The chernobyl nuclear power plant and disaster history essay

The meltdown of the Chernobyl reactor in Pripyat, Ukraine was the worst nuclear power disaster of all time, and has left many areas of the Ukraine highly radioactive, increasing cancer rates and directly causing 57 deaths. The Soviet Government was dealt a strong blow by the severity of the disaster, and worldwide perceptions regarding nuclear power have been changed drastically, primarily due to the Chernobyl incident. The disaster occurred due to failures in the reactor design and poorly informed employees being rushed to complete their work. The response to the disaster was also inadequately handled, due mostly to a lack of information that was caused by a combination of a lack of foresight to have accurate radiation detection available to nearby rescue crews and the government’s unwillingness to admit to severity of the situation both to their own people and those in the international community. The events which occurred prior to, during and following the Chernobyl Nuclear Reactor Explosion are a tightly knit web of unethical decisions all of which served to intensify the severity of the disaster.

Introduction

The Chernobyl disaster was the worst nuclear power plant disaster of all time and is the only event classified as level 7 (major accident) according the International Nuclear Event Scale. Many aspects of the process of developing the facility, as well as the safety protocols that were in place, were flawed. Many of these flaws and errors came about and/or were intensified by the level of secrecy demanded by the Soviet Government, combined with the haste to develop nuclear technology brought on by the arms race with the United States. Cover-ups, poor safety protocols, and a general lack of proper distribution of information were present throughout the construction and maintenance of the facility and continued to show themselves in the manner that the disaster itself was handled.

The incident took place on April 26, 1986 at the Chernobyl Nuclear Power Facility in Pripyat, Ukraine, then part of the former Soviet Union. During the testing of a new safety procedure, the ill-informed night shift, through a series of events detailed later, lowered reactor four's power level to a hazardously low level. Because the reactor was designed with a positive void coefficient, the reactivity continued to increase as the workers increased the power level. This caused a massive steam explosion to occur and was followed by a chemical explosion that ripped the top from the reactor and exposed the core. The exposed superheated core then came in contact with the oxygen in the atmosphere, and set alight the 1700 tons of graphite moderator that was designed to absorb the radioactive particles. The ignition of the graphite led to a much greater increase in radioactive emissions through the smoke. This situation was greatly intensified by the fact that Soviet power plants were not designed with any sort of hard containment vessel to contain the radioactive particles in the case of an explosion.

Following the explosion, firefighters were dispatched to the location to put out the flames. Unfortunately, the firefighters were not informed that the reactor was exposed, and were operating under the assumption that it was a simple electrical fire. This was caused by a fatal flaw in the design of reactors three and four. Unlike the first two reactors, their control rooms were placed next to the reactor cores, and as such when the explosion occurred in reactor 4, all of reactor four's most accurate Geiger counters and equipment were no longer available. As a result these men were dispatched with improper gear, and many were diagnosed with acute radiation poisoning, most were dead in a few weeks. Many of the fires were extinguished by 5am that day, but the fires in reactor four continued to burn until the 10th of May.

Pripyat was not immediately evacuated, and in fact, the Soviet Union did not inform anyone of the danger until the next day when Swedish nuclear plant noticed higher levels of radiation, and discovered that they had originated from the Chernobyl Plant. On April 27th, the day after the explosion, the city was evacuated. Residents were told that that the reactor had sustained damages, but the evacuation would be temporary. Nothing close to the actual extent of damages was divulged to the public, and the radiation levels were strongly downplayed.

Flaws of the Reactor

One of the major reasons that this accident happened was the design of the reactor. Initial blame fell on the operators of the test, but another report was made by the International Atomic Energy Agency, or IAEA, Nuclear Safety Advisory Group (INSAG) which stated that the chief reason the accident took place was the design of the reactor was flawed. This report also stated that while the operators had been working outside the normal range of power for the reactor, it was not forbidden by regulations to do so. This refuted a previous soviet report that the chief cause of the explosion was due to human factors and did not mention the flaw in the design of the reactor. This may be due to Soviet Russia trying to place blame on the individual operators rather than take the blame of creating a reactor with flaws [1].

The reactor was cooled by boiling water, and as such, contained steam. The proportion of the bubbles in this steam is called the void fraction. Reactivity changes as the void fraction changes. The ratio of these changes is called the void coefficient. The coefficient can either be positive or negative. A positive coefficient means that an increase in steam will increase the reactivity. The reactor had a positive void coefficient due to the fact that it used graphite as a neutron moderator to facilitate nuclear reactions. Steam absorbs fewer neutrons than water and because of this; more steam means that there are more neutrons to split uranium atoms. This increases the power output and can cause sudden increases in energy production when the reactor is at lower power levels. This was a major design flaw in the reactor and a contributing factor to its eventual explosion [2].

Another design flaw was that the controls rods that were designed to absorb neutrons and decrease reactivity used in the Reaktor Bolshoy Moschnosti Kanalniy (RBMK) reactors were 1. 3 meters shorter than necessary. Additionally the lower portion of the control rod was made of graphite, which facilitates reactivity, while the upper part was made of boron carbide. Underneath the rods were channels that contained water. When the rods were inserted it displaced the coolant which created an increase in fission reactions. Therefore when the control rods are first inserted the power of the reactor is actually increased briefly before it is decreased [2].

The crew was not aware of either of these counter-intuitive behaviors of the reactor. If they had known they might not have performed some of the unsafe procedures that they did during the safety test that caused the reactor to explode.

Figure 1. RBMK 1000 reactor design [2].

A figure showing the important components of a RBMK reactor.

http://www. world-nuclear. org/images/info/chornobyl. gif

A Problem Switching to Backup Power and a Proposed Solution

The disaster at the Chernobyl Power Plant originated in an effort to test a new safety feature. The power plant was designed to enter an emergency shutdown mode upon loss of power, whereby the nuclear fission process in the reactor core would be stopped by the insertion of control rods. This process halts almost all of the heat production of the core. However, due to the radioactive products of the fission reaction, some residual heat production remains after fission has stopped. Although this only leaves a small fraction of the heat production of the core’s normal operation, it is enough that continued cooling must be maintained to prevent melting. Normally, this heat is removed by water pumped through tubes through the reactor, but if power is lost, the pumps will not work [1].

The power plant had backup diesel-powered generators, but upon power loss, the generators would take approximately a minute to start, which was enough time for core damage, and possibly disaster, to occur. For several years prior to the disaster, engineers had been trying to find a way to correct this problem; however during this time the reactor was still in use [1]. This in itself is a serious violation of engineering ethics. If something as simple as a loss of power is enough to create the possibility of a major disaster, then the problem clearly needs to be corrected before the plant is allowed to run.

It was proposed that the energy stored in the angular momentum of the steam-turbine could be used to sustain the water pumps long enough for the backup generators to attain full power [3]. This is another violation of good engineering principles. It is not a good long term plan to use a device, which has already been designed and built, to function in a way other than the way it in which it was originally designed to function. Such ad-hoc solutions are often acceptable ways of improving performance when implemented in careful, well though-out ways, but particularly in matters of safety a lack of careful planning can be disastrous. It is better to design a new feature which will handle the problem correctly.

The engineers theorized that the turbine stored enough power to maintain the pumps for about a minute, which was enough time for the diesel generators to start. However, in 1982, six years prior to the disaster, the first experimental test of this idea was conducted, and it did not confirm the validity of the idea. The magnetic field, which is necessary for the conversion of mechanical energy to electrical energy, was not maintained. After attempting to alter this system so that the magnetic field would be maintained, the test was repeated in 1984 and again failed to supply the power necessary for the pumps to run. Further modifications led to a third test in 1985, which was again unsuccessful [3]. These successive failures perhaps should have provided a warning that a much more serious examination was necessary to maintain safety, and after years of running the plant in perilous conditions, energy production should have been halted to allow for a serious solution. It was perhaps this desperation for a solution that led to the poor decision making which caused the disaster.

The Experiment and the Disaster

The engineers sought to test this turbine-momentum system again in 1986, and it was this fourth experiment which ended in disaster. The core was scheduled to undergo a routine scramming, the process whereby fission in the core is immediately halted by the insertion of control rods. The experiment was planned to begin with the plant operating at low rate of heat production, but not below 700 megawatts (MW), as safety standards prohibited operation at powers lower than this. The engineers intended to bring the steam turbines up to full speed before cutting the steam supply, at which point they would allow the turbines to run down as they observed the adequacy of the supplied power during the half-minute-long gap [1].

Because the test was planned to begin upon a routine shutdown of the reactor and was concerned only with the switching of power from the main power supply to the backup-generators, the experiment was not considered to be a nuclear safety hazard. As a result, the experiment was not planned in accord with normal safety regulations, but was instead treated with more relaxed standards. This led to the much of the reactor’s staff being underprepared. It also led to the disabling of some of the backup safety systems, such as the Emergency Core Cooling System, in an effort to hurry the test [3]. Perhaps, if the plant had not already been running in an unsafe manner for several years, which is obviously not good ethics, they would not have rushed the experiment to an extent that further violated good safety procedures. This disregard of precaution shows a disregard for the potential implications of an accident at the plant.

As according to plan, the staff began gradually decreasing the power output of the reactor starting at 1: 00 a. m. on April 25 so that the reactor would be ready for testing during the following daytime. Later that morning, however, the lowering of the reactor power had to be interrupted. At that point in time, the reactor power had been dropped about halfway from capacity, to 1600 MW. The plan had been to bring the power close to the safe lower limit of 700 MW, but another nearby power plant unexpectedly shut down, and the power from the nuclear reactor was needed to meet this unexpected demand for electricity. The power plant staff was forced to keep the reactor running at the halfway point of 1600 MW and to delay continuation of the experiment [3].

Many poor decisions were made through the course of the Chernobyl incident, but if there was a single decision that should have been made and that would have prevented the disaster, it would have been the decision to postpone the experiment after the unexpected interruption. This postponement did not happen. Many aspects of the experiment plan were not up to standard to begin with, but the experiment absolutely should have been stopped when no longer able to follow the approved plan. The decision was made to continue the experiment by improvising on the original plan without a review of the safety hazards of the proposed changes. This is not an acceptable strategy in any effort where human life is at stake, and it is particularly flagrant in the case of nuclear power where, potentially, thousands of lives are at stake.

The plant continued to run at half-power throughout the day, but at 11: 00 p. m on April 25, the reactor shutdown was allowed to resume. At this point, however, the day-shift workers had departed and had been replaced with the night-shift workers, who were not fully informed of the planned experiment and its procedures [3]. This was a symptom of the relaxed safety standards that resulted from the need for a hurried experiment.

At approximately 12: 00 a. m. on April 26, the reactor achieved the desired 700 MW thermal output. However, instead of stabilizing, the power output continued to drop to 500 MW, due to the core’s natural production of xenon, which absorbs neutrons and deters fission. Then, possibly due to an operational error, the power then dropped all the way to 30 MW, perhaps due to the accidental insertion of control rods [3]. Again, the reactor should have been allowed to fully shut down, and the experiment should have been postponed. Instead, the operators continued to push the experiment.

The buildup of xenon had caused the reactivity of the core to drop more than anticipated, and the decreasing heat output of the core caused much of the steam to condense into liquid water. Decreases in steam content led to further decreases in reactivity. This further lowered the heat output, which in turn led to more steam condensation, creating what is known as a “ negative feed-back loop”. The operators completely removed many of the control rods so that the reactor power would stabilize. They were effectively depending on the xenon poisoning and the steam condensation, both factors sensitive to changes, to maintain the level of reactivity. At about 1: 00 a. m. on April 26, the reactor’s thermal output was stabilized at 200 MW, and the operators chose to begin the experiment [3].

At 1: 23 a. m., the steam supply to the turbines was cut, as originally planned. The coolant pumps began to slow down, and as a result the coolant began to warm. As the water coolant warmed, more water began to evaporate. This increase in steam content led to a higher reactivity, due to the positive void coefficient, which in turn led to more boiling. As the reactivity increased, the residual xenon began to burn off, leading to continued boosting of the reactivity. Just as these factors had led to a negative-feedback loop during the reactor power down, they later created a " positive-feedback loop" as the reactor power increased. With the xenon levels decreasing and the water boiling once again the power output of the reactor grew quickly [3].

During the forty seconds following the steam supply being cut, the thermal output of the reactor quickly doubled and grew beyond 500 MW. At 1: 23: 40 a. m. a scram of the reactor was activated, and the control rods that had been removed began reinsertion. The full removal of the control rods had been a disastrous mistake, however. The tips of the rods were made from the fission-moderating graphite, rather than the neutron-absorbing boron carbide, which composed the bulk of the control rods. In the case where the control rods are already partially inserted, their lowering only adds neutron absorption to the reactor, as the graphite tips are already inside. In the case of this disaster, however, the graphite tips entered the core before the neutron-absorbing upper section entered. Not only did this increase the reactivity by addition of a moderator, but it also displaced neutron-absorbing water, doubly adding to the reactivity until the rods were lowered enough to compensate for the graphite tips. Unfortunately, the rods lowered at a slow speed, and the core temperature quickly skyrocketed. This effect of increasing reactivity temporarily before decreasing reactivity, known as positive scramming, was a fatal flaw in the reactor design, and the operators' ignorance of this effect is the direct cause of the disaster [3].

This plot shows the thermal power output (y-axis) of the reactor as a function of time (x-axis). Figure 2. A plot of the reactor output as a function of time [4]. C: UsersDan & MalloryDesktopcher4. jpg

Several seconds later, due to the increasing temperature and the growing steam pressure, the reactor fuel channels began to rupture. The control rods were blocked from further insertion, and the internal pressure continued to escalate. The entire series of variations in thermal power output was a long and somewhat counterintuitive sequence that led to the explosion, so the power level of the reactor as a function of time is shown in Figure 2. The precise details of the ensuing explosion are not known, but the explosion is thought to consist of an initial explosion resulting from steam pressure, followed by a second explosion several seconds later that resulted from nuclear reactions [3].

Aftermath of the Explosion

One of the main ethical problems with Chernobyl is that the Soviet Government kept it a Secret. Immediately following the explosion of reactor 4 at the Chernobyl Nuclear Plant, firefighters were sent to put out the fires. The firefighters were never informed of the possibility of nuclear radiation poisoning. As a result of this, the firefighters did not wear their radiation suits and within a few months most if not all of the firefighters died due to radiation poisoning. Some of the firefighters went on to the roof of reactor 4 in order to extinguish the main fire and received high doses of radiation and died within the next two weeks.

Furthermore, the government did not inform the international community of the disaster until the next day, when the Swedish nuclear power plant in Forsmark noticed irregularly high radiation levels, and determined the source to be originating from the Ukraine. After this the government told the townspeople that it would be a temporary evacuation which would only last about three days. This city now lies inside of the exclusion zone (30km) abandoned with peoples’ personal belongings where they left them.

Workers that were brought in to help with the clean up and sealing of the nuclear reactor after its explosion were not very well informed of the possible harmful reactions to the radiation that they could have. Due to this information, according to the World Nuclear Organization, “ Acute radiation syndrome (ARS) was originally diagnosed in 237 people on-site and involved with the clean-up and it was later confirmed in 134 cases” [3]. Two weeks later 28 of these workers had died due to ARS.

Additionally, at the Chernobyl facility the most accurate Geiger counters were within the reactor facility itself, and none were readily available to rescue crews or personnel outside of the building. This, combined with the Soviet government’s attempts to downplay the severity of the explosion, meant that rescue crews were not properly informed of the danger, specifically in regard to the levels of radiation present. By reading interviews with the rescue crews it was noticed that the fire fighters sent into the facility when initially interviewed, stated that they had knowledge that the reactor core was exposed or that there was any dangerous levels of radiation present [5], but when interviewed later stated that they had been informed of the radiation, but entered the facility regardless out of a sense of duty [6]. However, despite these later testimonies, the majority of the rescue workers arrived under the incorrect assumption that they were dealing with an electrical fire at the facility, and that the core was still protected.

To solve the problem with the radiation that was leaking from the remains of the reactor workers air-dropped sand and cement into the reactor creating a shelter-like capsule over it. This shelter was later to be called the sarcophagus. The sarcophagus did hold back some of the radiation, but it was the only thing done to hold back the radiation. The sarcophagus was a quick fix solution so that the other reactors could still be used; however it is now cracking and leaking radiation. Some work took place in the late 1990s to remove materials containing fuel which could ignite, possibly creating another explosion, and some work on the shelter itself was also performed. A new shelter funded by the Chernobyl Shelter Fund is to be finished building in late 2011 and then moved by rail into place in 2012. The plant is now closed with the work load transferred over to other plants in Eastern Europe.

Conclusion

The Chernobyl disaster was brought about through many ethical problems. One of the ethical issues starts with the design of the nuclear reactor at reactor 4. With reactor 4 being designed differently than reactors one and two, and without the same safety features, it was more prone to an accident. Additionally, its poorly designed control rods and positive void coefficient were negligently ignored. Another issue is the management at the Chernobyl nuclear plant, and the lack of information they provided to the employees charged with running the experiment. The third ethical issue involved with the Chernobyl nuclear disaster was the secrecy proliferated by the Soviet Government. With the government trying to keep the disaster a secret they put the lives of the nearby towns and all of the workers in danger. The last issue is the with the safety experiment that caused the disaster. It is possible that if the safety test had been postponed until a safer time, or the facility shut down until the proper safety features in place, the poor reactor design would never have led to the cataclysmic explosion that occurred within reactor 4. All of these factors were tied together to create a complex web of unethical behavior that led to one of the most tragic and devastating engineering disasters of all time.