ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

UNITED STATES ATOMIC ENERGY COMMISSION

WASHINGTON 25, D.C.

September 17, 1965

Mr. R. E. Hollingsworth
General Manager
U. S. Atomic Energy Commission
Washington, D. C.

Subject: REPORT ON PROPOSED REACTIVITY ACCIDENT TEST PROGRAM

Dear Mr. Hollingsworth:

The following Advisory Committee on Reactor Safeguards views are in response to the letter of July 19, 1965 from Dr. J. A. Lieberman, concerning a proposed reactivity accident test program. Dr. Lieberman provided copies of two related reports by Phillips Petroleum Company, and the Reactor Safety Research Subcommittee of the ACRS heard a presentation by representatives of Phillips Petroleum Company at a Subcommittee meeting on August 3, 1965.

In his letter, Dr. Lieberman posed four questions, as follows:

(1) "Is a damaging reactivity excursion still considered credible? If so, what are the most likely means of initiating such excursions? What is the maximum reactivity insertion possible from a single ejected control rod or a single dropped fuel element?"

(2) "Can you identify the probable initiating mechanisms and, if so, why can it not be designed against?"

(3) "If your recommendation is to conduct an integral destructive reactivity accident test to realistically assess the consequences, should a PWR or BWR be tested -- or should both? Why?"

(4) "If you consider it necessary to perform destructive reactivity accident tests, should they be done on clean cores to minimize construction and operating costs or should they be done in a contained facility after a long period to build in the fission product neutronic effects, fission product gas pressure, radiation and

cycling effects in the cladding, and high burnup materials' properties in the fuel? Do you know of any methods by which all these high burnup effects can be simulated to permit valid scoping tests to be run on a clean core?"

The Committee's views are as follows:

Generally speaking, a damaging reactivity excursion is still considered credible. The ways of initiating such accidents depend on the particular reactor. In reactors with rod drives from below, a rod drop-out is considered credible in some cases. In reactors which are pressurized, some combinations of thermal stress, brittleness, corrosion, manufacturing defects, and pressure-induced stresses could cause failure of a control rod housing nozzle, or of its means of attachments, so that the control rod is ejected rapidly from the reactor core. Where control rod drives are mounted on the reactor vessel head, failure of head bolts or of other vessel head hold-down devices could cause rapid lifting of the head and removal of the attached control rods from the core en masse. A fire in control circuitry could simultaneously cause control rod withdrawal and failure of scram capability. Sudden injection of coolant at a lower than normal temperature could cause a "cold water accident" through a sudden increase in reactivity. In reactors with soluble neutron poison, a sudden injection of unpoisoned water could begin a reactivity transient. In some reactors, sudden shifts in the position of core components could cause an increase in reactivity. During reloading, there could be inadvertent dropping of fuel or fuel casks, removal of neutron poison such as control rods or poison shims, or assembly of a highly undermoderated reactor in a partly loaded geometry which is more reactive than the fully-loaded one. Future large, water-cooled reactors using boron shim may have positive central void reactivity effects, which could lead to a sudden increase of reactivity. In boiling reactors with a large reactivity defect due to the existence of voids, a sudden rise in pressure could add significant amounts of reactivity. This list is not exhaustive, nor is it implied that all possibilities exist for all reactors.

The maximum worth of a single ejected control rod or a single dropped fuel element depends on the reactor in question. As nuclear power plants become larger, the trend may be to make fuel elements and control rods larger; this may lead to greater individual reactivity worths. Methods have been proposed by which rod withdrawal is programmed, so that individual rod worths are kept below limiting values. The limits are usually chosen so that a rod ejection or drop-out accident would not lead to major damage to the core or primary system. The Committee has considered such proposals on a case-by-case basis.

In some cases, design against possible initiating mechanisms can be done. For instance, interlocks and slow-opening valves are sometimes used to preclude the initiation of a cold water accident. Structural members could presumably prevent single-rod ejection or the lifting of the reactor vessel head if head bolts were to fail.

It is difficult to foresee the course of future large pressurized or boiling water reactor designs, but it is likely that potential reactivity excursions involving significant amounts of reactivity will remain a factor in evaluating their safety. The Committee would be reluctant to conclude that all possible initiating mechanisms could be prevented by design with enough reliability to render reactivity accidents incredible, or even that all possible initiating mechanisms have been identified in any given case. Inclusion of preventive systems is necessary, and is considered vital in the review of the safety of reactors and their locations. But it is not considered likely that accident prevention alone can remove the need for consequence-limiting features of the plants. The safety of reactors continues to depend on compounding the low probability of a major accident and the low probability of failure of features to limit the effect of accidents.

The Committee believes that an integral, destructive reactivity excursion test, or tests, would be valuable. However, the Committee believes that a careful and thorough program should be laid out before experimental work begins. The program should specifically outline the objectives to be achieved and the data or measurements to be taken, and should demonstrate that theoretical interpretation of the results is feasible. The Committee believes that the experimental program and a strong accompanying theoretical program should go hand-in-hand.

There are several possible objectives for the experimental program. Perhaps the most urgent objective is to obtain a better definition of the accident magnitude which would lead to rupture of the pressure vessel in water-cooled power reactors currently in the design stage, or likely to be built in the near future. Another possibility is to look for a natural limit to the energy release in reactivity accidents of interest. Another objective could be to look for unforeseen effects. Or, one could devise an experiment to check theoretical methods of calculating the course and consequences of postulated violent reactivity accidents in boiling and pressurized water reactors.

The Committee feels that the last two objectives, namely, providing a check point for analytical techniques, and possibly uncovering additional phenomena or a different course of events than hypothesized, are likely to be the most fruitful objectives for destructive, integral reactivity tests.

The schedule for the proposed experimental program is quite long. Dr. Lieberman's letter states that the completion of the test program described in PTR-738 is not expected until 1972; the results therefore could not be applied to reactors operating much before 1975. The Committee believes that a well thought-out experimental and theoretical program should be initiated at an early date and that the program schedule must be shortened to give information urgently needed within the next five to six years.

The Committee feels that there could be considerable difference between the course of reactivity accidents in pressurized water reactors and in boiling water reactors. Experimental programs on both seem equally desirable. The possibility of using SPERT-III for both should be investigated further.

Dr. Lieberman's questions concerning the possible need for separate experiments on a PWR and a BWR, and on the significance of fission products and pre-irradiation on the course of a destructive reactivity accident, are representative of some of the many significant parameters which can influence such an experiment. This is particularly true if it is hoped to apply the results of an experiment empirically to the safety analysis of future large reactors. Concrete pressure vessels, new cladding materials, positive void coefficients, and superheat are some possible different aspects of water reactors to be built in the 1970's.

All features cannot be tested full-scale and in timely fashion. Small-scale, in-pile experiments in the Power Burst Facility, coupled with other work aimed at providing a basic knowledge of the phenomena involved, and corroborated or redirected by a carefully designed, integral destructive reactivity experiment can provide increased understanding to help judge the safety of large boiling and pressurized water reactors in this respect. Careful review is required to decide which individual features may be vital to any specific integral experiment.

The Committee does not believe that the effects of high burnup can be simulated adequately with tests on a clean core.

In summary, the ACRS recommends that planning for a meaningful, destructive reactivity experiment begin immediately, together with an accelerated program of analyses, and that the program be pursued vigorously.

Sincerely yours,

/s/

W. D. Manly
Chairman

References attached.

References

1. PTR-738 (Rough Draft), "A Review of the Generalized Reactivity Accident for Water-cooled and-Moderated, UO_2-Fuelled Power Reactors", undated, received July 20, 1965 (OUO).

2. PTR-755 (Rough Draft), "Reactivity Accident Test Program, Proposal Number One: Integral System Scoping Tests", dated May 28, 1965 (OUO).