APPENDIX 14B – IODINE REMOVAL ESTIMATES

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APPENDIX 14B

IODINE REMOVAL CAPABILITIES OF THE TMI-1 REACTOR BUILDING SPRAY SYSTEM

1.0 IODINE REMOVAL ESTIMATES

The iodine removal estimates were performed using the NRC-sponsored computer code RADTRAD. The model included in the code was utilized. The discussion to follow is included to document the development of spray system physical parameters (e.g., spray droplet size). Reference 1 documents and uses these parameters.

The effectiveness of spray solutions in removing iodine from the containment atmosphere during a postulated loss of coolant accident is calculated using removal or washout coefficients which describe the rate of uptake of the various forms of iodine (elemental, organic, and particulate) by the containment spray droplets.

2.0 ELEMENTAL IODINE SPRAY REMOVAL COEFFICIENT

The containment spray elemental iodine coefficient can be determined by solving the following equation from SRP 6.5.2 (Reference 2).

Equation 1:

$$\lambda_E = \frac{6K_gTF}{Vd}$$

where:

K_g = gas phase mass transfer coefficient

T = time of fall of the spray drops which is equal to the fall height divided by the terminal velocity

F = spray pump flow rate

V = sprayed containment volume

d = spray drop mean diameter

3.0 PLATEOUT OF ELEMENTAL IODINE ON CONTAINMENT SURFACES

Removal of elemental iodine by wall deposition is conservatively ignored, so the wall deposition removal coefficient is not required.

4.0 ORGANIC IODINE SPRAY REMOVAL COEFFICIENT

Removal of organic iodine by containment spray is conservatively ignored, so the organic iodine spray removal coefficient is not required.

5.0 PARTICULATE IODINE SPRAY REMOVAL COEFFICIENT

The containment spray particulate iodine removal coefficient can be determined by solving the following equation from SRP 6.5.2.

Equation 2:

$$\lambda_p = \frac{3hFE}{2Vd}$$

where:

h	=	spray drop fall height
F	=	spray pump flow rate
V	=	sprayed containment volume
(E/d)	=	ratio of a dimensionless collection efficiency (E) based on a spray drop mean diameter (d). (E/d) is 10/meter (0.1 cm) until the aerosol mass has been depleted by a factor of 50 at which time (E/d) is 1/meter (0.01 cm).

6.0 Deleted

7.0 IODINE DECONTAMINATION FACTORS

The effectiveness of the spray in removing elemental iodine is presumed to end when the maximum elemental iodine decontamination factor (DF) is reached. The elemental iodine decontamination factor can be determined by solving the following equation from SRP 6.5.2.

Equation 3:

$$DF = 1 + (V_s H/(V_c - V_s))$$

where:

V_s = volume of liquid in the containment sump and sump overflow

V_c = containment building net free volume

H = effective iodine partition coefficient

Since the removal mechanisms for particulate iodines are significantly different from and slower than the mechanisms for elemental iodine, there is no limit on the DF for particulate iodines.

8.0 Deleted

9.0 CALCULATION OF REMOVAL COEFFICIENTS AND DECONTAMINATION FACTORS

9.1 SPRAY DROP MASS MEDIAN DIAMETER

The TMI-1 containment spray system is equipped with SPRACO Model 1713 spray nozzles. Drop size distribution data for these nozzles are not available from the manufacturer. However, SPRACO was able to supply drop size distribution data for their Model 1713A spray nozzles. According to SPRACO, the model 1713A is almost identical to the Model 1713 and has the same drop size distribution, which is reported here as Figure 14B-1. The spray drop cumulative volume frequency calculated from these data is given on Figure 14B-2. The mass median diameter $F_v(\bar{d}_m) = 50\%$ obtained from Figure 14B-2 is approximately $\bar{d}_m$ = 1070 μm.

The calculation of $\bar{d}_m$ is most heavily influenced by the largest drops. Figure 14B-1 shows an unusually large drop frequency in the size range 1725 to 1750 μm. Figure 14B-1 was obtained from a finite sample. The expected drop frequency in this size range will probably decrease as the sample size increases. Therefore, the true mass median diameter for the spray is probably a little less than 1070 μm.

9.2 REACTOR BUILDING SPRAY SYSTEM DESIGN PARAMETERS

Relevant containment volumes (gas and liquid), spray flow rates, and other required dimensions are given in Table 14B-1. The containment temperature and pressure were assumed to be 250°F and 75 psia, respectively - typical conditions following a LOCA. The spray solution at time of recirculation was assumed to be at the same temperature as the containment atmosphere and to have a pH of at least 7.3.

It is known that the spray solution temperature is actually less than 250°F and that once the spray is activated, the containment temperature and pressure will both decrease with time. It will be shown later that choosing temperature and pressure to be as high as realistically possible will result in the most conservative estimates of the removal coefficients.

9.3 CALCULATION OF PHYSICAL PROPERTIES

Physical properties and related parameters such as terminal velocity and mass transfer coefficients were obtained at 250°F and 75 psia and are summarized in Table 14B-2.

9.4 CALCULATIONS OF SPRAY REMOVAL COEFFICIENTS AND DECONTAMINATION FACTORS

Spray removal coefficients for elemental and particulate iodine are given in Table 14B-3 for conditions when only one spray header is operating (minimum safety feature) and when both spray headers are in operation.

Decontamination factors for the iodine forms are also given in Table 14B-3.

10.0 REFERENCES

1. AmerGen Calculation C-1101-900-E000-087, Rev. 3, "Post-LOCA EAB, LPZ, TSC, and CR Does Using AST and RG 1.183 Requirements."

2. Standard Review Plan 6.5.2, "Containment Spray as a Fission Product Cleanup System," USNRC NUREG-0800, Rev. 4.

TABLE 14B-1
(Sheet 1 of 1)

REACTOR BUILDING SPRAY SYSTEM DESIGN PARAMETERS

Spray Flow Rate, F	
One header operating	800 gpm
Two headers operating	1600 gpm
Average drop fall height, h	96 ft
Containment Building free volume, V_C	2.16×10^6 ft^3
Containment Building sprayed volume, V	1.23×10^6 ft^3
Volume of liquid in sump plus overflow from containment sump for use in equation 2, V_s	54,519 ft^3

TABLE 14B-2
(Sheet 1 of 1)

PHYSICAL PROPERTIES OF CONTAINMENT ATMOSPHERE
SPRAY SOLUTION

Temperature	250°F
Pressure	75 psia
Gas phase mass transfer coefficient	2.27 cm/sec
Terminal velocity	228.30 cm/sec
Spray drop fall time	12.82 sec
Spray drop mass mean diameter	0.107 cm
Effective iodine partition coefficient	300

TABLE 14B-3
(Sheet 1 of 1)

SPRAY REMOVAL COEFFICIENTS AND DECONTAMINATION FACTORS

Removal Coefficients for Spray Flow Rate of 800 gpm per Header

Iodine Form	One Header Operating	Two Headers Operating
Elemental, λ_S, HR^{-1}	8.51	17.02
Particulate, λ_p, HR^{-1}	2.29	4.58

Decontamination Factors

Iodine Form	Maximum Decontamination Factor (DF)
Elemental	8.77
Particulate	50