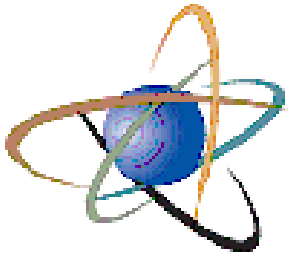


Three Mile Island

Chapter 18.0
B&W Cross-Training Course
R-326C

HRTD
Human Resources
Training & Development

OBJECTIVES

1. Explain how a loss of feedwater resulted in a reactor trip and subsequent LOCA.
2. Describe the major radiation release paths which occurred at TMI-2.
3. Describe the decay heat removal methods used at TMI-2 during the transient.
4. Explain which parameters are used and how they indicate decay heat removal by natural circulation (or loss of natural circulation).

OBJECTIVES

5. List the operational conditions which enhance natural circulation. Include which systems may be operated different from normal conditions.
6. List the sources of hydrogen and oxygen within the primary system and containment.
7. Determine which RCS parameters can be used as possible indications of boiling (steam formation) within the system.

Appendix – Sequence of Events

Initial Conditions:

- Reactor Power 97%
- Average Temp 581°F
- RCS Pressure 2155 psig
- Pressurizer Level 229 inches
- Pressurizer Heaters and Sprays in Manual
- ICS in Full Automatic
- RCS Boron = 1030 ppm
- RCS Activity 0.397 µC/ml
- 6 gpm Identified RCS Leakage

Appendix – Sequence of Events

Transient Initiator - Loss of Condensate Booster Pump

Two licensed control room operators were on duty in the control room. The shift superintendent was in his office adjacent to the control room. The shift foreman and two auxiliary operators had been working in the auxiliary building on the No. 7 condensate polisher.

The condensate polishers use ion exchange resins for purification of the feedwater. Flow through the resin bed tends to compact the material into a solid mass. The transfer procedure utilizes demineralized water and station compressed air to break up this mass. During this transfer process a resin block developed in the transfer line.

At this point, the plant operators had hypothesized that water pressure may have exceeded air pressure, forcing water into the air system. Further, the water made its way to the polisher isolation valve controls causing them to drift toward the close position. It is assumed that the condensate booster pumps tripped first, since the polisher outlet is operated within 50 psig of the NPSH limit for the booster pumps. This problem had occurred before.

Appendix – Sequence of Events

Sequence of Events:

04:00:00	Condensate pump "1A" tripped. Feedwater pumps "1A" and "1B" tripped. Main Turbine tripped. EFW pumps "1"," 2A", and "2B" started
04:00:03	Pressure setpoint of Power Operated Relief Valve (PORV) was exceeded (2255 psig).
04:00:08	Reactor tripped on high RCS pressure (2355).
04:00:12	RCS pressure decreased below PORV setpoint. Solenoid de-energizes providing a closed indication to the operator.
04:00:13	Indicated Pzr level peaked at 256 inches and began a rapid decrease. Letdown flow was isolated. Makeup pump "1A" was started and a HPI isolation valve opened. This pump kept tripping (reason unknown) Pzr sprays and heater control returned to automatic.
04:00:15	SG "A" level indicates 74 inches (S/U range). SG "B" level indicates 76 inches (S/U range).
04:00:30	PORV and Pzr safety valve outlet temperatures alarmed high. RCS low pressure trip setpoint reached.
04:00:58	Pzr low level alarm. SG levels are very low, and the differential temperature, hot to cold leg, rapidly approaching zero indicating that OTSGs are going dry.

Appendix – Sequence of Events

04:01:45	Both SGs are boiled dry
04:02:01	ESFAS on low RCS pressure. Makeup pump "1B" tripped. HPI pump "1C" started.
04:02:04	DHR pumps "1A" and "1B" started.
04:03:13	The safety injection portion of ESF was manually bypassed. RCDT relief valve lifted.
04:03:28	Pzr high level alarm
04:04:38	The operator stopped makeup pump "1C" and throttled the HPI isolation valves.
04:05:00	Pzr level reached 377 inches and continued to rise (pressure continued to decrease).
04:05:30	Indicated RCS Th and pressure reached saturation (582°F and 1340 psig).
04:08:18	OTSG level at 10 inches on the startup range. The EFW pumps were running, but the discharge valves were closed. The valves are now opened resulting in a dry OTSG being fed with relatively cool water. T_h and T_c decreased. RCS pressure, now under control of the loop saturation considerations, followed.
04:10:19	Reactor building sump pump "2B" started.
04:11:43	Pzr level came back on scale and dropped rapidly, as RCS loop temperature continued to decrease from the heat being removed by the OTSGs and EFW pumps.

Appendix – Sequence of Events

04:13:13	DHR pumps "1A" and "1B" were shut down.
04:14:48	The RCDT rupture disc failed (191.6 psig).
04:14:50	RCP related alarms actuated. Reactor coolant flow indicated oscillations. (RCS pressure = 1275 psig, T_c = 567°F).
04:24:58	PORV outlet temperature = 285.4°F. Safety valve outlet temperature = 270°F
04:27:51	Reactor coolant temperature begins to stabilize at approximately 550°F. Pressure = 1040 psig. OTSG level = 30 inches
04:38:10	Reactor building sump pumps "2A" and "2B" were stopped.
04:40:00	Increasing count rate continued on the Source Range neutron detector.
04:46:23	Letdown cooler monitor count rate began increasing. It will increase by a factor of 10 within the next 40 minutes.
05:13:40	Stopped loop "B" RCPs ("1B" and "2B").
05:30:00	NI-3 (IR) came on scale (increasing).
05:40:40	Stopped loop "A" RCPs ("1A" and "2A") due to high vibration, erratic flow, and decreasing flow.
05:41:00	Excore instrumentation indicated a decreasing flux (factor of 30).
05:42:30	Excore instrumentation indicated increasing flux levels.
05:51:27	Loop "A" and "B" Th temperatures were increasing (eventually went off scale high - 620°F). Cold leg temperatures were decreasing.
06:14:23	Reactor building radiation monitor (particulate sample) went off-scale high.

Appendix – Sequence of Events

06:19:00	PORV outlet temperature 228.7°F. Safety valve outlet temperature 189°F and 194°F. Operator closes PORV block valve
06:38:23	Letdown cooler "A" rad. monitor off-scale high.
06:39:23	Two samples indicate RCS boron is 400 ppm. Emergency boration started (feared restart).
06:47:00	Alarm typewriter indication showed SPNDs responding to high temperatures down to 4' level of the core. 90% of the core exit thermocouples >700°F.
06:54:09	After attempting to start RCPs "2A" and "1B", the operator successfully started RCP "2B" by jump starting the interlocks. "2B" ran with high vibration. Flow was indicated for only a few seconds and returned to zero.
06:54:50	ESFAS logic automatically reset (HPI injection) on increasing pressure (1845).
06:55:00	Site emergency declared Radiation alarms: waste gas discharge, station vent, fuel handling building exhaust
06:55:13	ESF bypasses were cleared.
07:00:00	RCS pressure at 2045 psig.
07:12:00	Opened PORV block valve (RCS pressure control).
07:13:00	RCP "2B" was stopped (zero flow, low current, high vibration).
07:17:00	PORV block valve was closed.

Appendix – Sequence of Events

07:19:45	Manually initiated safety injection (low RCS pressure).
07:20:13	Makeup pump "1C" started (rapid quenching probably caused major fuel damage).
07:21:00	Excore instrumentation indicated sharp decrease (reflood).
07:23:23	General emergency declared. Notified the off-site authorities.
07:32:26	High pressurizer level alarm.
07:37:00	Tripped makeup pump "1C."
07:40:00	Opened PORV block valve.
07:55:39	ESF "A" and "B" actuated on high reactor building pressure. Makeup pump "1C" started.
08:00:00	Over the next 90 minutes, core exit thermocouple readings were manually obtained ranging from 217 to 2580°F. Pzr level = 380 in. RCS pressure = 1500 psig. ESF actuation cleared.
08:18:00	Makeup pumps "1A" and "1C" tripped. Operator attempted to restart "1A" (switch then placed in "Pull to Lock")
08:22:00	Makeup pump "1B" was started.
09:15:00	Decision made to repressurize RCS. Closed the PORV block valve. RCS pressure = 1250 psig
09:43:00	By cycling the PORV block valve, RCS pressure was maintained 1865-2150 psig during the next 2 hours.
10:04:00	Commenced filling OTSG "A" (to 97%) using condensate pumps.

Appendix – Sequence of Events

10:04:00	Commenced filling OTSG "A" (to 97%) using condensate pumps.
11:08:00	EFW pump "2A" was started. OTSG "A" level reached 100% (operating range)
11:38:54	Station manager ordered the PORV block valve opened.
11:41:35	Bypassed ESFAS
12:30:00	Power operated emergency main steam dump valve was closed at the request of corporate management.
12:31:00	RCS pressure had decreased to 600 psig (indicates floating on CFT).
13:04:00	Makeup pump "1C" stopped (concerned with BWST inventory).
13:10:00	PORV block valve was closed. RCS pressure had decreased to 435 psig and then began to increase (could not get on DHR).
13:50:00	ESF on high-high RB pressure (28 psig). HPI, RB isolation, RB spray pumps & valves, DHR pumps started, Makeup pump "1C" started. Makeup pump "1A" - no indication of starting or running.
13:50:30	Makeup pump "1C" was stopped. RB spray pumps were stopped
13:57:00	DHR pumps "1A" and "1B" were stopped.
13:58:38	Cleared ESFAS
14:00:00	Opened PORV
14:26:15	Loop "A" Th <620°F. Stays on scale 10 minutes.
14:35:00	RCS pressure decreased to 410 psig and began to increase.
15:06:00	Pzr level decreases to 180" in the next 18 minutes. RCS loop "A" temperature increasing.

Appendix – Sequence of Events

16:00:00 PLANT STATUS: No RCPs running, Makeup pump "1B" running, RCS pressure = 560 psig (increasing), Pzr level = 294" (increasing) Loop "A", T_h = 590°F, T_c = 340°F, OTSG without heat sink, 44 psig decreasing, nearly full. Loop "B", T_h = 620°F, T_c = 180°F, OTSG - isolated & full.

There is no indication of natural circulation. Very little of the decay heat is being removed, except by makeup water and by occasional opening of the PORV block valve. Gradual heatup of the RCS is causing temperature and pressure to rise. Pressure control is being attempted by juggling makeup and PORV block valve.

17:20:00

Reactor building pressure starts to go negative. Pressurizer level starts to drop. RCS pressure = 637 psig (decreasing). Two HPI pumps are providing 425 gpm (total) makeup flow. It is now the intention to repressurize, hopefully to collapse bubbles and begin steaming from OTSG "A".

High points were actually hydrogen filled. Collapse of loop bubbles was still impossible. It is the operator's belief that the main condenser will soon be available.

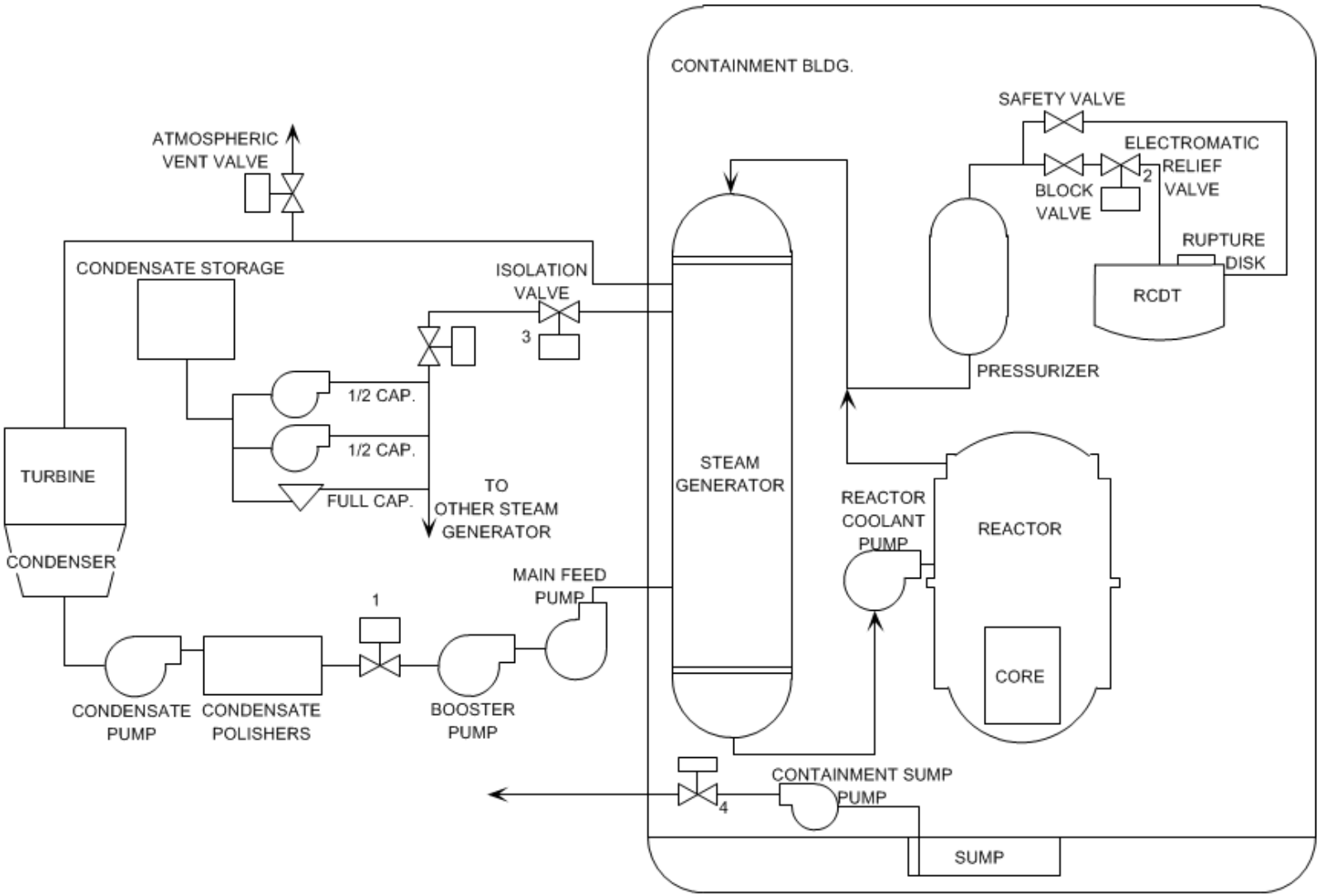
Appendix – Sequence of Events

20:00:00

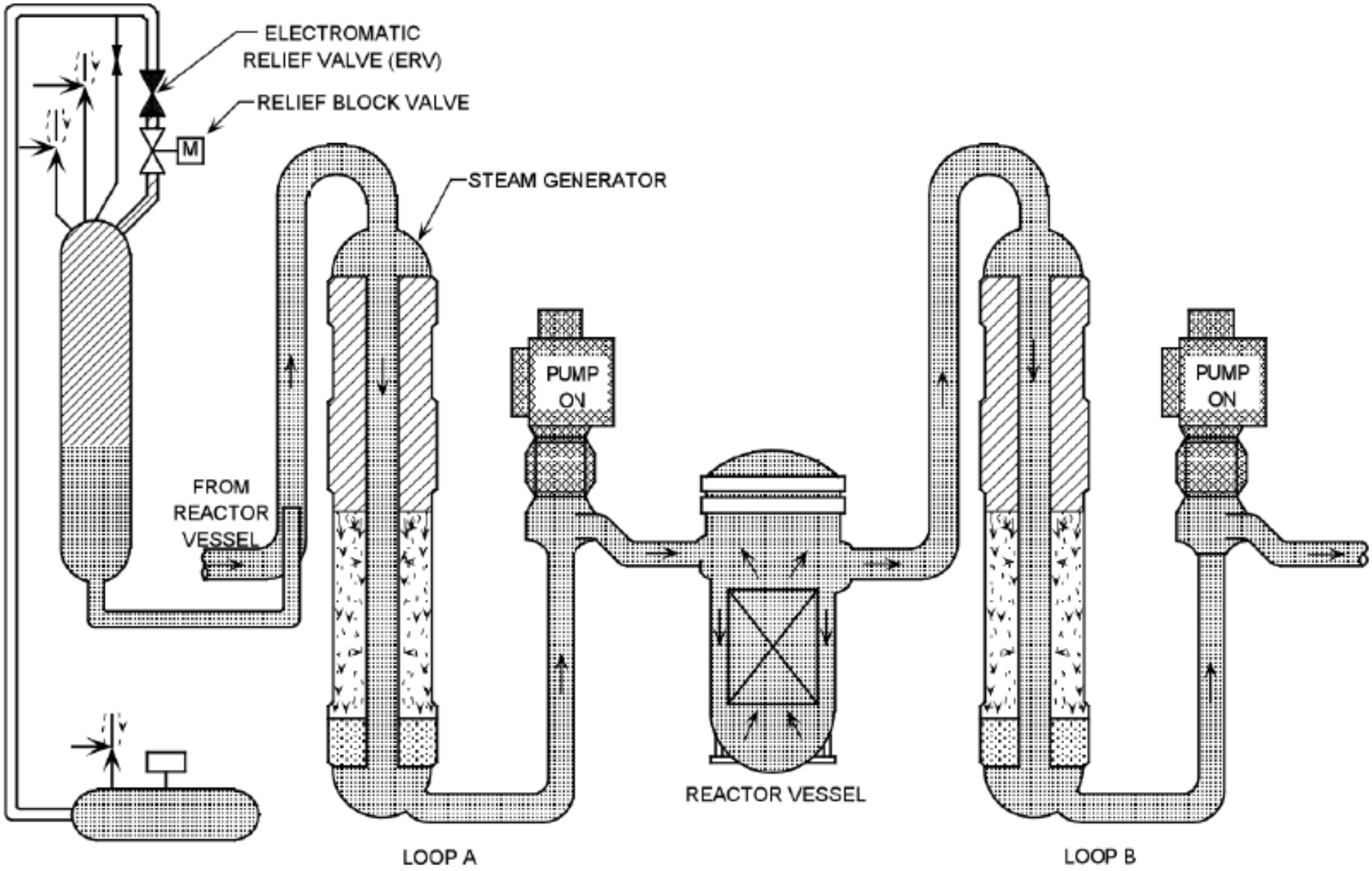
Indications show that forced circulation had been reestablished using RCP "1A." RCS pressure was being maintained at 1000 - 1100 psig with temperatures indicating a cooling trend. Heat was being removed from the RCS using OTSG "A". OTSG "B" was isolated and condenser vacuum had been established.

During the accident, there apparently was much concentration on the water level in the pressurizer. This, by the way is natural, because the operators knew to never let the pressurizer get empty (or full). It is, therefore, understandable that they would not be trying to imagine boiling occurring elsewhere in the system.

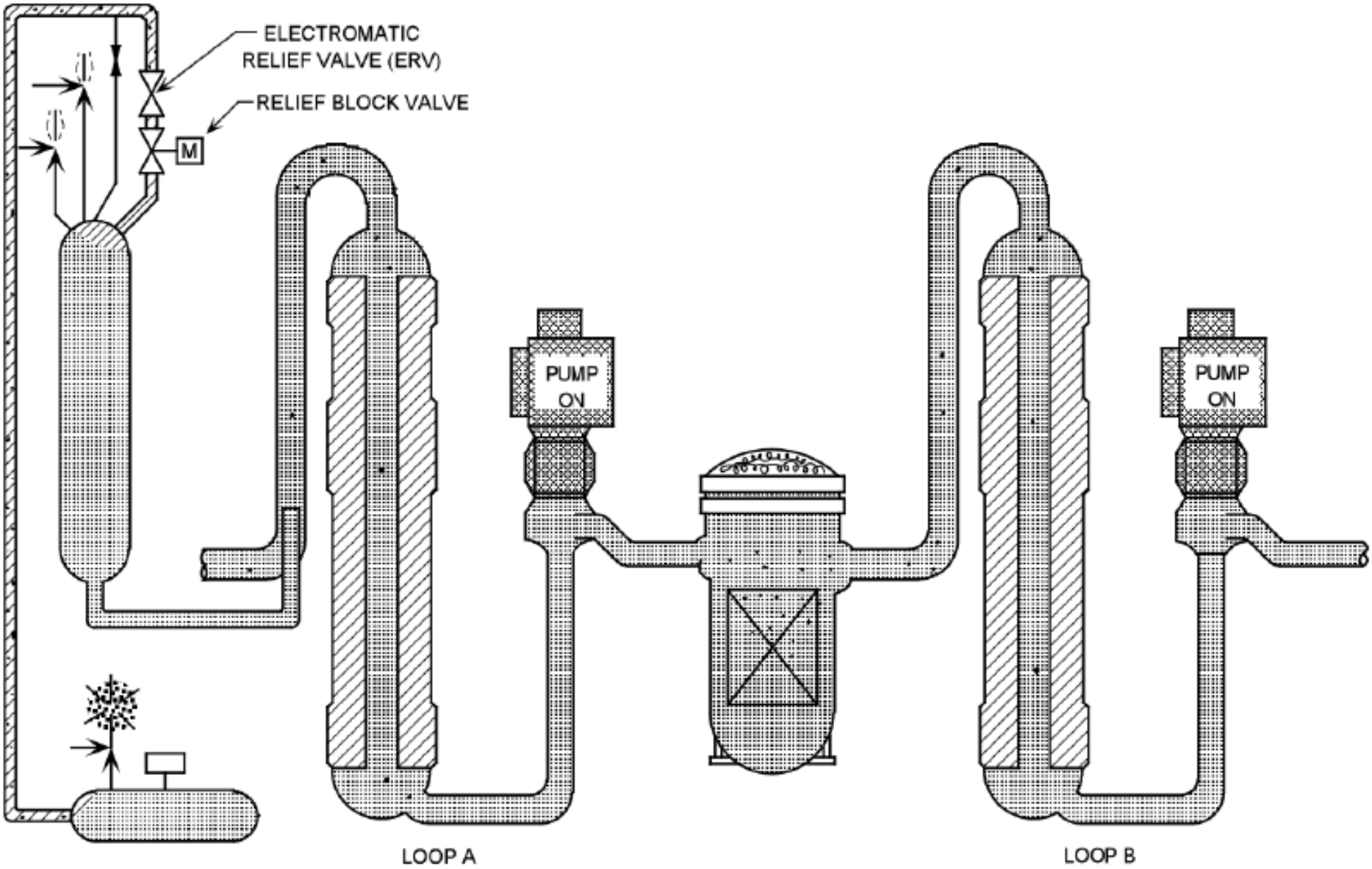
During this transient, the system pressure and temperature and their relationship to saturated steam conditions were not correlated, at least not in the control room; the operators were much too busy to think about the steam tables. We must endeavor to keep in mind the fact that if pressure drops, we can have DNB occur which ultimately will create partial film boiling in the reactor.



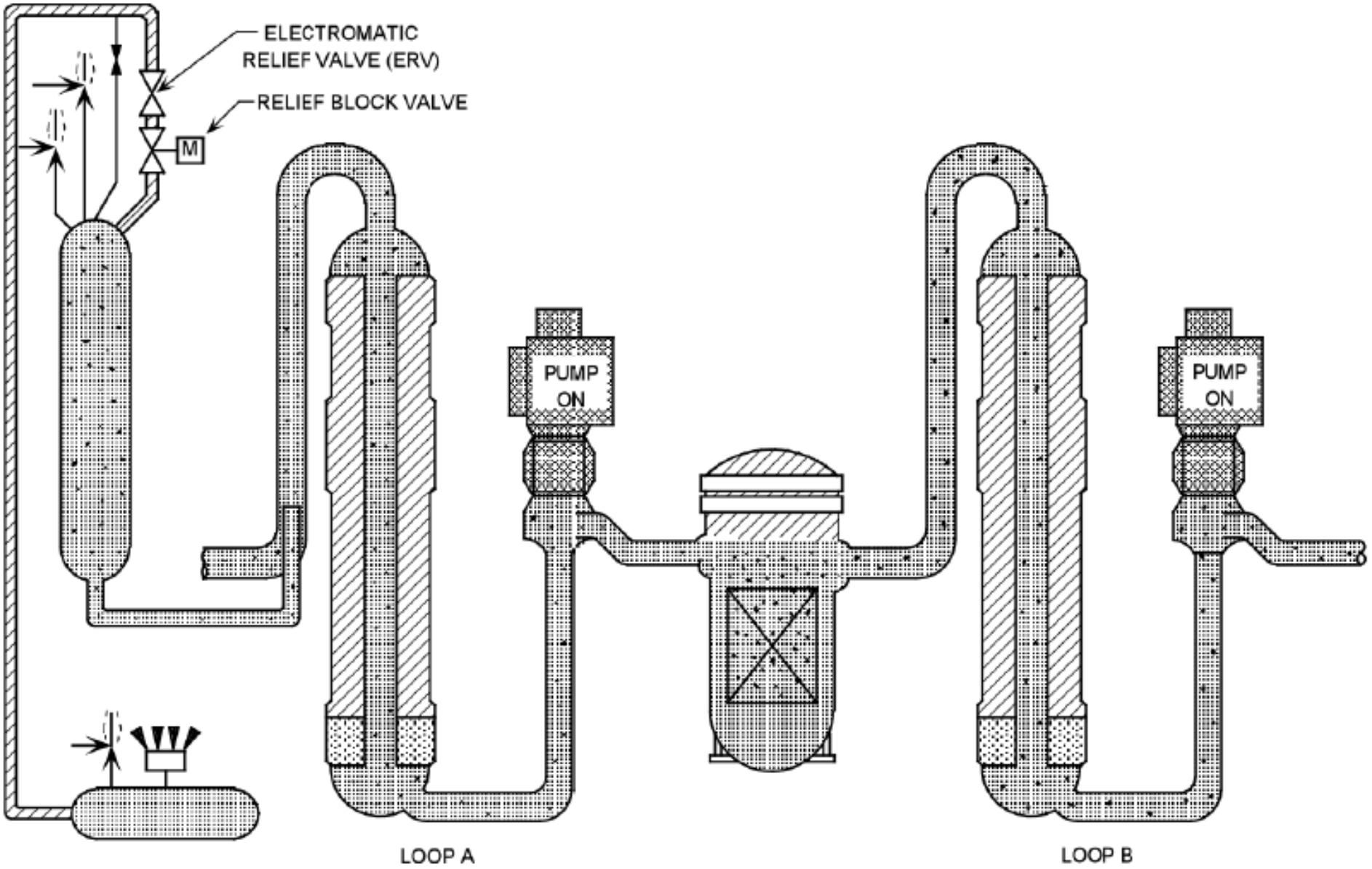
Three Mile Island (Fig. 18-1)



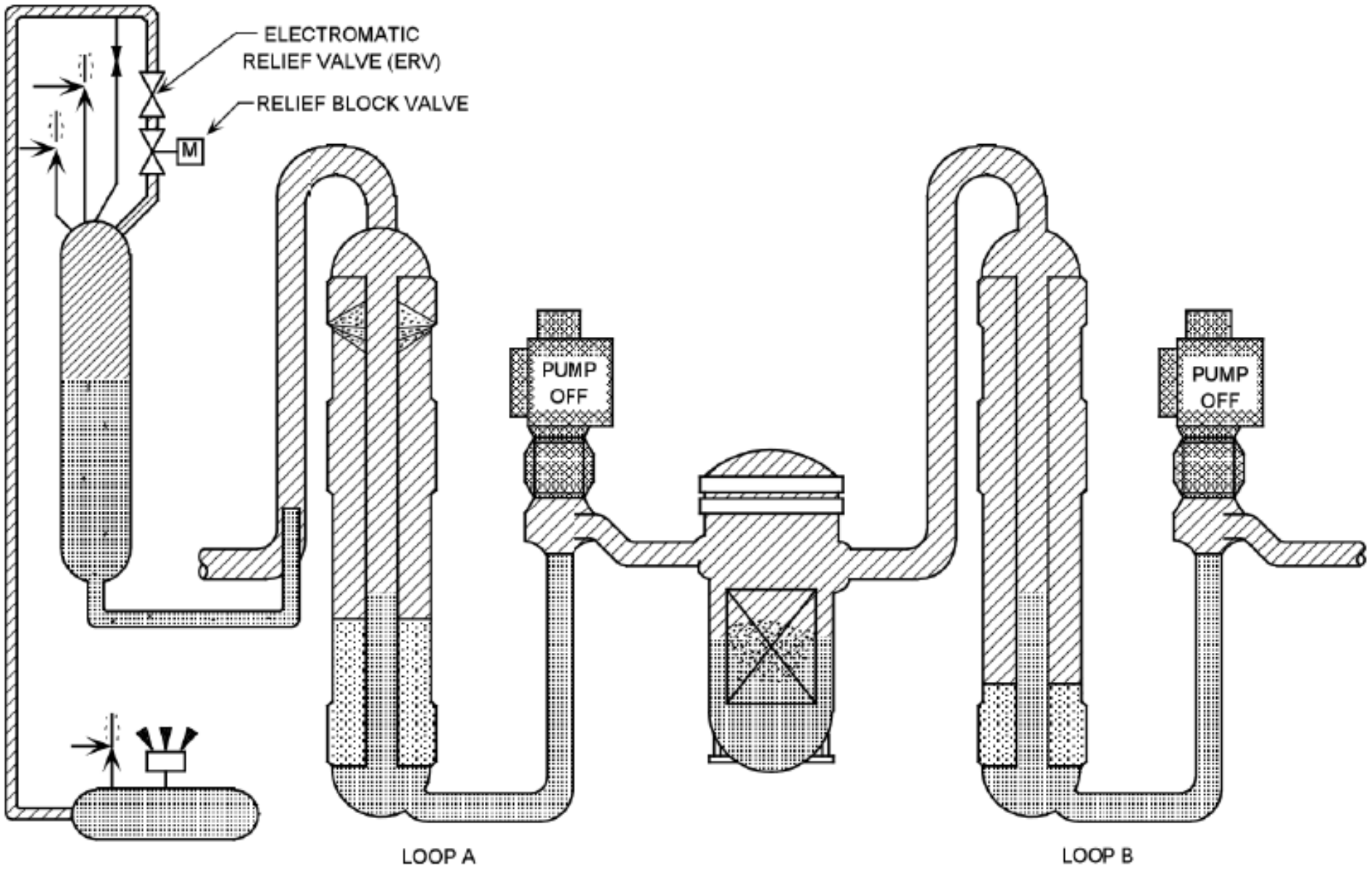
T=0 Minutes (Fig. 18-2)



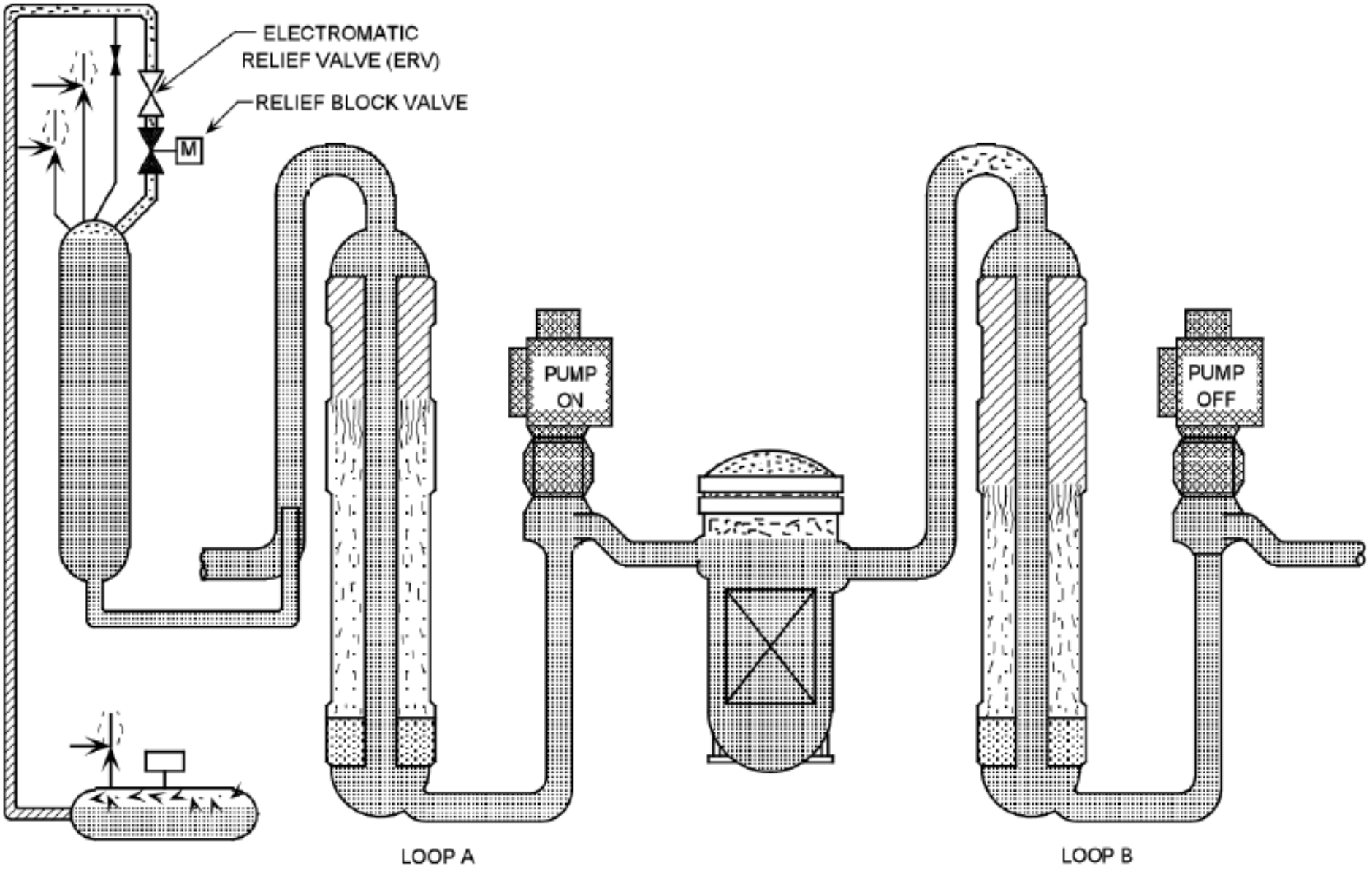
T=8 Minutes (Fig. 18-3)



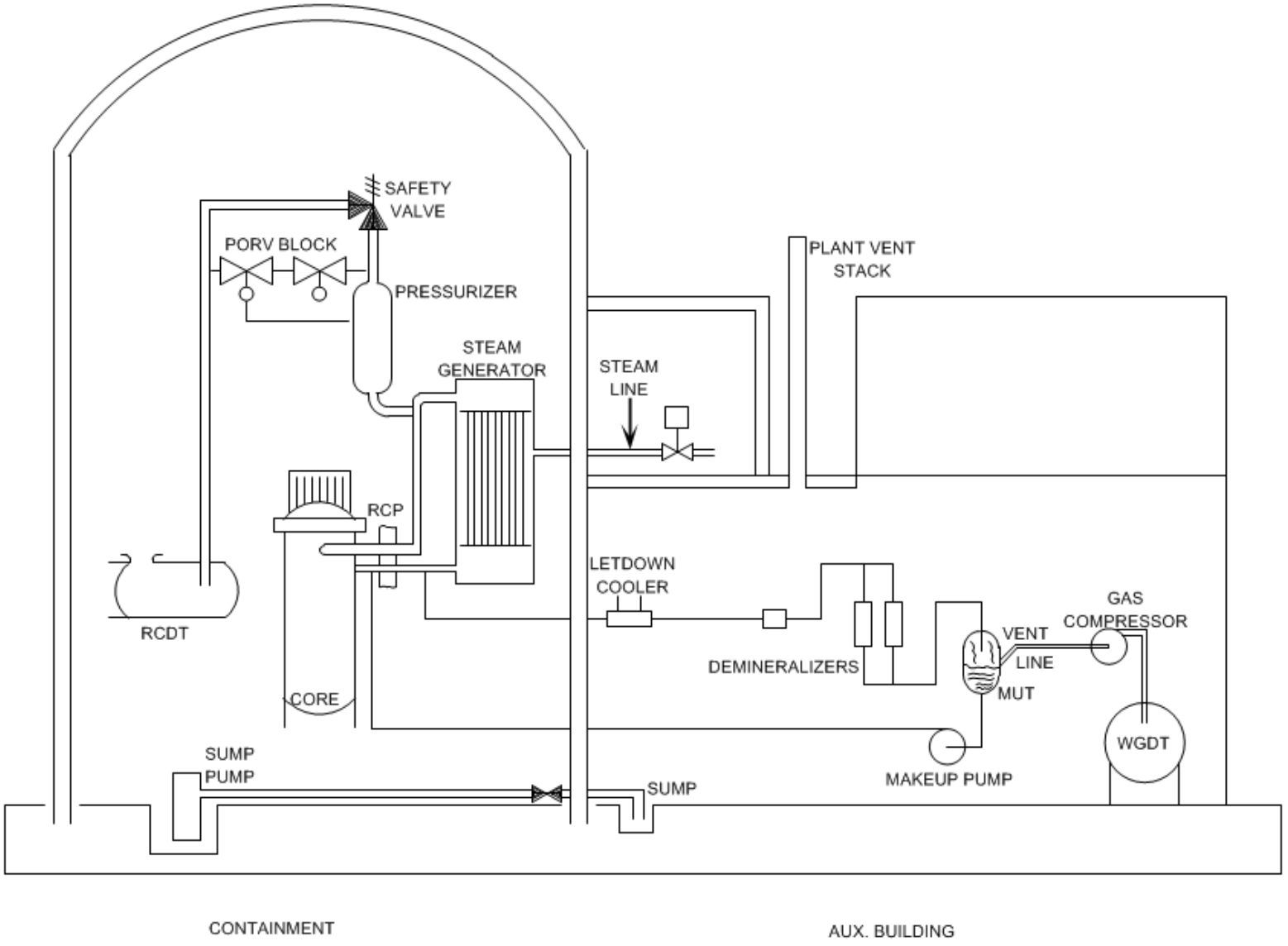
T=1 Hour (Fig. 18-4)



T=2 Hours (Fig. 18-5)



T=16 Hours (Fig. 18-6)



TMI Radiation Release Path (Fig. 18-7)