SUSQUEHANNA JL 28 '82 0172824

POST-ACCIDENT AIRBORNE AND PLATEOUT DOSE CALCULATION FOR EQUIPMENT QUALIFICATION PER NUREG-0588

1. INTRODUCTION

The objective of this analysis is to evaluate the post-accident airborne and plate-out radiation doses for equipment qualification using the guidelines and methodology described in NUREG-0588, Rev. 1, Section 1.4 and Appendix D. A consistent, time-dependent, mechanistic approach is used to develop the radiation source distribution among the drywell and the reactor building. The major assumptions and results are discussed below.

2. CORE INVENTORY

Radioactive materials will be released from the reactor core due to fuel rod cladding failure after a postulated major accident (e.g., LOCA). The core is considered to be at an equilibrium end-of-cycle stage, and the core inventory is calculated by the ORIGEN2 code[(1)] based on the following fuel cycle information.

a) Maximum operating power level - 3,440 MWt.
b) Effective fuel power days per cycle - 523 days.
c) Refueling down time - 25 days/cycle.
d) Average initial enrichment - 2.82% U-235.
e) Total U mass of core - 135 MT.
f) Zirc-4 cladding material - 1.79×10^4 Kg.
g) The core is consisted of three batches. The burnup scheme for each batch is considered to be 120% full power (1376 MWt) for cycle 1, 105% full power (1204 MWt) for cycle 2 and 75% full power (850 MWt) for cycle 3.

[illegible]

The calculated 100% noble gases and 50% halogens of core inventory are given in Table 1.

3. ASSUMPTIONS IN CALCULATING THE AIRBORNE AND PLATE-OUT ACTIVITY IN DRYWELL

Per NUREG-0588, the 100% noble gases and 50% halogens of the core inventory are released instantaneously to the drywell atmosphere. Initially, all the activity is contained in the drywell, which has a free volume of 2.4×10^5 ft^3. The airborne activity will then be reduced and redistributed by the following processes:

3.1 Plate-out:

Previous calculations had assumed that 50% of the halogen releases plate-out instantaneously. That is, only 25% of the core halogens is in the drywell atmosphere at time t = 0. Per NUREG-0588, the present calculation evaluates the plate-out mechanistically. Using the methodology of NUREG/CR-0009[2] and a drywell plate-out surface area of 1.5×10^5 ft^2, the elemental iodine plate-out constant is calculated to be 10.2/hr by the Bechtel computer code REMOVE which is similar to the NRC code SPIRT. This value is about 8 times larger than the plate-out constant obtained in NUREG-0588, Appendix D for a PWR plant. The larger values for Susquehanna is due to the facts that a) Susquehanna has a larger drywell internal surface-to-volume ratio; and b) the average mass transfer coefficient for Susquehanna is calculated to exceed the maximum allowable value of 0.137 cm/sec[2]; the latter is therefore used.

The plate-out of elemental iodine is allowed to continue until the airborne elemental iodine concentration is reduced by a factor of 30 (about 20 minutes). This ratio of 30 is maintained constant throughout the remainder of the accident. The ratio R is defined as:

$$R = \frac{\text{total iodine activity}}{\text{iodine activity in the air}}$$

The value of R is determined by the condition that the iodine concentration in the air is in equilibrium with that in the suppression pool water; this gives[3]

$$R = 1 + H \cdot V_S/V_C$$

Where:

H = elemental iodine partition coefficient for water[3]
= 100

V_S = liquid volume of suppression pool
= 122,410 ft^3

V_C = drywell free volume plus suppression pool air space
= 388,190 ft^3

The above equation and parameters thus yield a value of about 30 for R.

In evaluating the above value of R, it is assumed conservatively that all of the plate-out iodine will be washed down to the suppression pool. If part or all of the plate-out is retained by the drywell internal surface, then a larger ratio R will result. For example, if 50% of plate-out iodine stays on the surface, the resulting R will be larger by a factor of 2 than the one evaluated above.

It is assumed, per NUREG-0588, Rev. 1., Appendix D that 5% of the iodine released is particulate iodine, 4% is organic iodine and 91% is elemental iodine. It is further assumed in this calculation that both particulate and organic iodines are unaffected by the plate-out mechanism, and that no credit is taken for iodine removal by spray.

3.2 Drywell Leakage:

Leakage from the drywell to the reactor building is assumed to be 1% per day.

3.3 Decay and daughter products:

Reduction of drywell airborne radioactivity due to isotopes decay is considered in this calculation. The daughter products from the decay chain of the isotopes are also explicitly taken into account.

4. ASSUMPTIONS IN CALCULATING THE AIRBORNE ACTIVITY IN REACTOR BUILDING

The airborne activity within the reactor building is due to drywell leakage. It is filtered by the Standby Gas Treatment System (SGTS) before being released to the environment. Reactor Building airborne activity and the source accumulated on the SGTS filters are calculated with the following assumptions and parameters:

a) Reactor Building including refueling floor free volume is 3×10^6 ft^3.

b) SGTS process rate is 1 reactor building/refueling floor volume per day.

c) SGTS filter activity is based on an assumed 100% charcoal filter efficiency for halogens and 0% charcoal filter efficiency for noble gases.

d) Credit for isotopes decay is taken into account; daughter products from radioactive decay are also considered explicitly.

5. MODEL FOR CALCULATING THE ACTIVITY

The time-dependent and location-dependent distributions of noble gases and halogens within the drywell, on the drywell plate-out surface, inside the reactor building and on the SGTS filters are calculated by the Bechtel standard computer codes SOURCE2 and LOCADOSE. SOURCE2 can calculate the activities of isotopes in multiple gamma and beta decay chains as a function of time. LOCADOSE is similar to the NRC computer program TACT and can calculate the distribution of activity in multiregion of a nuclear power plant as a function of time. The code LOCADOSE does not have the option to explicitly evaluate the decay daughter products. However, it can be calculated by combining results of LOCADOSE with those of SOURCE2 which does include daughter products. This methodology is based on the following conditions:

a) The distribution fraction, fi, is defined as the ratio of the activity of an isotope in region i to the total activity (sum over all regions) of that isotope. The fraction fi depends only on the flow rates between regions, the filtration efficiency, and time, but is independent of the decay constant of that isotope..

b) The distribution fraction fi of daughter products is the same as that of their parent product.

Based on these conditions, the daughter products can be considered explicitly in this calculation by combining results of LOCADOSE with SOURCE2.

6. MODEL FOR CALCULATING THE DOSE AND DOSE RATE OF GAMMA AND BETA RADIATIONS

The gamma dose rate from the airborne activity within the drywell is conservatively calculated at a midpoint in the drywell midway between the reactor shield wall and the drywell wall. The region is modeled as an annular cylinder. The reactor building airborne gamma dose rate is calculated for a midpoint in a cylinder with an equivalent volume of 3.3×10^5 ft^3.

The airborne beta dose rates of the drywell and reactor building are calculated for a semi-infinite cloud.

The gamma and beta plate-out dose rates are calculated at the surface of an infinite plane with the average plate-out activity per unit area. The beta plate-out dose rate calculated assumed one-half of the beta energy contributes to the absorbed dose. The gamma dose rate assumes all gamma energy contributes to the dose.

The gamma dose rates at the surface of the SGTS filters are calculated for an effective charcoal density of 0.43 g/cc.

7. DOSE RATES AND TOTAL INTEGRATED DOSES

The gamma and beta dose rates as a function of time are calculated for the drywell airborne, drywell plate-out, reactor airborne and SGTS filters. The results are given in Tables 2, 3 and 4. The total integrated doses are given in Table 5.

REFERENCES

1. ORIGEN2: Oak Ridge National Laboratory Isotope Generation and Depletion Code, Matrix Exponential Method.

2. NUREG/CR-009, Technological Bases for Models of Spray Washout of Airborne Contaminants in Containment Vessels (October 1978).

3. Standard Review Plan 6.5.2, Containment Spray as a Fission Product Cleanup System, Rev. 1, July 1981, US NRC.

TABLE 1

100% Noble Gases and 50% Halogens of Core Inventory

ISOTOPE	ACTIVITY (Ci)	ISOTOPE	ACTIVITY (Ci)
KR-83M	1.08+7	BR--80	4.19+1
KR--85	1.03+6	BR-80M	2.73+1
KR-85M	2.26+7	BR--82	2.23+5
KR--87	4.29+7	BR-82M	9.14+4
KR--88	6.03+7	BR--83	5.42+6
KR--89	7.29+7	BR--84	9.28+6
KR--90	7.19+7	BR--85	1.11+7
KR--91	5.31+7	BR--86	7.93+6
KR--92	2.61+7	BR--87	1.80+7
KR--93	9.57+6	BR--88	1.89+7
KR--94	3.39+6	BR--89	1.30+7
KR--95	4.23+5	BR--90	8.19+6
XE131M	1.04+6	I--128	5.06+5
XE-133	1.88+8	I--129	1.84+0
XE133M	5.91+6	I--130	1.68+6
XE-135	4.88+7	I--131	4.66+7
XE135M	3.75+7	I--132	6.72+7
XE-137	1.63+8	I--133	9.39+7
XE-138	1.52+8	I-133M	2.98+6
XE-139	1.18+8	I--134	1.02+8
XE-140	7.64+7	I--135	8.80+7
XE-141	2.65+7	I-136B	4.12+7
XE-142	8.86+6	I-136A	2.45+7
XE143A	1.47+6	I--137	3.99+7
XE-144	2.49+5	I--138	1.95+7
		I--139	8.52+6
		I--140	2.33+6

TABLE 2

Airborne and Plate-out Dose Rates for
Gamma and Beta Radiations within Drywell

	DOSE RATE (Rad/hr)			
	GAMMA		BETA	
TIME (hr)	AIRBORNE	PLATE-OUT	AIRBORNE (1)	PLATE-OUT
0.0	1.37+7	0.0	2.17+8	0.0
.33-1	7.09+6	8.85+4	9.15+7	4.21+6
.17+0	3.47+6	2.23+5	4.60+7	1.12+7
.33+0	2.51+6	2.46+5	3.65+7	1.27+7
.50+0	2.29+6	2.30+5	3.46+7	1.22+7
.10+1	1.77+6	1.93+5	3.01+7	1.11+7
.20+1	1.27+6	1.37+5	2.32+7	7.73+6
.40+1	7.17+5	9.39+4	1.47+7	7.74+6
.80+1	3.86+5	5.61+4	8.45+6	6.03+6
.16+2	1.89+5	3.11+4	4.81+6	4.41+6
.24+2	1.24+5	2.14+4	3.65+6	3.56+6
.48+2	5.83+4	1.09+4	2.35+6	2.35+6
.96+2	3.18+4	5.83+3	1.59+6	1.54+6
.17+3	2.05+4	3.83+3	1.06+6	1.09+6
.24+3	1.41+4	2.89+3	7.10+5	8.34+5
.34+3	8.67+3	2.04+3	4.20+5	5.90+5
.72+3	1.38+3	5.10+2	6.90+4	1.48+5
.14+4	6.98+1	3.81+1	1.84+4	1.10+4
.22+4	1.00+1	2.84+0	1.28+4	8.21+2
.43+4	2.58+0	1.18-3	5.10+3	4.11-1

(1) Based on semi-infinite beta cloud model.

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TABLE 3

Gamma and Beta Airborne Dose Rates inside Reactor Building

	DOSE RATE (Rad/hr)	
TIME (hr)	GAMMA	BETA[1]
.00	0.0	0.0
.33-1	1.30+1	1.05+2
.17+0	4.00+1	2.88+2
.33+0	5.88+1	4.53+2
.50+0	7.30+1	6.15+2
.10+1	1.01+2	1.02+3
.20+1	1.34+2	1.53+3
.40+1	1.40+2	1.82+3
.80+1	1.37+2	1.93+3
.16+2	1.14+2	1.88+3
.24+2	9.76+1	1.85+3
.48+2	6.29+1	1.63+3
.96+2	3.93+1	1.26+3
.17+3	2.58+1	8.45+2
.24+3	1.76+1	5.65+2
.34+3	1.08+1	3.37+2
.72+3	1.70+0	5.50+1
.14+4	8.57-2	1.48+1
.22+4	1.26-2	1.05+1
.43+4	3.22-3	4.11+0

(1) Based on semi-infinite beta cloud model.

TABLE 4

Gamma Contact Dose Rates at the SGTS Filters

TIME (hr)	DOSE RATE (Rad/hr)
.00	0.0
.33-1	1.78+0
.17+0	2.87+1
.33+0	7.80+1
.50+0	1.31+2
.10+1	2.99+2
.20+1	6.21+2
.40+1	1.31+3
.80+1	2.55+3
.16+2	4.69+3
.24+2	6.38+3
.48+2	9.32+3
.96+2	1.15+4
.17+3	1.45+4
.24+3	1.53+4
.34+3	1.54+4
.72+3	8.15+3
.14+4	1.13+3
.22+4	1.17+2
.43+4	8.03-3

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TABLE 5

Total Integrated Doses for Equipment Qualification

Location and Type of Radiation	Total Integrated Dose[1] (Rad)
1. Drywell:	
gamma, airborne	2.2×10^{7}
plateout	3.6×10^{6}
beta, airborne	7.4×10^{8} [2]
plateout	6.9×10^{8}
2. Reactor Building:	
gamma, airborne	1.5×10^{4}
beta, airborne	4.3×10^{5} [2]
3. SGTS Filter:	
gamma (contact)	1.2×10^{7}

Notes: (1) Calculated for a period of 180 days after LOCA.

(2) Based on semi-infinite beta cloud model.