THE WINDSCALE FIRE

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A graphite fire in the Windscale No. 1 reactor occurred during the period October 8-12, 1957. The Windscale reactors were located on a coastal plain in northwest England and were used to produce plutonium. A great wealth of information was gathered on the causes, handling, decontamination, and environmental effects of reactor accidents.

Figure 1 shows the front face of the Windscale reactor, which is similar to the X-10 reactor at Oak Ridge, Tennessee. The X-10 pile operated from 1943 to 1963, and it also used natural uranium "slugs" as fuel. As at Windscale, the fuel was pushed into horizontal tubes on "channels" that penetrated the huge "pile" of graphite. Inserted from one face, the fuel was left in the channels for a predetermined number of megawatt days per ton and then pushed out the opposite face. The ejected fuel slugs fell into a canal for underwater loading into casks and transport to the chemical processing area.

Cooling for these reactors was by forced draft, and the cooling air was passed through filters in a large gallery atop a 400-foot stack from which it was released into the environment. Figure 2 shows a front view of the loading face of the reactor. The Windscale reactors were hexagonal when viewed from the front or back. The graphite core measured 50 feet by 50 feet, was 25 feet thick, and was surrounded by concrete shielding; the charging face, shown edge on in Figure 2, was shielded so that work could be done in this area when the pile was not in operation. The control room was located outside a second concrete shield. The control rods were positioned vertically in the graphite, suspended, and operated from the top. A special scanner gear was located in a void in the discharge space behind the core so that readings could be made to determine which channels were involved when fuel failures occurred.

THE CAUSE OF THE FIRE

When the Windscale reactors were built, it was known that graphite irradiated by neutrons could store energy in the crystalline lattice, and, if allowed to build sufficiently, could be released quickly in an uncontrolled fashion to result in very high temperatures. It also was known that the build-up could be controlled by a thermal annealing process. This "Wigner" energy was to be annealed by the operating crew on October 7, 1957. In order to accomplish this, the blowers were switched off early in the afternoon on October 7, and in the

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early evening the reactor was brought to low power to provide the heat to anneal the graphite. By early morning on October 8, the crew stopped the nuclear heating. A few hours later, they concluded that the temperature in the core was falling too soon, so they elected to apply more heat. Later, the accident-investigating committee concluded otherwise: two thermocouples were dropping in temperature but the majority were not.

Before noon on October 8, the second heating began. Within 15 minutes, the temperature was rising rapidly and the control rods were run in to reduce power. Later, the investigation committee concluded that the damage was done early in the second heating period when the cladding of one or more elements in the lower front section of the reactor failed. The instrumentation played an important part during this time, and the catastrophe at Chernobyl had some similarities, that is, the placement of the thermocouples was such as to be optimized for power distribution during normal operation. However, the distribution of temperature with the blowers off and the releases of Wigner energy were sufficiently different from normal that the operators could be misled and might react improperly to readings.

As the temperatures continued to rise, the equipment was operated to draw cooling air through the core, but the temperature rose faster. The cooling fans were operated at normal for 15 minutes in an attempt to reverse the rise. This intermittent cooling continued until the morning of October 10, at which time there was a sharp increase in radioactivity at the top of the stack. Further cooling efforts did not lower the temperature in the core but increased the readings of radioactivity at the stack top. By midmorning on October 10, preparations were made to use the scanning gear to determine which channels might have fuel that had failed. However, the scanning gear would not operate, and a charge plug in the front of the inner shield was removed at the hottest channel so that the channel could be viewed with a periscope. Fuel elements were seen glowing red hot, but the channel could not be ejected. The channels surrounding those that were burning were emptied to create a fire break. Carbon dioxide was used without success in an attempt to quench the burning channels.

Shortly after midnight on October 11, the chief constable of Cumberland was warned of the possibility of an emergency, and the decision was made to use water if the fire was not controlled soon. Water hoses were put in place. At 8:55 AM, the hoses were turned on and operated for 24 hours after which time the reactor was cold.

The investigation committee concluded that the fire was caused by the unnecessary second heating. Responsibility for the second heating appears to rest with the operators, who were misled by the choice of location of thermocouples. As at the later emergencies at Three Mile Island (TMI) II and Chernobyl 4, an unusual event or operation had been underway and operators were unable to observe and evaluate instruments properly to make the correct response. At TMI the sequence started with a turbine trip and some pumps that were valved off improperly. At Chernobyl it began with an experimental turbine "run down" to determine how long a turbine, without steam, would continue to generate sufficient electricity to operate key safety systems.

HANDLING OF THE INCIDENT

Once the initial mistake was made, that is, the second heating of the core, the investigating committee, various international reviewers, and more recent re-evaluations by the British concluded that the incident was handled well. Community warnings and communications were handled efficiently and promptly, environmental survey teams and equipment were assembled and dispatched promptly, and there was an atmosphere of quiet professionalism. Because of the nature of the releases, the British Medical Research Council, after an all night study, recommended that the maximum allowable concentration (MPC) of iodine-131 in milk for human consumption be 0.1 microcurie per liter and that milk with higher levels be dumped. They also concluded that the only significant exposures to the public would be through milk.

RADIATION DOSES TO THE POPULATION

Soon after deposition of the fission products on the ground, I-131 was detected in milk. A reasonably good correlation existed between the gamma radiation exposure rate above the ground in a farm area and the concentration of iodine in milk in the area surrounding Windscale. Figure 3 shows the concentration of iodine in milk in the area around Windscale. The highest level detected was about 10 miles from Windscale, where 1.4 microcuries of iodine per liter was present in a sample. By November 23, there were no areas in which milk contained more than 0.1 microcuries per liter; after November 4, there was only a small area south of the reactor site with such a level.

Drinking water from throughout the area was sampled and none exceeded the drinking water standards of the International Committee on Radiation Protection (ICRP). In addition to environmental sampling and analysis, an iodine scan was made of the thyroid glands of people living downwind. When measured by scintillation counter, concentrations of iodine-131 in the glands indicated that doses to thyroids were as high as 16 rads in children and as high as 9.5 rads in adults. Both values were considered to be quite safe. Although the external gamma exposures were of less importance, they were readily measurable; the geographical distribution is shown in Figure 4. The total releases of the isotopes of significance are shown in Table 1.

RADIATION EFFECTS ON THE POPULATION

On the basis of the exposures measured, there were no expected deleterious effects except for the premise that any radiation carried some risk. In 1986, formal risk calculations such as those given in the BEIR III report allow us to compute these small risks, although there is no evidence that they are real. Following that methodology, taking an average risk coefficient from the radioepidemiological tables of the National Institutes of Health of 3.3 cancers per million children per year per rad per 50 years and using the doses from Dunster,[1] we computed the highly conservative values given in Table 2. For children who may have received approximately 15 rem to the thyroid, the lifetime risk was one-quarter of one percent.

References

1. Dunster HJ: Windscale: The committee's report. Nuclear Engineering 1957;2:510-512.

2. Dunster HJ, Howells H, Templeton WL: District surveys following the Windscale incident, in Proceedings of the Second United Nations' Conference on Peaceful Uses of Atomic Energy: Waste Treatment and Environmental Aspects of Atomic Energy. Geneva, 1958, vol 18, pp 296-308.