PROFESSIONAL ETHICS

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Case Study – Three Mile Island

The Biggest Nuclear Accident in the US

The Three Mile Island Disaster

- Location:
- Three Mile Island Nuclear Generating Station sits on an island of area of 3.29 km2 (814 acres) in the Susquehanna River Pennsylvania near Harrisburg.

The Three Mile Island Disaster

- The Three Mile Island Nuclear Power Plant was split into 2 units. TMI 1 and 2, each with its own reactor and power generating equipment.
- The incident occurred on March 28, 1979 in TMI-2.
- The reactor was operating normally and at 97% of its 1000 Megawatt capacity.

The TMI-2 Reactor

- Like any nuclear power plant, the TMI system was split into 3 sections to keep the radioactive reactor coolant contained.
- The Primary Loop, which includes the reactor and the coolant.
- The Secondary Loop, which deals with the actual power generation.
- And the Tertiary Loop, which cool the plant and contains the large cooling towers.
- For this incident we are only concerned with the Primary and Secondary loops.
- Each loop relies on the other working correctly.

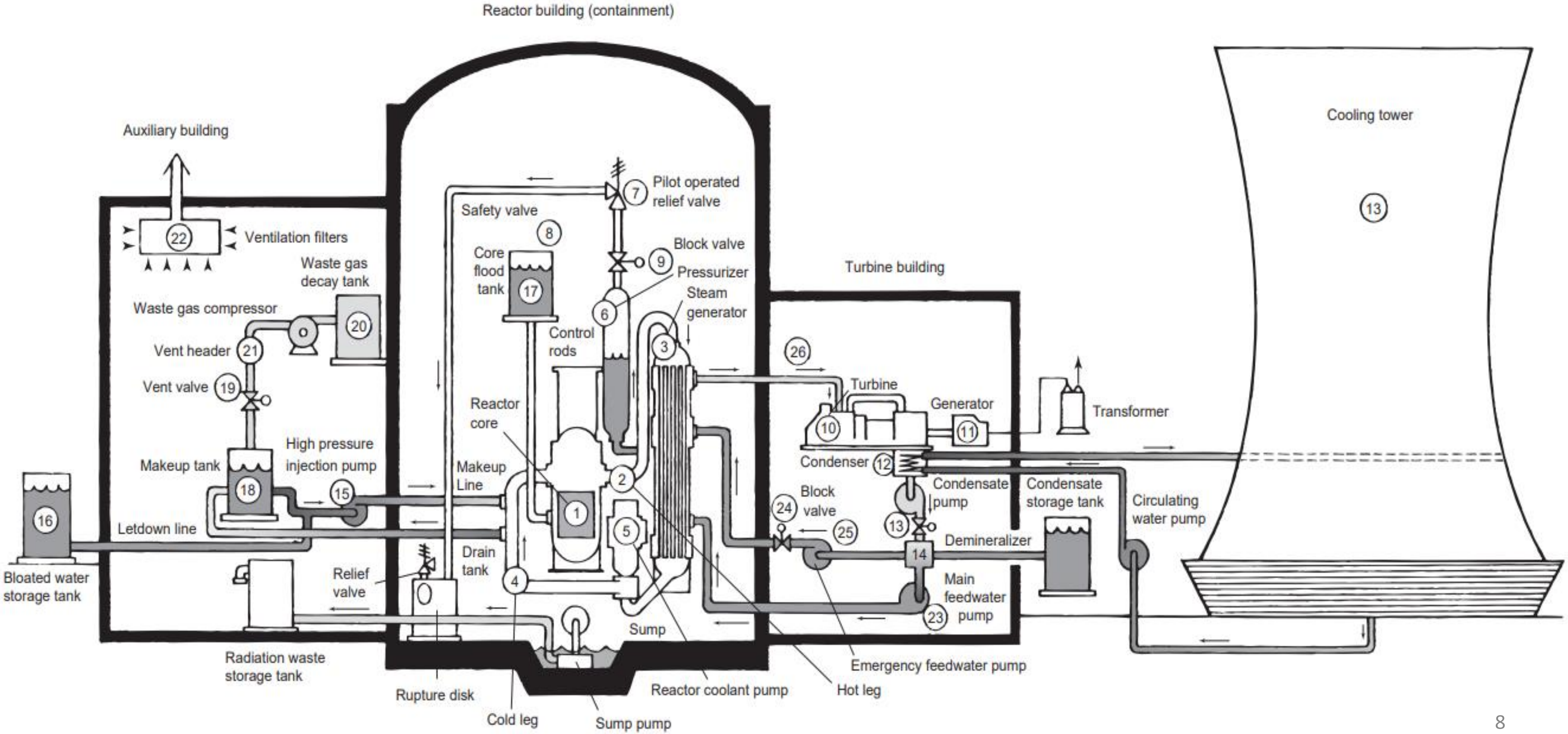
The Primary Loop

- The Reactor core heats up the surrounding coolant water.
- This water then passes through the steam generator, which is essentially a heat exchanger.
- The cool water then carries on through the primary loop and back to the reactor core.
- The pressurizer maintains the correct water pressure in the loop by creating a controlled steam bubble.

The Secondary Loop

- The steam comes from the steam generator and passes through the safety valves into the turbine, which produces the electricity.
- The steam then passes into the condenser.
- The now cool feedwater returns to the steam generator.

Three Mile Island nuclear power plant Unit 2



Feedwater Shutdown

- A mechanical or electrical maintenance interrupted the water flow in the secondary loop.
- As a result one of the condensate booster pumps turned off. That caused the main feedwater pumps (23) and the turbine (10) to shut down as well.
- An automatic emergency system started up the auxiliary feedwater pumps (25).

Emergency Feedwater Pumps Started

- But with the turbines inoperative, there was little outlet for the heat generated by the fission process in the reactor core.
- The pressure in the reactor rose to more than 2,200 pounds per square inch, opening a pressure relief valve (7).
- Moreover, the control rods were lowered into the reactor core to stop the main fission process.

Automatic Pressure Relief Valve Opens

- To control pressure, a pilot-operated relief valve (a valve located at the top of the pressurizer) opened.
- The valve should have closed when the pressure fell to proper levels, but it became stuck open.
- Staff was unaware that cooling water was pouring out of the stuck-open valve.
- As coolant flowed from the primary system through the valve, other instruments available to reactor operators provided inadequate information.

Block valves left closed after maintenance

- Apart from this failure everything else had proceeded automatically as it was supposed to.
- Except for one other serious omission: The auxiliary pumps (25) that had been started automatically could not supply the auxiliary feedwater because block valves (24) had inadvertently been left closed after maintenance work done on them two days earlier.

Steam Generator Boils Dry

- As the emergency feedwater valves were still closed no heat was being taken out of the steam generators.
- This in turn led to a temperature rise in the primary loop.
- The staff didn’t realize why, as they didn’t know that the valves were closed.
- Without feedwater in the loop (26), the steam generator (3) boiled dry.
- The reactor had not yet cooled down, and even with the control rods shutting off, the main fission reaction was still generating energy.

Primary Loop Temperature Rises

- Because there was no feedwater going in, the temperature was not being taken from the reactor coolant.
- Due to the open relief valve pressure, however, pressure was dropping.
- This confused the operators as generally if temperature rises, so does the pressure.

Disaster Approaches

- If the primary loop pressure fell low enough or the temperature rose enough then the coolant would boil.
- This could lead to the fuel rods being uncovered.
- This would lead to the fuel rods overheating, which could in turn lead to a meltdown.

The feedwater valves are Closed!

- Finally, one of the operators decided to check the feedwater system.
- He moved the paper tag and noticed that the emergency feedwater valves (24) were closed.
- He opened them and feedwater at last entered in the primary loop and began to take some heat from the reactor.
- The temperature rise slowed, but didn’t stop.

Main Coolant Pumps Shut Down

- As the relief valve was still venting pressure, and the temperature was high the coolant began to boil.
- Steam bubbles moved through the system until they got to the main coolant pumps.
- These began to vibrate as they strained to move the steam.
- The operators had to shut them down before they got damaged and caused a coolant leak.

Automatic Pressure Relief Valve Still Open

- Water escaping through the valve reduced the primary system pressure so much that reactor coolant pumps had to be turned off to prevent dangerous vibrations.
- To prevent the pressurizer from filling completely, staff reduced emergency cooling water amounts into the primary system – starving reactor core of coolant, causing it to overheat.

Fresh Eyes

- Fuel overheated to the point at which the zirconium cladding ruptured and the fuel pellets began to melt.
- As the new shift began to arrive one of the engineers spotted the link between low pressure and high temperature.
- He closed the open pressure valve.
- As he did this the coolant pressure began to rise.

Evacuation

- The water that had leaked into the containment building found its way into the plants auxiliary building, via the drains.
- This caused the radiation alarms to sound, and the building was evacuated.
- A site emergency was then declared, and nearby towns began to be evacuated.

Hydrogen

- When the material that was used in the fuel rod cladding is exposed to steam and high temperature, a chemical reaction occurs.
- The cladding is destroyed and hydrogen released.
- This hydrogen collected in both the reactor vessel and the containment building atmosphere.

Explosion

- The hydrogen in the containment building was ignited by a spark from a relay.
- The resulting explosion was as powerful as several thousand pounds of explosive, and created around 80psi of strain on the containment building.
- Luckily, this was easily absorbed by the over engineered structure and no damage was caused.

The Aftermath

- Every one of the 36,000 fuel rods in the core had ruptured, contaminating the primary coolant with radioactive gases.
- For 2 hours, over 70% of the core had been out of water.
- Parts of the core had reached over 4000 degrees, only a few hundred below the fuel rods melting point.

The Aftermath

- Thousands of curies of radioactive gases had been released into the atmosphere.
- Radioactive water had been dumped into the Susquehanna river.
- All of the contaminated water was then evaporated.
- Most of the fuel was removed and radiation levels then came down relatively low.

Amount of Contamination

- Hydrogen & some radioactive gases were released into atmosphere.
- A maximum of 13 million Curie of radioactive gases release.
- The maximum dosage to a person at the site boundary have been less than 100 mrem.

Cleanup

- Around 12 years to complete.
- Plant was not reopened until 1985.
- Plan was to keep the TMI-2 facility in long-term, monitored storage until the operating license for the TMI-1 plant expires in 2005, at which time both plants will be decommissioned.

Health Effects

- Government claimed no injuries or adverse health effects from accidents.
- Only one additional cancer death from radiation absorbed following the accident would result to those living within 50 miles of the plant.
- Studies however found:
- An increase in infant death.
- An increase in babies born with hypothyroidism.
- By late 1990, there had been no peer-reviewed articles that present any data on rates of cancer or other diseases.

Iodine - 131

- Radiation form of iodine.
- Affects thyroid gland.
- Children have much smaller thyroid gland.
- More energy per gram = higher dose.

Recommendations

- Use human factors principles to design the control panels.
- Better training program for operators.
- Better indicators for status of valves.
- Shift of plant priorities from continuing power production to safety.

Issues/Concerns

- Why was the plant allowed to function when the emergency feedwater was blocked?
- Why were the indicators on the control panel covered?
- The plant warning system was clearly inefficient the warnings were being printed, but the printer was 2 hours behind due to the number of warnings.
- There was no warning at all of the stuck release valve? The system only showed what the valve had been commanded to do, rather than its actual status.

Assignment 3

Case Study – Bhopal Disaster

Case Study – Chernobyl Accident

References

- Mike Martin and Ronald Schinzinger, “Introduction To Engineering Ethics”, McGraw Hill, New York, 2010
- Miscellaneous Journals and Internet Resources.