Rad Monitor Dose Rates Due to Postulated Steam Tunnel Leakage

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Abstract

Rad monitor dose rates due to postulated steam leakage in the LaSalle County Station steam tunnel have been calculated. The calculations indicate that a steam leak of 100 gallons per minute may result in measurable dose rates at the plenum rad monitor locations due to nitrogen-16 (N-16) in the steam. N-16 decays releasing high energy gamma rays (6.13 and 7.12 Mev). However, because of the short half life of N-16 (7.13 seconds), measurable dose rate fields are present only for leak locations near the plenum (i.e. minimum decay time). Leaks near the far end (away from the plenum) of the tunnel will undergo approximately 8 half lives of decay (3e-3 factor reduction) and may not be measurable at the monitor locations. In summary, the rad monitors may indicate steam leakage in the tunnel, but only if the leakage location is near the plenum viewed by the rad monitors. The monitors thus cannot be relied upon as the sole indicator of leakage in the tunnel.

Table of Contents

List of Tables

1. Introduction

The purpose of this calculation is to determine the dose rates in the VR plenum containing radioactivity due to steam leakage to the main steam tunnel. The dose rates would be measured by rad monitors which view the VR plenum.

2. Model Description and Assumptions

2.1 Noble Gases

Noble gases are assumed to be released from the reactor fuel at the design-basis rate given in Table 3-3 of NEDO-10871 (Ref. 1) . This release rate is the commonly referenced "100,000 uCi per second at 30 minutes decay" and is the design basis for all BWR radiological calculations. For this calculation, no credit is taken for radiodecay. Table 1 lists the nuclides considered [col. 1], their half-life and decay constant [col. 2 & 3], the average gamma ray energy released per disintegration [col. 4 (Ref. 5)], and the release rates at 30 minutes and zero decay time [col. 6 and 7, respectively]..)

The data of Table 1, column 7 (zero radiodecay), is the release rate of radioactivity from the reactor fuel and is assumed to be mixed in the total steam flow for the present calculation. The data of Table 1, column 8, are the products of the amount of radioactivity (curies) and the energy released per disintegration (MeV). Dose rates due to these nuclides are proportional to this product and are provided for comparison with nitrogen-16 activity later.

2.2 Nitrogen-16

Nitrogen-16 (N-16) is produced in the reactor by activation of oxygen-16 in the reactor water. This results in an N-16 concentration of 50 uCi/gm (Reference 2) in the reactor steam. This is assumed to be mixed completely with the total steam flow for the present calculation.

2.3 Steamline Flow

The radionuclides are assumed to be borne by the total steam flow [14.3 million pounds per hour]. Only a part of this, 50,000 pounds per hour, (assuming a sump liquid flow rate of 100 gallons per minute at 62.4 pounds of water per cubic foot) is released to the steam tunnel. Thus the doses due to the leakage are only 5E+4/14.3E+6 (or 0.0035) of that due to releasing all of the radioactivity released from the fuel. This scaling will be used in this calculation.

2.4 Steam tunnel concentrations and Dose rates

Radioactivity released by steam leakage in the main steam tunnel (MST) is assumed to be completely mixed in the tunnel air flow. This flow rate ranges from 40,000 cfm at the beginning of the MST to 100,000 cfm at the discharge. (Reference 4, personal communication, Bill Burns, ComEd-LaSalle Engg).

2.5 Dose rates at rad monitors

The dose rates at the rad monitor sites are calculated by assuming that the concentrations calculated above are present in the 5x12x30-foot VR plenum viewed by the monitors. Radiologically, this is assumed to be equivalent to a 30-foot long line source. The dose rate is calculated by standard shielding formulae (Reference 3) as provided in the Table 2 spreadsheet.

3. Calculations

3.1 Total Steam Concentrations

Table 1 below shows the calculations for the radioactivity concentrations in the main steam line. Also shown is the release rate of radioactivity into the steam tunnel which corresponds to a 100 gpm leak.

Table 1 Radioactivity Release Rate to MST

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Ref NEDO-10871 and NUREG/CR-1413(Kocher)

					RELEASE RATES, uCi/sec	\\\\\V/////	E*Release [MeV*uCi]
Nuclide	Half-life	Decay const, 1/sec	Ebar,gamma MeV	Decay, min=0 Seconds = 0	30.00 1.80E+03	0.00 0.00E+00	0.00 minutes decay
Kr-83m	1.86 h	1.03E-04	0.0026	3.40E+03	2.82E+03	3.40E+03	8.84E+00
Kr-85m	4.4 h	4.38E-05	0.1577	6.10E+03	5.64E+03	6.10E+03	9.62E+02
Kr-85	10.74 y	2.05E-09	0.0022	1.50E+01	1.50E+01	1.50E+01	3.30E-02
Kr-87	76 m	1.52E-04	0.7931	2.00E+04	1.52E+04	2.00E+04	1.59E+04
Kr-88	2.79 h	6.90E-05	1.9545	2.00E+04	1.77E+04	2.00E+04	3.91E+04
Kr-89	3.18 m	3.63E-03	1.8344	1.30E+05	1.89E+02	1.30E+05	2.38E+05
Kr-90	32.3 s	2.15E-02	1.2715	2.80E+05	4.36E-12	2.80E+05	3.56E+05
Xe-131m	11.96 d	6.71E-07	0.0201	1.50E+01	1.50E+01	1.50E+01	3.02E-01
Xe-133m	2.26 d	3.55E-06	0.0415	2.90E+02	2.88E+02	2.90E+02	1.20E+01
Xe-133	5.27 d	1.52E-06	0.0453	8.20E+03	8.18E+03	8.20E+03	3.71E+02
Xe-135m	15.7 m	7.36E-04	0.4307	2.60E+04	6.91E+03	2.60E+04	1.12E+04
Xe-135	9.16 h	2.10E-05	0.2479	2.20E+04	2.12E+04	2.20E+04	5.45E+03
Xe-137	3.82 m	3.02E-03	0.1877	1.50E+05	6.54E+02	1.50E+05	2.82E+04
Xe-138	14.2 m	8.13E-04	1.1258	8.90E+04	2.06E+04	8.90E+04	1.00E+05
Xe-139	40 s	1.73E-02	0.0000	2.80E+05	8.38E-09	2.80E+05	0.00E+00
			TOTAL uCi/sec	1.04E+06	9.94E+04	1.04E+06	7.96E+05
						Ebar gamma	7.69E-01

For main steam flow	1.43E+07 lb/hr					
get concentrations--->		[uCi/gm]		5.74E-01	5.51E-02	5.74E-01
N-16	7.13 s	9.72E-02	4.6			
		concentration, uCi/gm		5.00E+01		
		uCi/sec		9.02E+07		
		flow				

For a steam leak of 100 gpm (50,000 lb/hr), the leak rate of N-16 to the tunnel is 3.15E5 uCi/sec.

For this release calculation, it is noted that the product of concentration and energy for fission products (0.57 uCi/gm , 0.796 MeV) is substantially less than that for N-16 (50 uCi/gm, 4.6 MeV). The effect of fission products will therefore not be aaddressed in the ramainder of this calculation as the dose rates due to fission products are negligible compared to N-16 with small decay times.

3.2 100 GPM Leak Dose Rate at Rad Monitors

Table 2 below shows the calculations for the whole body dose assuming a 100 gpm leak into the steam tunnel.

Table 2 100 GPM Leak Rad Monitor Dose Rate

Tunnel air flow rate	1.00E+05 cfm, or	4.72E+07 cc/sec	
N-16 concentration	6.68E-03 uCi/cc		
For volume of	1.80E+03 cubic feet (5*12*30), or	5.10E+07	cm**3
N-16 inventory is	3.41E+05 uCi		
line source dose rate [>>>no decay<<<]			
k(E) R/hr per Mev/cm**2 sec	1.14E-06		
E, MeV	4.60E+00		
S-sub-l dis/cm/sec	1.38E+07		
a, cm	1.83E+02		
dose rate, R/hr	6.29E-02		
dose rate, mR/hr	6.29E+01		

Decay time:
For 40,000 cfm thru a 20x20 foot tunnel, get 100 ft/minute flow velocity;
for an 100 foot flow path, get a 60 sec travel time; at 7.13 sec half life, this corresponds to 8.4 half lives or decay by a factor of about 3E-3.

4. Results

The results show that the rad monitors will see a radiation dose field of about 60 mR/hr for a 100gpm steam leak, IF RADIODECAY IS NOT TAKEN INTO ACCOUNT. The importance of radiodecay for the shortlived N-16 may be demonstrated for the case of a leak at the beginning of the tunnel where the air flow rate is about 40,000 cfm and the tunnel cross section is about 20x20 feet. The linear air speed is 100 ft/minute. For an 100 foot path to the plenum, about 60 seconds of transit time (8.4 half lives) results in a factor of 3E-3 reduction in the rad monitor (or about 0.2 mR/hr) reading in the plenum.

The rad monitor dose rates for a specific steam leakage of 100 gpm (50,000 pounds per hour) were caclculated assuming design basis radionuclide concentrations. The results indicate that N-16 released to the MST by leakage could be measured by the plenum rad monitors well only if the leakage site was near the plenum and radiodecay was negligible. Leakage near the beginning of the tunnel may not be detected due to the radiodecay of N-16.

5. Conclusions

Based on the model, assumptions and calculations presented above, a postulated 100 gallon per minute release of steam to the steam tunnel may, but will not aways be measurable at the rad monitor location due to radiodecay of N-16 prior to reaching the plenum viewed by the rad monitors.

6. References

1. General Electric Licensing Topical Report, "Technical Derivation of BWR 1971 Design Basis Radioactive Material Source Terms", NEDO-10871, March 1973

2. ANSI/ANS-18.1-1984, "American National Standard, Radioactive Source Term for Normal Operation of Light Water Reactors".

3. A. Foderaro, "The Photon Shielding Manual", Penn State University Press, Pg. 14

4. William * Burns, LaSalle County Station - Engineering, personal communication

5. D. C. Kocher, "A Radionuclide Decay Data Base--Index and Summary Table", NUREG/CR-1413, ORNL/NUREG-70, May 1980.