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US ponders possible runaway reactors

The effect of a major accident at a nuclear power plant verges on the limits of human imagination, which may be why reactor manufacturers, electric utilities, and the US Atomic Energy Commission (AEC) are clearly unwilling to contemplate such an accident. But they have been forced to do so by a small group of New England scientists who believe that the essential safety devices on light water reactors may not work. For the past eight months, the AEC has been holding hearings in a small side room in Bethesda, Maryland, just outside Washington. As the hearings grind doggedly to a close, it seems apparent that the reactor adherents have failed to meet the challenge.

Light water reactors (LWR) are widely used throughout the world. US General Electric last week announced that it had sold an LWR to Mexico, bringing the number of GE LWRs built, under construction, or planned to 69. The US already has 26 LWRs operating and this type would be used for the proposed floating power station described in the preceding article.

In Britain, gas cooled reactors dominate the nuclear power scene - there are no commercial LWRs in operation. The British government grabbed at the light water safety problems as an excuse for delaying any decision about building LWRs in the UK. In his recent statement on UK reactor policy (see New Scientist, vol 55, p 324) the Secretary of State for Trade and Industry told parliament that "for LWR our objective is to achieve assurance about the questions that have arisen as to its safety."

If cooling flow fails

The emergency systems in question are those intended to provide extra cooling water to the core of the LWR if the main cooling flow should fail. In the core of an operating reactor heat comes from the fission of the heavy nuclei in the fuel (almost entirely uranium-235) and from the radioactive decay of the accumulated fission products. Emergency shut-down arrangements, by inserting neutron absorbers, can reliably bring the fission chain reaction to a swift halt; but the heating from the intensely radioactive fission products cannot be stopped. If a broken pipe were to allow the cooling water to escape from the core of a light water reactor, the fission product heating would cause a rapid temperature rise. Within 15 seconds the fuel cladding would begin to give way; within a minute the fuel itself would begin to melt. If this were to happen, the result would he an uncontrollable accident, with appalling consequences.

Accordingly, both forms of light water reactors have emergency core cooling systems (ECCS). In pressurised water reactors (PWR) the cooling water floods the core from below; in boiling water reactors (BWR) the water is sprayed from above.

However, the credibility of the emergency core cooling systems depends only on trials carried out on models, plus a number of computer simulations. There has never been a loss of coolant accident in a full scale reactor - not even one experimentally induced

for test purposes. The reactor manufacturers, the utilities and the AEC have all pointed to these model tests and simulations as the basis for their faith in present ECCS designs. But an independent and devastating critique of the model tests and simulations has been developed by a nuclear physicist from Massachusetts Institute of Technology, assisted by two other nuclear scientists and a Harvard economist.

Damning evidence

The Union of Concerned Scientists, a Boston-based group of several hundred scientists, engineers and other professionals, first published a commentary on ECCS in July 1971, under the title Nuclear Reactor Safety: An Evaluation of New Evidence. This 16-page survey had grown, by March 1972, into a blue covered document almost an inch thick. It is a damning chronicle. It itemises and dissects the long sequences of studies carried out since before 1967 to validate the design and putative performance of ECCS, and finds very little to suggest that the problem has been either adequately recognised or seriously confronted. After the expenditure of several years of effort and hundreds of thousands of dollars the status of ECCS remains as dubious as ever. Furthermore, the performance of the reactor manufacturers and the AEC, in generating and evaluating the ECCS data, seems as questionable as the data themselves.

If the criteria of sheer bulk or even density are applied, the weight of ECCS supporting research is impressive. In 1966-67 AEC's Division of Reactor Development and Technology commissioned three separate studies of reactor safety, by Oak Ridge National Laboratories, Battelle Memorial Institute and an ad hoc task force under the AEC's W. K. Ergen. All three, from various viewpoints, expressed concern over the lack of experimental evidence on which to base confidence in ECCS, and put forward proposals for priority research to fill the gaps.

These studies prompted the AEC to set up two experimental projects, research into fuel rod failure and FLECHT (Full Length Emergency Cooling Heat Transfer tests). The fuel rod failure tests, carried out by Oak Ridge and several of the reactor manufacturers, were more or less competently designed and executed, although they omitted to investigate critical phenomena relating to the blockage of cooling channels by deformed rods. But the FLECHT tests are a numbing example of industrial research at its most misconceived and dishonest.

In 1968 the AEC contracted with Idaho Nuclear Company (which operated the AEC's reactor testing station at Idaho Falls) to carry out tests on heat transfer in emergency core cooling. Idaho Nuclear then subcontracted the experimental and some of the analytical work to General Electric (for spray cooling in boiling water reactors) and to Westinghouse (for reflooding in pressurised water reactors); in other words, the two major manufacturers were invited to determine whether their own designs worked.

The pattern was established when General Electric for its BWR-FLECHT programme used stainless steel cladding for 138 out of 143 test set-ups, and Westinghouse for PWR-FLECHT used stainless steel for 84 out of 88. Stainless steel is no longer used for cladding in any light water reactors. The material which is used, a zirconium alloy called Zircaloy, was used in only five of the GE tests and only four of the Westinghouse tests. Of the five GE Zircaloy tests only one used rods pressurised to

simulate the effect of gaseous fission products inside the rod, a crucially important factor in possible rod-deformation or rupture. The rods were provided with internal heaters to simulate the effect of the radioactive decay heating but, in the single GE test carried out with pressurised Zircaloy rods, three out of the 49 had heaters which failed before the test even started, and another seven heaters failed before the test bundle reached its maximum temperature. Yet the whole point of the exercise was to gather data on the temperature distribution within the bundle, and how it varies with time under simulated loss of coolant conditions - particularly how high the temperature gets.

Westinghouse did only slightly better. Experimental design flaws meant that maximum temperature was underestimated here as well. For example, Westinghouse added two extra unheated rods to the 49-rod test bundle.

Fears and reactors sprout

While the reactor manufacturers were performing this discreditable charade, the AEC was circulating through the industry a draft Water Reactor Safety Program Plan. When finally published in February 1970, it declared that "the most urgent problem areas in the safety program today" are "all factors affecting ECCS effectiveness." The European Nuclear Energy Agency's Committee on Reactor Safety Technology issued its Water Cooled Reactor Safety Report at about the same time. According to the UCS blue book, this report is "replete with discussions of problem areas connected with emergency core cooling system performance and with suggestions for research." By this time American light water reactors were already sprouting in Europe and elsewhere.

All these calls for research prompted the AEC to commission its Idaho colleagues - now re-christened Aerojet Nuclear - to carry out tests on a miniature model reactor. In the autumn of 1970 five such tests took place; in all five cases the emergency cooling mechanism failed completely. Essentially no cooling water reached the core, and the computer models could not predict the test results.

In February 1971, after a panic stricken convocation of the AEC, Aerojet Nuclear, Oak Ridge and the reactor manufacturers yet another task force was set up under Dr Stephen Hanauer of the AEC Regulatory Staff. True to form, the task force delegated the job to Aerojet Nuclear; and then Aerojet's two-volume report was totally disregarded. Hanauer admitted subsequently that he had not even read the Aerojet report.

Not all AEC staff were so casual about the situation. In mid-1971 Drs Morris Rosen and Robert Colmar, chief and deputy chief of the Systems Performance Branch of the AEC Division of Reactor Standards, stated in a memo that "the system performance cannot be designed with sufficient assurance to provide a clear basis for licensing." Other senior men were known to share these concerns. The AEC then demonstrated its priorities by adopting, on 29 June 1971, a set of Interim Acceptance Criteria to allow licensing to proceed, and issued an Interim Policy Statement which made no reference whatever to the looming doubts and differences of opinion, even within its own Regulatory Staff.

Shortly thereafter the Union of Concerned Scientists published its first assessment of the situation, and the fat began to edge toward the fire. Virtually every nuclear reactor in the US was surrounded by agitated citizens, and as word began to filter through about the shattering results of the miniature reactor tests, citizen groups seized upon it and charged into the fray. In consternation the AEC decided to hold national "rule making hearings" in which the reactor manufacturers, the utilities, the reactor opponents and the AEC itself would participate in a single massive confrontation about the status of the emergency core cooling systems. These hearings were convened in the small side room in Bethesda in January this year.

Intervenors in the courtroom

By this time, more than 60 citizen groups from all over the US had banded together to form the Consolidated National Intervenors and threw their support behind the Union of Concerned Scientists. The National Intervenors retained as their counsel, Myron "Mike" Cherry, a trial lawyer from Chicago, whose flamboyant courtroom tactics had already earned him a measure of fame in earlier local nuclear powerplant hearings. With Cherry were Dr Henry Kendall of MIT, leading author of the UCS blue book, and Daniel Ford, a 24-year-old Harvard economist who became the team's technical interrogator.

The hearings took place before a specially set Atomic Safety and Licensing Board of the AEC, a three-man panel chaired by Nathaniel Goodrich, an experienced AEC hearing officer. First to take the stand were the AEC Regulatory Staff. Incisive cross-examination by Ford and Cherry brought forth some further disconcerting revelations, particularly after Cherry succeeded in forcing the AEC to table a thick sheaf of previously confidential internal documents which laid bare the extent of the in-house dissatisfaction with the ECCS situation.

Several episodes of concealment and suppression of information and dissent within the AEC were also brought to light during the hearings. The Reactor Development and Technology Division, for example, concealed from their own AEC colleagues in the Reactor Licensing group a damaging 1971 Aerojet report on safety research. This report itemised 28 areas of knowledge of capability critical to effective ECCS operation. In seven of these areas, techniques for handling the problems were said to be completely missing. The remaining 23 were variously called incomplete, unverified, inadequate, imprecise, or preliminary. The Regulatory Staff first saw this report when the Intervenors passed over to them a copy they had received in March.

When the reactor manufacturers - Westinghouse, General Electric, Combustion Engineering and Babcock & Wilcox - took the stand they said that the data were trade secrets, but that matters were in good hands and everything was under control. Given the demonstrated quality of their visible performance, such assertions instilled little confidence. The manufacturers even took issue with the Interim Criteria and licensing procedures on the grounds that they were unnecessarily restrictive. It would indeed be a chilling irony if these rule-making hearings were to prompt a relaxation of licensing criteria.

The hearings lurched into their final phase at the beginning of August, and at once achieved their most bizarre development. A concerted challenge from the reactor

adherents succeeded in having Daniel Ford extensively debarred from participation as a witness for the Intervenors on the grounds that as an economist he was not a nuclear "expert." Considering that James R. Schlesinger, Chairman of the AEC, is (like Ford) a Harvard economist, this seems a trifle severe - the more so when one notes that previous confrontations during the hearing had shown Ford more expert than some AEC executives. Kendall was then the sole witness for the Intervenors. With only occasional assistance permitted from Ford, Kendall successfully stood up to the two-week onslaught of the AEC, the utilities, Babcock & Wilcox, Combustion Engineering, General Electric and Westinghouse. The questioning failed to discredit his expertise, to reveal gaps in his aquaintance with the subject, or to show bias.

The one victory clearly registered by the reactor proponents was to have chapter two of the UCS blue book testimony stricken from the record. This chapter, entitled "Major Accidents: Causes and Consequences", is a hair raising survey of what would happen "in the unlikely event of an accident" - a favourite nuclear industry phrase. Unfortunately, a judicial decision does not eliminate the possibilities referred to in the deleted chapter, including lethal effects extending 75 miles downwind.

The Bethesda hearings accumulated a transcript 13ft thick; in the latter stages of the hearings, copies were wheeled about the room on heavy-duty trolleys. Since 1966, the AEC has been studying emergency core cooling and the safety of light water reactors. Hopefully 13ft of transcript should satisfy its appetite for study - and lead to far more stringent safety requirements.