Laura:
Welcome to "Did History Actually Teach Us Anything?"
The podcast where we unravel the most well-known tales of calamity, mishap, and unforeseen consequences that have shaped the course of history. And consider whether we've actually learned anything from them all these years later..
In this podcast, we examine the historical events that you may think you know about already and the causes that led to them, be they icebergs or bakers ovens.
We will consider whether these tragedies could have been avoided, and some of the surprising things we do differently now as a result.
But this podcast, isn't just about dates and events. It's about learning from the past, drawing insights from hindsight, and gaining a deeper appreciation for the complexities of what really happened in these events we think we know so well. So get ready to encounter remarkable individuals, pivotal moments and fascinating insights that will make you appreciate health and safety and environmental management as far more than just red tape.
In this episode, we travel back to March 28th, 1979, where the tranquility of the Susquehanna River was shattered by the partial nuclear meltdown at the Three Mile Island nuclear generating station in Pennsylvania, marking the darkest chapter in U. S. commercial nuclear power plant history.
Join us as we delve into the chilling details of the Three Mile Island accident, exploring its impact on the local community and enduring legacy it left on the nation's nuclear industry.
To begin, Kevin, our health and safety expert, will set the scene of the worst accident in U. S. commercial nuclear power plant history.

Kevin Coley:
Imagine, if you will, a scenario where you're driving an unfamiliar hire car along a four lane highway, in fast flowing traffic, miles away from an exit. Then, suddenly, one, then another, and then yet another warning light starts to flash on the dashboard. One of them you have never seen before.
What does it mean? Is it a fault with the vehicle? Or was it something you did that started the chain of events? You cannot stop, but you don't know if it is safe to continue. How would you feel? To make things worse, not only are warning lights flashing, but now there are alarms sounding as well. What is happening?
What should you do? Something? Nothing? Hope everything sorts itself out or hope that the nearest exit appears soon? You must keep your eyes on the road ahead and around you, so reaching into the glovebox for the user manual is not an option and you're alone in the vehicle. You try pressing a few of the buttons on the dashboard, challenging a few of the settings in the hope that something works.
But the layout of the dashboard and the menu options are unfamiliar. So you now have more warning lights flashing and alarms sounding. Your nerves are jangling and you are struggling to think straight now.
Finally, in the distance, you can see the first signs for an exit ahead, but something is causing traffic in front of you to slow down, and you're worried you won't reach the exit before something dreadful happens.
Eventually, the traffic blockage ahead clears, and you can safely reach the exit, find somewhere safe to stop, and turn off the engine and relax. It sounds like a plot from an action movie, doesn't it?
And in one sense, you would be quite right, but it is also the basic plot for a real life drama that we're going to look at in detail in this podcast. Only this time, the stakes were much higher, and the faulty equipment much bigger.
Three Mile Island is a nuclear power plant consisting of two reactors, each capable of generating more than 800 megawatts of electricity, and which is located on an island in the Susquehanna River three miles from Harrisburg Airport in Pennsylvania, USA. The nuclear plant is named after the island on which it is located.
As the plant was large and would be generating a large quantity of electricity , it needed to be sited close to a reliable source of cooling water.
This would be used to remove excess heat left over after massive quantities of steam pass through the turbines. Locating it on an island in a river was an ideal solution. The area around the proposed site was also very sparsely populated. A census carried out in 1980 identified over 35, 000 people living within five miles of the plant and just under 2, 000 people within two miles of the plant.
There were no schools or major industries located near the plant but, within 5 miles of the plant were 100

summer cabins, located on the other islands in the river. Construction on the plant began in 1968 and ended in 1978 when the second reactor came online to produce electricity.
The first reactor came into service in 1974. A nuclear reactor splits atoms of radioactive elements, known as fission, to release heat energy. The heat energy is used to generate steam, which then drives turbines to produce electricity.

Laura:
So Kevin, can you talk us through the timeline of the disaster?

Kevin Coley:
4 a. m. on the 28th of March.
Reactor 2 was operating at 97 percent power when there was a minor malfunction in the secondary cooling circuit which caused the temperature in the primary cooling circuit to rise. This in turn caused the automatic shutdown of the reactor, which took around one second. Within seconds of the shutdown, a pilot operated relief valve on the reactor cooling system opened as it was supposed to. About 10 seconds later, the relief valve should have shut again, but it didn't.
This wasn't revered by the instrumentation panel, which didn't have an instrument to indicate the valve's actual position, merely that a closed signal had been sent. The open relief valve, allowed most of the primary coolant to drain away. As a result of the loss of cooling water, high pressure injection pumps automatically push replacement water into the reactor. Water and steam escape through the open relief valve into the pressurizer tank, raising its water level.
Operators then reacted by reducing the flow of replacement water as they had been trained to do, because they feared that the pressuriser might rupture if it was completely full.
Steam began to form in the primary cooling system. which caused the pumps to vibrate. Due to concerns that this would have damaged the pumps, the operators turned off the pumps.
But this stopped the force cooling of the reactor core. This meant that the residual decay heat in the reactor was not dampened. In fact, the core became even hotter and the fuel rods were damaged and released radioactive material into the cooling water.
6.22am on the 28th of March.
Operators closed a block valve between the relief valve and the pressuriser. which stopped the loss of coolant water through the relief valve. However, superheated steam and gases which had already built up in the system blocked the flow of water through the core cooling system. Throughout the morning, the operators continued to try forcing more water into the reactor system to condense steam bubbles and so clear the flow of cooling water.
The afternoon of the 28th of March
During the afternoon, operators attempted to decrease pressure in the reactor system to allow emergency water supplies to be put in. By late in the afternoon, they had completely changed their approach and had decided to start high pressure water injections into the cooling system to collapse the steam bubbles.
7.50pm on the 28th of March. The steam had been condensed and operators were able to restart one coolant pump without severe vibrations.
Radioactive gases from the cooling system had built up in the make up tank in the auxiliary building, which had to be moved using a system of pipes and compressors into waste gas decant tanks. However, the compressors leaked and some of the gases were released into the environment. Fortunately, the use of high efficiency particulate air filters removed most of the radioactive material, and what was released had a short half life and was biologically inert. So, it didn't pose a health hazard.
The morning of 29th March. The reactor's core was uncovered, which led to the discovery of a high temperature chemical reaction between water and the zircaloy metal tubes holding the nuclear fuel pellets that had created the hydrogen gas. During the afternoon of that day, a sudden rise in reactor building pressure, shown by the control panel instruments, indicated that a hydrogen burn had occurred.
Hydrogen gas had also gathered at the top of the reactor vessel.
Between the 30th of March and the 1st of April,
Operators worked to remove the hydrogen gas bubble by periodically opening the vent valve on the reactor cooling system pressuriser. For a while, Nuclear Regulatory Commission officials believed that the hydrogen bubble could explode. However, an explosion of this kind is subsequently found to be impossible due to a lack of oxygen in the system.

27th of April
After an anxious month, operators established natural convection circulation of coolant. This meant that the reactor core was being cooled by the natural movement of water rather than by mechanical pumping and the plant was said to be in cold shutdown. That is with the water at less than 100 degrees celsius at atmospheric pressure.

Laura:
So could the outcome of the accident have been any different?

Kevin Coley:
Although the Three Mile Island incident was the worst nuclear incident in US history, it had a death and injury toll of zero. More importantly, radiation exposure to the public was slight, and the short half life of the radioactive xenon gas released on the first day had quickly dissipated into the atmosphere. The concrete containment dome around the reactor prevented a catastrophe, such as Chernobyl from happening.
This all means that the outcome of the incident on the public was minimized. Because of the concerns of radiation induced health effects on the public, Pennsylvania Department of Health maintained a registry of more than 30, 000 people living near the plant for over 18 years. This was discontinued in mid 1997 without any evidence of unusual health trends within the population monitored.
The damage to the nuclear reactor, TMI 2, was also not as severe as had previously been expected. Although the clean up took almost 12 years and cost over 900 million dollars the clean up program was named by the Society of Professional Engineers as one of the top engineering achievements in the USA in 1990.
Today, TMI 2 is in long term monitored storage. At the time of the TMI 2 incident, TMI 1 was shut for refueling, so it was kept shut down during the NRC investigation, during which period it was modified and training and operating procedures revamped, considering lessons learned from TMI 2. TMI 1 was restarted in 1985 and it continued to operate without incident until it was finally shut down in 2017.

Laura:
What was the China Syndrome and what was its lasting impact on the USA?

Kevin Coley:
The film, The China Syndrome, was released nationwide in America on the 16th of March 1979, 12 days before the Three Mile Island incident. The premise of the film was a nuclear plant meltdown, which was kept secret from the public, and the concern that the meltdown could tunnel its way through the crust of the earth into China The idea is debunked in the film because the meltdown would generate steam when encountering groundwater, which would then create an explosion releasing radiation into the air.
So the products could never make it through the earth to China.
However the timing of its release in proximity to the Three Mile Island incident made the film an instant blockbuster and made the public extremely wary about the inherent risks of nuclear energy. Some people even wondered if the reported incident at Three Mile Island was real or if it was only a publicity stunt to promote the film.
The film has several villains: the contractors who built the plant and who may have cut corners to cut costs, and the utility company who were more interested in profits and unwilling to hold the contractors accountable. And the audience were left to wonder whose fault the meltdown was.
Although the incident at Three Mile Island only started at 4am on the 28th of March by 8: 25am, it was being reported on WKBO well before the operators in the reactor control room even knew what was happening. This meant that the public were told about a general emergency at the plant without any real sense of how dangerous the situation was.
This only fuelled the existing public paranoia about the safety of nuclear power plants. The New York Daily News selected reporters to send to Three Mile Island specifically because they had seen the China Syndrome.
They were frustrated by the lack of information provided by the plant operators, at a time when they knew little anyway, so the reporters immediately assumed that there was a cover up, just like in the film. This only further fuelled public concerns that they were living through a China Syndrome event. The

Pennsylvania Governor ordered children and pregnant women to be evacuated to safety. But this caused an additional 100, 000 people to leave, all of whom wanted to withdraw funds from local banks.
This resulted in the Federal Reserve having to send armoured trucks filled with cash to meet withdrawal demands. Unfortunately, Associated Press then reported the possible danger of a hydrogen gas explosion inside the containment dome. And the NRC was insisting that many more hundreds of thousands of people needed to be evacuated. Although the incident was very real and serious, it is impossible to tell how much impact it had on the public's anti nuclear feeling because of the China Syndrome film.
It is certain that either or both caused the rise in the anti nuclear power movement and the decline in the usage of nuclear power in America.

Laura:
Did human mistakes impact the outcome of the Three Mile Island incident?

Kevin Coley:
A study was carried out by the U. S. Nuclear Regulatory Commission after the incident, with the report published in January 1980, to evaluate the degree to which operator errors were caused by human factors. In particular, control room design operator training and emergency procedures. Its conclusion was that the human factor errors experienced during the incident were not due to operator deficiencies at all, but inadequate equipment design, information presentation, emergency procedures and training.
Its key findings in respect of human factors were:
Information required by operators was either non existent, poorly located, unclear or difficult to read.
There were almost 2, 000 displays located on the vertical panels, of which over 500 could not easily be seen by someone standing at the front of the panels.
Labelling of controls and displays was inadequate or unclear, and operators had to make changes to around 800 of the provided labels to aid use.
Human engineering planning at TMI2 was virtually non existent.
Procedures were deficient in content and format.
Training in emergency procedures was deficient.
Based on the findings of the report, it's easy to deduce that an incident was inevitable at some time. The incident was already widely attributed to a combination of mechanical failure and operator confusion. In fact, the emergency core cooling system should have prevented any damage occurring to the reactor if the operators hadn't intervened.
The design of the controls in the control room meant that the operators were confused about what was going on. So they made incorrect decisions at key stages during the incident. There were analog details and these can be read differently depending on where in the control room you are standing. The control room was the product of a bottom up engineering approach.
As the designers had assumed that several critical operational states were impossible, many of the displays required to deal with those impossible states were not even included in the control room design. In fact, the control room was designed for normal operation, which made it unable to provide operation critical information during the incident, when it was needed most. This was particularly an issue when the incident occurred. None of the controls indicated that the pilot operated relief valve had failed to close. So staff were unaware that coolant was being lost. As the large pressure vessel holding the core was always filled to the top with water during normal operation, it was felt that there was no need to have a water level indicator. For TMI, the belief in the water level never being lower than full meant that the operators were unaware that the water level had dropped and that the core wasn't properly covered. Instead of having integrated displays indicating the overall safety of the plant, the control room boards had thousands of displays and alarms, each showing the detailed states of separate components. During the incident, the operators were left to put together a picture of what was happening by comparing several displays in random locations across the 900 square feet of control boards.
To visualize this, imagine 150 people standing shoulder to shoulder, or the parking space for five parked cars and a motorbike. When the alarm sounded, and there were more than 200 of them sounding at once, they couldn't be overridden. So the operators were left to struggle to concentrate in an extremely noisy environment. The operators may also have been aware of the China Syndrome and panicked about the possible results of an incident in the reactor.

This may well have influenced their ability to think calmly through the options and follow the emergency procedures logically.

Laura:
Well, is there any way that the incident could have been avoided?

Kevin Coley:
The incident at Three Mile Island was caused by design errors, component failure, and a series of errors of judgment in turn caused by inadequate training and emergency procedures. Had the right training and emergency procedures been put into place when the plant was designed, then the outcome of the incident could have been completely different. ,
It's difficult to know if it could have been completely avoided, as the chain of events was originally started by component failure. This is the only reported incident at Three Mile Island. And the negligible effects measured on the population located within 5 miles of the plant indicates that safety and containment measures built into the plant were more than adequate to ensure their health and safety.
However, with the confusing and unhelpful control room layout, and the lack of experience the operators had in handling emergency situations, they made many wrong decisions about how to deal with the problems arising during the incident.
This led to at least 45 percent of the core in the TMI 2 reactor being melted and rendering it unusable. Approximately 100 tons of damaged uranium fuel had to be removed from the reactor without creating risk to the clean up crew or the public.

Laura:
So what lessons did we learn from the incident in 1979? And how has that impacted modern nuclear power plant control room design?

Kevin Coley:
Investigations carried out after the incident led to a new focus on human factors in nuclear safety. Its aftermath caused sweeping changes in emergency response planning, operator training, human factors engineering, radiation protection and many other areas of nuclear power plant operations.
The Nuclear Regulatory Commission also tightened and enhanced its regulatory oversight. Plant design and equipment requirements have been upgraded and strengthened, including fire protection, piping systems, auxiliary feedwater systems, containment building isolation, reliability of individual components, and the ability of plants to automatically shut down.
Training has become centred around protecting a plant's cooling capacity, whatever the triggering problems. It now uses a symptom based approach underlined by giving operators a foundation of understanding both theoretical and practical aspects of the plant operations.
Communication and teamwork among new crew members has become part of TMI's training curriculum, half of which is carried out in a full scale electronic simulator of the TMI Control Room. This cost 18 million dollars and allows operators to be trained and tested in all kinds of scenarios. As a result of the incident, the Institute of Nuclear Power Operations and its National Academy for Nuclear Training were established in Atlanta.
They have been effective in promoting excellence in the operation of nuclear plants and accrediting their training programs. The Institute of Nuclear Power Operations members comprise of all U. S. utility companies with nuclear power plants in operation or under construction. Its aim is to enhance safety through peer review plant evaluation programs and to disseminate lessons learned from any reported events to members.
Many investigations were carried out on the Three Mile Island incident in subsequent years and it continues to inform human factors based control room design. Modern control room design teams are multidisciplinary, including human factors researchers, work study specialists, psychologists and designers. However, this change happens slowly as innovative technologies change the interface between human operators and automated systems.
The impact of Three Mile Island on the US nuclear power industry has been to virtually kill it off. Strong opposition made nuclear power plants too expensive to build and most of the nuclear power plants

that were scuttled were replaced by coal or other fossil fuel burning plants. This has had a far reaching impact for climate change. In comparison, France now generates 75 percent of its electricity from 18 nuclear plants and has a much smaller carbon footprint than the rest of Europe, with cleaner air and no serious nuclear incidents.
This is achieved by uniformity and simplicity in reactor design.
This was explained by the NRC chairperson in the 1990s in an amusing way: in France, there are 365 kinds of cheese and one kind of reactor; in the United States, it’s the opposite.

Laura:
Thanks for joining us on this episode of "Did History Actually Teach Us Anything?".
If you enjoyed this episode, please follow our social media channels, leave us a rating and review, and share our podcast with anyone who wants to learn more about the risky side of history.
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