Nuclear Reactor Safety: A Skeleton at the Feast?

The nation's electrical utilities are engaged in a nuclear buying spree this year, apparently undeterred by a running controversy among industrial and government authorities over the adequacy of a crucial emergency safeguard system used on nearly every nuclear power plant.

Since January, power companies have ordered 13 new reactor units, in contrast with 14 during all last year and 7 in 1969. The Atomic Energy Commission (AEC) predicts that, if the utilities sustain their purchasing pace, then by 1980 nuclear power will be producing 150,000 megawatts of electricity or one-fifth the nation's demand.

Such enthusiasm, however, tends to obscure the fact that important technical issues of reactor safety—quite apart from those of thermal or radioactive pollution—still remain to be settled.

Emergency Cooling

Currently the most controversial of these lingering safety issues concerns the adequacy of the emergency core cooling systems (ECCS) used on light water reactors. Since March, a newly created "senior task force" of four AEC executives has been evaluating recent research which suggests to some authorities that the backup cooling systems of these reactors might not perform satisfactorily. The research in question is said to be especially disquieting in regard to pressurized water reactors, although the task force has asked manufacturers for performance information on backup coolers for boiling-water reactors as well. All of the reactors aboard the Navy's nuclear-powered vessels are the pressurized water type, as are nine of the 22 civilian nuclear plants in operation as of the end of March.

The AEC task force was established to "provide overall management review of important safety issues," the commission chairman, Glenn T. Seaborg, has said. The group expects to finish its scrutiny of cooling systems sometime in June.

Until then, the issue's significance to public safety will remain difficult to judge, although some AEC officials are frankly skeptical that it has more than remote bearing on the public interest. Milton Shaw, AEC's director of reactor development and technology, scoffs that the issue of backup cooling performance has been exaggerated by "some people who have taken a little data and made a big thing out of it." Shaw contends that "this is just part of a debate that has gone on for 2 or 3 years" concerning the development of more stringent design codes for reactor emergency cooling. He also suggests that talk among researchers who are worried that their reactor safety work may be phased out for lack of money might have helped inflate the importance to public safety of this "little data."

But the AEC's official responses to the cooling system "flap" may be the best measure of its significance. The agency has held up operating license hearings and one safety review for five big new power reactors until the task force finishes its work. (Harold Price, the AEC's director of regulation, declines to speculate as to how ten other reactors scheduled to begin operating this year, or the 22 now generating electricity, may be affected by the deliberations.) In addition, the AEC asked Congress this month for an extra $2 million in fiscal 1972 for research on the safety of light water reactors. This would be above and beyond $36 million requested for the entire safety program in 1972. A staff member of the Joint Committee on Atomic Energy describes this constellation of events as "not unheard of" but still "uncommon."

The issue of backup cooling performance bubbled up into public view early this month when the Joint Committee released a letter that Seaborg had written to Senator John O. Pastore (D–R.I.), vice chairman of the committee, on 27 April. In the letter, Seaborg said he anticipated reactor licensing delays while the new task force took a long, hard look at emergency cooling systems. The reasons for this scrutiny, as Seaborg explained them, were that:

"The use of recently developed improved techniques for calculating fuel cladding temperatures following postulated loss-of-coolant accidents, and the results of recent preliminary safety research experiments, have indicated that the predicted margins of ECCS performance may not be as large as those predicted previously."

Emergency core cooling systems are intended to quench a reactor's extremely hot core (see box, opposite page) in the unlikely event that it loses its normal bath of cooling water through a ruptured pipe, a broken weld, or a key valve opened in error. Deprived of cooling water, a reactor's core temperature would quickly rise to the melting point of fuel element metals. A scenario of an uncooled reactor's fate, composed several years ago by an AEC advisory group, depicts the 250-ton core of a large reactor as dripping and finally slumping into a molten pool at the bottom of the reactor vessel within an hour after the reactor has lost its coolant.

Experts say that a loss of neutron-moderating water would prevent a nuclear "excursion" from occurring, but residual heat in the core—plus heat released by decaying fission products in the fuel and by violent chemical reaction between metal and remaining water—could still amount to 50 megawatts. This would be more than enough to allow the core to melt through the steel reactor vessel, and to carry it through tons of concrete beneath, within another hour or so. Beyond this point, nuclear engineers speak, half tongue-in-cheek, of the "Chinese Syndrome," a term derived from the presumption that the core would continue melting its way into the earth, in the general direction of Asia.

Unexpected Results

As a final result, steam explosions and gas pressure could breach the reactor containment building, scattering radioactive material. Or, as the scenario script delicately phrased it, there might be "subsequent deposition at undesirable locations" of fission-product material.

In the view of responsible nuclear scientists and engineers, emergency cooling systems now in use make such events highly improbable. Last year, however, a series of small-scale experiments which the AEC conducted at its National Reactor Testing Station near Arco, Idaho, indicated to some researchers that emergency cooling water might have unexpected difficulty in entering a reactor that had lost its normal cooling water. The experiments, which were performed in November and December, used a 9-inch mock-up of a reactor pressure vessel containing electrically heated "fuel" elements bathed in cooling water. In half a dozen tries, investigators found that when they allowed 30 to 100 percent of the tiny vessel's cooling water to escape—as it would in a "loss-of-coolant accident"—high steam pressures inside the vessel kept all but about 10 percent of "emergency" cooling water from entering. A brief description of the work which the AEC filed with the Joint Committee in March indicated that the high-pressure steam in the vessel blew the remainder of the "emergency" water through an outlet before it reached the "core."

The experiments were part of preliminary work leading up to research with the Loss of Fluid Test (LOFT) facility in Idaho, a $35-million domelike structure in which the AEC will progressively starve a 55-megawatt reactor of cooling water and measure its behavior. The LOFT experiments, which are scheduled to begin in 1975, will provide the first test of an emergency core cooling system under actual operating conditions.

A second point of concern which Seaborg's letter touched upon involves new analytical evidence showing that temperatures of some of the long, thin fuel elements in reactor cores may go higher during loss of coolant than previously believed. This is a matter of concern because the higher a fuel element's temperature rises, the more likely it is to fracture, spilling intensely radioactive fission products into the reactor vessel. Moreover, the higher temperature of the fuel rods, which are typically clad in zirconium alloy, would intensify a chemical reaction between the metal and quenching water. This would release hydrogen, generate still more heat, and thus place an even heavier demand on the emergency cooling system.

Shaw insists these findings have little direct bearing on the safety of nuclear reactors. While some fuel elements may be hotter than would be expected during loss of coolant, he says that others may be cooler, leaving no net effect on safety. As for the Idaho experiments, he points out that their objective was to help refine mathematical models to be used for predicting the course of LOFT experiments, and not to evaluate systems used on real reactors. The 9-inch vessel was not meant to fully simulate a reactor, he said in an interview. "You can't use that phraseology. It's just not in that ball game."

When a Core Runs Dry

A power reactor's core typically consists of a bundle of thin metal tubes, or fuel elements, containing uranium dioxide. The tubes are suspended vertically inside a thick steel vessel as tall (inside) as 72 feet, with a diameter of as much as 21 feet. Heat generated by a controlled fission reaction among the fuel elements is removed by circulating ordinary water around and between the elements. Normal operating temperature of the elements is about 315°C, but in the absence of cooling water the temperature would rise to the melting point of zirconium (1800°C) in 1 minute or less. Water-metal reactions are said to become "significant" at about 1100°C.

Safety Data Lacking

Nevertheless, Seaborg and a delegation of AEC executives appeared before the Joint Committee in supplemental authorization hearings on 13 May to request, among other things, $2 million more for next year to "help resolve significant technical issues" of water reactor safety. George M. Kavanagh, the assistant general manager for reactors, explained in part that, "Heavy reliance has been placed on engineering safety features such as the ECCS, where the technology is complex. . . . Some of the information needed to confirm convincingly the adequacy of such systems, which are intended to arrest the course of hypothetical large primary system failures is not yet available."

Kavanagh told the committee that limited AEC budgets and a certain reluctance on the part of industry to support more research have prevented gathering all the technical information necessary to fully confirm the adequacy of reactor safeguards.

The committee had already been briefed on the apparent import of the Idaho experiments and the activities of AEC's senior task force, so there was understandably little discussion of such matters in the day-long hearing. Kavanagh, however, did mention that "limited experiments" supported by the AEC at its Idaho test site "have not resolved some of the areas of major uncertainty raised by differences among the analyses [furnished by reactor manufacturers] particularly with regard to their evaluation of the operating effectiveness of emergency core cooling."

His remark prompted Senator Howard H. Baker (R–Tenn.) to ask what "differences" he was talking about. This question led to the following interchange:

Kavanagh: ". . . [The experiments] have had results which have not been confirmatory of what the people doing those experiments thought might happen. Now, they are not conclusive. . . ."

Baker: ". . . meaning that it was worse than you thought?"

Kavanagh: "Yes, worse. If it were better we might not have been allowed to come up here asking for money. But they [the results] are not conclusive. In other words, the experiment was done on something far from a reactor. . . . It is difficult to draw conclusions from those experiments. . . . What we want to do are more of those experiments."

Little else was said during the May hearing, but the subject is sure to come up again in nuclear reactor safety hearings, which the Joint Committee expects to hold late in June. "We couldn't avoid the issue if we wanted to," a committee staff member said.

It remains to be seen whether an obscure research project in a desolate corner of Idaho has indeed uncovered a flaw in nuclear reactor safeguards, or whether it has merely triggered a troublesome false alarm. In either instance, the current controversy has at least served to illuminate a chronic complaint from the AEC's division of reactor development that its safety research program is being shortchanged. That complaint will be discussed in another article.—Robert Gillette