http://en.wikipedia.org/wiki/Three_Mile_Island_accident

Three Mile Island accident

The **Three Mile Island accident** was a partial core meltdown in Unit 2 (a pressurized water reactor manufactured by Babcock & Wilcox) of the Three Mile Island Nuclear Generating Station in Dauphin County, Pennsylvania near Harrisburg, United States in 1979.

The power plant was owned and operated by General Public Utilities and the Metropolitan Edison Co. It was the most significant accident in the history of the USA commercial nuclear power generating industry, resulting in the release of up to 481 PBq (13 million curies) of radioactive gases, and less than 740 GBq (20 curies) of the particularly dangerous iodine-131.[1]

The accident began at 4 a.m. on Wednesday, March 28, 1979, with failures in the non-nuclear secondary system, 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. The scope and complexity of the accident became clear over the course of five days, as employees of Metropolitan Edison (Met Ed, the utility operating the plant), Pennsylvania state officials, and members of the U.S. Nuclear Regulatory Commission (NRC) tried to understand the problem, communicate the situation to the press and local community, decide whether the accident required an emergency evacuation, and ultimately end the crisis.

In the end, the reactor was brought under control, although full details of the accident were not discovered until much later, following extensive investigations by both a presidential commission and the NRC. The Kemeny Commission Report concluded that "there will either be no case of cancer or the number of cases will be so small that it will never be possible to detect them. The same conclusion applies to the other possible health effects".[2] Several epidemiological studies in the years since the accident have supported the conclusion that radiation releases from the accident had no perceptible effect on cancer incidence in residents near the plant, though these findings have been contested by one team of researchers.[3]

Public reaction to the event was probably influenced by *The China Syndrome*, a movie which had recently been released and which depicts an accident at a nuclear reactor.[4] Communications from officials during the initial phases of the accident were felt to be confusing.[5] The accident crystallized anti-nuclear safety concerns among activists and the general public, resulted in new regulations for the nuclear industry, and has been cited as a contributor to the decline of new reactor construction that was already underway in the 1970s.

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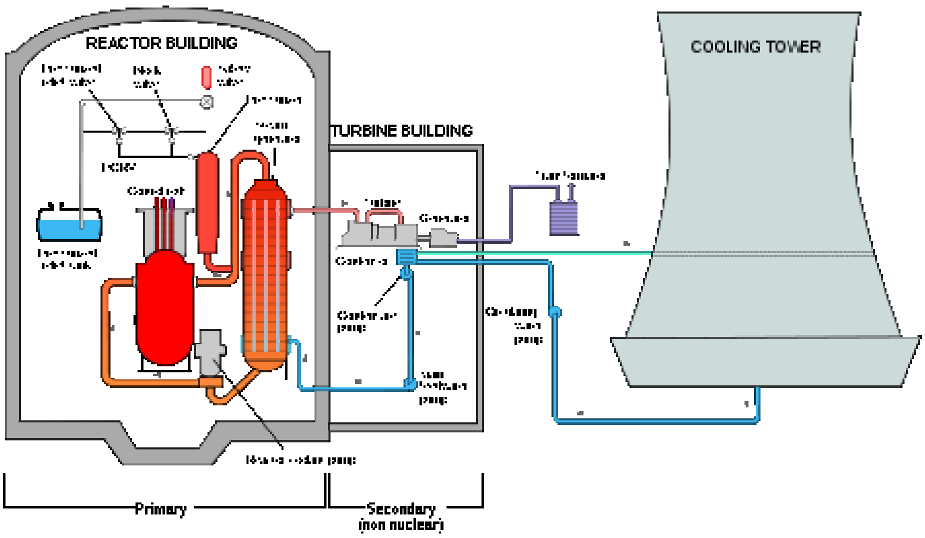
[edit] Accident

[edit] Stuck valve



Simplified Schematic Diagram of the TMI-2 plant.[6]

In the nighttime hours preceding the incident, the TMI-2 reactor was running at 97% of full power, while the companion TMI-1 reactor was shut down for refueling.[7] The chain of events leading to the partial core meltdown began at 4 a.m. EST on March 28, 1979, in TMI-2's secondary loop, one of the three main water/steam loops in a pressurized water reactor.

Workers were cleaning a blockage in one of the eight condensate polishers (sophisticated filters cleaning the secondary loop water), when, for reasons still unknown, the pumps to the polishers stopped running. When a polisher bypass valve did not trip, the polisher water stopped flowing to the secondary's main feedwater pumps, which also shut down. When the steam generators stopped receiving water, this triggered the turbine to shut down and the reactor to scram: control rods were inserted into the core to control the rate of fission. All this happened in eight seconds. But the reactor continued to generate decay heat, and because steam was no longer being used by the turbine, the steam generators no longer removed that heat from the reactor's primary water loop.[8]

Once the secondary feedwater pumps stopped, three auxiliary pumps activated automatically. However, because the valves had been closed for routine maintenance, the system was unable to pump any water. The closure of these valves was a violation of a key NRC rule, according to which the reactor must be shut down if all auxiliary feed pumps are closed for maintenance. This failure was later singled out by NRC officials as a key one, without which the course of events would have been very different.[9]

Due to the loss of heat removal from the primary loop and the failure of the auxiliary system to activate, the primary loop pressure began to increase, triggering the pilot-operated relief valve (PORV) at the top of the pressurizer (a pressure active-regulator tank) to open automatically. The relief valve should have closed again when the excess pressure had been released, and electric power to the solenoid of the pilot was automatically cut, but the relief valve stuck open due to a mechanical fault. The open valve permitted coolant water to escape from the primary system, and was the principal mechanical cause of the true coolant-loss meltdown crisis that followed.[10]

[edit] Human factors – confusion over valve status

Critical human factors problems were revealed in the investigation about the user interface engineering of the reactor control system's user interface. A lamp in the control room, designed to illuminate when electric power was applied to the solenoid that operated the pilot valve of the PORV, went out, as intended, when the power was removed. This was incorrectly interpreted by the operators as meaning that the main relief valve was closed, when in reality it only indicated that power had been removed from the solenoid, not the feedback of the actual position of the pilot valve or the main relief valve. Because this indicator was not designed to unambiguously indicate the actual position of the main relief valve, the operators did not correctly diagnose the problem for several hours.[11]

The design of the PORV indicator light was fundamentally flawed, because it implied that the PORV was shut when it went dark. When everything was operating correctly this was true, and the operators became habituated to rely on it. However, when things went wrong and the main relief valve stuck open, the dark lamp was actually misleading the operators by implying that the valve was shut. This caused the operators considerable confusion, because the pressure, temperature and levels in the primary circuit, so far as they could observe them via their instruments, were not behaving as they would have done if the PORV was shut — which they were convinced it was. This confusion contributed to the severity of the accident: because the operators were unable to break out of a cycle of assumptions which conflicted with what their instruments were telling them. It was not until a fresh shift came in who did not have the mind-set of the first set of operators that the problem was correctly diagnosed. But by then, major damage had been done.

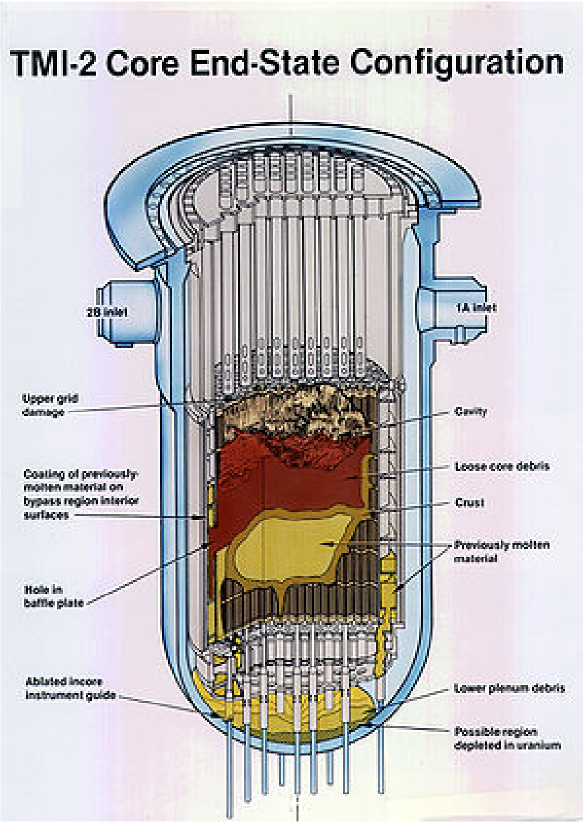
The operators had not been trained to understand the ambiguous nature of the PORV indicator and look for alternative confirmation that the main relief valve was closed. There was a temperature indicator downstream of the PORV in the tail pipe between the PORV and the pressurizer that could have told them the valve was stuck open, by showing that the temperature in the tail pipe remained high after the PORV should have, and was assumed to have, shut, but this temperature indicator was not part of the "safety grade" suite of indicators designed to be used after an incident, and the operators had not been trained to use it. Its location on the back of the desk also meant that it was effectively out of sight of the operators.[*citation needed*]

[edit] Consequences of stuck valve

As the pressure in the primary system continued to decrease, reactor coolant continued to flow, but it was boiling inside the core. First, small bubbles of steam formed and immediately collapsed, known as nucleate boiling. As the system pressure decreased further, steam pockets began to form in the reactor coolant. This departure from nucleate boiling caused steam voids in coolant channels, blocking the flow of liquid coolant and greatly increasing the fuel plate temperature. The steam voids also took up more volume than liquid water, causing the pressurizer water level to rise even though coolant was being lost through the open PORV. Because of the lack of a dedicated instrument to measure the level of water in the core, operators judged the level of water in the core solely by the level in the pressurizer. Since it was high, they assumed that the core was properly covered with coolant, unaware that because of steam forming in the reactor vessel, the indicator provided false readings.[12] This was a key contributor to the initial failure to recognize the accident as a loss-of-coolant accident, and led operators to turn off the emergency core cooling pumps, which had automatically started after the PORV stuck and core coolant loss began, due to fears the system was being overfilled.[13]

With the PORV still open, the quench tank that collected the discharge from the PORV overfilled, causing the containment building sump to fill and sound an alarm at 4:11 a.m. This alarm, along with higher than normal temperatures on the PORV discharge line and unusually high containment building temperatures and pressures, were clear indications that there was an ongoing loss-of-coolant accident, but these indications were initially ignored by operators.[14] At 4:15, the quench tank relief diaphragm ruptured, and radioactive coolant began to leak out into the general containment building. This radioactive coolant was pumped from the containment building sump to an auxiliary building, outside the main containment, until the sump pumps were stopped at 4:39 a.m.[15]

After almost 80 minutes of slow temperature rise, the primary loop's four main pumps began to cavitate as a steam bubble/water mixture, rather than water, passed through them. The pumps were shut down, and it was believed that natural circulation would continue the water movement. Steam in the system prevented flow through the core, and as the water stopped circulating it was converted to steam in increasing amounts. About 130 minutes after the first malfunction, the top of the reactor core was exposed and the intense heat caused a reaction to occur between the steam forming in the reactor core and the Zircaloy nuclear fuel rod cladding, yielding zirconium dioxide, hydrogen, and additional heat. This fiery reaction burned off the nuclear fuel rod cladding, the hot plume of reacting steam and zirconium damaged the fuel pellets which released more radioactivity to the reactor coolant and produced hydrogen gas that is believed to have caused a small explosion in the containment building later that afternoon.[16]



NRC Image of Graphic TMI-2 Core End-State Configuration.

At 6 a.m., there was a shift change in the control room. A new arrival noticed that the temperature in the PORV tail pipe and the holding tanks was excessive and used a backup valve — called a block valve — to shut off the coolant venting via the PORV, but around 32,000 US gal (120,000 L) of coolant had already leaked from the primary loop.[17] It was not until 165 minutes after the start of the problem that radiation alarms activated as contaminated water reached detectors; by that time, the radiation levels in the primary coolant water were around 300 times expected levels, and the plant was seriously contaminated.

[edit] Emergency declared

At 6:56 a.m., a plant supervisor declared a site emergency, and less than half an hour later station manager Gary Miller announced a general emergency, defined as having the "potential for serious radiological consequences" to the general public.[18] Metropolitan Edison notified the Pennsylvania Emergency Management Agency (PEMA), which in turn contacted state and local agencies, governor Richard L. Thornburgh and lieutenant governor William Scranton III, to whom Thornburgh assigned responsibility for collecting and reporting on information about the accident.[19] The uncertainty of operators at the plant was reflected in fragmentary, ambiguous, or contradictory statements made by Met Ed to government agencies and to the press, particularly about the possibility and severity of off-site radiation releases. Scranton held a press conference in which he was reassuring, yet confusing, about this possibility, stating that though there had been a "small release of radiation,... no increase in normal radiation levels" had been detected. These were contradicted by another official, and by statements from Met Ed, who both claimed that no radiation had been released.[20] In fact, readings from instruments at the plant and off-site detectors had detected radiation releases, albeit at levels that were unlikely to threaten public health as long as they were temporary, and providing that containment of the then highly contaminated reactor was maintained.[21]

Angry that Met Ed had not informed them before conducting a steam venting from the plant and convinced that the company was downplaying the severity of the accident, state officials turned to the NRC.[22] After receiving word of the accident from Met Ed, the NRC had activated its emergency response headquarters in Bethesda, Maryland and sent staff members to Three Mile Island. NRC chairman Joseph Hendrie and commissioner Victor Gilinsky[23] initially viewed the accident, in the words of NRC historian Samuel Walker, as a "cause for concern but not alarm".[24] Gilinsky briefed reporters and members of Congress on the situation and informed White House staff, and at 10 a.m. met with two other commissioners. However, the NRC faced the same problems in obtaining accurate information as the state, and was further hampered by being organizationally ill-prepared to deal with emergencies, as it lacked a clear command structure and the authority to tell the utility what to do, or to order an evacuation of the local area.[25]

In a 2009 article, Gilinsky wrote that it took five weeks to learn that "the reactor operators had measured fuel temperatures near the melting point".[26] He further wrote: "We didn't learn for years—until the reactor vessel was physically opened—that by the time the plant operator called the NRC at about 8 a.m., roughly one-half of the uranium fuel had already melted."[26]

It was still not clear to the control room staff that the primary loop water levels were low and that over half the core was exposed. A group of workers took manual readings from the thermocouples and obtained a sample of primary loop water. Seven hours into the emergency, new water was pumped into the primary loop and the backup relief valve was opened to reduce pressure so that the loop could be filled with water. After 16 hours, the primary loop pumps were turned on once again, and the core temperature began to fall. A large part of the core had melted, and the system was still dangerously radioactive.

On the third day following the accident, a hydrogen bubble was discovered in the dome of the pressure vessel, and became the focus of concern. A hydrogen explosion might not only breach the pressure vessel, but, depending on its magnitude, might compromise the integrity of the containment vessel leading to large scale release of radiation. However, it was determined that there was no oxygen present in the pressure vessel, a prerequisite for hydrogen to burn or explode. Immediate steps were taken to reduce the hydrogen bubble, and by the following day it was significantly smaller. Over the next week, steam and hydrogen were removed from the reactor using a catalytic recombiner and, controversially, by venting straight to the atmosphere.

Radioactive material release

Once the first line of containment is breached during a reactor plant accident, there is a possibility that the fuel or the fission products held inside can be released into the environment. Although the zirconium fuel cladding has been breached in other nuclear reactors without generating a release to the environment, **at TMI-2 operators permitted fission products to leave the other containment barriers.**[*citation needed*] **This occured when the cladding was damaged while**

the PORV was still stuck open. Fission products were released into the reactor coolant. Since **the PORV was stuck open** and **the loss of coolant accident was still in progress**, **primary coolant with fission products and/or fuel was released**, and **ultimately ended up in the auxiliary building**. **This auxiliary building was outside the containment boundary.** This was evidenced by the **radiation alarms** that eventually sounded. However, since very little of the fission products released were solids at room temperature**, very little radiological contamination was reported in the environment. No significant level of radiation was attributed to the TMI-2 accident outside of the TMI-2 facility.**

Noble gases made up the bulk of the release of radioactive materials from TMI-2, with the next most abundant element being iodine.

Within hours of the accident the United States Environmental Protection Agency (EPA) began daily sampling of the environment at the three stations closest to the plant. By April 1, continuous monitoring at 11 stations was established and was expanded to 31 stations two days later. **An inter-agency analysis concluded that the accident did not raise radioactivity far enough above background levels to cause even one additional cancer death among the people in the area. The EPA found no contamination in water, soil, sediment or plant samples**.[27]

Researchers at nearby Dickinson College, which had radiation monitoring equipment sensitive enough to detect Chinese atmospheric atomic weapons testing, collected soil samples from the area for the ensuing two weeks and **detected** no **elevated levels of radioactivity**, except **after rainfalls** (likely due to natural radon plate out, not the accident).[28] Also, **white-tailed deer tongues harvested over 50 mi (80 km) from the reactor subsequent to the accident were found to have significantly higher levels of Cs-137 than in deer in the counties immediately surrounding the power plant.** Even then, **the elevated levels** were still below those **seen in deer in other parts of the country during the height of atmospheric weapons testing**.[29] Had there been elevated releases of radioactivity, increased levels of **Iodine-131 and Cesium-137** would have been expected to be detected **in cattle and goat's milk** samples. Yet elevated levels were not found.[30]

A later scientific study noted that the **official emission figures** were consistent with available dosimeter data,[31] though **others have noted the incompleteness of this data, particularly for releases early on**.[32]

According to **the official figures, as compiled by the 1979 Kemeny Commission** from Metropolitan Edison and NRC data, a maximum of 480 petabecquerels (13 million curies) of **radioactive noble gases (primarily xenon) were released** by the event.[1] However, these noble gases were considered **relatively** harmless,[33] and only 481–629 GBq (13–17 curies) **of thyroid cancer-causing iodine-131** were **released**.[1] Total releases according to these figures were a relatively small proportion of the estimated 37 EBq (10 billion curies) in the reactor.[33] **It was later found that about half the core had melted, and the cladding around 90% of the fuel rods had failed**,[6][34] with **five feet of the core gone**, and **around 20 tons of uranium flowing to the bottom head of the pressure vessel**, forming a mass of corium.[35] **The reactor vessel, the second level**

of containment after the cladding, maintained integrity and contained the damaged fuel with nearly all of the radioactive isotopes in the core.[36]

Anti-nuclear political groups disputed the Kemeny Commission's findings, claiming that **independent measurements provided evidence of radiation levels up to five times higher than normal in locations hundreds of miles downwind from TMI**.[37] **According to Randall Thompson, a health physics technician employed to monitor radioactive emissions at TMI after the accident, radiation releases were hundreds if not thousands of times higher**.[33][38] **Some other insiders, including Arnie Gundersen, a former nuclear industry executive who is now an expert witness in nuclear safety issues,[39][40] make the same claim**; Gundersen offers evidence, based on pressure monitoring data, for **a hydrogen explosion shortly before 2 p.m. on March 28, 1979, which** would have **provided the means for a high dose of radiation to occur**.[33] **Gundersen cites affidavits from four reactor operators according to which the plant manager was aware of a dramatic pressure spike, after which the internal pressure dropped to outside pressure. Gundersen also notes that the control room shook and doors were blown off hinges.** However **official NRC reports refer merely to a "hydrogen burn."** [33] The Kemeny Commission referred to "a burn or an explosion that caused pressure to increase by 28 pounds per square inch in the containment building".[41] *The Washington Post* reported that "At about 2 p.m., with pressure almost down to the point where the huge cooling pumps could be brought into play, a small hydrogen explosion jolted the reactor."[42]

Aftermath

Voluntary evacuation

Twenty-eight hours after the accident began William Scranton III, the lieutenant governor appeared at a news briefing to say that **Metropolitan Edison, the plant's owner assured the state that "everything is under control".[43], had Later that day, Scranton changed his statement**, saying that **the situation was "more complex than the company first led us to believe**".[43] There were **conflicting statements** about radiation releases.[44] **Schools were closed and residents were urged to stay indoors.** Farmers were told to keep their animals under cover and on stored feed.[43][44]

Governor Dick Thornburgh, **on the advice of NRC Chairman** Joseph Hendrie, **advised the evacuation "of pregnant women and pre-school age children ... within a five-mile radius of the Three Mile Island facility."** Within days, 140,000 people had left the area.[6][43][45]

Post-TMI surveys have shown that **less than 50% of the American public were satisfied with the way the accident was handled by Pennsylvania State officials and the NRC**, and people surveyed were even less pleased with the utility (General Public Utilities) and the plant designer.[46]

Investigations

Several state and federal government agencies mounted investigations into the crisis, the most prominent of which was the President's Commission on the Accident at Three Mile Island, created by Jimmy Carter in April 1979.[47] The commission consisted of a panel of twelve people, specifically chosen for their lack of strong pro- or anti-nuclear views, and headed by chairman John G. Kemeny, president of Dartmouth College. It was instructed to produce a final report within six months, and after public hearings, depositions, and document collection, released a completed study on October 31, 1979.[48] The investigation strongly criticized Babcock and Wilcox, Met Ed, GPU, and the NRC for lapses in quality assurance and maintenance, inadequate operator training, lack of communication of important safety information, poor management, and complacency, but avoided drawing conclusions about the future of the nuclear industry.[49] The heaviest criticism from the Kemeny Commission concluded that "fundamental changes were necessary in the organization, procedures, practices 'and above all – in the attitudes' of the NRC [and the nuclear industry.]"[50] Kemeny said that the actions taken by the operators were "inappropriate" but that the workers "were operating under procedures that they were required to follow, and our review and study of those indicates that the procedures were inadequate" and that the control room "was greatly inadequate for managing an accident."[51]

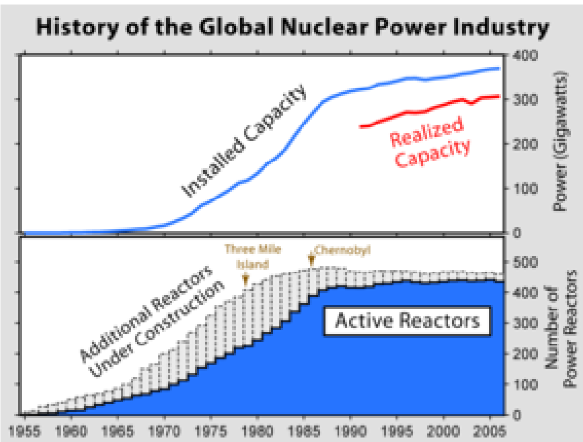
The Kemeny Commission noted that Babcock and Wilcox's PORV valve had previously failed on 11 occasions, nine of them in the open position, allowing coolant to escape. More disturbing, however, was the fact that the initial causal sequence of events at TMI had been duplicated 18 months earlier at another Babcock and Wilcox reactor, owned by Davis-Besse. The only difference was that the operators at Davis-Besse identified the valve failure after 20 minutes, where at TMI it took 80 minutes; and the Davis-Besse facility was operating at 9% power, against TMI's 97%. Although Babcock engineers recognised the problem, the company failed to clearly notify its customers of the valve issue.[52]

Upon his return to Dartmouth, Kemeny addressed Dartmouth college students. When asked what caused the meltdown, he replied that the proximate cause would probably never be known. The Government Affairs Vice President confirmed that the Metropolitan Edison Company, which operated the company, had shortly before received a warning from the Nuclear Regulatory Commission (NRC) that Babcock and Wilcox reactor valves were vulnerable to failure under certain conditions. He said he had sent it on to the Vice President of Engineering, who confirmed that he had read it. Shortly after that, the two men met at the water cooler where the Government Affairs VP asked the Engineering VP a question. The Government Affairs VP remembered the question as "Is there a problem here?". The Engineering VP thought the question was "Have you solved the problem?". Both VPs agreed that the answer was "no". One walked away believing that the problem was solved. The other believed that he had informed his bosses that there was a problem. The issue was never resolved. Kemeny told the students that he believed it never would be. The proximate cause of the meltdown remains unknown and no proof of negligence was ever uncovered.

The Pennsylvania House of Representatives conducted its own investigation, which focused on the need to improve evacuation procedures.

In 1985, a television camera was used to see the interior of the damaged reactor. In 1986, core samples and samples of debris were obtained from the corium layers on the bottom of the reactor vessel and analyzed.[53]

Effect on nuclear power industry



Global history of the use of nuclear power. The Three Mile Island accident is one of the factors cited for the decline of new reactor construction.

According to the IAEA, the Three Mile Island accident was a significant turning point in the global development of nuclear power.[54] From 1963–1979, the number of reactors under construction globally increased every year except 1971 and 1978. However, following the event, the number of reactors under construction in the U.S. declined every year from 1980 to 1998.[citation needed] Many similar Babcock and Wilcox reactors on order were canceled — in total, 51 American nuclear reactors were canceled from 1980–1984.[55]

The 1979 TMI accident did not, however, initiate the demise of the U.S. nuclear power industry. As a result of post-oil-shock analysis and conclusions of overcapacity, 40 planned nuclear power plants had already been canceled between 1973 and 1979. No U.S. nuclear power plant had been authorized to begin construction since the year before TMI. Nonetheless, at the time of the TMI incident, 129 nuclear power plants had been approved; of those, only 53 (which were not already operating) were completed. Federal requirements became more stringent, local opposition became more strident, and construction times were significantly lengthened to correct safety issues and design deficiencies.[citation needed]

Globally, the cessation of increase in nuclear power plant construction came with the far worse Chernobyl disaster in 1986 (see graph).

Cleanup

Three Mile Island Unit 2 was too badly damaged and contaminated to resume operations; the reactor was gradually deactivated and mothballed. TMI-2 had been online only thirteen months but now had a ruined reactor vessel and a containment building that was unsafe to walk in — it has since been permanently closed. Cleanup started in August 1979 and officially ended in December 1993, having cost around US$975 million. Initially, efforts focused on the cleanup and decontamination of the site, especially the defueling of the damaged reactor. Starting in 1985, almost 100 short tons (91 t) of radioactive fuel were removed from the site. The defueling process was completed in 1990, and the damaged fuel was removed and disposed of in 1993.[citation needed] However, the contaminated cooling water that leaked into the containment building had seeped into the building's concrete, leaving the radioactive residue impractical to remove.[citation needed] In 1988, the Nuclear Regulatory Commission announced that, although it was possible to further decontaminate the Unit 2 site, the remaining radioactivity had been sufficiently contained as to pose no threat to public health and safety. Accordingly, further cleanup efforts were deferred to allow for decay of the radiation levels and to take advantage of the potential economic benefits of retiring both Unit 1 and Unit 2 together.[56]

Health effects and epidemiology

Main article: Three Mile Island accident health effects

In the aftermath of the accident, investigations focused on the amount of radiation released by the accident. According to the American Nuclear Society, using the official radiation emission figures, "**The average radiation dose to people living within ten miles of the plant** was eight millirem, and **no more than 100 millirem to any single individual.** **Eight millirem is about equal to a chest X-ray**, and 100 millirem is about a third of the average background level of radiation received by US residents in a year."[36][57]

Based on these low emission figures, early scientific publications on the health effects of the fallout estimated one or two additional cancer deaths in the 10 mi (16 km) area around TMI.[37][*unreliable source?*] **Disease rates in areas further than 10 miles from the plant were never examined.**[37] Local activism in the 1980s, based on anecdotal reports of negative health effects, led to scientific studies being commissioned. A variety of studies have been unable to conclude that the accident had substantial health effects.

The Radiation and Public Health Project cited calculations by Joseph Mangano, who has authored 19 medical journal articles and a book on *Low Level Radiation and Immune Disease*, that reported **a spike in infant mortality in the downwind communities two years after the accident.**[37][58] Anecdotal evidence **also** records **effects on the region's wildlife.**[37] For example, according to one anti-nuclear activist, Harvey Wasserman, **the fallout caused "a plague of death and disease among the area's wild animals and farm livestock", including a sharp fall in the reproductive rate of the region's horses and cows,** **reflected in statistics from Pennsylvania's Department of Agriculture**, though **the Department denies a link with TMI.**[59]

Activism and legal action

See also: List of anti-nuclear groups in the United States#Three Mile Island Alert

Anti-nuclear protest at Harrisburg in 1979, following the Three Mile Island Accident.

The TMI accident **enhanced the credibility of anti-nuclear groups**, who had predicted an accident,[60] and **triggered protests around the world**.[61]

The American public was concerned about the release of radioactive gas from the TMI accident and **many mass anti-nuclear demonstrations took place across the country in the following months. The largest one was held in New York City in September 1979 and involved 200,000 people;** speeches were given by Jane Fonda and Ralph Nader.[62][63][64] The New York rally was held in conjunction with a series of nightly “No Nukes” concerts given at Madison Square Garden from September 19–23 by Musicians United for Safe Energy. **In the previous May, an estimated 65,000 people, including the Governor of California, attended a march and rally against nuclear power in Washington, D.C.**[63]

In 1981, citizens' groups succeeded in a class action suit against TMI, winning $25m in an out-of-court settlement. Part of this money was used to found **the TMI Public Health Fund**.[65] In 1983,

a federal grand jury indicted Metropolitan Edison on criminal charges for the falsification of safety test results

prior to the accident.[66] Under a plea-bargaining agreement, **Met Ed pleaded guilty to one count of falsifying records and no contest to six other charges**, four of which were dropped, and agreed to pay a **$45,000 fine** and set up a $1 million account to help with **emergency planning in the area surrounding the plant**.[67]

According to Eric Epstein, chair of Three Mile Island Alert, the TMI plant operator and its insurers paid at least $82 million in publicly documented compensation to residents for "loss of business revenue, evacuation expenses and **health claims**".[68] Also according to Harvey Wasserman, **hundreds of out-of-court settlements have been reached with alleged victims of the fallout, with a total of $15m paid out to parents of children born with birth defects**.[69] However, **a class action lawsuit alleging that the accident caused detrimental health effects was rejected by Harrisburg U.S. District Court Judge Sylvia Rambo. The appeal of the decision in front of U.S. Third Circuit Court of Appeals also failed**.[70]

Design changes

The **PORV position indicator design flaw** was corrected, and more PORV testing was done. Dedicated instruments directly measure core water level. Vents were added at the top of the pressure vessel.[*citation needed*]

Lessons learned

Three Mile Island has been of interest to human factors engineers as an example of how groups of people react to and make decisions under stress. There is now a general consensus that the accident was exacerbated by wrong decisions made because the operators were overwhelmed with information, much of it irrelevant, misleading or incorrect. As a result of the TMI-2 incident, nuclear reactor operator training has been improved. Before the incident it focused on diagnosing the underlying problem; afterward, it focused on reacting to the emergency by going through a standardized checklist to ensure that the core is receiving enough coolant under sufficient pressure.

In addition to the improved operating training, improvements in quality assurance, engineering, operational surveillance and emergency planning have been instituted. Improvements in control room habitability, "sight lines" to instruments, ambiguous indications and even the placement of "trouble" tags were made; some trouble tags were covering important instrument indications during the accident. Improved surveillance of critical systems, structures and components required for cooling the plant and mitigating the escape of radionuclides during an emergency were also implemented. In addition, each nuclear site needed to have an approved emergency plan to direct the evacuation of the public within a ten mile Emergency Planning Zone (EPZ); and to facilitate rapid notification and evacuation. This plan is periodically rehearsed with federal and local authorities to ensure that all groups work together quickly and efficiently.

In 1979, as Pennsylvania state secretary of health in the Thornburg administration Gordon K MacLeod, MD, managed the health effects of the Three Mile Island nuclear accident, he **criticized Pennsylvania's preparedness, in the event of a nuclear accident, at the time for not having potassium iodide in stock, which protects the thyroid gland in the event of exposure to radioactive iodine,** as well as for not having any physicians on Pennsylvania's equivalent to **the Nuclear Regulatory Commission**.

The Three Mile Island accident inspired Charles Perrow's 1982 exposition of Normal Accident Theory, which became widely known through his 1984 book. TMI was an example of this type of accident because it was "unexpected, incomprehensible, uncontrollable and unavoidable".[71] But Perrow's conclusion that the accident was unavoidable is belied by **the fact that a TMI control room operator wrote a memo warning of "a very serious accident" if the condensate system problems were not properly addressed.** He stated that "the resultant damage could be very significant." [72] Additionally, **James Cresswell, an NRC inspector, warned for two years [73] that a design flaw with U-shaped tubes could prevent coolant circulation and cause an accident like that which would occur at TMI.** His **warnings were ignored** until the NRC met with him six days before the accident at TMI.[74]

The China Syndrome

The accident at the plant occurred 12 days after the release of the movie *The China Syndrome*, however, the film had been completed and reviewed 3 months earlier. It featured Jane Fonda as a news anchor at a California television station. In the film, a major nuclear plant crisis takes place while Fonda's character and her cameraman (Michael Douglas) are at the plant producing a series on nuclear power. She proceeds to raise awareness of how unsafe the plant is. Coincidentally, there is a scene in which Fonda's character speaks with a nuclear safety expert, who says that a meltdown could render an area "the size of Pennsylvania permanently uninhabitable." Also, the fictional near-accident in the movie stems from plant operators overestimating the amount of water within the core.

After the release of the film, Fonda began lobbying against nuclear power — the only actor in the film to do so. In an attempt to counter her efforts, the nuclear physicist Edward Teller, "father of the hydrogen bomb" and long-time government science adviser, personally lobbied in favor of nuclear power, and the 71-year-old scientist eventually suffered a heart attack on May 8, 1979, which he later blamed on Fonda: "You might say that I was the only one whose health was affected by that reactor near Harrisburg. No, that would be wrong. It was not the reactor. It was Jane Fonda. Reactors are not dangerous."[75]

Current status

Viewed from the west, Three Mile Island currently uses only one nuclear generating station, TMI-1, which is on the left. **TMI-2, to the right, has not been used since the accident.** Note that this is a pre-accident photo taken when TMI-2 was in operation.

Unit 1 had its license temporarily suspended following the incident at Unit 2.

Although the citizens of the three counties surrounding the site voted by a margin of 3:1 to permanently retire Unit 1, it was

permitted to resume operations in 1985.

General Public Utilities Corporation, the plant's owner, formed General Public Utilities Nuclear Corporation (GPUN) as **a new subsidiary** to own and operate the company's nuclear facilities, including Three Mile Island. The plant had previously been operated by Metropolitan Edison Company (Met-Ed), one of GPU's regional utility operating companies. In 1996, General Public Utilities **shortened its name** to GPU Inc. Three Mile Island Unit 1 **was sold** to AmerGen Energy Corporation, a joint venture between Philadelphia Electric Company (PECO), and British Energy, in 1998. In 2000, PECO merged with Unicom Corporation to form Exelon Corporation, which acquired British Energy's share of AmerGen in 2003. Today, AmerGen LLC is a fully owned subsidiary of Exelon Generation and owns TMI Unit 1, Oyster Creek Nuclear Generating Station, and Clinton Power Station. These three units, in addition to Exelon's other nuclear units, are operated by Exelon Nuclear Inc., an Exelon subsidiary.

General Public Utilities was legally obliged to continue to maintain and monitor the site, and therefore retained ownership of Unit 2 when Unit 1 was sold to AmerGen in 1998. **GPU Inc. was acquired by FirstEnergy Corporation in 2001, and subsequently dissolved.** FirstEnergy then **contracted out the maintenance and administration of Unit 2** to AmerGen. Unit 2 has been administered by Exelon Nuclear since 2003, when Exelon Nuclear's parent company, Exelon, bought out the remaining shares of AmerGen, inheriting FirstEnergy's maintenance contract. Unit 2 continues to be licensed and regulated by the Nuclear Regulatory Commission in a condition known as Post Defueling Monitored Storage (PDMS).[76]

Today, **the TMI-2 reactor is permanently shut down with the reactor coolant system drained**, **the radioactive water decontaminated and evaporated**, **radioactive waste shipped off-site to a disposal site**, **reactor fuel and core debris shipped** off-site to a Department of Energy facility, and **the remainder of the site being monitored**. The owner says **it will keep the facility in long-term, monitored storage** until the operating license for the TMI-1 plant expires at which time both plants will be decommissioned.[6] **In 2009, the NRC granted a license extension which means the TMI-1 reactor may operate until April 19, 2034**.[77][78]

Timeline

Date	Event
1968–1970	Construction
April 1974	Reactor-1 online
Feb 1978	Reactor-2 online
March 1979	TMI-2 accident occurred. Containment coolant and unknown amounts of radioactive contamination released into environment.
April 1979	Containment steam vented to the atmosphere in order to stabilize the core.
July 1980	Approximately 1591 TBq (43,000 curies) of krypton were vented from the reactor building.
July 1980	The first manned entry into the reactor building took place.
Nov. 1980	An Advisory Panel for the Decontamination of TMI-2, composed of citizens, scientists, and State and local officials, held its first meeting in Harrisburg, PA.
July 1984	The reactor vessel head (top) was removed.
Oct. 1985	Defueling began.
July 1986	The off-site shipment of reactor core debris began.
Aug. 1988	GPU submitted a request for a proposal to amend the TMI-2 license to a "possession-only" license and to allow the facility to enter long-term monitoring storage.
Jan. 1990	Defueling was completed.
July 1990	GPU submitted its funding plan for placing $229 million in escrow for radiological decommissioning of the plant.
Jan. 1991	The evaporation of accident-generated water began.
April 1991	NRC published a notice of opportunity for a hearing on GPU's request for a license amendment.
Feb. 1992	NRC issued a safety evaluation report and granted the license amendment.
Aug. 1993	The processing of accident-generated water was completed involving 2.23 million gallons.
Sept. 1993	NRC issued a possession-only license.

Sept. 1993	The Advisory Panel for Decontamination of TMI-2 held its last meeting.
Dec. 1993	Post-Defueling Monitoring Storage began.
Oct. 2009	TMI-1 license extended from April 2014 until 2034.

See also

- International Nuclear Events Scale
- Nuclear and radiation accidents
- Lists of nuclear disasters and radioactive incidents
- Chernobyl disaster
- Forked River Nuclear Power Plant
- Process control
- Human-machine interaction
- Generation II reactor
- List of articles about Three Mile Island
- List of books about nuclear issues
- List of civilian nuclear accidents
- Nuclear accidents in the United States
- Nuclear power whistleblowers
- Nuclear safety
- Nuclear safety in the U.S.
- Three Mile Island accident health effects
- Three Mile Island: Thirty Minutes to Meltdown
- TMI 25 Years Later: The Three Mile Island Nuclear Power Plant Accident and Its Impact
- Robert Del Tredici

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13. ^ Rogovin, p. 16, Walker, pp. 76–77
14. ^ Kemeny, p. 96; Rogovin, pp. 17–18
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16. ^ Kemeny, p. 99
17. ^ Rogovin, p. 19; Walker, p. 78
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External links

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- "Three Mile Island 1979 Emergency" – website about the accident, with many reports and other documents relating to the accident, created by nearby Dickinson College
- Step-By-Step account of the accident with illustrations from pbs.org
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President Jimmy Carter leaving Three Mile Island for Middletown, Pennsylvania, April 1, 1979

President Jimmy Carter leaving Three Mile Island for Middletown, Pennsylvania, April 1, 1979