8-2000

Major Industrial Accidents: The Reasons and the Reactions

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The Reasons and the Reactions

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Senior Honors Project
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August 8, 2000

Abstract

Industrial accidents occur everyday around the world, claiming countless victims whether through disability or death. However, very few of these accidents are brought to the public's attention unless the accident's effects leave the boundaries of the plant. My research centers on four industrial accidents that have occurred in the past twenty years: Three Mile Island, Bhopal, Chernobyl, and Tokaimura. The objective of my research is to classify the real causes of the accidents into one or a combination of the following categories:

- Human Error
- Engineering/Instrumentation Failure
- Management Philosophy

Further, I hope to show how the media and thus the public viewed each event. Each of the accidents to be studied plays a major role in the definition of industrial safety and in the development of public perception. When the accident at Three Mile Island occurred in 1979, the public did not understand the technology or the consequences of the "meltdown". However, through the course of two decades and several more serious accidents such as Bhopal and Chernobyl, the public learned to understand the technology at use and the devastating effects of industrial accidents. However, through this learning process the public became desensitized as can be seen with the Tokaimura radiation release that happened in September of 1999 in Japan. The results of this accident were much worse than Three Mile Island, but very few people have actually ever heard about it. Thus from this standpoint, my research focuses on comparing both the true causes and the media's perception of these accidents as well as highlighting alarming trends that are clear examples that another accident is just a mistake away.

Introduction

On September 30, 1999, an industrial accident occurred at a private nuclear facility near Tokaimura, Japan. The result of this accident was the exposure of 83 individuals to ultra high levels of radiation, and the isolation of 300,000 other people in the community. In contrast, a partial nuclear meltdown occurred on March 28, 1979 at the Three Mile Island facility in Pennsylvania. The result of this incident was the release of small levels of radiation to the surrounding community. In examining the facts above, one would say that the Tokaimura incident was a much more serious affair, but the question is raised: *Which event have you heard of?*

The sense of unfamiliarity associated with Tokaimura is a startling example of how the media, and as a result the public, have become desensitized to the news of major industrial accidents. This report will review four major industrial accidents of the last 20 years in an attempt to briefly summarize the true causes of each event and classify them into one or more of the following categories: human error, engineering/instrumentation failure, and management philosophy. Further, research has been conducted to investigate how media portrayed the accidents, including the causes, reported effects, and the overall attitude associated with the events. Since each catastrophe could be a thesis in itself, a brief overview of the facts of each case will be presented. Findings from private investigations and inquiries were used to assemble these facts presented. Further, to ensure consistency for the comparison of the actual events to the media portrayals articles where gathered from *The New York Times* for the days following each accident.

Three Mile Island (TMI)

The Accident

In the early morning of March 28, 1979, a plug developed in a resin bed used to purify process water in the plant. To alleviate the plug, an operator hooked an air line into the water line in hopes of "blowing out the plug". However, unbeknownst to the operator, the water had built up to a higher pressure than the air; thus when the connector valve was opened, water rushed through into the air line. This resulted in the water going to the pneumatic valves used for controlling the flow of cooling water to the nuclear reactor core. These valves instantaneously slammed shut, causing a phenomenon known as water hammer and the ceasing of cooling water flow to the reactor core. As a result, the core overheated and pressurized. Operations were immediately halted until assessment of the damage could be made.

It was determined that the safety systems implemented in the facility had indeed done their job. This allowed for the operations officials to begin emergency shutdown procedures. However, the damage had already been done, as 90% of the reactor core had been damaged. As a result of the pressurization of the reactor, a pressure safety valve had opened, as it was supposed to do, however, trouble began after depressurization, when the valve failed to completely close. Without knowing this malfunction, operations personnel continued their emergency shutdown procedures. During these shutdown procedures, the reactor core continued to overheat which when coupled with the fuel meltdown caused the release of hydrogen, further accelerating the "meltdown" process. The product of this meltdown was a large amount of radioactive gas being released into the containment vessel. The partially open pressure valve allowed for the release of small amounts of this radioactive gas into the environment surrounding TMI. The radioactive readings around TMI showed "<100 millirems maximum dose to the environment".

The Causes

It is obvious that there were several causes that played a role in the accident at TMI. First, a minor malfunction occurred in a resin bed, requiring action by an operator to clear the plug. This minor malfunction resulted in the operator making a judgement error by not checking the pressure in the two respective lines before trying to blow out the

plug. This human error led to the water hammer and the resulting shut off of cooling water flow to the reactor core. After the overheat and pressurization, the safety systems of the plant responded as planned until a minor valve malfunction allowed for one pressure valve to remain open during the plants emergency shutdown. This malfunction was compounded by other instrumentation malfunctions, which kept the operators from realizing that the reactor was still overheating and that radioactive gas was escaping. A primary example of these malfunctions was a thermocouple near the reactor core that measured 700°C, when the actual temperature was nearly 4300°C. The reason for the discrepancy was that the thermocouple was only rated for 700°C which was believed to be accurate enough for all situations to be encountered within the core. The lack of accurate knowledge about the reactor during the crisis is a main contributor to the release of radioactive gases to the environment. From this analysis it is clearly seen that several reasons such as human error and engineering/instrumentation failure accumulated to produce the end result.

The Media Response

News of the accident at TMI made the front page of *The New York Times* the morning after the accident, but only as a small article following the news of a peace treaty between the Arabs and the Israelis over the Sinai Peninsula. The opening paragraph of the article read "An accident... released above normal levels of radiation into the central Pennsylvania countryside...". The article went on to admit that the precise cause of the accident was unknown. However, an article embedded within section A of the paper began speculation into the causes of the accident, citing two theories. One reported cause speculated that " a series of filters did not operate properly", while the other possible cause was "the failure of a valve in a pump that helped circulate water around the reactor core". This speculation on causes would remain a stable news source for the paper for several days to come.

Two days after the accident, the paper opened with the headline "Atomic Plant Is Still Emitting Radioactivity" in conjunction with a picture of a family at play with the foreboding towers of the plant in the immediate background. The articles of that days paper surrounded several issues of the accident including the continued release of small

amounts of radiation, the slow acknowledgement time (approximately 4 hrs.) by the company before admitting that some radioactive material had been emitted, and further speculation into the causes including the presentation of a new idea that the safety systems had failed. The paper also gave the country its first glance into the technology in use at the reactor by presenting a process schematic and jargon glossary to assist readers in understanding the articles. This technical offering seemed necessary upon reviewing a statement made by a 24-year-old woman who happened to be 7 months pregnant living within the shadows of the plant. She responded with the following when questioned about the radiation and the plant, "I've never thought about it. We don't really know much about it. People don't know what radiation is. You just have to take the Government's word that it is safe". It was this sense of ignorance that pervaded throughout the country, and thus drove the articles of speculation and technical substance that appeared in *The New York Times* in the days following the meltdown.

Within three days of the accident, the articles in the paper began to shift from the immediate effects to the long-term possibilities associated with the accident. By this time, it was evident that the gravest danger had passed without incident. The articles of the day included a story on the brief evacuation of pregnant women and children, a story on the small towns surrounding TMI, and finally an article that cleared speculation that the safety systems had failed to respond. In this article, it was reported that the "network of safety equipment at the Three Mile Island nuclear generating plant had held up well despite the failure of some of its components". During the following days, attention on the accident shifted to the large-scale government investigation that ensued.

The Results of TMI

The physical result of the partial meltdown at TMI was the release of low-level radiation into the environment surrounding TMI. The measured radiation levels were only 3 millirems at a location of a third of a mile outside the plant. This number can be compared to the "standard diagnostic x-ray at 72 millirems". Still though this release of small amounts of radiation maintained for several days until the reactor could be evacuated. The national effect of TMI was an increased knowledge to the public of the technology and of the potential dangers of nuclear energy. The media reports from the

days following the accident provided individuals with a brief summary of the process and a general understanding as to what had occurred. The lasting effects of TMI included the shutdown and eventual decommission of the TMI nuclear reactors, and a ten year "nuclear cleanup and research" effort. In summary, TMI served to give America a nuclear scare and an opportunity to learn from its mistakes.

Bhopal

The Accident

During the night of December 3, 1984, a cloud of toxic methyl isocyanate gas enveloped the town of Bhopal, India, killing 3800 people and leaving 11,000 more with disabilities. The gas had escaped from a plant in which Union Carbide held a majority ownership. The chemical cause of the accident was the addition of water to a storage tank of methyl isocyanate. This resulted in an exothermic reaction and the buildup of pressure within the tank, "quickly transforming the chemical compound into a lethal gas that escaped into the cool night air". Residents of the town awoke "coughing, choking, and rubbing painfully stinging eyes". Although the chemistry behind the accident was simple, the exact cause was unknown.

The Causes

In response to the catastrophe, Union Carbide launched an intensive investigation to identify the cause. However the investigation was thwarted by the Indian government, which had seized crucial plant documents and prohibited interviews of the plant workers. The Indian government then filed suit against Union Carbide claiming the company to be liable. During the lawsuit, the Indian government was required to make the seized information public. Among the seized material were plant documents showing no alarming trends until shortly before a shift change. During the shift change, the temperature and the pressure in the storage tank had increased dramatically. This led the investigation team to the conclusion that sabotage had played a part in the disaster. Further investigation and interviews led to the discovery that plant logs and journals had been altered and that a cover up was apparent. Nearly two years passed before the exact cause was known; a disgruntled employee who was merely hoping to ruin a batch of the

methyl isocyanate product had committed the act of sabotage. The motive of his attack was poor worker relations with management, thus allowing for this accident to fall under the category of poor management philosophy. While Union Carbide owned a majority interest in the plant, they allowed their Indian counterpart to run the daily operations. This freedom resulted in a worker attitude and morale unlike an American Union Carbide plant. The worker felt he had been mistreated on several occasions and thus saw this as an opportunity to retaliate against the company.

The Media Response

On the morning following the accident, the headline of *The New York Times* read "Gas Leak in India Kills at Least 410 in City of Bhopal". The article documented the catastrophe and presented several theories about the cause of the accident. These theories centered on a valve malfunction that later proved to be completely false. The other major article related to the gas leak was the announcement by Union Carbide that it would close a similar production plant in West Virginia until after the Bhopal incident was investigated. Two days after the accident, the headline read "GAS DEATHS IN INDIA EXCEED 1,000, WITH THOUSANDS HURT". This article, accompanied by three other articles explained in detail the degree of suffering in Bhopal. They covered the reasons for blindness, irritated eyes and throats, and lung failure deaths. The articles also discussed in detail about the collection of bodies and the subsequent burials. Missing from any of these articles was further discussion about any potential causes. Instead, the articles focused on the human aspects of the story and the gruesome details.

The Results of Bhopal

Upon completion of the Union Carbide investigations nearly three years after the release, it was clearly evident that employee sabotage was indeed the primary cause. The facts were so transparent that even the Indian government settled for $470 million in damages instead of the $3 billion for which they had originally sued. The lessons learned through Bhopal were that companies must work together to foster a productive environment. After the investigations, facts were released which showed that very little worker training was conducted in the plant and that worker morale was low. These facts astonished the management of Union Carbide because they were under the impression

that there superior worker relations were the groundwork for which their Indian counterparts were building. Instead, Union Carbide, along with other major American companies, learned a valuable lesson about the importance of implementing successful strategy and worker relations throughout all the aspects of their organizations. Bhopal serves as the starting point for research on the importance of personnel training and worker relations.

Chernobyl

The Accident

During the night of April 25 and early morning of April 26, 1986, the world's worst nuclear power accident occurred at Chernobyl in the USSR. The exact physical causes of the accident are not well known except that during routine maintenance and testing, several safety procedures were disregarded. This resulted in an uncontrollable chain reaction within the reactor core. At 1:23 a.m., the chain reaction caused several explosions and a fireball that blew off the reactor's "heavy steel and concrete lid". As a result of the accident, 30 people died instantly within the plant and 135,000 people within a 20-mile radius had to be evacuated. Due to the massive devastation of the Chernobyl accident, exact numbers of people affected are hard to gather; instead only estimates can be made:

- "estimated 20 million Soviets exposed to radioactivity"
- "number of deaths as high as 5,000"
- "the accident may yet cause up to 300,000 deaths"
- "the Chernobyl accident may ultimately claim more victims than did World War II"

The Causes

Although very little detail of the accident has ever been made public, it is known that the control of the chain reaction was lost during routine maintenance and testing. Several international investigations have been conducted on the Chernobyl incident; the outcome of these inquiries point to a deficient "safety culture" within the nuclear facility.

Further, the reports indicate that "the accident can be said to have flowed from a deficient safety culture, not only at the Chernobyl plant, but throughout the Soviet design, operating and regulatory organizations for nuclear power that existed at the time". This lack of a safety culture shows that management philosophy was the real root cause of the accident. Other findings upon investigation of the accident point show that "there were important admissions of management errors, as distinct from operator errors". This shows that it was more than an actual human error that caused the disaster, instead it was the overall safety atmosphere and attitude that led to the catastrophe.

The Media Response

The initial reports of the radiation release did not surface until two days after the accident when Scandinavian countries started reporting rising radioactive levels. It was at this point when the Soviet Union admitted that a nuclear accident had indeed occurred. Since very little was known about the accident, this very informal announcement was the only news to reach the American public in the three days following the accident.

On the fourth morning after the accident, news of the devastation and speculated amounts of radioactive release finally started surfacing. *The New York Times* had several stories related to the disaster covering its front page. These stories ranged from a reported two deaths inside the plant, even though the actual number was 30, to a story on United States intelligence sources which knew the accident and meltdown had begun days earlier. An interesting detail about the coverage of the Chernobyl incident was the tone of the articles. First, several articles condemned the Soviets initial silence on the days immediately following the accident, with one headline reading, "Moscow's Silence on Disaster Assailed in Europe". Several other articles had a negative tone when reporting on the technical aspects of the nuclear meltdown. *The New York Times*, in a manner similar to the Three Mile Island event, presented several articles and process schematics as a general overview of the Soviet nuclear facility. However, the paper highlighted several aspects of the Soviet process that were different and assumed inferior to the American facilities. Unlike the Bhopal tragedy, the media had very little coverage on the possible human casualties, mostly due to the limited knowledge about the level of radioactive release. Instead over the course of several days the paper continued to report

on the world's negative response to the Soviets' unwillingness to release more information.

The Results of Chernobyl

As highlighted earlier, the main cause of the Chernobyl accident was the lack of a "safety culture" at the plant. Major investigations into the accident proved that safety was never a "real issue" at the facility. Chernobyl serves as the world's second reminder that nuclear accidents are real and can be very dangerous. Numerous safety research efforts spawned from the disaster at Chernobyl. This research led to the following findings, "The root causes of most safety significant events were found to be deficiencies in: plant organization and management, the feedback of operational experience, training and qualification, quality assurance in the maintenance and procedures, and the scope of the corrective actions." The completeness of this statement hints that very few of the important aspects needed for safety at a nuclear facility were followed at Chernobyl. The facts and figures generated as results of Chernobyl are countless, but the real result of Chernobyl was the immediate global recognition to the potential dangers of nuclear power when not managed correctly.

Tokaimura

The Accident

On the morning of September 30, 1999, workers at a private nuclear facility in Tokaimura, Japan added 35 pounds of uranium into a purification tank containing nitric acid. Unfortunately the batch only required 5.2 pounds of uranium thus a nuclear fission chain reaction resulted. Reports from the accident record 83 people as being exposed to radiation, with the most severe being three workers who were exposed to 700,000 millirems at the time of the reaction. Further 300,000 individuals in the surrounding areas were ordered to stay indoors following the accident. Although none of the workers died at the scene, it is expected that several will die from complications associated with exposure to high levels of radiation.

The Causes

The physical cause of this uncontrollable chain reaction is simple to understand, workers added too much uranium to the batch. However, it is the motive behind their actions that makes this case intriguing. After the accident, investigations were undertaken by the Japanese government to study the causes. During these investigations, it was discovered that the company used an "illegal manual", which advocated the use of shortcut methods. The shortcuts "recommended the use of stainless steel buckets to move and mix the uranium manually instead of utilizing complex machines that were specifically designed for such tasks". This makes this accident the clear result of a poor management philosophy. The investigations discovered that safety was a small concern to the company as compared to profits. The following quote from the head of the nuclear fuel processing plant illustrates the low concern for safety, "the company trains new employees on safety for one week but teaches nothing about the dangers of a self-sustaining nuclear reaction".

The Media Response

The morning after the Japanese accident, the headline of *The New York Times* read, "Japanese Fuel Plant Spews Radiation After Accident". This article gave very specific details of the accident including a map of Tokaimura showing the plants location in relation to the residencies. Further, the paper presented a chart showing the radiation levels measured in the region surrounding the plant for a 5-hour period after the accident. Another article in that day's edition gave an overview about how uranium is processed and the dangers that are associated with the task. Finally, the last article present in that day's edition was one about the possible casualties and potential affects that the Japanese people could expect. Two days after the accident, the only mention of the accident was a small article announcing that investigations by the Japanese government would begin immediately.

The Results of Tokaimura

Since this accident happened less than a year ago, the lasting results are not yet known. However, what this accident has produced are questions about the future of nuclear power. It has been well documented that management shortcuts were to blame for the chain reaction and the resulting radiation release. So the question is asked, "Why did

management allow and even encourage unsafe practices?" The answer is very simple. Japan is a country with no oil reserves and nuclear power accounts for 37% of its energy needs. Thus, management was trying to increase profits by the use of their "shortcut manual". This fact is illustrated by the following statement from an interview following the investigations, "Before the accident, supervisor(s) and, possibly, manager(s) directed personnel to accelerate [the nuclear fuel] processing further. Apparently, workers were directed to use the buckets, overbatch [processing two "orders" for nuclear fuel into one process in order to save time and increase profits], and possibly, skip other steps." It is a statement like this that makes one wonder about the pressures capitalism can put upon such a dangerous process.

Conclusions

By evaluation of the four major industrial accidents of the last 20 years, Three Mile Island, Bhopal, Chernobyl, and Tokaimura, it is evident that several factors play a part in every disaster. However, the predominant factor is that of a poor management philosophy. This is a surprise since many people consider an industrial accident to be due to a human error or an instrumentation failure. Instead it has been seen that the major tragedies have been because of issues such as poor worker relations, lax safety standards, and irrational motivation for profits. In reviewing each of the four cases, it was seen that by far, the most technical failures occurred at Three Mile Island, however it should be noted that their safety systems were also the best equipped to deal with the situation. Bhopal was the story of a tragedy due to a worker's disgruntlement with his employers. Chernobyl was the result of a lax safety environment which resulted in "routine maintenance" resulting in the greatest industrial accident in history. Finally, Tokaimura was the product of misguided management, where workers were encouraged to cut corners and accelerate the process in hopes of increasing the profits of the organization.

Following each accident, several investigations were conducted in hopes of explaining the tragedy. Comparison of the facts to the media response for each event was very enlightening. In an attempt to be consistent, *The New York Times* was used as a representation of the media. Before the research was begun, it was hypothesized that the

media reports would be mostly erroneous and very non-technical in nature. It was also believed that these reports would improve dramatically over time, as people desired to understand the events in the world around them. Upon conclusion of this research, it has been seen that the early media coverage of TMI was more technical than expected, however it still was laced with false speculation as to the causes behind the radiation release. This trend of technical journalism seemed to continue through Bhopal and Chernobyl as both accidents were reported with fairly strong technical detail. This trend reached an apex after the Tokaimura accident when the following day's paper came out with descriptions of the process, a diagram of uranium fuel processing and specific details about measured radiation levels across the city. The speed with which this information was available was very impressive considering that in the other cases, similar information (i.e. process diagrams) took several days to get in print. Over time, it was also seen that the media coverage tended to speculate less on the actual causes of each event. After TMI and Bhopal, the articles had several possible reasons, but after Chernobyl and Tokaimura, the paper seemed to report the known facts obtained through government press releases instead of "jumping to conclusions".

The only surprising trend seen throughout the articles of the two decades was the amount of coverage. Coverage about TMI consumed the front-page for several days, as did Bhopal and Chernobyl. This amount of coverage is expected considering the severity and possible ramifications of each. However, Tokaimura did not receive the same attention even though in truth it was a more serious accident than TMI. In comparison, TMI was a partial nuclear meltdown in which <100 millirems of radiation was released, while Tokaimura was an uncontrolled reaction in which 700,000 millirems of radiation were released! Further, TMI resulted in zero casualties with the only physical results being several cases of psychological stress, while Tokaimura exposed 83 people to high levels of radiation and confined 300,000 more individuals to their homes. It is easily seen that in true results, Tokaimura was a much larger accident than TMI. Thus the question arises, "Why have we heard of TMI and not Tokaimura?" The answers to this question are quite simple. First, TMI was an American nuclear accident and Tokaimura was not. Secondly, TMI was the first major nuclear scare and Tokaimura was not. Thirdly, TMI

happened at a time in which the general public did not understand that technology at use, while Tokaimura occurred after the public stopped caring any more. Basically the differences in the exposure of the two events to the general public lies with the general public themselves. During the days following TMI, Bhopal and Chernobyl, the public wanted information and details about the accidents. During the days following Tokaimura, people wanted to know if the Mets were going to advance in the playoffs. It is this difference in public desires that separates these events. Knowing this fact now raises several questions such as,

- When did people become desensitized?
- How severe must a disaster be to get the public eye?
- Is this lack of public concern a reason why poor management philosophy is still the leading cause of these major accidents?

These questions and more are beyond the scope of this research, but the analysis of these events has shown that peoples thoughts, actions, and intentions play a more important role in accidents and disasters than does technology failures.

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UNIVERSITY HONORS PROGRAM

SENIOR PROJECT - APPROVAL

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I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

Signed: _____, Faculty Mentor

Date: 6/8/00

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