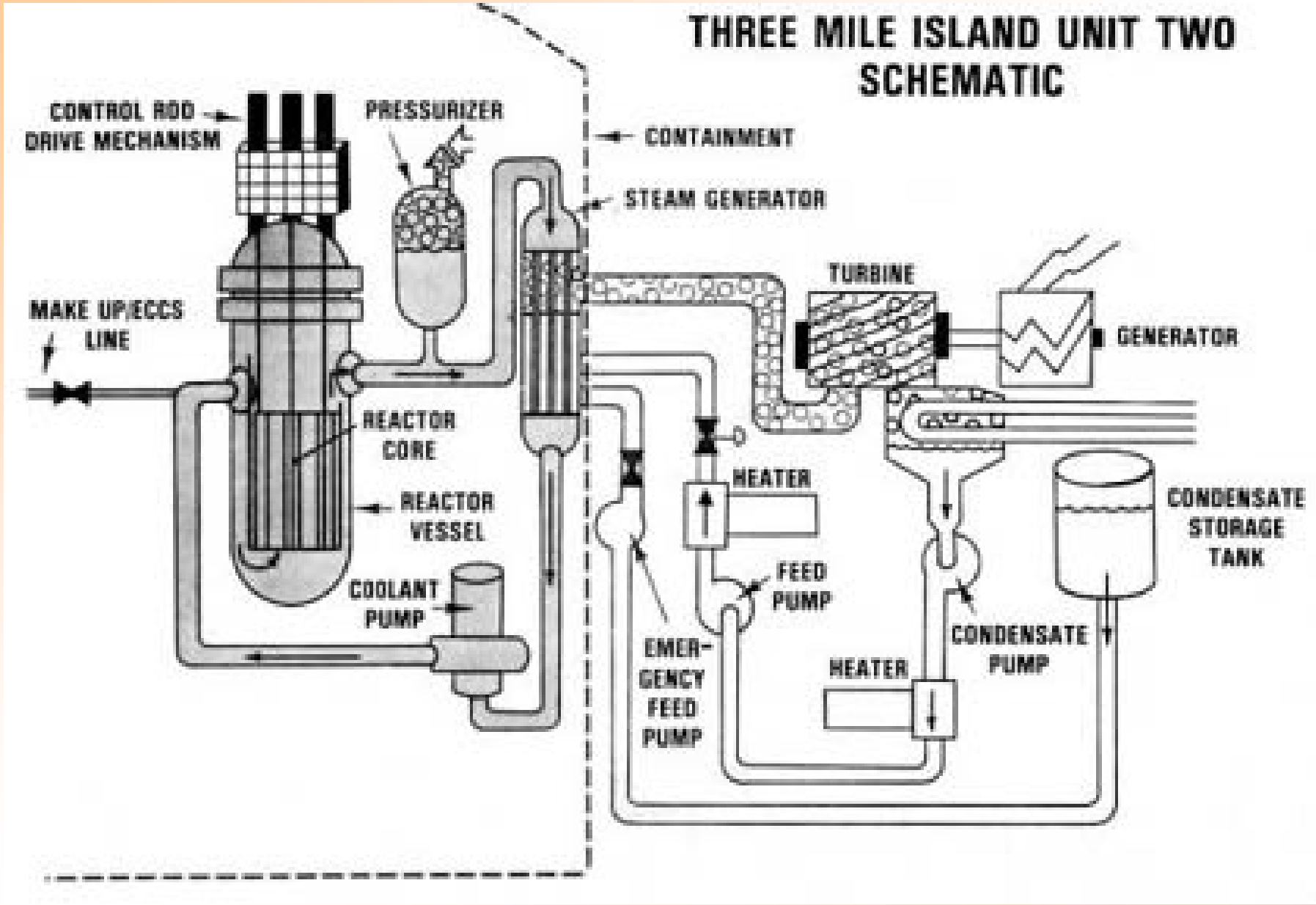


FIGURE 18-2
Schematic layout of the TMI-2 reactor. (Reprinted, and adapted with permission of IEEE, from *IEEE Spectrum*, November 1979 issue, special report on Three Mile Island.)



S. T. Revankar-36-4

Initial Status

Early hours of March 28, 1979 operating under automatic control at 97% rated power of 2772 MWt (961 MWe)

- Slight leakage from PORV or from ASME code safety valves (0.3 kgls)
- Difficulty in transferring resin from isolated condensate water system to a regeneration tank. (done by compressed air and deionized water inject into condensate polishing vessel)

Initiation of accident (Turbine Trip)

Clogged Resins – Water Got In Service Air System. Instrument Air Line → Shut Isolation Valve → Condensate Booster Pump to Trip – Turbine Trip

Reactor Trip (0-6 minutes)

- Bypass valve open to dump steam to condenser
- Auxiliary feed water pumps started (but valves closed)
- Small transient 3 to 6 seconds RCS pressure 15.5 MPa
- Open PORV - however at 8 seconds RCS pressure 16.2 MPa
- Reactor Trip (high RCS pressure)

Maintenance Fault
Abnormal Event

Decay Heat: 1m 97MWT

1 hr	36 MWT
1 day	13 MWT
1 week	5.1 MWT
1 month	2.1 MWT

- At 13 seconds RCS pressure back to 15.2 MPa
- PORV failed to close

Instrument Failure

- Since status tags were not clear on auxiliary feed water valves – steam generator drying fast
- RCS Pressure Dropping

Instrument Failure

- 2 minutes 4ses Pressure 11.MPa – ECCS (HPIS) started (Shut of 19.7 MPa)
- Pressurized level increasing
- 4minutes 38 sec one of HPIS pump stopped 2 phase system unrecognized

Loss of Coolant (6 – 20 minutes)

- 6minutes Pressurized steam bubble lost
- Quench tank pressure rise
- At 7minutes 43s Sump pump switches on to transfer water from sump to auxiliary (good practice) – (valve open at 27 KPa automatically)
- 8 minutes auxiliary feed water valve opened by operator – sounds in steam generator
- 10 minutes 24 sec 2nd HPIS Pump Tripped out-Restored-Tripped again – Restarted at 11 minutes 24 sec in throttled condition
- Actual balance in RCS is loss of coolant
- 11minutes pressurized scale on back
- 15minutes quench tank rupture disc blew
- 18minutes slight activity in ventilation system monitors
- RCS pressure 8.3 MPa and Falling

(At this point if PORV was closed should have been OK but was not)

Continued Depressurization (20 minutes – 2 hrs)

- Between 20minutes to 1 hr - System stable at Saturation:7 MPa 290^{0}C
- 38 minutes sump pump turned off (about 30 m^3 – water transferred)
- At 1 hr 14 min RCs main pump was tripped – High vibration
- At 1 hr 40 min RCS 2nd pump was tripped – Low pressure and low coolant flow
- Operating staff expected natural circulation – too late - 2/3rd of water was lost
- Water level only 30 cm above core top

Core Heat "Up" Transient

- At 2 hr 18 minutes PORV Closed by Operator
- (Even at this point HPIS injection could have stopped accident)
- At 2 hr 55minutes site emergency declared, high radiation detected
- RCS pressure increasing – Core Uncovered- Zr + H_2O – Reactions etc
- Attempt to Restart RC pump – One pump in loop B worked for 19 minutes but tripped – vibration, vapor binding at 3 hr 13 minutes
- Soon after 3 hr Peak Fuel Temperature > 2000^{0}C

"**General Emergency**" declared 3 hr 30 min – High radiation in reactor bldg, auxiliary bldg + fuel handling.

At 4 hr Detector Shielded with 4"lead → 200 Rad/hr

4.2 hr 600 Rad/h
4.4 hr 1000 Rad/h
5.0hr 6000 Rad/h

Between 4 hr 30 min to 7 hr attempts to establish pressure by HPIS failed – had to use PORV valve

Extended Depressurization (6 hr – 11 hr)

- Operators reduced system pressure by opening PORV at 7 hr 38 minutes to activate Core Flooding System to establish core cooling (at 2.8 MPa)
- At 8 hr 41 min RCS pressure - 4.1 MPa →CFS activated but failed to inject water to core
- At 9hr 50 min bldg pressure spiked to 1.9 MPa – (Hydrogen released to bldg) - Bldg spray started within 6 seconds lasted 6 minutes

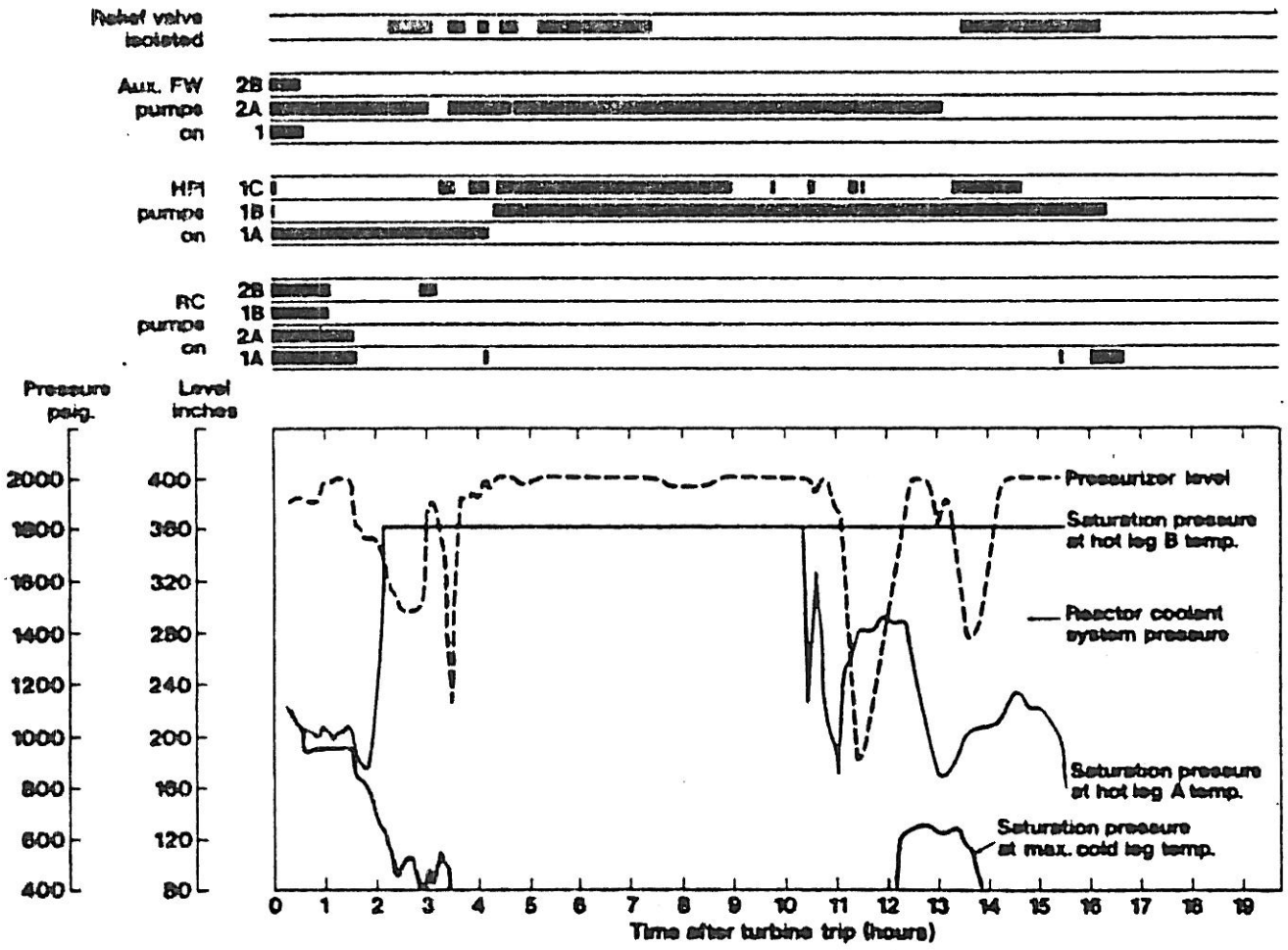
- Depressurized could not be brought below 3.0 MPa
  Could not use (2.8MPa) LPIS
- Operator closed PORV at 11 hr 8 min.
- No-effect core ceiling

Repressurization and ultimate stable cooling (13hr – 16hr)

- 13 hr 30 min HPIS started
- At 15 hr 51 min RC pump started.
- Hot by temp decreased 293^0C, and cold leg 205^0C -so net cooling occurred.

Removal of Hydrogen Bubble (Day 1 – Day 8)

- Voidage (of 28 m^3) in pressure vessel was H_2
- This volume was decreased over 1 to 8 days using PORV and recombiner system
- Over spills from auxiliary bldg water was pumped back to reactor bldg
- 1 month – RC pumps stopped let core cool by natural circulation



Reactor Coolant System Parameters in Hours after turbine trip at Three Mile Island, Unit 2, March 28, 1979.

Figure 10

Consequence of Events

- Core Uncovered – Partial Melt Down
- Hydrogen evaluation
- 30-40 % Zr oxidized
- 30 – 40% N gas generated released
- 3 to 5 mill Ci of I-131
- 0.2 to .3 M Ci of I-133
- Actual discharge from site Xe-133 (13×10^6Ci), Kr (13×10^6Ci)
  Iodine 16 Ci I-131 (filter retained rest)
- Remaining activity in building after 1 year
  - 50,000 Ci of $^{85}K_r$
  - 850,000 Ci of ^{137}Cs, ^{90}Sr in water

- Off site exposure small
  - 2000 to 5000 person rem up to 7th April 1979
- (3300 rem average)
- Individual ~ 1-5 mrem (background 100 mrem/annual)

- Large Economic Blow ($10, to $20 billions damage)
- Bad Publicity to Industry

S. T. Revankar-36-11