Regulatory File Cy.

12-22-70

REVISION NO. 2 OF

PROPOSED CHANGE NO. 4

FOR THE

SOUTHWEST EXPERIMENTAL FAST OXIDE REACTOR

RE: LICENSE DR-15

DOCKET NO. 50-231

GENERAL ELECTRIC COMPANY

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Sunnyvale, Calif.

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Revision No. 2 of

Proposed Change No. 4

for the

SEFOR Technical Specifications

1. Introduction

Revision 1 of Proposed Change No. 4 was submitted by letter dated December 11, 1970, with the notation that additional information concerning the criteria for continued operation with failed fuel would be provided later. This document contains that additional information.

2. Proposed Changes

Pursuant to the provisions of 10 CFR 50.59, General Electric requests that the SEFOR Technical Specifications be changed by adding pages 3.13-1 through 3.13-7 in Attachment A of this document to the current Technical Specifications. These pages replace those previously submitted as Revision 1, changes having been made to those parts related to cover gas activity and criteria for operation with failed fuel.

3. Purpose of the Proposed Change

Specification 3.10.E of the present SEFOR Technical Specifications requires that certain additional specifications be approved and incorporated into the Technical Specifications prior to initial operation at 20 MWt. These specifications are submitted herewith, based on experience gained in operating SEFOR up to and including the 10 MWt power level, to satisfy the requirements of Specifications 3.10.E and 6.6.B.3.

4. Discussion

4.1 General

The basic fuel failure detection system in SEFOR is the Gross Cover Gas Monitor (GCGM). Information obtained from the GCGM is supplemented by isotopic analysis of the fission products in

cover gas and sodium samples and by examination of fuel rods in the refueling cell. The GCGM provides a continuous indication of the gross gamma activity in the reactor vessel cover gas. Isotopic analysis of the fission products in the cover gas and fuel rod examinations are performed on a routine basis as specified in 4.4.P and 4.3 of the Technical Specifications. Proposed Specification 3.13.A.1 provides a specific change in level for the GCGM reading that will be treated as anomalous fuel behavior. Proposed Specification 3.13.B provides a limiting condition for operation that assures that the GCGM is always capable of detecting an anomaly as defined by proposed Specification 3.13.A.1.

Specification 4.9.B.1 outlines specific steps to be taken in the event of a cover gas anomaly as defined by proposed Specification 3.13.A.1. Cover gas samples will be taken for isotopic analysis as part of the diagnosis of a cover gas anomaly. (Specification 4.4.P) If the results of this analysis give positive indication that cladding failure has occurred (as indicated by a significant increase in short half-lived [less than three hours] isotopes in the cover gas as discussed below), Specification 4.9.B.3 and 4.9.B.4 require that the reactor be shut down for examination of all fuel rods which are accessible under the through-head ports and that at least two sodium samples be obtained from the reactor vessel. Section 4.9.B also specifies the conditions under which reactor operation may be resumed. In this regard, it should be noted that a decision to resume steady state operations may be made with an indication of failed fuel as well as leakers in the core. However, excursion tests with an indication of failed fuel would be prohibited by Specification 3.12.B.10.

The technical bases for the proposed specification covering operation in the presence of a known loss of clad integrity is given in the following discussion and in the bases for proposed Specification 3.13.A.1 and 3.13.B.

4.2 Technical Bases:

The reactor cover gas monitoring function includes: (1) a continuous gross gamma activity detection capability and (2) specific provisions for isotopic analyses at routine intervals or following detection of anomalous conditions. Taken together, these two functions provide an effective method of detecting anomalous fuel behavior and characterizing the nature of such behavior.

The GCGM responds to four decades (1 mr/hr to 10 R/hr) of activity, ranging well above and below the normal reading of 50 to 100 mr/hr during reactor operation. Its response to activity release events (∿3 min) is approximately equivalent to that of a delayed neutron monitor (∿1 min).

A significant increase in delayed neutrons in the primary sodium is regarded as indicative of a significant cladding failure, since the short-lived delayed neutron precursors are not released to the sodium unless some fuel surface is exposed to flowing coolant. Requirements for cover gas analysis at SEFOR provide a similar cladding failure detection capability. Rather than detecting the presence of short-lived species by delayed neutron release, their noble gas daughters which are released to the cover gas, are detected by gamma emissions and are measured by means of gamma ray spectroscopy of cover gas samples. It should be noted, however, that of the two methods, detection of delayed neutrons is related more conclusively to exposure of fuel material to flowing sodium, while detection of the noble gas daughters (which, compared to neutrons, possess significantly long half-lives) may also indicate the release (from a leaking fuel rod) of the low equilibrium levels of these species which are normally held within the cladding. However, through determination of the isotopic ratios of various fission products, including these short half-life noble gas daughters, it is possible to distinguish between exposure of fuel to flowing sodium and leakage of gases through small defects. Minute quantities of such fission products, apparently due to the presence of tramp fissile material in the sodium or plated on surfaces in the vicinity of the core, have been identified at SEFOR; these are listed in Table I and discussed below.

The background effects of A^{41} and Ne^{23} have also been measured at 10 MWt operation. A^{41}, at a level of 0.016 μCi/cc, produces a response of 4 mr/hr on the GCGM. Ne^{23} activity was determined to be 0.88 μCi/cc, producing a response of 22 mr/hr.

A previous submittal[1] indicated that the GCGM response was due to A^{41}. However, improved analytical techniques detected the 38 sec Ne^{23} and determined that its contribution to cover gas activity was significantly greater than that of A^{41}. The dominant influence of the 38 sec Ne^{23} on the GCGM reading causes a larger variation in the reading of the GCGM than originally anticipated due to small flow variations in the system. For this reason, the anomaly limit on the GCGM reading has been expressed in terms of an incremental change rather than a multiple of the background reading proposed in Reference 1.

Provision has been made in the SEFOR design for accommodation of the fission gas which might realistically be released from a large number of leaking fuel rods.[2] Complete depressurization of a fuel rod would yield a small fraction of this amount. However, such a release level could also accompany the occurrence of a more serious cladding defect and has been used to determine the incremental release which necessitates special diagnostic activities. The response of the GCGM to the principal noble gases released from an average rod following three days' irradiation at the 20 MWt level is given in Table II. The 1610 mr/hr increase is more than three times the proposed anomaly limit of 500 mr/hr. The fractional release-to-birth ratios of Reference 3 have been adopted for this estimate.

Diagnosis of cladding failure characteristics on the basis of isotopic analysis of the cover gas has the potential of higher resolution than diagnosis by delayed neutrons because of favorable branching ratios. Thus, fuel condition diagnosis by radiometric assay of cover gas samples is practical due to the abundance of released gamma activity and the relatively high efficiency of gamma-counting equipment. The fractional decay chains of the longest-lived precursor isotopes are given in Table III.

Received w/ Ltr. 12-31-70
Regulatory File Cy.

It is pertinent to note in this connection that the trip setting above background of the FERD* system at EBR-II has been related to an exposed fuel surface area. The relation was made on the basis of measured incremental count rates due to the deliberate introduction of a known (recoil surface) fission product source in the reactor.[4,5] This bare fuel experiment determined that the full power background count rates can be correlated with approximately 11 cm^2 surface of the unclad fuel. Since trip levels are set at twice background (on two-out-of-three channels), automatic protective action is taken if the delayed neutron signal increases by an amount equivalent to that produced by the 11 cm^2 source.

More generally, this trip-increment source is computed to correspond to the effect of 5.8×10^{10} fissions/second (determined from fission fragment range data) or 1.6×10^{10} fissions/second (based on Xe^{135} production observed during the bare fuel experiment). The latter value is adopted as a more conservative estimate.

Exposure of SEFOR fuel to sodium would produce a weaker source per unit area than the EBR-II bare fuel, smaller by a factor of 15, since the source is proportional to the fission density (and the effective recoil skin depth). Thus, 11 cm^2 of exposed SEFOR fuel surface would contribute approximately 10^9 fissions/second.

Radiometric assay of reactor cover gas samples at SEFOR has shown a fission product activity of approximately 1×10^{-4} μCi/cc for short (<3 hrs) half-life isotopes and 2×10^{-4} μCi/cc for the longer-lived isotopes. Computations show that this activity would be produced by a source level of approximately 10^8 fissions/second. This level therefore corresponds to an effective recoil surface area of 1.1 cm^2 at an average flux position, or a total in-core surface contamination level of 0.22 mg fissile (the corresponding tramp level in EBR-II is 8.0 mg fissile).

*Fuel Element Rupture Detector, based upon detection of delayed neutrons.

Replacement Page
December 31, 1970

Consequently, the technique of cover gas analysis to detect and measure the short-lived fission products, as demonstrated at SEFOR, can effectively determine the condition of the fuel and can detect significant changes which may occur as a result of operation with known loss of clad integrity.

It is pertinent to note in this connection that the trip setting above background of the FERD* system at EBR-II may be related to an exposed fuel surface area. The relation is made on the basis of measured incremental count rates due to the deliberate introduction of a known (recoil surface) fission product source in the reactor.[4] This bare fuel experiment determined that the full power background count rates can be correlated with approximately 8 cm^2 exposed fuel surface. Since trip levels are set at twice background (on two-out-of-three channels), automatic protective action is taken if an additional effective source corresponding to 8 cm^2 of fuel surface should develop.

Cover gas analyses at EBR-II established a fission product Xe^{135} production rate of 1.1×10^{10} atoms/second due to presence of the bare fuel pin.[5] Assuming a fission chain yield of 0.06, the fission rate is 1.8×10^{11} fission/second. Since the fuel surface area was 40 cm^2, exposure of 8 cm^2 of fuel would provide a source of 3.6×10^{10} fissions/second.

Exposure of SEFOR fuel to sodium would produce a weaker source per unit area, smaller by a factor of 30, since the source is proportional to the fission density (and the effective recoil skin depth). Thus, 8 cm^2 of exposed SEFOR fuel surface would contribute approximately 10^9 fissions/second.

Radiometric assay of reactor cover gas samples at SEFOR have shown a fission product activity of 1×10^{-4} μCi/cc for short (<3 hrs) half-life isotopes. Computations show that this activity would be produced by a source level of 1×10^5 fissions/second. This level therefore corresponds to an effective recoil surface area of only 8×10^{-4} cm^2, which provides a measure of the capability of current diagnostic methods at SEFOR to detect small changes in fuel condition.

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* Fuel Element Rupture Detector, based upon detection of delayed neutrons.

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A factor of 1000 increase in the present short-lived fission product background would be related to the presence of 0.8 cm^2 of exposed fuel, if it were not accompanied by a corresponding increase in long life isotopes. Consequently, sensitive measuring capabilities are available at SEFOR to determine the condition of the fuel and to detect any changes in the fuel which may occur as a result of operation with a known loss of clad integrity.

TABLE I

COVER GAS ISOTOPES DETECTED IN SEFOR

Isotope	Half-Life	Principal γ E (Mev)	Comment
Ne^{23}	38.6 sec	0.440	$Na^{23} + n \rightarrow Ne^{23} + p + \gamma$
A^{41}	1.83 hr	1.29	$A^{40} + n \rightarrow A^{41} + \gamma$
Na^{24}	15.0 hr	1.37	$Na^{23} + n \rightarrow Na^{24} + \gamma$
Xe^{133}	5.27 d	0.081	Fission Product
Xe^{135}	9.16 hr	0.250	Fission Product
Xe^{135m}	15.7 m	0.527	Fission Product
Xe^{138}	14.2 m*	Cs^{138} Daughter	Detected by Cs^{138} $E(\gamma)$ = 0.46, 1.01, 1.426 Mev
Kr^{85m}	4.4 hr	0.150	Fission Product
Kr^{87}	76 m*	0.196	Fission Product
Kr^{88}	2.79 hr*	0.403	Fission Product

* Daughters of delayed neutron precursors, alternate branch.

TABLE 11

GCGM RESPONSE TO ROD DEPRESSURIZATION*

Isotope	Calculated Rod Activity	Isotopic Release/Birth(3) Ratio (3 days)	μCi/cc In Cover Gas	mr/hr GCGM Reading
Xe^{133}	3.00×10^{2} Ci	3×10^{-2}	15.0	75
Xe^{135}	1.76×10^{3}	6×10^{-3}	17.6	880
Kr^{85m}	1.92×10^{2}	6×10^{-3}	1.92	60
Kr^{88}	3.91×10^{2}	2×10^{-3}	1.30	505
Kr^{87}	3.22×10^{2}	1×10^{-3}	0.54	90

Total GCGM Response = 1610

* Assumes 3 days operation at 20 MWt and no significant holdup (delay) within the cladding. Additional contributions from shorter-lived isotopes may increase the total response, if their release/birth ratios prove to be significant.

TABLE III

DELAYED NEUTRON PRECURSOR DECAY BRANCHING

Precursor Isotope	Half-Life	γ - Emitting Daughter (Fraction)	n - Emission Branch Daughter (Fraction)
Br^{87}	54.8 sec	Kr^{87} (0.97)	Kr^{86} (0.03)
I^{137}	24.4 sec	Xe^{137} (0.97)	Xe^{136} (0.03)
Br^{88}	16.3 sec	Kr^{88} (0.94)	Kr^{87} (0.06)
I^{138}	6.3 sec	Xe^{138} (0.98)	Xe^{137} (0.02)

References

(1) Proposed Change No. 4 to the SEFOR Technical Specifications, Sept. 3, 1970

(2) SEFOR FDSAR, Supplement 21, pages 32, 33.

(3) A.W. Longest (ORNL) et.al., "Fission Gas Release Measurements from Fast Breeder (U, Pu)O_2 Fuel," Transactions of the American Nuclear Society Winter Meeting, November 15-20, 1970, Washington, D.C.

(4) R.R. Smith, et.al., "Exposed Fuel Calibration Study in EBR-II - Second Series," ANL-7558, January, 1970.

(5) G.G. Brunson, "Studies with the Reactor Cvoer Gas Monitor," ANL - Reactor Development Program Progress Report, ANL-7679, March, 1970, p. 91.