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Three Mile Island and Chernobyl: What Went Wrong and Why Today's Reactors Are Safe

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This Saturday marks the 30th anniversary of the partial meltdown of the Three Mile Island (TMI) nuclear reactor. This occasion is a good time to consider the advances in nuclear power safety since that time and discuss the misinformation about this incident and the 1986 nuclear accident in Chernobyl, Ukraine, which is often associated with TMI.

Three Mile Island: What Happened. On March 28, 1979, a cooling circuit pump in the non-nuclear section of Three Mile Island's second station (TMI-2) malfunctioned, causing the reactor's primary coolant to heat and internal pressure to rise. Within seconds, the automated response mechanism thrust control rods into the reactor and shut down the core. An escape valve opened for 10 seconds to vent steam into a pressurizer, as it was supposed to, but it failed to close. Control room operators only saw that a "close" command was sent to the relief valve, but nothing displayed the valve's actual position.[1] With the valve open, too much steam escaped into the pressurizer, sending misinformation to operators that there was too much pressure in the coolant system. Operators then shut down the water pumps to relieve the "pressure."

Operators allowed coolant levels inside the reactor to fall, leaving the uranium core exposed, dry, and intensely hot. Even though inserting control rods halted the fission process, the TMI-2 reactor core continued to generate about 160 megawatts of "decay" heat, declining over the next three hours to 20 megawatts.[2] Approximately one-third of the TMI-2 reactor was exposed and began to melt.

By the time operators discovered what was happening, superheated and partially radioactive steam built up in auxiliary tanks, which operators then moved to waste tanks through compressors and pipes. The compressors leaked. The steam leakage released a radiation dose equivalent to that of a chest X-ray scan, about one-third of the radiation humans absorb in one year from naturally occurring background radiation.[3] No damage to any person, animal, or plant was ever found.[4]

The Outcome. The local population of 2 million people received an average estimated dose of about 1 millirem—miniscule compared to the 100–125 millirems that each person receives annually from naturally occurring background radiation in the area. Nationally, the average person receives 360 millirems per year.[5]

No significant radiation effects on humans, animals, or plants were found. In fact, thorough investigation and sample testing of air, water, milk, vegetation, and soil found that there were negligible effects and concluded that the radiation was safely contained.[6] The most recent and comprehensive study was a 13-year evaluation of

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32,000 people living in the area that found no adverse health effects or links to cancer.[7]

Technological Improvements and Lessons Learned. A number of technological and procedural changes have been implemented by industry and the Nuclear Regulatory Commission (NRC) to considerably reduce the risk of a meltdown since the 1979 incident. These include:

- Plant design and equipment upgrades, including fire protection, auxiliary feedwater systems, containment building isolation, and automatic plant shut down capabilities;
- Enhanced emergency preparedness, including closer coordination between federal, state, and local agencies;
- Integration of NRC observations, findings, and conclusions about plant performance and management into public reports;
- Regular plant performance analysis by senior NRC managers who identify plants that require additional regulatory attention;
- Expansion of NRC's resident inspector program, whereby at least two inspectors live nearby and work exclusively at each plant;
- Expanded performance- and safety-oriented inspections;
- Additional accident safety equipment to mitigate and monitor conditions during accidents; and[8]
- Establishment of the Institute for Nuclear Power Operators, an industry-created non-profit organization that evaluates plants, promotes training and information sharing, and helps individual plants overcome technical issues.

Chernobyl: What Happened. Seven years after the incident at Three Mile Island, on April 25, 1986, a crew of engineers with little background in reactor physics began an experiment at the Chernobyl nuclear station. They sought to determine how long the plant's turbines' inertia could provide power if the main electrical supply to the station was cut. Operators chose to deactivate automatic shutdown mechanisms to carry out their experiment.[9]

The four Chernobyl reactors were known to become unstable at low power settings,[10] and the engineers' experiment caused the reactors to become exactly that. When the operators cut power and switched to the energy from turbine inertia, the coolant pump system failed, causing heat and extreme steam pressure to build inside the reactor core. The reactor experienced a power surge and exploded, blowing off the cover lid of the reactor building, and spewed radioactive gasses and flames for nine days.

The episode was exacerbated by a second design flaw: The Chernobyl reactors lacked fully enclosed

1. World Nuclear Association, "Three Mile Island: 1979," March 2001, at *http://www.world-nuclear.org/info/inf36.html* (March 26, 2009).
2. Smithsonian Institution, National Museum of American History, "Three Mile Island: The Inside Story," at *http://americanhistory.si.edu/tmi/tmi03.htm* (March 26, 2009).
3. American Nuclear Society, "What Happened and What Didn't in the TMI-2 Accident," at *http://www.ans.org/pi/resources/sptopics/tmi/whathappened.html* (March 26, 2009).
4. U.S. Nuclear Regulatory Commission, "Fact Sheet on the Three Mile Island Accident," *http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html* (March 26, 2009).
5. United States Department of Energy, Office of Civilian Radioactive Waste Management, "Facts About Radiation," *OCRWM Fact Sheet*, January 2005, at *http://www.ocrwm.doe.gov/factsheets/doeymp0403.shtml* (November 6, 2008).
6. Nuclear Regulatory Commission, "Fact Sheet on the Three Mile Island Accident."
7. World Nuclear Association, "Three Mile Island: 1979."
8. Fact Sheet on the Three Mile Island Accident" Nuclear Regulatory Commission at *http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html* (June 24, 2008).
9. For full description of what caused the accident at Chernobyl, see Richard Rhodes, *Nuclear Renewal* (New York: Penguin Books, 1993), ch. 5.
10. World Nuclear Association, "Chernobyl Accident," May 2008, at *http://www.world-nuclear.org/info/chernobyl/inf07.html* (March 26, 2009).

containment buildings, a basic safety installation for commercial reactors in the U.S.[11]

The Outcome. Chernobyl was the result of human error and poor design. Of the approximately 50 fatalities, most were rescue workers who entered contaminated areas without being informed of the danger.

The World Heath Organization says that up to 4,000 fatalities could ultimately result from Chernobyl-related cancers. Though these could still emerge, as yet, they have not. The primary health effect was a spike in thyroid cancer among children, with 4,000–5,000 children diagnosed with the cancer between 1992 and 2002. Of these, 15 children unfortunately died. Though these deaths were unquestionably tragic, no clear evidence indicates any increase in other cancers among the most heavily affected populations.

Interestingly, the World Health Organization has also identified a condition called "paralyzing fatalism," which is caused by "persistent myths and misperceptions about the threat of radiation."[12] In other words, the propagation of ignorance by anti-nuclear activists has caused more harm to the affected populations than has the radioactive fallout from the actual accident. Residents of the area assumed a role of "chronic dependency" and developed an entitlement mentality because of the meltdown.[13]

Technology Improvements and Lessons Learned. Comparing the technology of the nuclear reactor at Chernobyl to U.S. reactors is not fair. First, the graphite-moderated, water-cooled reactor at Chernobyl maintained a high positive void coefficient. While the scientific explanation[14] of this characteristic is not important, its real-life application is. Essentially, it means that under certain conditions, coolant inefficiency can cause heightened reactivity. In other words, its reactivity can rapidly increase as its coolant heats (or is lost) resulting in more fissions, higher temperatures, and ultimately meltdown.[15]

This is in direct contrast to the light-water reactors used in the United States, which would shut down under such conditions. U.S. reactors use water to both cool and moderate the reactor. The coolant keeps the temperature from rising too much, and the moderator is used to sustain the nuclear reaction. As the nuclear reaction occurs, the water heats up and becomes a less efficient moderator (cool water facilitates fission better than hot water), thus causing the reaction to slow down and the reactor to cool. This characteristic makes light water reactors inherently safe and is why a Chernobyl-like reactor could never be licensed in the U.S.

Given the inherent problems with the Chernobyl reactor design, many technological changes and safety regulations were put in place to prevent another Chernobyl-like meltdown from occurring. Designers renovated the reactor to make it more stable at lower power, have the automatic shutdown operations activate quicker, and have automated and other safety mechanisms installed.[16]

Chernobyl also led to the formation of a number of international efforts to promote nuclear power plant safety through better training, coordination, and implantation of best practices. The World Association of Nuclear Operators is one such organization and includes every entity in the world that operates a nuclear power plant.

11. Simon Rippon et al., "The Chernobyl Accident," *Nuclear News*, June 1986, at *http://www.ans.org/pi/resources/sptopics/chernobyl/docs/nn-1986-6-chernobyl-lores.pdf* (March 26, 2009).
12. Press release, "Chernobyl: The True Scale of the Accident," World Health Organization, International Atomic Energy Agency, and U.N. Development Programme, September 5, 2005, at *http://www.who.int/mediacentre/news/releases/2005/pr38/en/print.html* (November 6, 2008).
13. World Nuclear Association, "Chernobyl Accident."
14. "Neutron Kinetics of the Chernobyl Accident," *ENS News*, Summer 2006, at *http://www.euronuclear.org/e-news/e-news-13/neutron-kinetics.htm* (March 27, 2009).
15. International Atomic Energy Agency, "The Chernobyl Accident: Updating of INSAG-1," 1992, at *http://www-pub.iaea.org/MTCD/publications/PDF/Pub913e_web.pdf* (August 27, 2008).
16. *Ibid.*

Myths Persist. The circumstances, causes, and conditions of the Chernobyl meltdown are far removed from the American experience. Important lessons should be taken from both accidents. Thankfully, many improvements in the technology and regulatory safety of nuclear reactors are among them.

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