

PSAT 04000U.04

**Attachment 5**

PSAT Calculation 04011H.03

"Maximum Elemental Iodine Decontamination Factors"

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## CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04011H.03

CALCULATION TITLE:

"Maximum Iodine Decontamination Factor"

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REASON FOR REVISION:

Nonconformance Rpt

0 - Initial Issue

N/A

1 - Changed title to clarify fact that DF applies to all iodine  
Changed Reference 3 and added Assumption 3

N/A

2

3

4

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### Purpose

The purpose of this calculation is to determine the maximum DF for elemental iodine (and for Te-132 which is being treated as elemental I-132 except for half-life) that can be credited in the Browns Ferry drywell and torus for the purpose of applying the revised DBA source term of Reference 1.

### Methodology

The methodology will be that of References 2 and 3.

### Assumptions

Assumption 1: The suppression pool pH will be maintained at a value of 6.0 or above.

Justification: A separate TVA project is being undertaken by Polestar (in progress at the time of this calculation preparation) to ensure that the suppression pool pH in the long term is not less than 7. According to Reference 4, Item 6.1, the initial suppression pool pH is not less than 6.0.

Assumption 2: The water on the drywell floor and that in the suppression pool will be

well-mixed.

Justification: The approach to maintaining an adequately high suppression pool pH will be to inject the SLCS sodium pentaborate as a buffer for any accident involving substantial core damage (such as the accidents identified in Reference 1 as the basis for the DBA source term). Mixing of this sodium pentaborate solution with all available water inside containment (which is a recognized necessity in the work of the separate TVA pH control project mentioned above) will also provide mixing and a uniform distribution of the radioiodine between water on the floor of the drywell (or in the reactor vessel) and that in the suppression pool.

Assumption 3: Iodine core inventories (by mass) based on NRC-sponsored analyses from 1984-1986 will be increased by a factor of 1.5 to account for increased burn-up associated with transition from 12-month to 18-month cycles.

Justification: Most iodine (by mass) in the core is stable or near-stable; therefore, a 50% increase to account for longer cycle length and burn-up is appropriate.

### References

- Reference 1: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995
- Reference 2: Beahm, E. C., Lorenz, R. A., and Weber, C. F., "Iodine Evolution and pH Control", NUREG/CR-5950, November 1992
- Reference 3: Beahm, E. C., Weber, C. F., Kress, T. S., and Parker, G. W., "Iodine Chemical Forms in LWR Severe Accidents", NUREG/CR-5732, April 1992
- Reference 4: PSAT 04000U.03, "Design Data Base for Application of the Revised DBA Source Term to the TVA Browns Ferry Nuclear Power Plant", Revision 0

### Calculation

From Reference 4, Items 3.3 and 6.9, the water volume which could ultimately dissolve the iodine released from the core is:

$$V = 127800 \text{ ft}^3 (\text{suppression pool volume}) + 1.22\text{E}6 \text{ lbm} / 62.4 \text{ lbm/ft}^3 (\text{mass of RCS, recirc loops, and LPCI loops/ nominal water density at low temperature})$$

$$= 127800 \text{ ft}^3 + 19550 \text{ ft}^3 = 147350 \text{ ft}^3$$

$$= 147350 \text{ ft}^3 \times 28.3 \text{ liters/ft}^3 = 4.17\text{E}6 \text{ liters}$$

From Reference 3, Table D-1, for the Peach Bottom BWR (similar to Browns Ferry with the same nominal power level of 3293 Mw(t)) the core iodine mass is 16.6 kg. From Reference 4, Item 8.3 the core power for this analysis is 3458 Mw(t), 105% of nominal. This assumed increase in core power yields an iodine mass of approximately 17.4 kg. Assuming further a 50% increase in the iodine core inventory (by mass) to account for a higher burn-up than that used in the 1984-1986 NRC-sponsored analyses identified in Reference 3 (see Assumption 3), the iodine core inventory would be approximately 2.6E4 grams. This would result in a containment water concentration of 2.6E4 grams/4.2E6 liters or 6.2E-3 grams per liter if 100 percent were released. The Reference 1 source term, however, involves only a 30% release of iodine for a BWR; and therefore, the iodine concentration (taken to be I<sup>-</sup>) is 1.87E-3 grams per liter or about 1.4E-5 gm-atoms per liter.

From Reference 2 if  $H^+ = 10^{-6.0}$  (i.e., pH = 6.0 - see Assumption 1), then:

$$I_2 = (H^+)^2(I^-)^2/[d + e(H^+)] \text{ where: } d = 4.22\text{E-}14, \text{ and}$$

$$e = 1.47\text{E-}9$$

$$I_2 \text{ in the liquid phase} = 4.5\text{E-}9 \text{ gm-moles/liter}$$

$$I \text{ in the liquid phase} = 9.0\text{E-}9 \text{ gm-atoms/liter}$$

Since I<sup>-</sup> in the liquid phase = 1.45E-5 gram-atoms/liter, then I/I<sup>-</sup> = 6.2E-4 in the liquid phase.

From Reference 2, the partition coefficient is:

$$\log_{10} PC(I) = 6.29 - 0.0149T, \text{ where } T \text{ is in K}$$

From Reference 4, Item 8.12, the maximum pool temperature is 173 F = 352 K

Then:

$$PC(\text{minimum}) = 11.1 \text{ (i.e., the minimum concentration of iodine, as } I_2 \text{ in the liquid phase is 11.1 times that in the gas phase. A lower temperature would yield a higher PC)}$$

$$\begin{aligned} \text{Since the gas phase volume} &= \text{volume of drywell} + \text{volume of torus airspace} \\ &= (159000 + 124000) \text{ ft}^3 \text{ (based on Reference 2, Items 3.1 and 3.2)} \end{aligned}$$

$$= 283000 \text{ ft}^3$$

And since the volume of the liquid phase is  $127800 \text{ ft}^3$  (suppression pool volume, Reference 4, Item 3.3), the ratio of the gas phase volume to the liquid phase volume is 2.2:1. This means that once removed from the gas phase, the mass of iodine, as  $I_2$ , in the liquid phase would never be less than  $(11.1/2.2 = 5)$  that in the gas phase. Since the maximum mass ratio of  $I/I^*$  in the liquid phase is  $6.2E-4$ , the maximum mass ratio of  $I$  in the gas phase to  $I^*$  in the liquid phase is  $6.2E-4/5 = 1.2E-4$ . This means that the minimum ultimate DF of elemental iodine (i.e., of molecular  $I_2$  in the gas phase) for this system is approximately  $1/1.2E-4 = 8000$  if the iodine can be removed from the gas phase initially.

Reference 1 indicates that 0.0015 of the iodine released to containment must be considered to be organic. This fraction is 13 times larger than the fraction of the iodine released which could re-evolve as  $I_2$  (as calculated above). Therefore, as a practical matter, there is no need to limit the removal of inorganic iodine in the analysis of the revised DBA source term for Browns Ferry; the organic iodine (which is not removed by deposition or pool scrubbing) will always dominate. By Assumption 2 the water in the drywell and that in the suppression pool will have the same pH and radioiodine concentration; therefore, the concentration ratio ( $I_2$  in the gas phase to  $I^*$  in the liquid phase) will be the same. This means that the  $I_2$  concentration in the gas phase of the torus and the drywell will be the same, and a single control volume model of the containment is acceptable in the long-term from the standpoint of the potential for iodine re-evolution.

### Results

The minimum justifiable long-term DF for elemental iodine in both the drywell and the torus is 8000. If this degree of decontamination can be achieved by removal mechanisms, then the associated re-evolved  $I_2$  will not exceed eight percent of the organic iodine in the Reference 1 source term specification.

### Conclusions

There is no need to limit elemental iodine removal in the analyses supporting application of the revised DBA source term to Browns Ferry.