APPENDIX 11B

PRIMARY-TO-SECONDARY LEAKAGE DETECTION

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The methods used to monitor steam generator leakage are as follows: (1) the steam generator blowdown monitor, which samples the secondary side liquid of steam generator, (2) the main steam line N-16 monitor, which detects N-16 activity in the main steam, and (3) the condenser vacuum vent effluent monitor, which monitors non-condensable gases released from the condenser.

This appendix describes the capability of the N-16 monitor to detect a steam generator leak rate of 4.73 L/day (30 gal/day), which is required by NEI 97-06.

The main steam line N-16 monitors (RE-217 ~ RE-220), which are designed to detect N-16 concentration in the main steam, are usually operated in a multi-channel analyzer mode with a certain energy window or in a gross counting mode with a lower level discriminator that is set to detect only high-energy gamma radiation. The effectiveness of leakage monitoring via the N-16 detectors varies depending on the primary-to-secondary (PTS) leak rate, reactor power level, transit time from the core to the detector, and amount of uranium depletion over the life of the core.

In order to correlate the PTS leak rate to the N-16 activity concentration in the main steam line at the detector location, the following assumptions and models are used:

a. A neutron energy level of 10.2 MeV is used as the threshold energy for the O-16(n, p) N-16 reaction.

b. The O-16(n, p) N-16 cross section for the neutron flux spectrum above 10.2 MeV is determined based on a weighted average cross section for the reaction.

c. N-16 activity in the primary coolant at the location of the leakage is calculated using the method described in Subsection 12.2.1.1.2.

d. N-16 activity concentration decreases linearly as the reactor power decreases.

e. The primary coolant transient time is obtained from Subsection 12.2.1.1.2.

f. The length of the main steam lines inside containment is 31.97 m (104.89 ft).

g. The N-16 monitors are assumed to be installed at 0.61 m (2 ft) away from the containment wall.

The SG leak rate is determined using the following equation:

$$\text{SG leak rate} = \frac{\text{count rate}}{A_v \cdot k}$$

Where:

count rate = detector count rate in count per second (cps)

k = detection efficiency in (cps)/(Bq/cm^3), which represents the conversion factor between the detector count rate in cps and the N-16 concentration in Bq/cm^3

A_v = N-16 concentration in Bq/cm^3 corresponding to a SG leak rate

Parameter k is dependent on the configuration of the detection such as thickness of the pipe, types of material in the pipe and insulation, and distance between the probe and the pipe. The value A_v is determined as follows:

$$A_V = 0.2778 \frac{L \cdot A_p}{Q_p \cdot A_s} \exp\left(-\lambda t\right)$$

Where:

0.2778 = unit conversion factor. (cm^3/sec) / (L/hr)

L = SG leakage rate, L/hr

A_P = N-16 activity concentration at the leakage location, which is proportional to the core power, Bq/cm^3

Q_P = steaming rate for a corresponding power level, which is the flow rate of the steam in the secondary loop, cm/sec

A_S = surface area of main steam line, cm^2

λ = decay constant of N-16, sec^{-1} (=0.097 sec^{-1})

t- = transit time ($t = t_1+t_2$) of N-16 from the leakage location to the N-16 detector, sec.

t_1 = transit time between the leak location and the steam generator outlet nozzle in the SG

t_2 = transit time from the SG outlet to detector

N-16 activity concentrations at the detector location calculated at a leak rate of 4.73 L/hr (30 gpd) with varying power levels are given in Table 11B-1 and Figure 11B-1. According to the calculation, the SG leakage rate of 4.73 L/hr (30 gal/day) can be detected within the N-16 monitor range from 1.0×10^{-4} to 1.0 Bq/cm^3. Figure 11B-2 presents the N-16 concentration in the main steam line as a function of SG leakage rate for different power levels. For the SG leakage rate of 23.66 L/hr (150 gal/day), which is the limiting condition of operation in the Technical Specifications, the N-16 concentrations range from 1.90×10^{-3} Bq/cm^3 (10 % power) to 8.64×10^{-1} Bq/cm^3 (100 % power).

Therefore, the N-16 detector, which is capable of monitoring N-16 concentrations from 1.0×10^{-4} to 1.0×10^{1} Bq/cm^3 satisfies the minimum SG leakage rate of 4.73 L/hr (30 gal/day) as well as the Technical Specification limit of 23.66 L/hr (150 gal/day).

Table 11B-1

N-16 Concentrations with Power Level at SG Leakage of 4.73 L/hr (30 gal/day)

Reactor Power Level (%)	N-16 Activity in RCS Bq/cm^3)	Steam Flow Rate from any SG (kg/hr)	Specific Volume of Steam (m^3/kg)	Transit Time (sec)	N-16 Activity at Detector Location (Bq/cm^3)
100 %	4.16E+06	2.036E+06	2.775E-02	7.240	1.728E-01
80 %	3.33E+06	1.584E+06	2.738E-02	9.068	1.508E-01
60 %	2.50E+06	1.141E+06	2.691E-02	12.184	1.181E-01
40 %	1.67E+06	7.255E+05	2.657E-02	18.212	6.991E-02
20 %	8.33E+05	3.320E+05	2.634E-02	36.338	1.328E-02
10 %	4.16E+05	1.522E+05	2.612E-02	73.932	3.809E-04

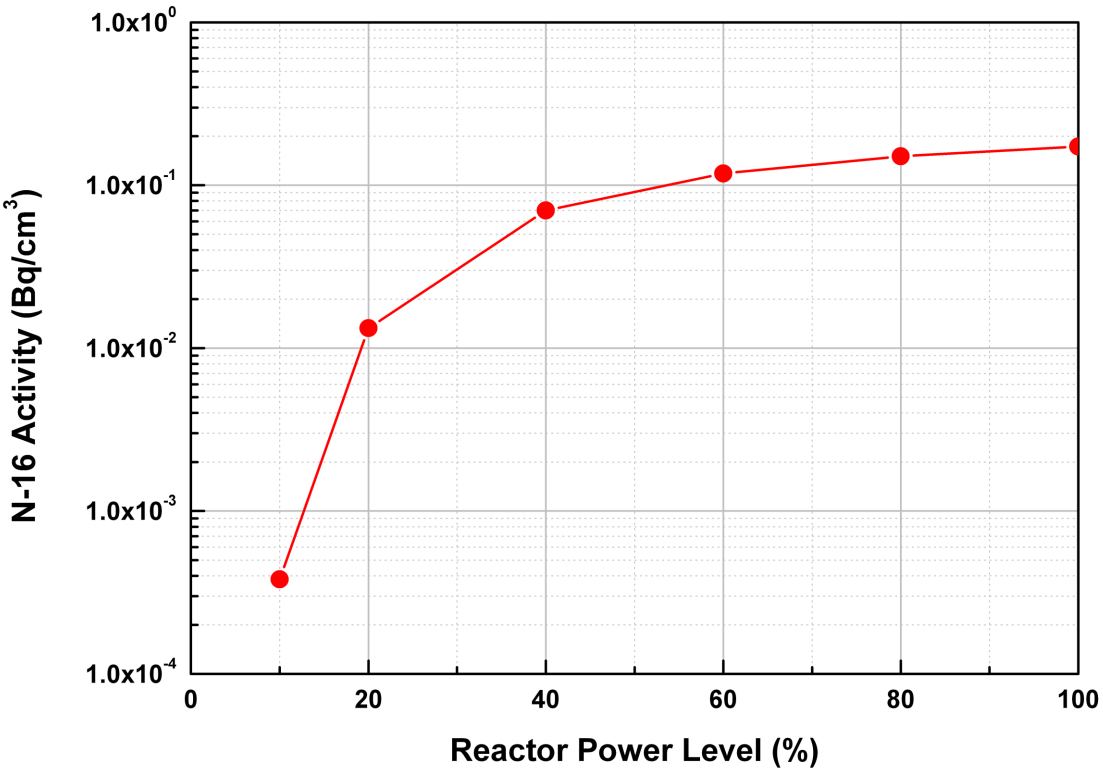

Figure 11B-1 N-16 Concentrations with Power at SG Leakage of 4.73 L/hr (30 gpd)

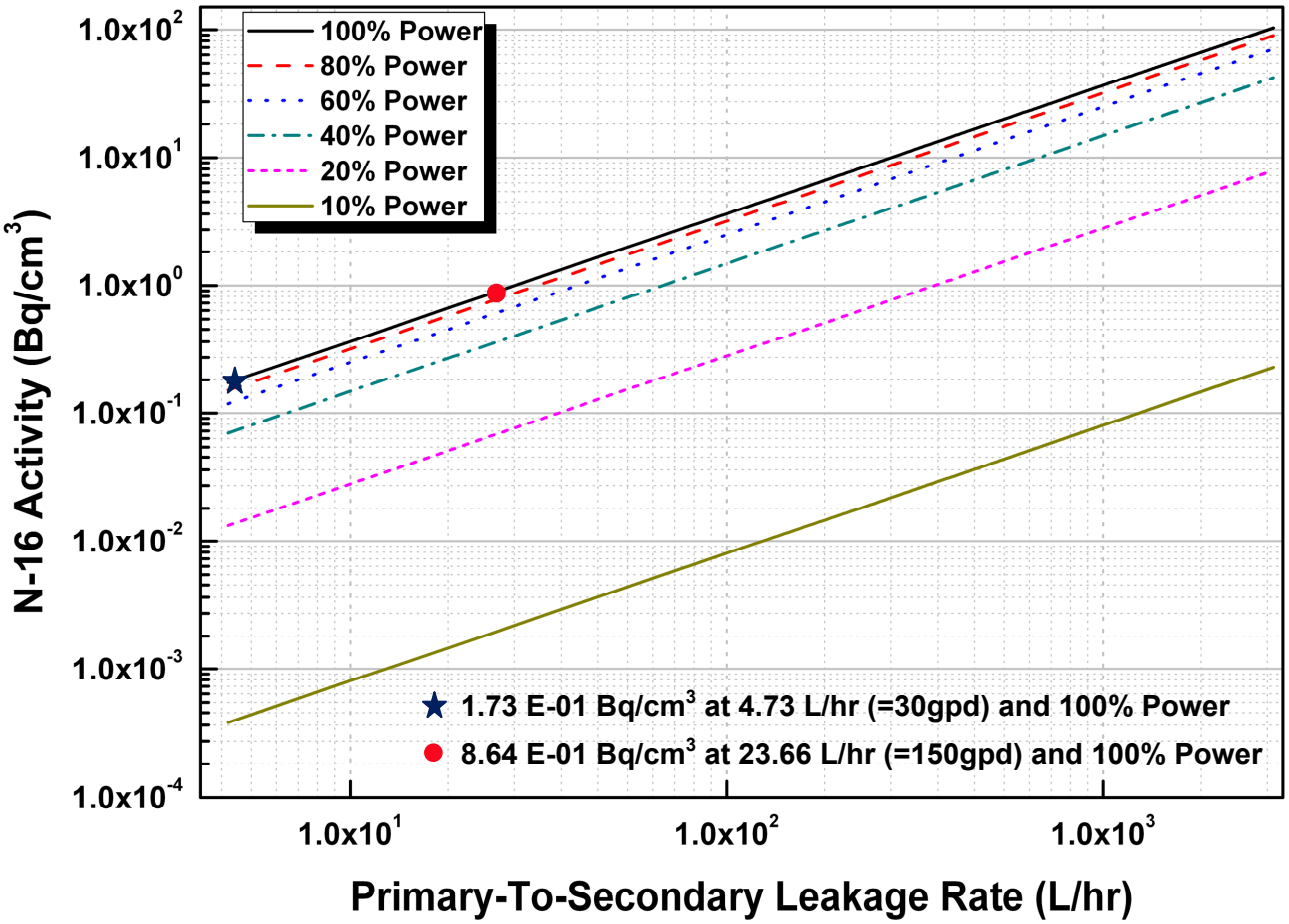

Figure 11B-2 N-16 Concentrations vs. Primary-To-Secondary Leakage Rate For Various Power Levels