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Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: Fission Converter Safety Evaluation Report, Massachusetts Institute of Technology Research Reactor, Docket No. 50-20, License No. R-37

Dear Sir or Madam:

The Safety Evaluation Report (SER) and associated technical specifications for the fission converter were submitted to the NRC in October 1997. Two sets of questions were subsequently received from NRC and responses have been submitted, the last in May 1999. We are currently in the process of preparing procedures for the initial fuel loading and startup of the fission converter. It was recognized during the course of those preparations that several changes would be necessary to the SER. These are:

a) It will not be possible to measure k-effective because spent fuel will be loaded into D_2O coolant. As a result, the photoneutron source will increase with each element that is loaded and hence render a 1/M plot meaningless. The value of k-effective will be determined by calculation. This is the approach now used for all fuel storage areas of the MIT Research Reactor.

b) It will not be possible to measure the temperature distribution of the fuel elements because the elements have been irradiated. The distribution will be calculated and the result correlated with the bulk coolant temperature. The latter will be measured. This approach has been used successfully on the MIT Research Reactor itself.

Copies of the revised pages of the Fission Converter SER and Technical Specifications are enclosed.

Sincerely,

Thomas H. Newton
Reactor Engineer

John A. Bernard, Ph.D.
Director

JAB/koc

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cc: USNRC - Senior Proejct Manager, NRR/ONDD

USNRC - Region I - Project Scientist
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FRSSB/DRSS

The second correlation was recently proposed by Kowalski et al. to predict OSV for coolant channels with finned surfaces [Ref. 3-4]. It is:

$$Xe_{OSV} = -\frac{q'' Pe^{0.18}}{0.0446\, G\, H_{fg}} \tag{3.4}$$

The equilibrium qualities predicted by the above two relationships are compared and the lesser of the two, which is the one that corresponds to a lower coolant temperature, is used to check for OSV. This yields a conservative prediction of OSV using the MULCH-FC code.

3.4 Fission Converter Operating Limits

The operating limits include the power deposition factor, nuclear hot channel factor, fueled region coolant flow factor, flow disparity factor, and the engineering hot channel factors. These factors are used in the calculation of the thermal hydraulics limits (Section 3.5). The nuclear hot channel factor, fueled region coolant flow factor, and the flow disparity factor will be determined prior to the initial startup test (Sections 8.4 and 8.6(5a)). If the determined values are less conservative than the ones used in the existing calculations, these calculations will be performed again and the operating condition or limits adjusted as necessary. The engineering hot channel factors are determined by statistically combining the uncertainties associated with design, calculation, and measurement. These uncertainties are governed by the MITR quality assurance program as well as by testing and calibration procedures for the fission converter.

3.4.1 Power Deposition Factor (F_p) and Nuclear Hot Channel Factor (F_{HC})

The power deposition factor defines the percentage of the fission power deposited in the fueled region (both fuel and coolant) of the fission converter tank. It is expected that at least a few percent of the fission power will be deposited outside the fission converter's fueled region because of the long mean-free-path of gammas and fast neutrons compared to the small size of the fission converter [Ref. 3-5]. However, the power deposition factor for the fission converter is conservatively assumed to be 100% in this analysis. That is, it is assumed that there is no energy escaping the fission converter tank.

8. Pre-operational Tests and Initial Operation

This chapter summarizes the pre-operational tests and initial operation of the fission converter. The pre-operational tests are designed to ensure that the fission converter has been constructed in accordance with the information presented in this report. Specifically, the tests are to prove the satisfactory operation of essential fission converter components. The procedure for the initial fuel loading of the fission converter is described. Calculation has shown that the maximum k_{eff} of the fission converter is 0.62. Hence, a criticality condition is not credible.

The major steps for the first approach for the fission converter's operation at power are summarized. These include measurement of the flow distribution in the fission converter fuel region and estimation of the fission converter reactivity effect on the MITR. The initial startup of the fission converter to its highest available operating power will be achieved by a stepwise rise of the reactor's power.

8.1 Pre-Operational Tests

Pre-operational tests will be performed to ensure that the facility will operate as designed. Dummy fuel elements and other items that replicate flow conditions are available for the pre-operational tests. These tests will be used to establish initial compliance with the approved technical specifications. The tests will include component inspection, verification that performance objectives are met, instrument calibrations, and the operability of interlocks. All tests will be conducted in accordance with the existing MITR quality assurance program.

8.1.1 Non-Nuclear Instrument Calibration

Instruments for measuring system pressure, temperature, and flow can be calibrated prior to the initial startup of the fission converter. The techniques used for these calibrations will be those currently employed to calibrate similar instruments on the MIT Research Reactor. Accordingly, these instruments will be calibrated prior to the initial startup of the fission converter and technical specifications pertaining to the signals from these instruments shall be in effect during the initial startup.

8.3 Initial Fuel Loading

The initial fuel loading will be made after the pre-operational testing has been satisfactorily completed. The reactor will be shutdown and the converter control shutter (CCS) fully closed before the fuel loading of the fission converter begins. Calculation has shown that the maximal reactivity of the fission converter is 0.67. So, a criticality condition is not credible (Section 2.3.1). Because irradiated fuel with a large gamma dose rate will be loaded into the D_2O-filled converter tank, a significant photoneutron flux will be produced with each loading. This would render a 1/M plot meaningless.

8.4 Fuel Region Flow Distribution Measurement

The flow distribution among the fuel elements will determined prior to startup of the fission converter. A Pitot tube or an equivalent device will be used to measure the flow rates through each fuel element position. The minimum flow rate through any of the fuel elements along with the flow distribution within a fuel element (this is known from the MITR-II startup test data [Ref. 8-1]) will be used to determine if the operating limits on the fueled region coolant flow factor and the channel flow disparity factor are satisfied (Section 3.4.2).

8.5 Reactivity Estimation of the Fission Converter

Estimation of the fission converter reactivity is divided into two parts. First, the integral reactivity associated with fully opening the CCS will be measured. Second, the differential reactivity worth associated with partial opening of the CCS will be measured.

2. All process and radiation monitoring systems will be placed in their normal operating condition with non-nuclear instruments calibrated.

3. The converter power will be increased by raising the reactor power in a stepwise manner. Radiation levels and system temperatures will be monitored during each power increment. This procedure will be repeated until the maximum available operating power is attained.

4. The following measurements will be made:

   a) <u>Temperature Distribution</u>
   The temperature distribution in the fission converter plate will be calculated using the actual fuel loading prior to the initial power ascension. The result of this temperature distribution determination will be used to identify the hot channel and to determine that both the operating limit for power deposition and the nuclear hot channel factor are satisfied (Section 3.4.1). This temperature distribution will be verified by correlating it with the bulk coolant temperature. The latter will be measured.

   b) <u>Process Parameters</u>
   Fission converter primary inlet and outlet temperatures as well as flow rate will be measured. This information will be used to perform a calorimetric.

   c) <u>Radiation Surveys</u>
   Radiation measurements will be made outside the fission converter facility and inside the fission converter medical therapy room via remote monitoring.

   d) <u>Nuclear Instrument Calibration</u>
   The fission converter power will be calculated via a calorimetric. Energy losses because of gamma radiation etc. will be taken into account. The equilibrium neutron count rate associated with the nuclear instrumentation will be measured. Correlation of these count rates with the calorimetric will be used to calibrate the nuclear instruments.

The above procedure for a stepwise increase of the fission converter operating power will be repeated if any one of the following design changes is made:

1. The maximum available operating power is increased,
2. The fission converter primary coolant is changed from H_2O to D_2O (the hot channel factor increases – see Table 2.4), or
3. Fresh fuel is used to replace burned fuel.
4. The aluminum block located between the fuel region and the tank wall is removed or replaced by another approved unit.

References

[8-1] MITR Staff, "MITR-II Startup Report", MITNE-198, Feb. 1977.

6.6.5 Reporting Requirements

Applicability

This specification applies to the reporting requirements and the contents of the initial startup tests of the fission converter system.

Objective

To assure that adequate management controls are available for safe operation of the fission converter.

Specification

1. A written report to the Document Control Desk, USNRC, Washington, D.C shall be made within 90 days after completion of the startup testing of the fission converter that is required upon receipt of a new facility license or an amendment to the license authorizing an increase in fission converter power level. This report shall describe the measured values of the operating conditions or characteristics of the reactor under the new conditions, including:
    a. An evaluation of facility performance to date in comparison with design predictions and specifications; and
    b. A reassessment of the safety evaluation submitted with the license application in light of measured operating characteristics when such measurements indicate that there may be substantial variance from prior evaluation.
2. The startup report shall include the following items:
    a. calculation of k-effective for the initial fuel loading,
    b. measurements and comparison to prediction of flow disparity,

c. determination and comparisons to prediction of nuclear hot channel factor, and

d. fission converter power measurements and calibrations.