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COVER: One of the most famous quasars, 3C273 (lower right), is accompanied by a previously unknown quasar (upper left) in this view formed from their X-ray emissions by the X-ray telescope on the satellite HEAO-2, known as the "Einstein Observatory." See. p. 229. (Photo: NASA)

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SCIENCE NEWS OF THE WEEK

The Three Mile Accident

The most serious accident ever to occur in a commercial nuclear-power plant appears to have been triggered last week by a series of valve problems. Although periodic emissions of radioactive gases from the plant worried residents in nearby Pennsylvania towns along the Susquehanna River — and even prompted many to evacuate — it was the threat of a reactor meltdown or explosions from hydrogen gas in the building housing the reactor that brought in a battalion of Nuclear Regulatory Commission specialists. With their counsel, engineers of the utility that runs the plant had, by the middle of this week, cooled the plant significantly and reduced the size of a potentially destructive gas bubble in the reactor.

Although the exact chain of events which caused the accident at the Three Mile Island nuclear plant #2 are still not known for certain, a rough scenario has been mapped out. It is believed that a valve in the demineralizer, through which feedwater flows to the steam generators, initiated the event. Probably due to moisture in the air line, a valve closed, halting the flow of water to one of the steam generators. This closure caused the suction pressure to pumps in the feedwater line to drop, causing them to shut down. At this signal, the turbines also shut down. Sensing trouble, the reactor should have automatically dropped its fission-quenching control rods. Even though shut down, the reactor would have continued to generate heat through radioactive decay.

An emergency backup system designed to kick in immediately didn't because two more valves failed to open the auxiliary feedwater line. All of this occurred in the secondary coolant system.

The primary system carries cooling water through the reactor core. Heat that it picks up in the reactor is transferred through the walls of its pipes to generate steam from clean nonradioactive water in the secondary system. Steam drives the power plant's turbines.

But in the early hours of March 28, with the secondary heat-removal system shut down, the primary had no place to dump its heat. As a result, pressure in the primary system rose to more than 2,200 pounds per square inch. When the pressure reached 2,350 psi, a relief valve opened on the primary system's pressurizer, venting water and steam from the reactor into a "quench" tank within the reinforced containment building housing the reactor system.

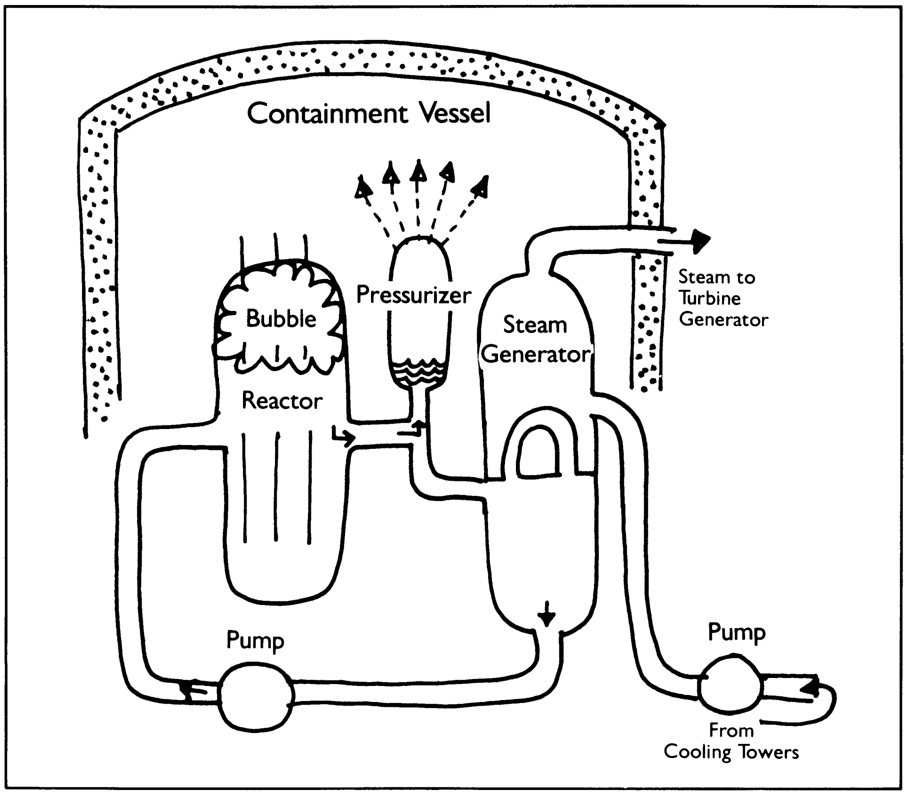
When the valve opened, the reactor's pressure immediately began to fall. The valve was supposed to close when the pressure returned to 2,300 psi. It attempted to but didn't. In the reactor's control room, however, engineers received signals indicating the valve had shut. As the coolant continued to escape via the unsealed valve, pressure in the reactor and its coolant system continued to fall.

Back in the control room, an operator noticed that the emergency feedwater valves had not opened. Opening them manually, he dumped cold water into the affected steam generator. Having gone without feedwater for some time, the circuit was now boiled dry. The shock of dumping cold water into overheated pipes ruptured primary coolant pipes running through the steam generator. Radioactively contaminated water from the reactor core poured into the formerly "clean" steam-generator system.

With the steam generator drawing heat out of the primary again, the reactor's pressure dove further. At 1,600 psi, the emergency core-cooling system (ECCS) began forcing high-pressure water into the reactor. Water continued to escape through the pressurizer, eventually bursting a rupture disk in the quench tank.

Thousands of gallons of radioactive water flooded onto the containment building floor until an operator manually shut a blocking valve in the pressure-relief circuit. But much of the overflow had already been transferred from a sump to a tank in an auxiliary building. It overflowed that and flowed onto the floor where it eventually began to evaporate, releasing radioactive gases into the environment. Radiation levels of 30 to 35 millirem per hour were monitored at the plant gate. Readings of 20 to 35 mr per hour across the river in Goldsboro, a town of 600, quickly dropped to about one mr per hour. Residents of the area normally receive 5 mr to 7 mr per month from natural background levels of radiation, according to Harold Denton, President Jimmy Carter's personal liaison at the site and director of NRC's division of reactor regulation. (One rem is considered to be the dose from any type of radiation that produces biological effects in humans equivalent to one rad of X-rays. Twenty mr is approximately the equivalent of two chest X-rays.)

Initial readings within the containment building were much higher. One monitor hit by steam from the pressurizer read 6,000 rem per hour but the utility said a more accurate measure was probably 80 rem per hour. By Sunday night, however,



readings had dropped to 9 rem/hr—still a very high rate.

Shortly after it had been activated, the ECCS was shut off manually. Metropolitan Edison, the utility that runs the Three Mile Island plant, said that operators were concerned about the pressurizer's water level; its steam to water ratio is used to maintain pressure in the reactor. When the primary cooling system temperature and pressure hadn't returned to normal, the operators became more worried and turned on the ECCS again.

Engineers speculate that the hydrogen-gas bubble formed when the ECCS was shut off. The reactor core overheated when it temporarily lost much of its cooling water. Severe damage to rods housing the fuel pellets — perhaps involving 25 percent of the rods — probably occurred at this time also.

While some of the zircalloy cladding on the rods may have melted, it's more likely that most damage involved only a cracking open of the cladding. Radioactive fission products, formed as the fuel is "burned," normally are trapped inside these rods. As the cladding cracked open, however, these gases escaped into the reactor coolant and probably into the containment building.

The big concern, of course, during the past week has been the cause and fate of the hydrogen bubble. A 30 psi spike in the containment building's pressure last Wednesday or Thursday — believed to be a small hydrogen explosion — illustrates part of the reason for alarm. The bubble, which occupied at times 1,000 cubic feet or more of the reactor vessel, may have formed any of several ways. One hypothesis is that when the ECCS was turned off, hydrogen was formed by zircalloy-water reaction. The water, already deliberately charged with extra hydrogen to scavange oxygen and prevent corrosion, may simply have been unable to maintain its hydrogen level when the pressure dropped. A third explanation is that gamma-radiation-activated electrolysis—radiolysis—of the cooling water generated the bubble. One thing all the engineers agree on is that formation of such a bubble had never been anticipated in the calculations of possible accident scenarios.

The bubble initially occupied a large portion of the reactor and threatened to uncover the already damaged fuel rods if the reactor pressure wasn't kept at about 900 psi—roughly half the normal operating pressure.

It appeared the hydrogen would have to be removed through the pressurizer and released into the containment building. That posed a new problem. The atmosphere already there would have turned flammable with a concentration of only four percent hydrogen and explosive at six to eight percent hydrogen. Met Ed's solution was to install two catalytic recombiners in the containment building. They would combine hydrogen and oxygen in the atmosphere into water vapor. With the recombiners installed, work began on reducing hydrogen levels in the containment building to make room for hydrogen from the bubble.

How to bleed hydrogen from the bubble proved to be more challenging. The interface of the hydrogen bubble and the coolant in the reactor was in equilibrium, the utility engineers figured, with as much hydrogen entering the bubble as was dissolving into the coolant. By reducing the hydrogen content of the coolant, the engineers reasoned, more hydrogen could be forced out of the bubble and into the coolant. The technique appeared to work well, albeit slowly. The bubble size had been reduced to 200 cubic feet by Sunday evening and had been eliminated "for all practical purposes" by Wednesday.

Once the bubble is gone and the reactor cooled, the mammoth job of cleaning up a critically damaged and severely contaminated reactor will begin. The most optimistic estimate, being made by NRC's Robert Bernero, is that it will be at least one or two years before the facility can be made operational. Others say four years. The cost would be at least $40 million.

Cleanup would involve removing nearly 80,000 gallons of radioactively contaminated water from the reactor's primary cooling system and as much as 200,000 gallons of radioactive water from the floor of the containment building. Then comes the problem of finding a way to dispose of this vast amount of waste. A nuclear power plant usually generates about 35,000 cubic feet of waste per year. Cleanup of the Three Mile Island plant may involve as much as ten times that amount.

In addition to the contaminated water, there is the problem of removing contaminated material and gas from the reactor and from the containment building. As of Tuesday, radiation levels registered near 30,000 rem in the dome of the building — enough to cause instant death to humans.

Although the initial stages of cleanup were underway by Wednesday, some federal officials and engineers were less than optimistic about the future of the plant. There was some speculation that damage to the plant may be so extensive that it may never operate again. Only three months old, it would be an expensive and untimely end — and one that consumers would pay for in much higher electric bills.

Of more immediate concern to residents of the Three Mile Island area are the potential health effects from the reactor accident. At a press conference on Tuesday, Denton said, "I think the danger point is considerably down from where it was a few days ago." But at the same time officials revealed that "very small amounts of radioactive iodine 131 had been detected in samples of milk taken from farms in the area. Measurements as high as 31 picocuries per liter were found in some samples, but this is far below the amount considered dangerous—12,000 picocuries per liter. According to Denton, levels of radioactive iodine were as high as 100 to 300 picocuries per liter during the Chinese fallout period.

Overall, for the population in the area of the plant, the entire incident, according to what Denton calls estimates and some guesswork, could result in an increase of 0.1 to 0.2 cancers. □