The Chernobyl disaster was a nuclear accident that occurred at the Chernobyl Nuclear Power Plant in on April 26, 1986. It is considered the worst nuclear power plant disaster in history. A nuclear meltdown in one of the reactors caused a fire that sent a plume of radioactive fallout that eventually spread all over Europe.

Introduction

On April 26, 1986, a test was scheduled at the Chernobyl Nuclear Power Plant to test a method of keeping the reactors properly cooled in the event of a power grid failure. If the test had gone as planned, the risk to the plant was very small. When things did go wrong, though, the potential for disaster was miscalculated and the test was continued even as serious problems arose. Meltdown occurred at 1:23 AM, starting a fire that dispersed large quantities of radioactive materials into the atmosphere. The amount of radioactive material released was 400 times more than the amount the atomic bombing of Hiroshima released. The fallout would be detected in almost all parts of Europe.

Before the accident

Nuclear reactors require active cooling in order to remove the heat generated by radioactive decay. Even when not generating power, reactors still generate some heat, which must be removed in order to prevent damage to the reactor core. Cooling is usually accomplished through fluid flow, water in Chernobyl's case.

The problem at the Chernobyl plant was that following an emergency shutdown of all power, diesel generators were needed to run the cooling pumps. These generators took about a minute to attain full speed, which was deemed an unacceptably long time for the reactor to be without cooling. It was suggested that the rotational momentum of the winding down steam turbine be used to power the pumps in the time between shutdown and the generators being ready. A test was devised to test this method in 1982, but the turbine did not prove to be successful in providing the required voltage as it spooled down. Two more tests would be conducted in the following years, but would also be unsuccessful. The fourth test was scheduled to be run on April 25, 1986.

The experiment was devised in such a way that if it had gone as planned, the disruption and danger to the plant would be very minimal. First, the reactors would be brought down to low power, between 700 and 800 megawatts. Then the steam turbine would be run up to full speed and then turned off. The power generated by the winding down generators would then be measured to determine if it was sufficient to power the cooling pumps in the time before the diesel generators got up to full speed.

By 1986, the plant had been running for two years without the implementation of a method to keep the cooling pumps running continuously following an emergency shutdown. This was an important safety measure that the plant was lacking, which presumably gave the plant managers a considerable amount of urgency in completing another test.

The experiment
Preparing for the experiment

The experiment was scheduled to run during the day shift of 1985, while the night shift would only have to maintain cooling of the radioactive decay in the shut-down plant. However, another power generator nearby unexpectedly shut down, necessitating the need for the Chernobyl plant to delay the test and continue producing power. The experiment would be resumed at 11:04 PM, by which time the day shift had departed and the evening shift was about to leave. This meant that the experiment would be conducted in the middle of two shifts, leaving very little time for the night shift employees to be briefed about the experiment and told what to do.

The power reduction of reactor 4 to 700 MW was accomplished at 00:05 AM on the 26th of April. However, the natural production of a neutrino absorber, Xenon-135, led to a further decrease in power. When the power dropped to about 500 MW, the night shift operator committed an error and inserted the reactor control rods too far. This caused the reactor to go into a near-shutdown state, dropping power output to around 30 MW.

Since this was too low for the test, it was decided to restore power by extracting the control rods. Power would eventually rise and stabilize at around 200 MW.

The operation of the reactor at such a low power level would lead to unstable temperature and flow. Numerous alarms and warnings were recorded regarding emergency measures taken to keep the reactor stable. In the time between 0:35 and 0:45 AM, alarm signals regarding thermal-hydraulic parameters were ignored in order to preserve the reactor's power level.

The test continued, and at 1:05 AM extra water pumps were activated in order to increase the water flow. The increased coolant flow rate led to an increase of the coolant temperature in the core, reducing the safety margin. The extra water flow also led to a decrease in the core’s temperature and increased the neutron absorption rate, decreasing the reactor's power output. Operators removed the manual control rods in order to maintain power.

All these actions led to the reactor being in an unstable state that was clearly outside safe operation protocol. Almost all the control rods had been removed, which reduced the effectiveness of inserting safety rods in an emergency shutdown. The water was very close to boiling, which meant that any power increase would cause it to boil. If it started boiling, it would be less effective at absorbing neutrons, further increasing the reactor's power output.

Conducting the experiment

The experiment was started at 1:23:04 AM. The steam to the turbines was shut off, causing the turbines to start spooling down. Four of the eight cooling pumps were also shut down. The diesel generator was started and began powering the cooling pumps after at 1:23:43. Between this time, the four pumps were powered by the slowing steam turbines. As the turbines slowed down, their power output decreased, slowing the cooling pumps. This lead to increased formation of steam voids in the core, reducing the ability of the cooling water to absorb neutrons. This increased the power output of the reactor, which caused more water to boil into steam, further increasing the reactor's power. However, during this time the automatic control system was successful in limiting power increase through the insertion of control rods.

At 1:23:40, a button was pressed that initiated the emergency shutdown of the reactor and the insertion of all control rods. It is believed that this was done as a routine method to shut down the reactor to conclude the experiment and not as an
emergency measure.

The process of inserting the control rods was initiated, but it took about 20 seconds for the rods to be completely inserted. A flawed design in the graphite-tip control rod meant that coolant was displaced before the neutron absorbing material could be fully inserted and slow down the reaction. This meant that the process of inserting the control rods actually increased the reaction rate in the lower half of the core.

A massive power spike occurred, causing the core to overheat. Some of the fuel rods fractured, causing the control rods to become stuck before they were fully inserted. Within three seconds the core's power output rose to above 500 MW. According to simulation, it is estimated that power output then rose to 30 GW, ten times the normal power output. This was caused by the rising power output causing massive steam buildup, which destroyed fuel elements and ruptured their channels.

It is not possible to know precisely what sequence of events led to the destruction of the reactor. It is believed that the steam buildup entered the reactor's inner structure and lifted the 2000 ton upper plate. This steam explosion further ruptured fuel channels, resulting in more coolant turning into steam and leaving the reactor core. This loss of coolant further increased the reactor's power. A nuclear excursion (an increasing nuclear chain reaction) caused a second, even more powerful explosion.

The explosion destroyed the core and scattered its contents in the surrounding area, igniting the red-hot graphite blocks. Against safety regulations, a flammable material, bitumen, had been used in roof of the reactor. When this was ignited and scattered into the surrounding area, it started several fires on reactor 3. Those working there were not aware of the damage that had been done and continued running the reactor until it was shut down at 5:00 AM.

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**Crisis Management**

**Radiation Levels**

In the worst-hit parts of the reactor building, radiation levels were high enough to cause fatal doses in a matter of minutes. However, all dosimeters available to the workers did not have the ability to read radiation levels so high and thus read "off scale." Thus, the crew did not know exactly how much radiation they were being exposed to. It was assumed that radiation levels were much lower than they actually were, leading to the reactor crew chief to believe that the reactor was still intact. He and his crew would try to pump water into the reactor for several hours, causing most of them to receive fatal doses of radiation.

**Containment**

Fire crew were called in to protect the remaining buildings from catching fire and to extinguish the still burning reactor 4. While some firefighters were not aware of the harmful doses of radiation they were receiving and had assumed it to be a simple electrical fire, others knew that they would probably receive fatal doses of radiation. However, their heroic efforts were necessary in order to try to contain the large amounts of radiation being released into the atmosphere. The fires in the surrounding buildings were extinguished by 5:00 AM, but it would take firefighters until May 10 before they could fully extinguish reactor 4.
In order to prevent a steam explosion from occurring, volunteers were needed to swim through radioactive water and drain a pool of water under the reactor core. While they were successful, they would later succumb to the high doses of radiation that they had received.

The worst of the radioactive debris was shoveled back into the reactor by crew wearing heavy protective gear.

In total, 600,000 people worked in the cleanup, about 250,000 of which received their lifetimes' limit of radiation. It is estimated that over 10,000 eventually died from the radiation.

By December, a concrete sarcophagus had been completed that sealed off the reactor. This was never meant to be a completely permanent solution, however, and is now in danger of collapsing. A collapse could cause a large amount of radioactive material to once again be released and spread around the world. This is why it is necessary that a new structure be constructed to contain reactor 4.

Evacuation of Pripyat

Pripyat, a city nearby the power plant, was not immediately evacuated. At first, the government denied that the reactor had exploded and insisted that it was only a small accident. By April 27, though, investigators were forced to acknowledge that the reactor had exploded and ordered Pripyat to be immediately evacuated.

Effects

400 times more radiation was released by the disaster than had been by the atomic bombing of Hiroshima. The radiation would later be detected in almost all parts of Europe. Over one million people could have been adversely affected by the radiation. The radiation would cause numerous problems, including Down's Syndrome, chromosomal aberrations, mutations, leukemia, thyroid cancer, and birth defects.

The radiation would affect all parts of the environment surrounding the plant, killing plants and animals and infecting the soil and groundwater. Life has returned to the area and seems to be flourishing, possibly due to the lack of human intrusion. Remarkably, numerous species have been reported to have adapted to their environment and have developed increased tolerance of radiation, making it possible for them to live with the radiation that is still prevalent in the soil and plants around the plant. It has even been reported that radiotrophic fungi have been growing on the walls of reactor 4.

Today, radiation levels are still higher than normal in the areas surrounding the plant, but have dropped considerably from the levels that they were at twenty years ago. It is now considered safe to visit the areas immediately surrounding the plant for short periods of time. However, it is estimated that it will take 20,000 years for reactor 4's core to be completely safe.

References

Outside Links

- http://www.nucleartourist.com/events/chernobi.htm

Contributors

- Abheetinder Brar (UCD)