D.3 Three Mile Island

Arranged By:
Phathom Donald
Electrical Engineering, '14

BACKGROUND

- The Three Mile Island (TMI) Nuclear Generating Station is located in Pennsylvania.

- Two separate power plants: TMI-1 and TMI-2, each with a capacity of 1,700 megawatts.

- Jointly owned by Pennsylvania Electric Company, Jersey Central Power & Light Company, and Metropolitan Edison Company (Met Ed).

BACKGROUND

- At TMI-2, the reactor core holds approximately 100 tons of uranium, and contains 36,816 fuel rods.
- The reactor has 69 control rods used by operators to control how much power a plant produces.
- Control rods are held up by magnetic clamps.
- In an emergency, the magnetic field is broken and the control rods drop into the core to halt fission. This is called “scram.”

BACKGROUND

- There is a potential for the release of radioactive materials produced in the reactor core as the result of fission.
- Three Basic Safety Barriers:
  - The fuel rods.
  - The reactor vessel and the closed reactor coolant system loop.
  - The containment building.

Background

- Saturation" the temperature and pressure combination at which water boils and turns to steam.
- Problems from an uncovered core:
  - The temperature may rise to a point where a reaction of water and cladding could begin to damage the fuel rods and produce hydrogen.
  - The temperature may rise above the melting point of the uranium fuel.

ESSENTIAL ELEMENTS

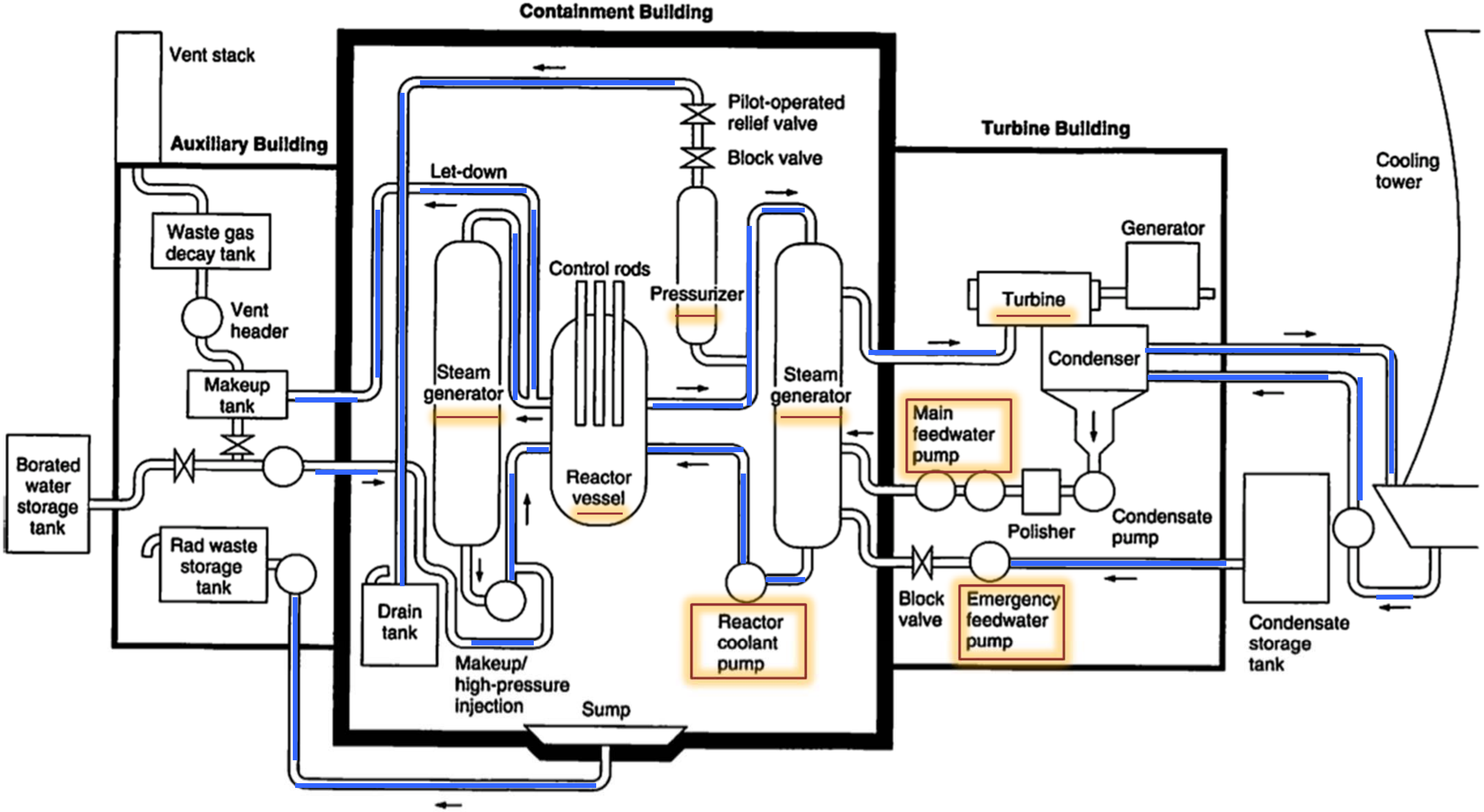


FIGURE D.2
The Three Mile Island nuclear power plant. (Source: John G. Kemeny. *Report of the President's Commission on the Accident at Three Mile Island*, U.S. Government Accounting Office, Washington, D.C., 1979.)

REACTOR COOLANT SYSTEM

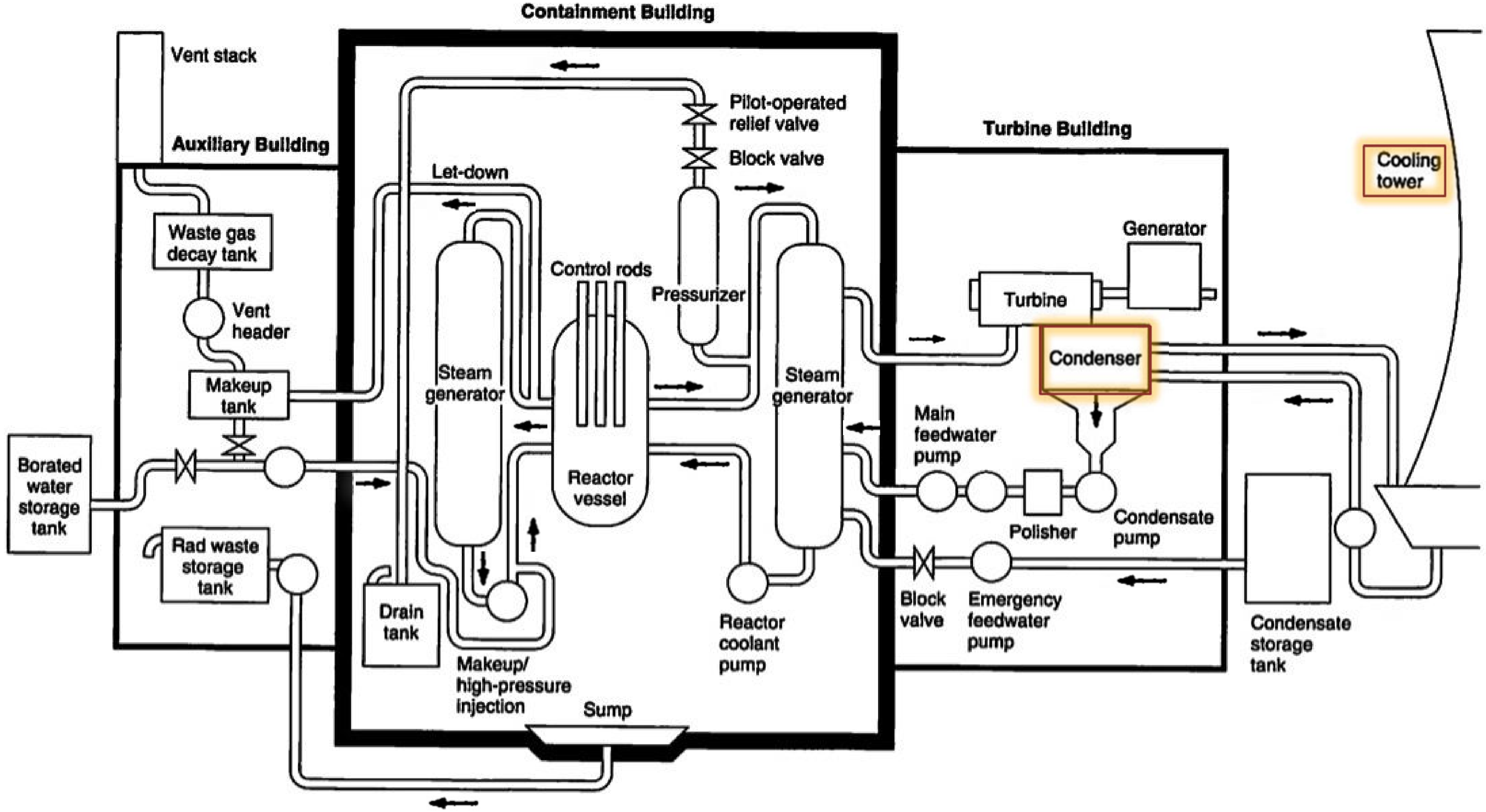
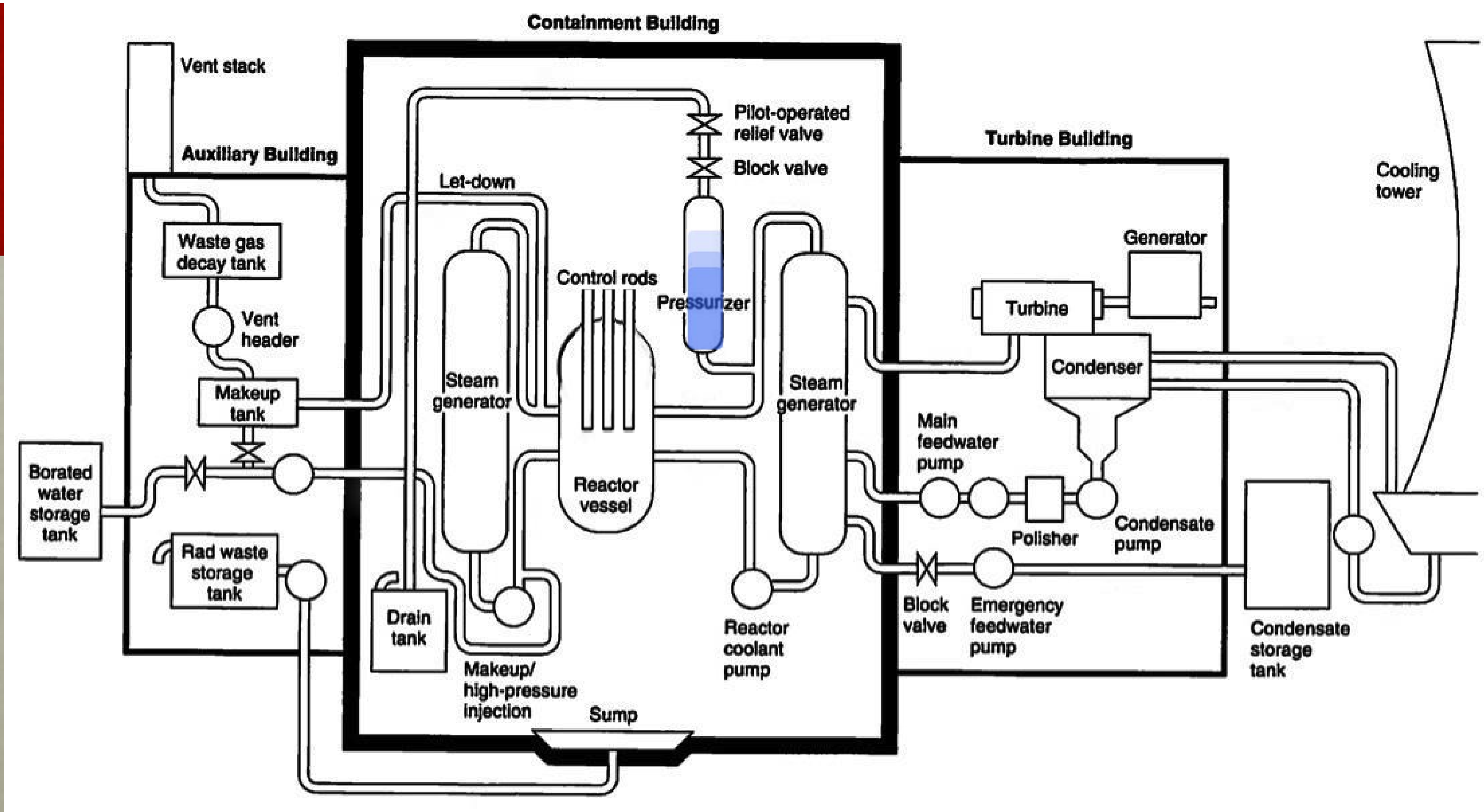


FIGURE D.2
The Three Mile Island nuclear power plant. (Source: John G. Kemeny. *Report of the President's Commission on the Accident at Three Mile Island*, U.S. Government Accounting Office, Washington, D.C., 1979.)



4am

- A series of feedwater system pumps supplying water to TMI's steam generators tripped.

4:00:13

- The PORV stuck open, unknowingly to operators who turned on a water pump.

4:00:48

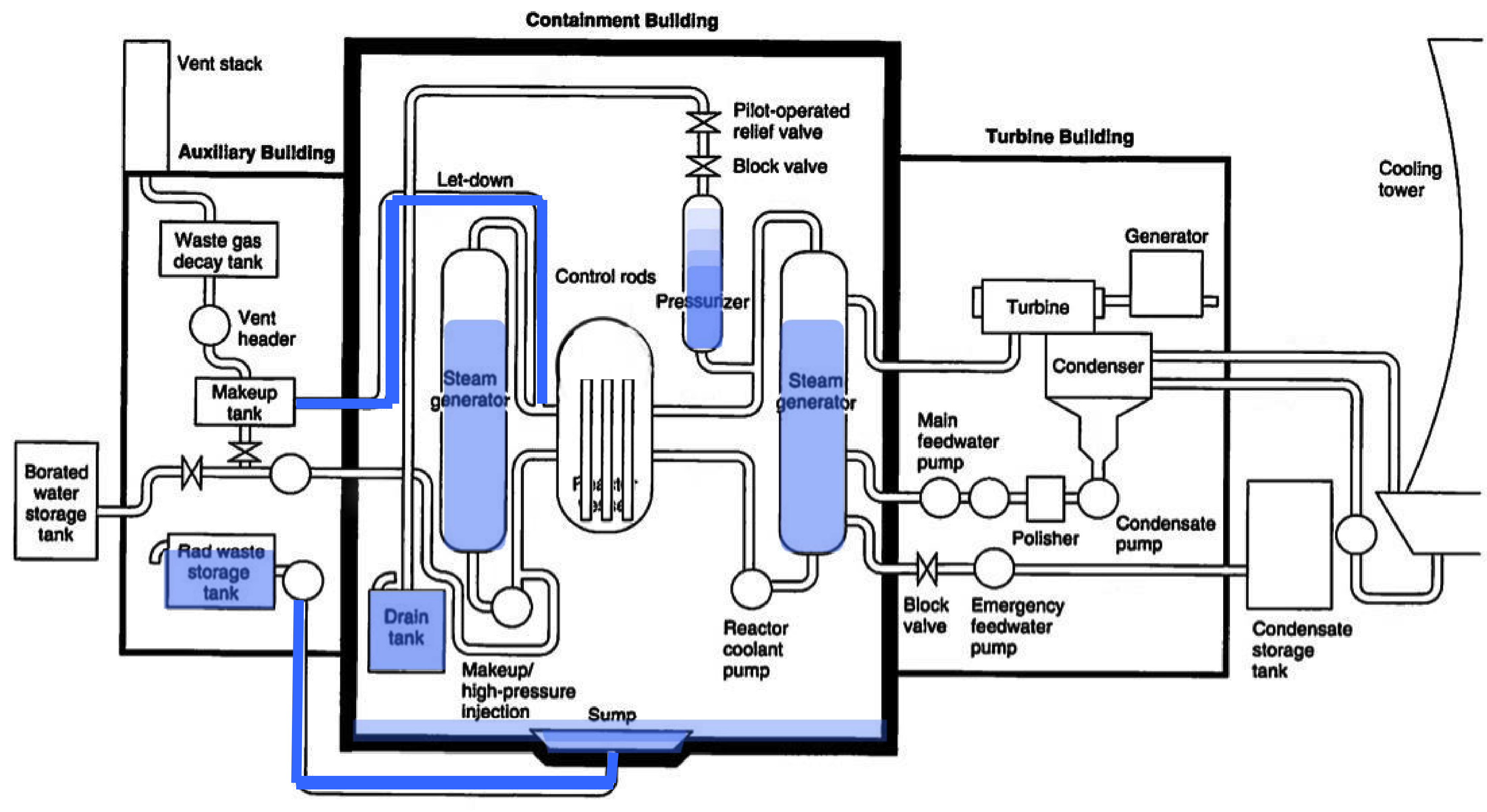
- Water in the pressurizer began to rise again due to more water being pumped than being lost to the PORV.

4:01:45

- The steam generators boiled dry because their emergency lines were cut off.

4:02:00

- Two large pumps, high pressure injection pumps began pouring water into the system.



4:05:30

- Saturation point reached. Steam bubbles formed in coolant system, displacing coolant water in the reactor.

4:08am

- Operator discovered that no emergency feedwater was reaching the generators.

4:11am

- An alarm signaled that there was high water in the containment building's sump.

4:15am

- A rupture disc on the drain tank burst as pressure rose. This sent more slightly radioactive water onto the floor.

4:20am

- A higher than normal count of neutrons inside the core indicated the presence of steam bubbles in the core.

EVENTS

4:39am
- Both sump pumps were stopped but about 8,000 gallons of slightly radioactive water was already pumped.

5:00am
- The four reactor coolant pumps began vibrating severely as a result of pumping steam as well as water.

5:14am
- Operators shut down two of the pumps.

5:41am
- They shut down other two remaining pumps stopping the forced flow of cooling water through the core.

6:00am
- Radiation alarms inside the containment building signaled that fuel rod claddings had ruptured.

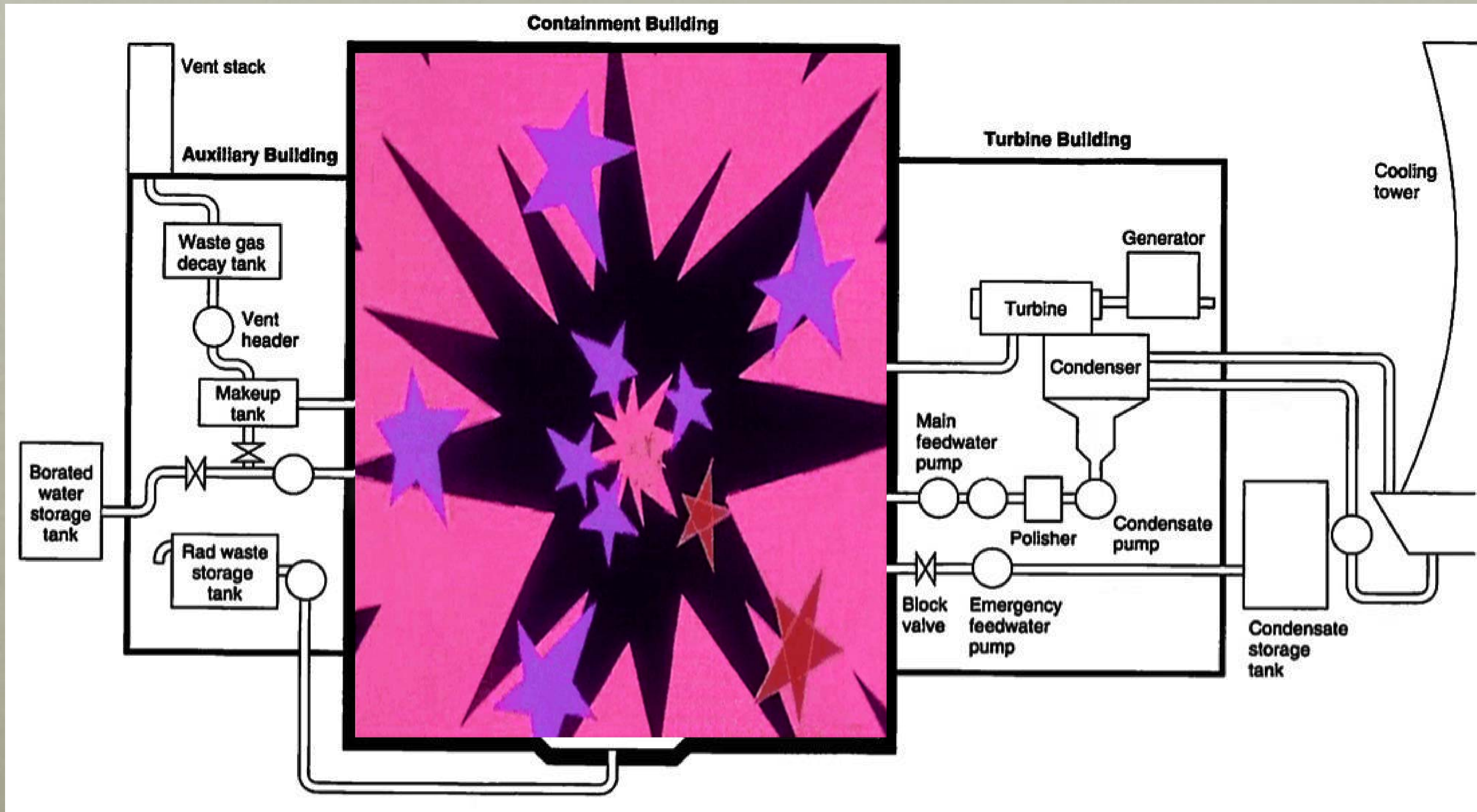
6:22am
- The open block valve was closed, and the loss of coolant was stopped and pressure began to rise.

6:54am
- Operators turned on one of the reactor coolant pumps, but it shut down 19 minutes later due to high vibrations.

8:00am
- The containment building isolated: a procedure to help prevent radioactive material from escaping into the environment.

8:26am
- Operators once again turned on the emergency core cooling system's high pressure injection pump.

10:30am
- Pumps finally cover the core again fully.



At 1:50pm on Wednesday, a "thud" was heard in the control room. It was the sound of a hydrogen explosion inside the containment building. However, it was not recognized until late Thursday. The noise was dismissed at the time as a slamming of a ventilation damper.

Aftermath of Accident

- Cost of accident, including cleanup of the buildings and disposal of approximately 1 million gallons of radioactive water, a substantial amount of radioactive gases, and solid radioactive debris: $1 billion to $1.86 billion.
- There was very little radioactive material released outside the plant.
- There was a lowering of public confidence in the industry and its regulatory agencies.

Causal Factors

Level 1
Separate the Events

Level 2
Conditions That Allow Those Events

Level 3
Constraints and Conditions That Account for the Level 2 Conditions

Level 2 Conditions

- Containment building remained intact, despite the explosion.
- Their training gave insufficient emphasis to a fundamental understanding of the reactor and to the principles of reactor safety.
- Inadequate written operating and emergency procedures in use at TMI. They contained many errors and imprecise terminology.
- TMI-2 had repeated problems with the condensate polishers. These polishers probably initiated the accident.

Level 2 Conditions

- Control room was not adequately designed with the management of an accident in mind.
- Control room design and information presentation that confused the operators:
  - No way to suppress unimportant signals so that they could concentrate on the important ones
  - Poor arrangement of controls and indicators. Information was not presented in a clear and understandable form.
- John Kemeny of the Kemeny report stated that the technology in the TMI control rooms were "at least twenty years behind in times."

Level 2 Conditions

- Plant procedures were deficient:
  - There was no systematic check required on the status of the plant.
  - Performance of surveillance tests was not adequately verified to be sure that the procedures were followed correctly.
  - After the accident, radiological control practices were observed to be deficient.
- The maintenance force was reduced to save money.
- There were many shutdowns, and a variety of equipment was out of order.
- A number of equipment had a poor maintenance history without adequate corrective action: pressurizer level transmitter, make-up pump switches, and the condensate polishers.

Level 3 Conditions & Constraints

- A control room operator complained to his management about problems with the control room, but no corrective action was taken.
- The reactor at TMI has a once-through cooling system, with a small volume of water compared to other U.S. reactors.
- Designers paid little attention to the interaction between humans and machines under the rapidly changing and confusing conditions of an accident.
- The U.S. nuclear industry felt that a major accident could not happen in the United States.
- Supervisors overloaded with excessive paperwork not related to supervision.

Level 3 Conditions & Constraints

- NRC requirements at that time were inadequate. They didn’t require a quality assurance plan to be applied to the plant as a whole, only “safety-related” systems.
- The operator instructional program did not lead to sufficient understanding of reactor systems.
- Licensing process also concentrated heavily on equipment. But, “safety-related” items didn’t need to be reviewed in the licensing process.
- At that time, plants could receive an operating license with several safety issues still unresolved.
- The existence of a state emergency or evacuation plan was not required. The emergency plan did not require the utility to notify state or local authorities in the event of a radiological accident.

THE END