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Mr. Victor Stello, Director
Division of Operating Reactors
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Stello:

MONTICELLO NUCLEAR GENERATING PLANT
Docket No. 50-263 License No. DPR-22

Failed Fuel Detection Report

This report is submitted in compliance with Technical Specification 6.7.C.2.3. During early licensing discussions there was an interest on the part of AEC personnel to see confirmatory evidence of certain analytical predictions presented by the licensee. One such area of interest was the sensitivity of the main steamline (MSL) radiation monitor and its ability to isolate the reactor in the event of a postulated control rod drop accident (RDA). Technical Specification 6.7.C.2.3 was therefore issued, requiring a summary technical report on "Failed Fuel Detection" to be submitted within five years of the initial commercial service date. This report concludes that, based on past operating data, the isolation signal will be generated as designed in the event of the highly unlikely event of an RDA.

The MSL monitor system consists of four area radiation monitors sensing radiation in the main steamlines. The four main steamlines go from the reactor vessel, through containment into the steam chase and to the turbine. In each MSL are two main steamline isolation valves (MSIV) in series, one immediately inside and the

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other immediately outside of the primary containment boundary. The four outboard MSIV's are located in the enclosed steam chase room. The MSL radiation monitors are mounted in the steam chase near the ceiling so as to have approximately equal sensitivity to all steamlines. There is a significant background radiation level in the steam chase due to the short-lived N^{16} mixed with the steam.

Section 14-6.2 of the Monticello FSAR discusses the postulated RDA event and its consequences. An extremely unlikely combination of plant conditions, operator errors and equipment failures are assumed. Under these conditions, the analysis shows that limited local fuel damage results and the offsite radiological consequences are determined. It is assumed that the plant has operated for a long period of time prior to being shutdown. Thirty minutes after the shutdown, the plant is assumed to have returned to hot standby and is passing 5% of rated steam flow to the condenser. The mechanical vacuum pump is assumed to be in service, transferring gases from the condenser to the plant stack through a short holdup line. In the event of such an RDA, the N^{16} contribution to the MSL monitor reading will be negligible. However, if fuel failures exist, it is assumed that noble gas fission products will pass through the steam lines, tripping the MSL monitors, resulting in a reactor isolation. Technical Specification 3.2.A requires the trip setting to be less than or equal to ten times normal background at rated power.

The FSAR analysis of the RDA is a unique analysis for the initial Monticello core. It later became apparent that a generic, bounding treatment of the RDA was appropriate. Through parametric studies of the parameters involved, bounds were defined such that if each parameter falls within the bounds, the RDA will be less severe than calculated. The dose consequence calculation assumes all parameters are at the bounding value; in reality, those conditions are not expected to occur simultaneously and therefore the RDA results are overly conservative. In adopting the bounding value concept, the source term and the resulting dose are double those reported in the FSAR. This was acceptable because of the relatively minor impact of the postulated RDA. The maximum offsite dose based on bounding values is less than 0.2% of the whole body dose limit and less than 10% of the thyroid dose limit of 10 CFR Part 100. Docketed information on the bounding value concept can be found in a March 2, 1973 letter from L. ?. Mayer (NSP) to D. L. Ziemann (USAEC) and references stated therein. The initial and modified source terms are tabulated below:

	FSAR	Bounding Value Concept
Number of Failed Fuel Pins (7x7)	330	660
Noble Gases Released to the Coolant	6.2×10^4 Ci	1.24×10^5 Ci
Noble Gases Carried to the Condenser	5.5×10^3 Ci	1.1×10^4 Ci

Operation at Monticello over the past years has provided sufficient data to calibrate the MSL radiation monitors. During the warranty run at the end of the startup test program in 1971, the average reading of the four MSL radiation monitors was 654 mr/hr. The air ejector offgas level was negligible during this time, indicating that essentially no fission gas was contributing to the MSL monitor reading. The 654 mr/hr was attributed to the N^{16} background. The background was conservatively defined as a nominal 500 mr/hr and Technical Specification 3.2.A interpreted as requiring the setpoint for isolation as 5000 mr/hr.

In early 1975 the MSL radiation monitor reading showed a noticable increase due to failed fuel rods in the reactor. (Since then the defective fuel has been replaced and the MSL monitor has shown a corresponding decrease.) The noble gas fission products, the significant contributors to the increased readings, are measured at the air ejector. When at rated power in early 1975, the average of the four MSL radiation monitors was 808 mr/hr. The corresponding air ejector offgas monitor reading showed basically a recoil mixture, which, for the sum of the 15 principal long-lived noble gas fission products, corresponds to 20.7 Ci/sec at the reactor core. The volume of steam in the reactor vessel head and the steam lines involves a 6.7 second transit time from the core to the MSL monitors at rated steam flow, at which time there is a significant contribution to the MSL monitor reading from short lived noble gases. The 21 principal noble gas isotopes after 6.7 seconds of decay represent 50.8 Ci/sec. This source term is responsible for the MSL monitor increase from 654 to 808 mr/hr. The sensitivity of the monitor is therefore 5640 $\frac{\text{mr/hr}}{\text{Ci/lb}}$. The noble gases considered are listed in Table I.

The performance of the MSL radiation monitor can be determined using the empirically established sensitivity. Two aspects must be considered; first, to verify that the sensor trip will occur as assumed in the analysis for the worst case release and second, if a smaller release is involved such that an automatic isolation does not occur, that the offsite dose is acceptable assuming sufficient time for manual isolation. The activity in the reactor is expressed as

$$\frac{d\,N_{r,i}}{d\,t} = -(\lambda_i + L)\,N_{r,i} \tag{1}$$

$$N_{r,i} = N_{o,i}\,e^{-(\lambda_i + L)t} \tag{2}$$

and the activity transferred to the condenser is expressed as:

$$\frac{d\,N_{t,i}}{d\,t} = N_{r,i}\;L = N_{o,i}L e^{-(\lambda_i + L)t} \tag{3}$$

$$N_{t,i} = \frac{N_{o,i}\,L}{\lambda_i + L}\left[1 - e^{-(\lambda_i + L)t}\right] \tag{4}$$

where

N_r = activity in the reactor vessel (curies)

L = steam flow rate from the reactor vessel divided by the vapor volume of the reactor vessel (sec^{-1})

λ = radioactivity decay constant (sec^{-1})

N_o = activity released to the reactor vessel from the perforated rods (curies)

N_t = activity transferred to the condenser (curies)

i = identifier of i^{th} isotope.

The activity flow rate past the MSL monitor is given by equation 3. This is at its maximum at time zero; the decay in transit to the MSL monitors is negligible. For the bounding value source term,

$$\sum_i N_{o,i} = 1.24 \times 10^5 \text{ Curie},$$

$$\frac{d\,N_t}{d\,t} = 924 \text{ Ci/sec.}$$

Multiplying by the MSL monitor sensitivity and dividing by the steam flow rate (5% of rated) gives

MSL monitor reading = 56,000 mr/hr.

This is well in excess of the Technical Specification trip setting of 5000 mr/hr, verifying that a trip will occur as designed. Since for the isotopes of significance after 30 minutes

$$\lambda_i \ll L,$$

equations 3 and 4 can be written

$$\frac{d\,N_t}{d\,t} = N_o\, e^{-Lt} \qquad (5)$$

$$N_t = N_o \left[1 - e^{-Lt}\right] . \qquad (6)$$

In the event that the number of failed fuel pins during the postulated RDA is sufficiently small such that the MSL monitor trip setting for isolation is not exceeded, the source term at 5% of rated steam flow would be

$$N_o < 1.24 \times 10^5 \left[\frac{5,000}{56,000}\right] = 1.11 \times 10^4 \text{ Ci.}$$

Using maximum steam flow (5% of rated) in the calculation is conservative because the activity passing the monitors is in its most diluted form. Greater than 5% steam flow while operating the mechanical vacuum pump is not a realistic plant condition. Using the above source term and assuming a manual isolation in 10 minutes, equation 6 indicates that

$$N_t < 1.1 \times 10^{-4} \text{ Ci.}$$

No decay has been assumed. At 5% of rated steam flow, 7.53 minutes are required to reach the condenser which will allow a measurable decay.

In the solution for N_t at 10 minutes, it should be noted that 99% of the source term, N_o, passes to the condenser. This means N_t will not be affected significantly if more than 10 minutes is required for operator action. Prompt operator action is expected, however, because the control room operator will receive alarms at 50% of the MSL monitor isolation setting and from a high neutrom flux scram. The operator has controls on the bench panel before him with which he can manually close the MSIV's and trip the mechanical vacuum pump.

In conclusion, a review of operation over the past years has confirmed the design and function of the MSL radiation monitor system. The bounding value analysis of the RDA shows the offsite dose consequence to be conservatively low with respect to 10 CFR Part 100 limits for a maximum transfer of 1.1×10^{-5} Curies of noble gases to the condenser. This report shows the ability to isolate under these maximum conditions. It also shows that for an RDA release source term too small to trip the

MSL monitor, the noble gases transferred to the condenser will not exceed that of the the automatic isolation for a 10 minute manual isolation.

Yours very truly,

L. O. Mayer

L. O. Mayer, PE
Manager, Nuclear Support Services

LOM/MHV/deb

cc: J. G. Keppler
G. Charnoff
MPCA
Attn: J. W. Ferman

Attachment

Table I

Principal Noble Gases Used in Analysis

Isotope	N_i - Yield %	$T_{\frac{1}{2}}$ - i	$\lambda_i(\text{sec}^{-1})$	$\lambda_i N_i$*	$\lambda_i N_i e^{-1800\lambda_i}$**
Kr^{94}	0.10	1s	6.93×10^{-1}	6.93×10^{-2}	--
Kr^{93}	0.48	1.3s	5.33×10^{-1}	2.56×10^{-1}	--
Xe^{141}	1.33	1.72s	4.03×10^{-1}	5.36×10^{-1}	--
Kr^{92}	1.87	1.84s	3.77×10^{-1}	7.04×10^{-1}	--
Kr^{91}	3.45	8.6s	8.06×10^{-2}	2.78×10^{-1}	--
Xe^{140}	3.80	13.6s	5.10×10^{-2}	1.94×10^{-1}	--
Kr^{90}	5.00	32.3s	2.15×10^{-2}	1.07×10^{-1}	--
Xe^{139}	5.40	40s	1.73×10^{-2}	9.36×10^{-2}	--
Kr^{89}	4.59	3.2m	3.61×10^{-3}	1.66×10^{-2}	2.50×10^{-5}
Xe^{137}	6.00	3.82m	3.02×10^{-3}	1.81×10^{-2}	7.85×10^{-5}
Xe^{135m}	1.80	15.7m	7.36×10^{-4}	1.32×10^{-3}	3.52×10^{-4}
Xe^{138}	5.90	14.2m	8.13×10^{-4}	4.80×10^{-3}	1.11×10^{-3}
Kr^{87}	2.53	76m	1.52×10^{-4}	3.84×10^{-4}	2.92×10^{-4}
Kr^{83m}	0.52	1.86h	1.03×10^{-4}	5.38×10^{-5}	4.47×10^{-5}
Kr^{88}	3.56	2.8h	6.88×10^{-5}	2.45×10^{-4}	2.16×10^{-4}
Kr^{85m}	1.30	4.4h	4.38×10^{-5}	5.69×10^{-5}	5.26×10^{-5}
Xe^{135}	6.30	9.16h	2.10×10^{-5}	1.32×10^{-4}	1.27×10^{-4}
Xe^{133m}	6.69	2.26d	3.55×10^{-6}	2.37×10^{-5}	2.98×10^{-5}
Xe^{133}	0.16	5.27d	1.52×10^{-6}	2.44×10^{-7}	2.43×10^{-7}
Xe^{131m}	0.44	12.0d	6.68×10^{-7}	2.94×10^{-7}	2.94×10^{-7}
Kr^{85}	0.27	10.8y	2.03×10^{-9}	5.51×10^{-10}	5.51×10^{-10}

*$\lambda_i N_i$ represents the relative isotopic distribution at time zero.

**$\lambda_i N_i e^{-1800\lambda_i}$ represents the relative isotopic distribution after 30 minutes of decay.

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