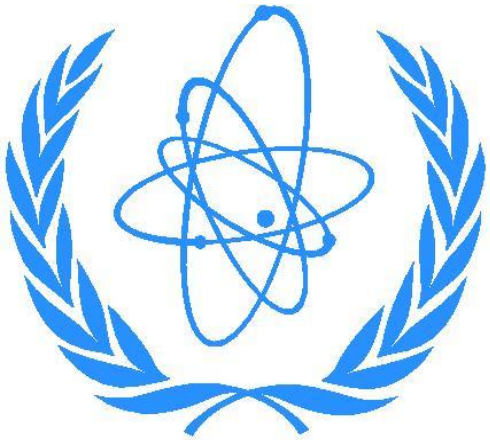

Nuclear Incidents in the World and Disaster Management

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3 Major Nuclear Incidents

- Chernobyl
- 3 Mile Island Incident
- Fukushima

Chernobyl

- Chernobyl was a combination of gross human incompetence and bad judgment at all levels.
- The disaster began during a systems test on Saturday, 26 April 1986 at reactor number four of the Chernobyl plant.

Events Leading to Chernobyl

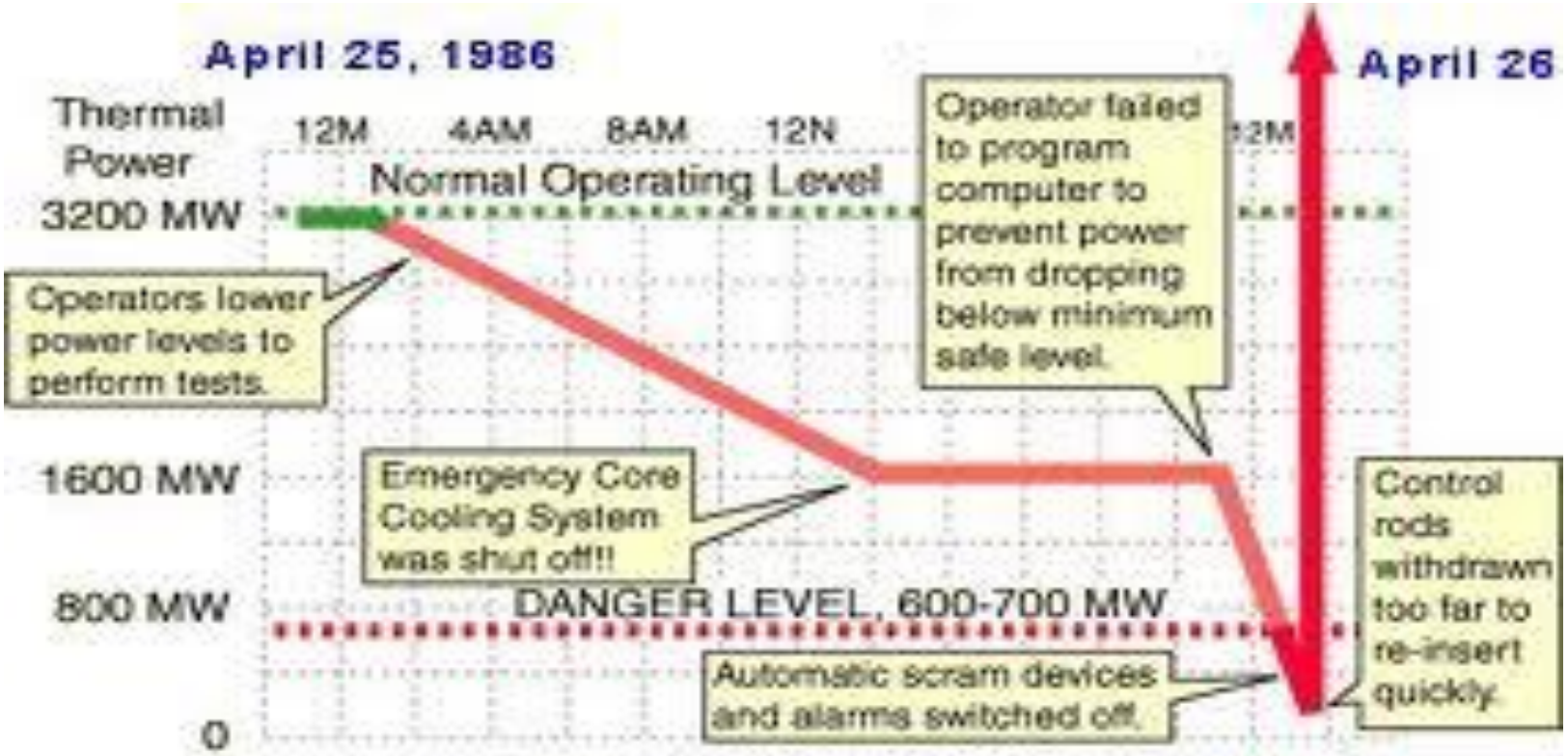
- They were trying to find out how long they could cool the reactor if they shut down using only the residual steam and coasting turbines for power to run the coolant pumps. **United States law does not allow such experiments at nuclear power plants**.
- In order to run this test they had to bypass several automated safety systems which was in violation of their own protocols. This was strongly objected to by the reactor operators, but unfortunately, an engineer was in charge. **An American reactor operator or engineer could be sent to jail for such behavior**.

Events Leading to Chernobyl

- This experiment had already been done several times unsuccessfully, and the only difference this time was a delay and the disabled safety systems. The reactor was run down to a low power and held there for the experiment.
- They removed the control rods completely during the experiment to stay in power.
- When the coolant cycle didn't complete, the reactor increased in heat exponentially and while SCRAM was initiated, it caused a runaway feedback loop.

Chernobyl: Result

- The heat and power increased so rapidly that there was a steam explosion that blew the 1,200 ton reactor head off the core and through the thin roof of the building. Without the reinforced concrete and steel containment structures of American reactors, the highly radioactive molten fuel and burning graphite was ejected into the atmosphere



A Chronology of Disaster, Chernobyl

Chernobyl: Aftermath

Three Mile Island Incident

- The **Three Mile Island accident** was a partial nuclear meltdown which occurred at the Three Mile Island power plant in United States on March 28, 1979. It was the worst accident in U.S. commercial nuclear power plant history, and resulted in the release of small amounts of radioactive gases and radioactive iodine into the environment

How it Happened?

- The accident began at 4 a.m. on Wednesday, March 28, 1979, with failures in the non-nuclear secondary cooling system.
- This was followed by a stuck-open pilot-operated relief valve (PORV) in the primary system, which allowed large amounts of nuclear reactor coolant to escape.
- The mechanical failures were compounded by the initial failure of plant operators to recognize the situation as a loss-of-coolant accident due to inadequate training and human factors, such as human-computer interaction design oversights relating to ambiguous control room indicators in the power plant's user interface.

How it Happened?

- A hidden indicator light led to an operator manually overriding the automatic emergency cooling system of the reactor because the operator mistakenly believed that there was too much coolant water present in the reactor and causing the steam pressure release.
- However, the system's own safety systems kicked in at high temperatures, but due to intense heat, some parts of the fuel had melted off and due to bad judgment, contaminated radioactive cooling water was released to the river by mistake.

Three Mile Island: Aftermath

- More then one billion dollars was spent on clean up operations at Three Mile Island Incident.
- As a result, US Government put new regulations in place for the training of nuclear engineers who work at US Power Plants.
- It also proved that the safety systems of nuclear power plants can work even with human negligence and error.

Fukushima Incident 2011

- Fukushima is the most recent Nuclear incident in history.
- It has caused a great bit of stir in the international community?
- But what really happened?

2011 Japan Earthquake

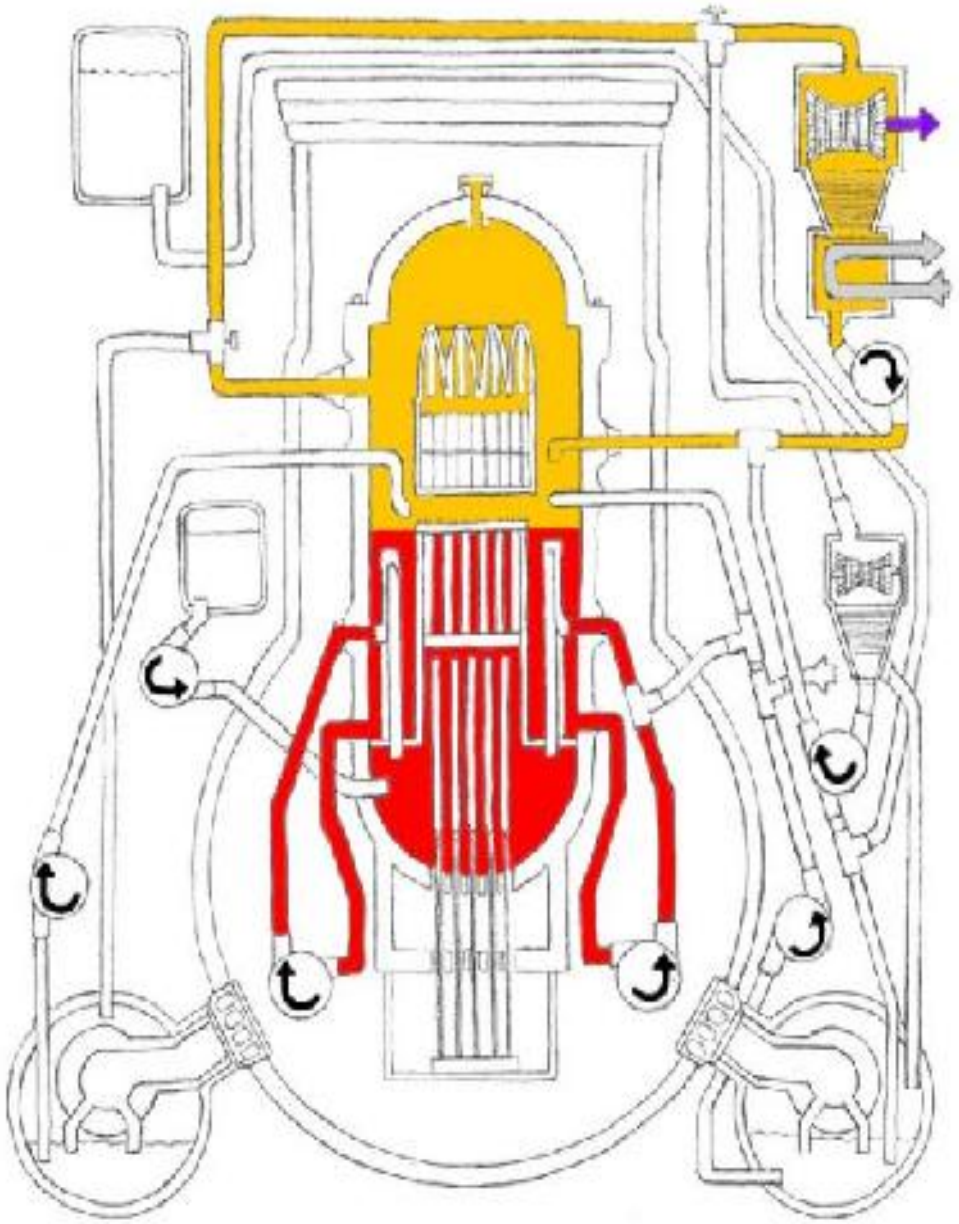
- It was the 5th biggest quake in the recorded history
- It is the most powerful earthquake in Japan, since recorded history of seismic activity from 1900
- Earthquakes of this magnitude like this hadn't happened in Japan for the last 1000 years
- It moved the Japanese mainland closer to US by 18 feet
- The destructive power was 1 million times the combined power of and Nagasaki

Fukushima Power Plant

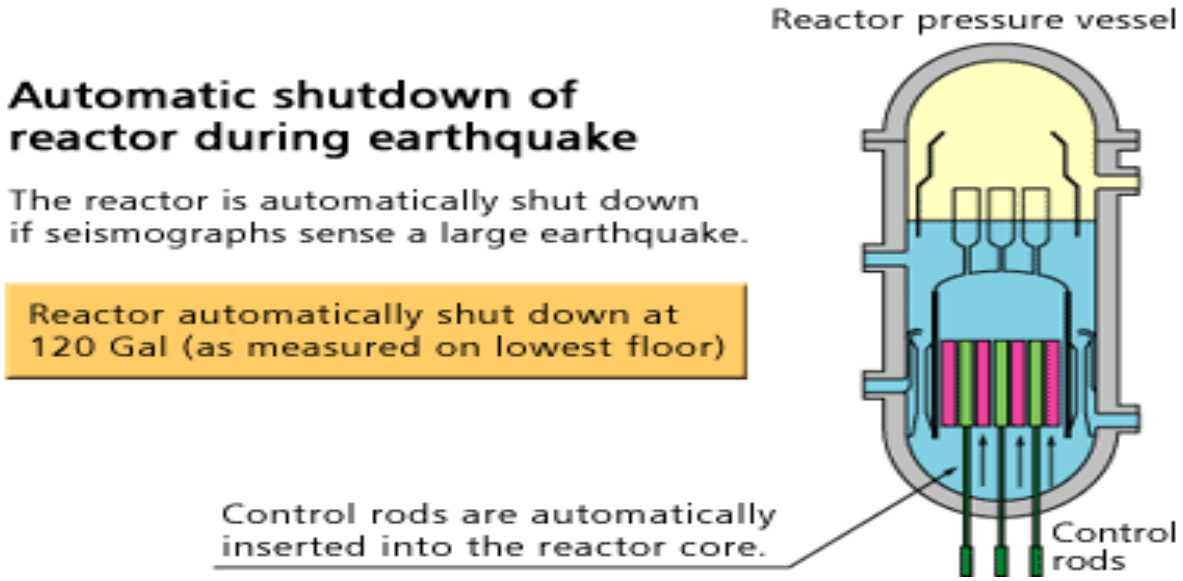
- In this huge devastating loss due to Earthquake and the Tsunami, Fukushima Power Plant (as well as other nuclear and thermal power plants) were effected
- The emergency response protocols could not deal with the devastative effect of the Tohoku Earthquake.

Before the Quake

- Fukushima power plant was working without any problems before the quake. Throughout its history, it had no serious incidents. It was a tested nuclear model, although it was an old system
- The energy was being produced and the coolant was being circulated non stop.

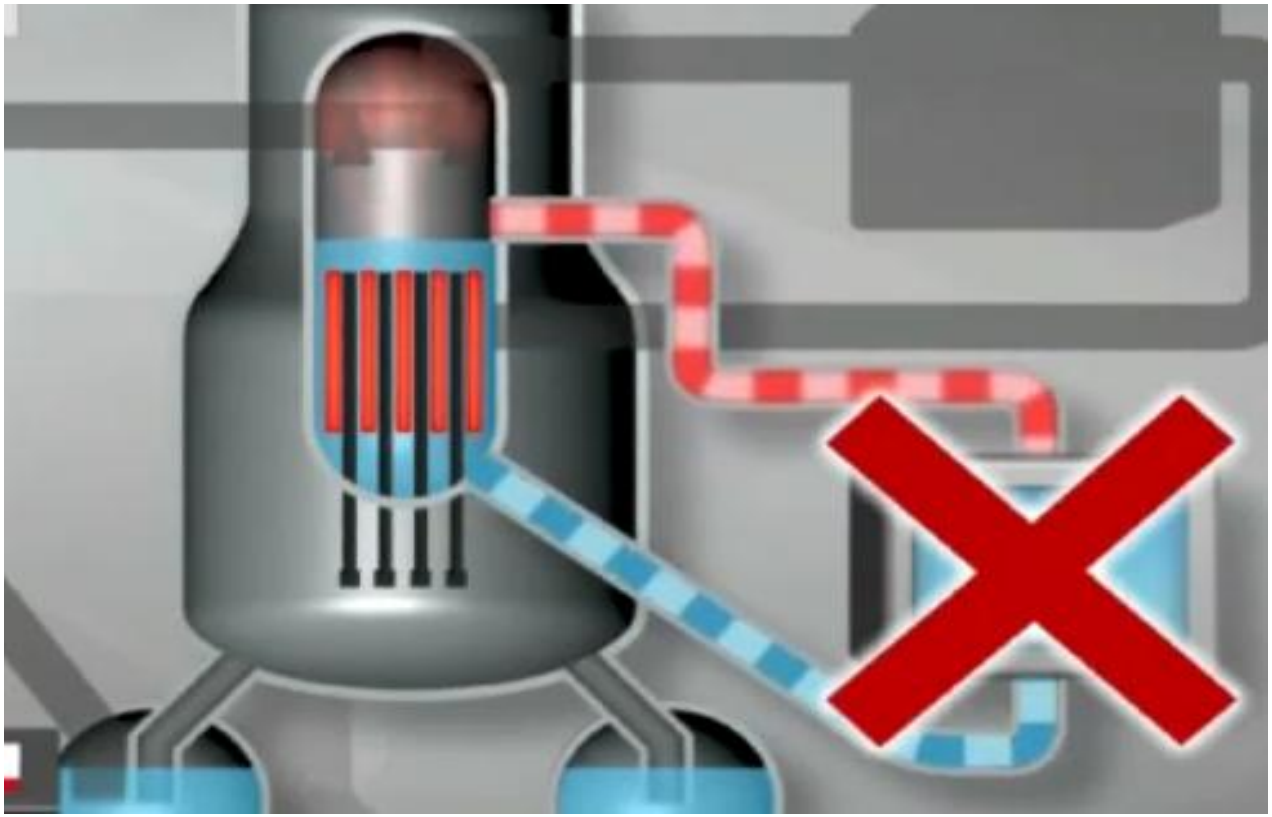


Events Leading to Nuclear Incident



1) When the earthquake hit the seismometers detected it and the nuclear reactors shut down immediately
2) Within seconds after the earthquake started, the control rods had been inserted into the core and the nuclear chain reaction stopped instantly.
3) Even though reaction was finished, residual heat began to build up in the react

Loss of Primary Cooling

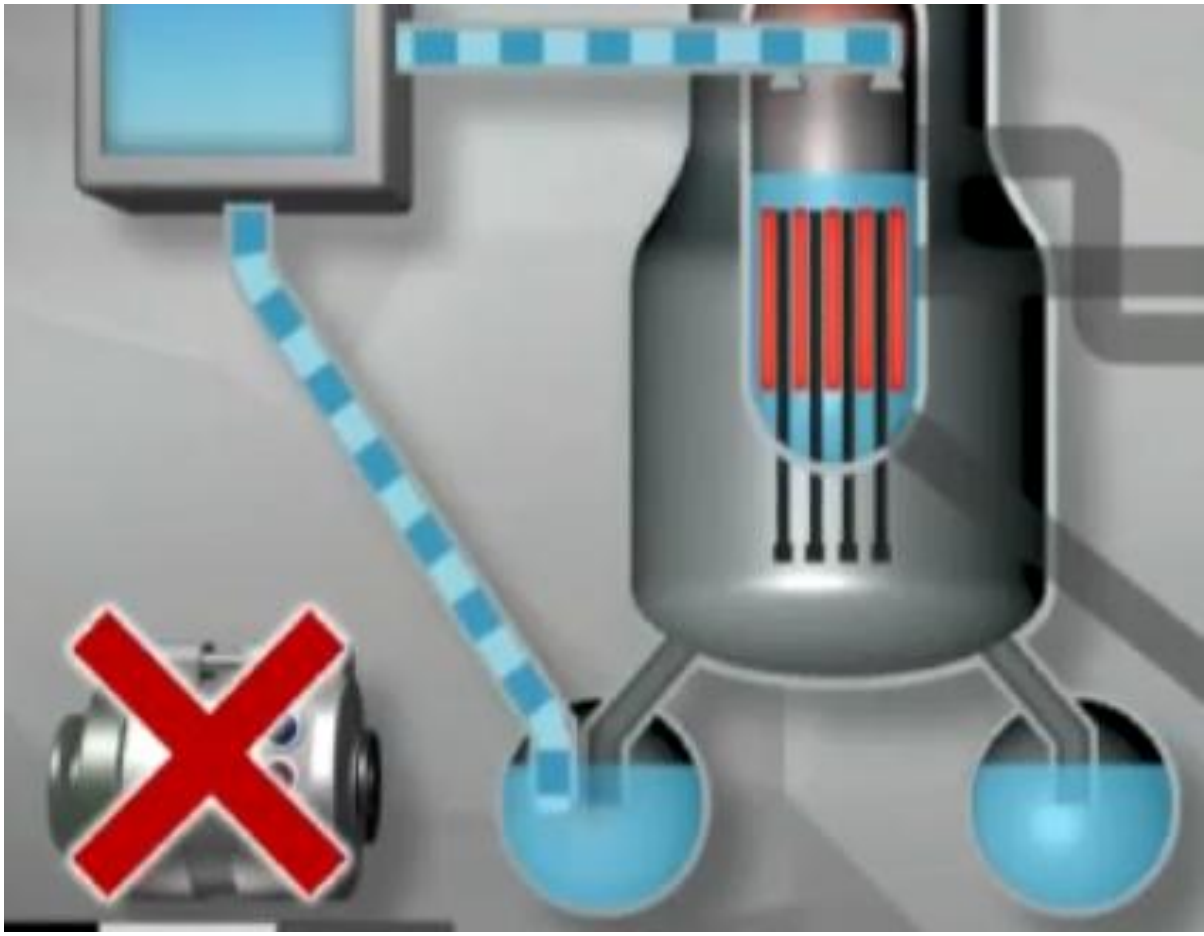


- Due to power outage, the main cooling system stopped working. Nuclear reactor uses external electricity as well as nuclear produced electricity to power the main cooling. Naturally both systems stopped after earthquake

Secondary Cooling System

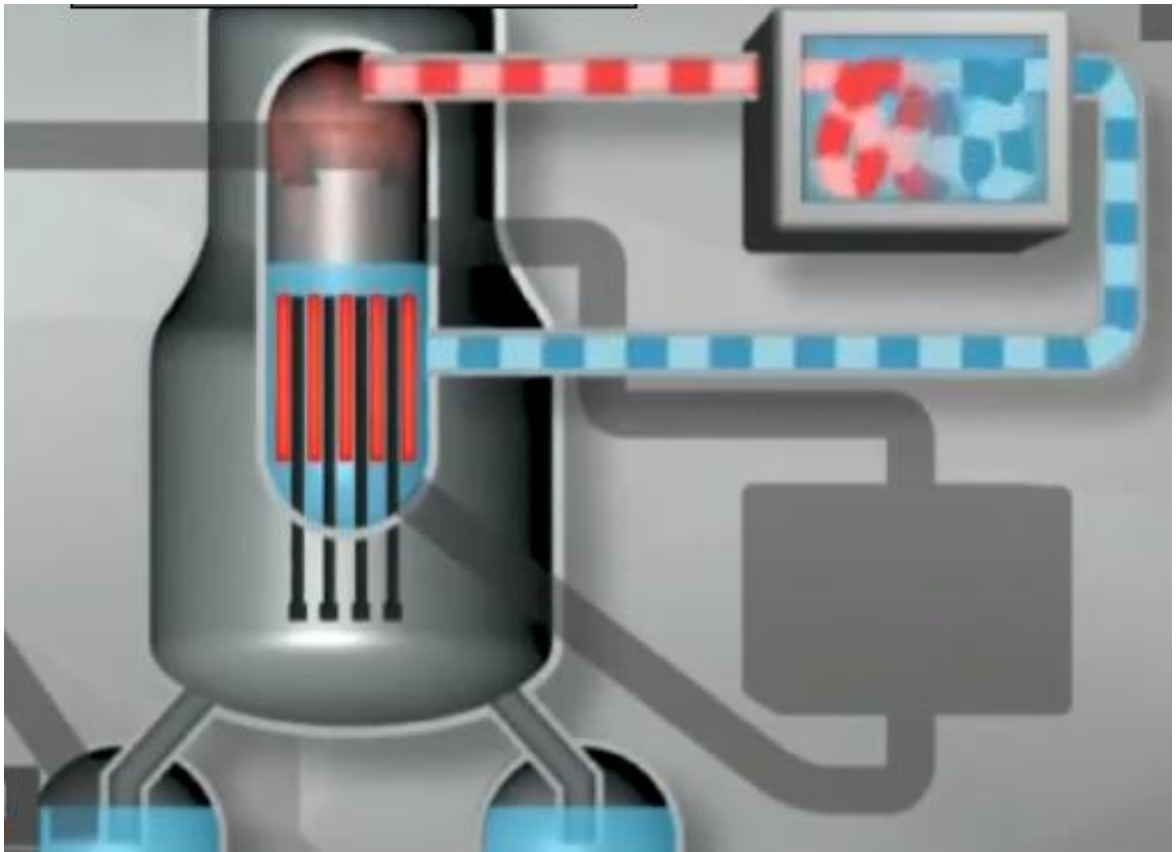
For the first hour, the first set of multiple emergency diesel power generators started and provided the electricity that was needed. The cooling process immediately lowered the temperature to manageable levels.

However, **the first set of generators also failed due to unknown reasons**.

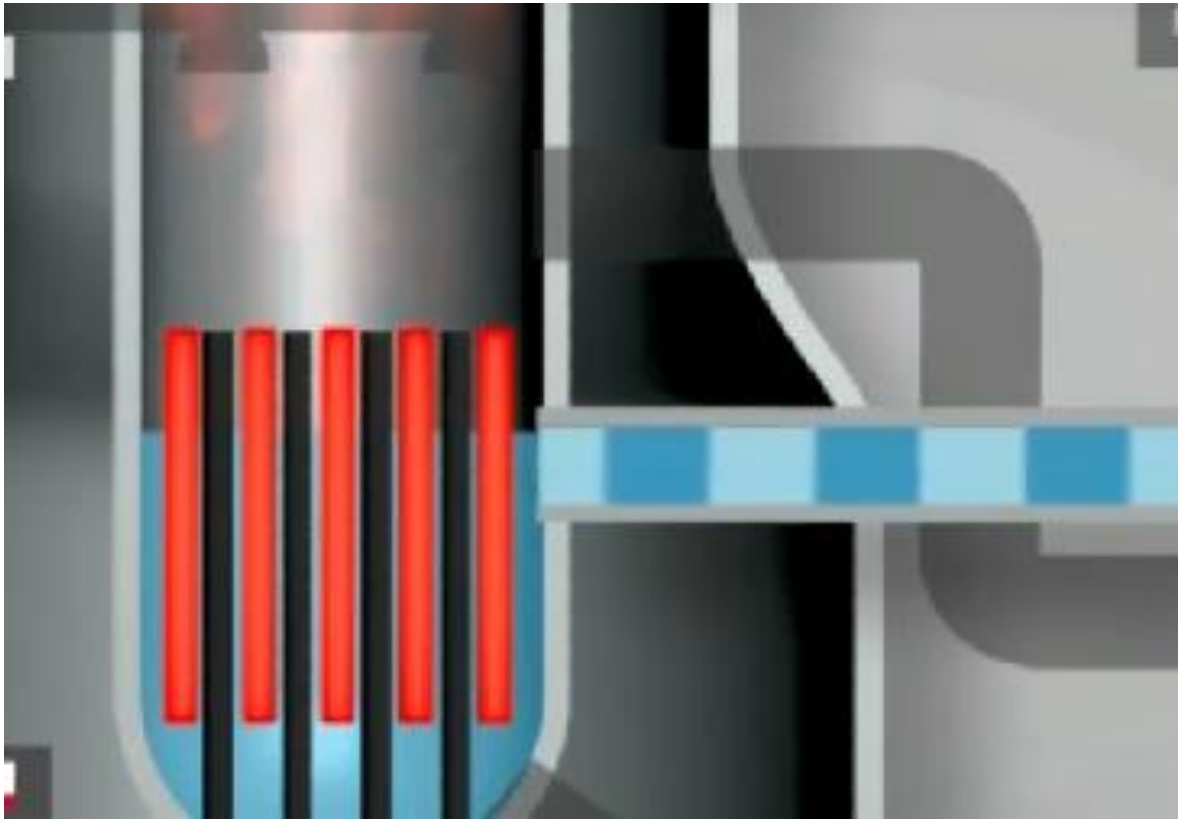


Third Cooling System

- As soon as secondary cooling system failed, third cooling system kicked in as the second set of generators started immediately to circulate water in the core



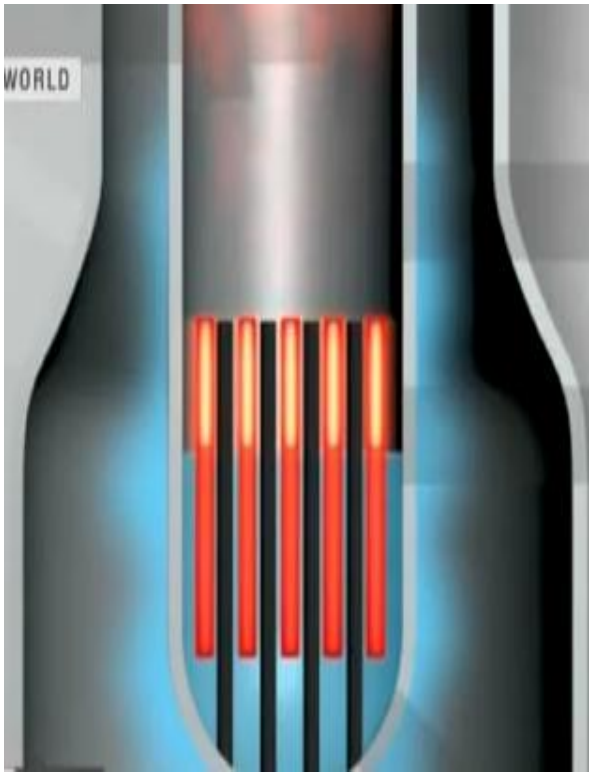
Tsunami Effect on Fukushima



- Then, the tsunami came and devastated the power plant. All of the diesel generators were under water . This caused loss of efficiency as the 3rd generators also failed and coolant was lessened in the core

Events Leading to Nuclear Incident

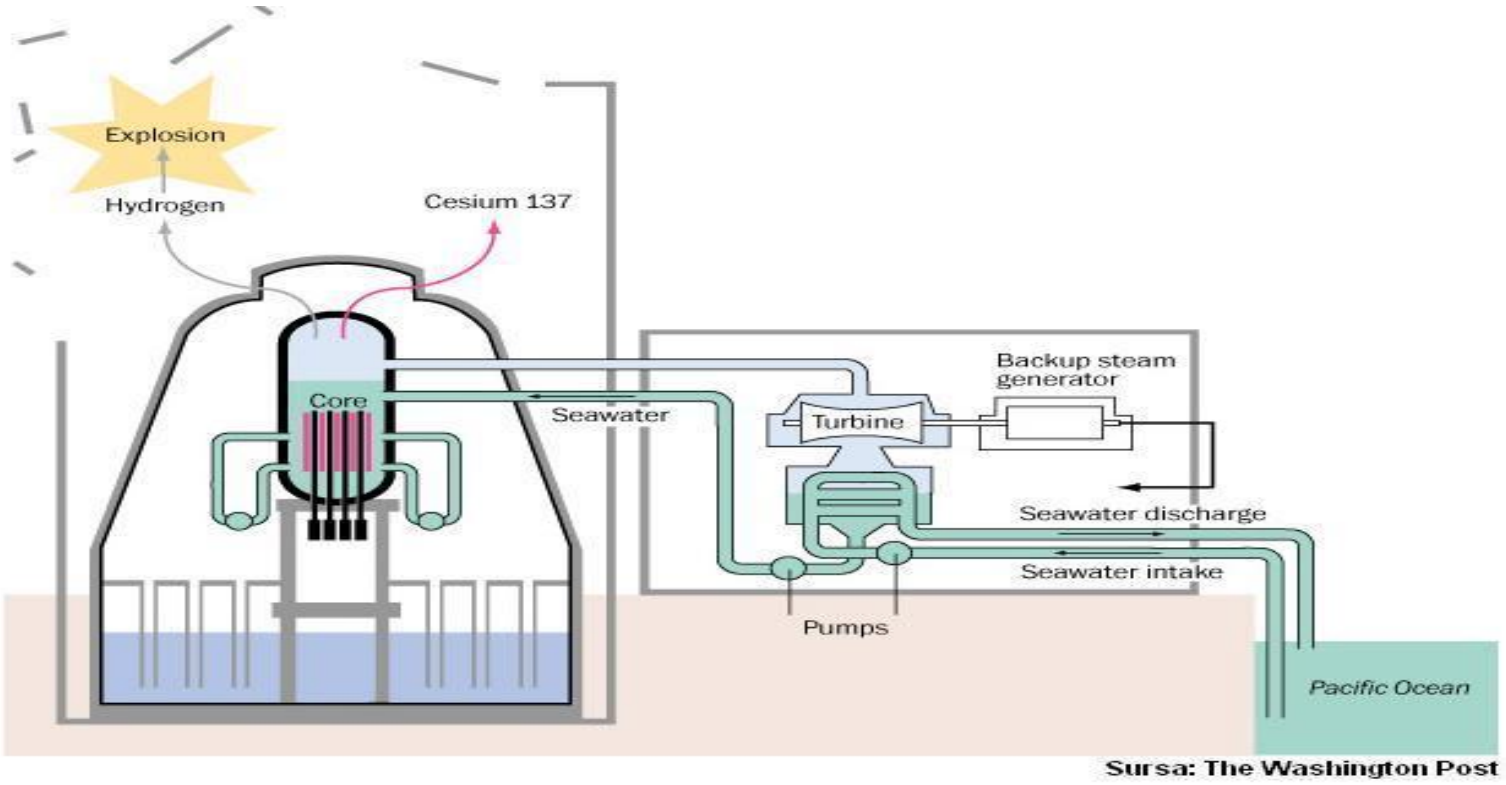
- Mobile generators were placed at the site, but total temperature exceeded 1200 C
- More water was boiling off and being vented than was being added to the reactor, thus decreasing the cooling ability of the remaining cooling systems
- The temperature of some of the fuel rod cladding exceeded 1200 °C, initiating a reaction between the Zirconium fuel rods and water which produced hydrogen gas



Explosion at Fukushima Plant

- Due to venting, some oxygen got mixed with hydrogen and this caused a hydrogen explosion which damaged the secondary containment

Radioactive Release

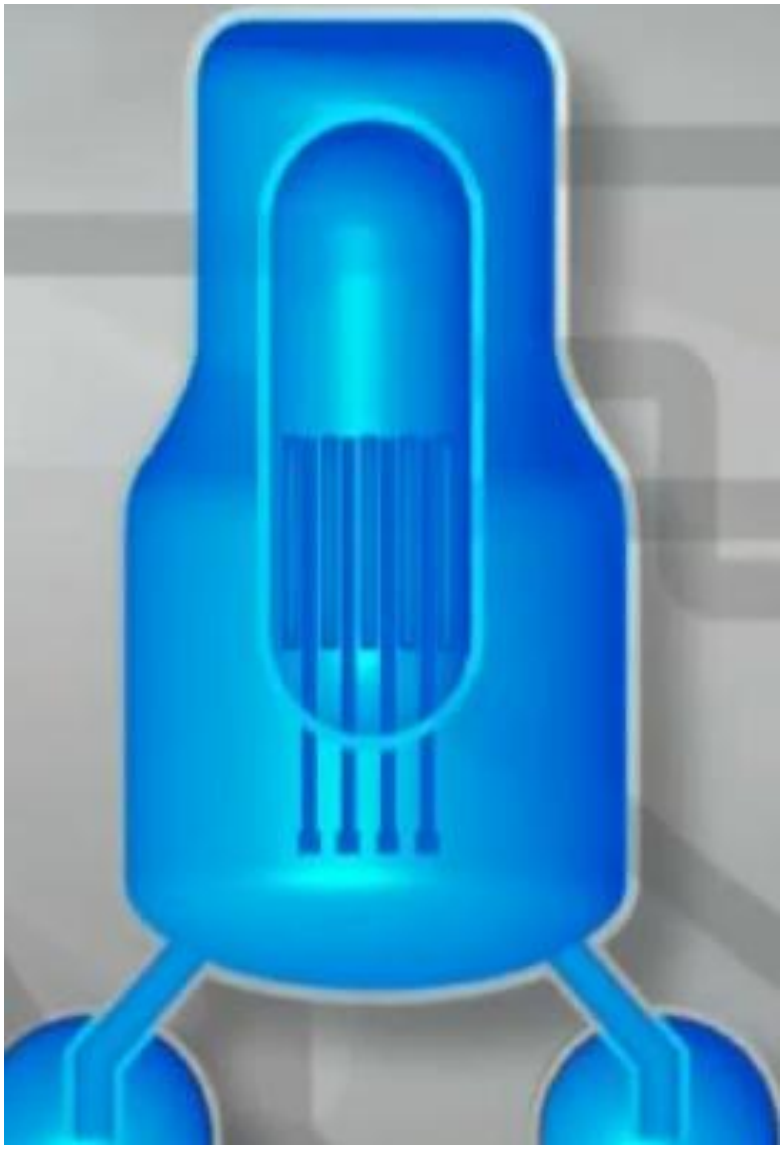


- Some of the radioactive fission products (cesium, iodine, etc.) started to mix with the water and steam, since the fuel rods were exposed to air due to loss of water in the main core.
- It was reported that a small amount of cesium and iodine was measured in the steam that was released into the atmosphere.

Sea Water Injection

- Since water inventory in the reactor was decreasing, **engineers decided to inject sea water** (mixed with boric acid – a neutron absorber) to ensure the rods remain covered with water

- Injection of the sea water helped to solve the problem as the whole system was covered with water. Also no other option was left, as all 4 cooling systems had failed



Problem with Old Reactors

- Most old reactors are based on American design of the 60's. They are high pressure water cooled reactors and most of these reactors still use analog pressure / temperature sensing systems and actuators
- None of them have advanced backup against Scale 10 catastrophes
- All of them are prone to human errors as automation is spars

Human Error is the Norm

- If you look at the three major Nuclear Incidents, you can see that there was an element of human error at each of them.
- Except for Fukushima which was a natural disaster, all of them had human error as origin
- Even Fukushima incident could have been stopped with human intervention.
- Furthermore regulations can increase safety (such as reduced moderation, limits on experiments etc)

Recommendation

- It is recommended that gravity based cooling systems with a reservoir of water on top of the reactors should be implemented with advanced nitrogen based emergency coolers. Also all analog systems should be changed to redundant digital systems
- New Generation IV reactors that uses gas cooling (helium or Carbon Dioxide) are the new design reactors. In fact, China, Korea and South Africa are investing heavily in these technologies
- Special Generation V reactors are being deployed in USA. These reactors are said to have zero chance of any incident occurring as reactivity will immediately die as the heat increases

Nuclear Energy can be Safe!!

- If properly trained personnel are used and if the old technology is updated with the new technology which has inherent passive safety systems (safety systems which doesn't require power or human intervention to work); then 100% safe and clean energy can be produced through nuclear means.

Thank You

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