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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

NUCLEAR SAFETY CRITERIA FOR SPECIAL
TEST LOADS - N-REACTOR

N. R. Miller

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NUCLEAR SAFETY CRITERIA FOR SPECIAL TEST LOADS - N-REACTOR

by

W. S. Nechodom and N. R. Miller

Process Evaluation and Control
Research and Engineering

October 14, 1963

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NUCLEAR SAFETY CRITERIA FOR SPECIAL TEST LOADS - N-REACTORINTRODUCTION

The initial fuel loading for the N-Reactor has been described in the N-Reactor Hazards Summary Review.⁽¹⁾ The use of a specific alternative fuel element is described in Reference 2. It is highly probable that it will also be desirable in the future to irradiate still other types of fuel elements in the reactor. If the test is of small scale, fewer than five channels, or if these elements vary only slightly from the initial fuel load (or any other fuel type approved for large-scale use at some future date), the irradiation will be accomplished within the normal administrative procedures and controls established for the Production Testing Program. In this context, in-reactor testing of minor changes in the fuel cladding alloy, alternate methods of affixing end closures, different fuel support designs or similar changes are considered to be within the scope of normal production testing.

It is possible, however, that it will be desirable to irradiate test fuel elements which are significantly different from any element approved for general use and in quantities of greater than five fuel columns at a given time. A more formalized review of such tests including approval by the AEC would appear appropriate in these instances.

The purpose of this document is to outline criteria which can be used to judge the suitability of all such tests from the standpoint of reactor nuclear safety. It is intended that these criteria apply to test fuel loadings comprising up to 50 fuel columns within the reactor at a given time.

Concurrent irradiation of more than one test where the aggregate number of tubes involved is greater than 50 is not precluded, provided that compliance with the nuclear safety criteria is insured by specific study of the reactor conditions with all such tests in place.

The criteria cover the following aspects of nuclear safety:

- 1) Total Nuclear Control
- 2) Speed-of-Nuclear Control
- 3) Thermal Hydraulics
- 4) Confinement
- 5) Ex-Reactor Criticality

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- 1) HW-76930 VOL 1 - 5, "N-Reactor Hazards Summary Report," April 15, 1963. (Secret)
 - 2) HW-79227, "N-Reactor Hazards Summary Report, Supplement No. 3, Use of 1.25% Enriched Uranium Fuel," W. S. Nechodom and N. R. Miller, October 14, 1963. (Confidential)

CRITERIA

The basic N-Reactor nuclear safety criteria must be satisfied with a test loading in place:

I. Total Nuclear ControlA. Criterion

Each of the two independent safety control systems must have adequate control strength to maintain the reactor subcritical under all normal operating conditions and credible accident conditions.

B. Considerations

1. Excess reactivity of the reactor must be calculated under all normal and accident conditions with the loading in place. Normal conditions are all phases of reactor operation and shutdown. Credible accidents are: coolant leakage into the graphite stack, cold water injection into the primary loop during reactor operation, primary coolant loss, and fuel melting subsequent to coolant system failure.

2. The control strength of each safety system must be calculated under normal and accident conditions with the test loading considered in place. Control strengths may be affected by either the lattice characteristics of the test loading, or by the introduction of flux distortions in the reactor by placement of a test load.

3. The consequences of fuel charging errors must be considered. Specifically, the effects of charging a more reactive fuel under the erroneous impression that it is a less reactive fuel must be considered if such an error could occur.

II. Speed-of-ControlA. Criterion

The primary (horizontal rod) safety system must respond fast enough to prevent the consequences of any accident from being made worse by a nuclear excursion caused by that accident. If an accident, in itself, could not damage the reactor, the rod safety system must limit the consequences of the accident to mild fuel stressing.

The secondary (ball) safety system must respond fast enough to prevent fuel melting under all credible accident conditions where melting would not result from the accident itself.

B. Considerations

1. The physical speed-of-response of the safety systems cannot credibly be affected by changing process channel loadings. However, any changes in safety system control strengths introduced by test loadings must be evaluated.

2. Test Load Characteristics

Kinetic calculations must be performed with the test load considered in place, or the significant parameters of the test loading shall be separately considered for their effects. Significant parameters may include:

- a. Reactor core flux distortions introduced by the test load;
- b. Prompt temperature coefficients of reactivity of the test loading;
- c. Delayed neutron fraction in the test lattices, and the prompt neutron lifetime;
- d. Melting point of the test load, if lower than that of uranium;
- e. Thermal hydraulics of the test loading if different than the base fuel loading; heat transfer coefficients, coolant flow rates and coolant outlet temperatures.

3. In practice, it is found that under Phase I operating conditions each of the safety systems will respond fast enough to prevent primary coolant boiling under all credible accident conditions which do not involve loss of cooling adequacy. This capability must be maintained under test conditions if possible, or a method of evaluating the post-boiling conditions must be developed.

III. Thermal Hydraulics Considerations

A. Criterion

The thermal hydraulic characteristics of the test fuel columns must be studied to determine safe single-tube operating limits. Specifically, there must be no boiling with net steam quality at any location within the process tube during normal operation. During all normal periods of operation, it is necessary that adequate cooling be provided to the test columns. Under accident conditions, inadequate cooling shall not occur in the test columns under conditions where normal columns are receiving adequate cooling. Adequate cooling is defined as a minimum as that required to prevent melting any of the contents of the process tube in question.

B. Considerations

1. The division of heat and flow to the various coolant channels must be determined to permit an assessment of the maximum allowable thermal power consistent with the requirement that there be no boiling with net steam quality. Coolant mixing devices within the process tube may be utilized to minimize this effect.

2. The thermal hydraulic characteristics of the test column must be reviewed to allow establishment of tube limits.

3. Subcooled burnout characteristics must be reviewed to insure that heat fluxes compared to burnout fluxes are no higher than allowed in the Operating Safety Limits.

4. The thermal hydraulic characteristics of the test columns must be reviewed to show that inadequate cooling will not preferentially occur in test columns following a credible accident. An acceptable alternative to this is to operate the reactor at a reduced power so that the test columns represent no more of a hazard than would normal columns at normally acceptable power levels.

IV. Confinement and Fuel Melting Considerations

A. Criterion

The operating principle of the confinement system is that the relatively non-contaminated steam would be released to the atmosphere if a primary loop rupture occurs. The confiner would then be resealed to provide a filtered release should the emergency coolant system also fail. It is thus necessary that resealing be effected prior to the melting of fission product-containing fuel or release of any biologically significant quantities of product material. The presence of the test material must not create conditions beyond the ability of the confinement system to fulfill this function.

B. Considerations

1. The elapsed time from initiation of an accident until the start of fuel melting must be determined. Significant parameters include:

- a. Melting point;
- b. Heat capacity up to the melting point;
- c. Energy generation in test pieces; rate of heat transfer to test piece, if significant (may be important in target pieces);
- d. Thermal hydraulic characteristics of test column (very important in avoiding selective coolant channeling and starvation of some fuel channels);
- e. Effect of graphite moderator cooling system on prolonging the time to start of melting.

2. Total fission product inventory of any special product materials in the test load.

3. Fraction of the test load that would melt following a credible accident.

4. Fractional release of fission products and of any special product materials from fuel, if different from the normal loading.

5. Efficiency of fog sprays and filters in removing any radiologically significant product material.

V. Ex-Reactor Nuclear Safety

A. Criterion

Each type of test fuel must be studied to determine its ex-reactor criticality parameters. Once these parameters are known, safe handling and storage procedures must be provided in writing.

B. Considerations

1. In addition to the conventional parameters such as safe batch limits and mass-per-unit-area limits, particular attention must be directed to the criticality parameters of each mechanical part of the fuel element when mechanical separation is possible. For example, where a driver-target combination fuel element is used, and it is mechanically possible that the parts be separated, the criticality parameters of the drivers alone are required, and the limits on batch size and mass-per-unit-area may be quite restrictive.

2. The possibility of mistaking one fuel type for another fuel type must be considered. If such a mistake would be intolerable, there must be self-evident (essentially unmistakable) means of identifying the more reactive fuel.

3. Special consideration must be given to fuel types where the possibility exists that criticality could occur in unmoderated (non-flooded) arrays. Methods of handling and storage of such material must be devised which essentially reduce the probability of accidental criticality to the levels achievable with materials of lower enrichment.

SPECIFICATIONS

In addition to requiring that the test fuel loadings fulfill the nuclear safety criteria above, the following additional specifications would simplify the evaluation of compliance with the nuclear safety criteria. These specifications are not mandatory; however, in instances where the provisions are not met, particular care in hazards evaluation would be required.

- I. The hydraulic resistance of test fuel channels should be equal to or less than that of the base reactor fuel load. "Short charging" of fuel columns is an acceptable means of meeting this requirement.
- II. Whenever possible, test loadings should be located so as to preserve the pre-test reactor flux distribution, and test loadings should not be selectively located outside the horizontal rod pattern (only possible in the front-to-rear dimension).
- III. Whenever possible, test fuel lattices should lose reactivity upon loss of primary coolant, thus greatly simplifying the evaluation of compliance with the speed-of-control criterion.
- IV. Test lattices should have an infinite multiplication factor of less than 1.2 under all in-reactor normal and credible accident conditions.

- V. No portion of a test fuel element should have a melting point lower than 1133 C, although non-fuel test items may have lower melting points.

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