# Attachment 11

PSAT Calculation 04002H.09

"Elemental Iodine Filter Efficiency in Main Steam Lines"

# CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04002H.09

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"Elemental Iodine Filter Efficiency in Main Steam Lines"

| | ORIGINATOR<br>Print/Sign Date | CHECKER<br>Print/Sign Date | IND REVIEWER<br>Print/Sign Date |
|---|---|---|---|
| REVISION: 0 | David Leaver 9/28/95 | James Metcalf 9/28/95 | James Metcalf 9/28/95 |
| 1 | | | |
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| REASON FOR REVISION: | Nonconformance Rpt |
|---|---|
| 0 - Initial Issue | N/A |
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## Purpose

The purpose of this calculation is to determine the effective filter efficiency for elemental iodine released into the main steam lines. Elemental iodine (i.e., $I_2$), released from the damaged core as specified in NUREG 1465 [1], plates out on the aerosol suspended in the drywell atmosphere and is transported with the aerosol. Thus the $I_2$ leaks with the aerosol through the MSIVs and deposits on the steam line pipewall (with the aerosol). A fraction of this $I_2$ resuspends as organic iodide and is then released to the environment. This calculation will estimate the fraction of $I_2$ which resuspends as organic and convert this resuspension fraction to an effective filter efficiency for $I_2$ entering the steam lines.

## Methodology

In order to determine the effective filter efficiency, a manual calculation will be performed which does the following:

- Evaluates the plateout of $I_2$ on aerosol.
- Compares the resuspension rate of $I_2$ with the fixation rate in order to determine the fraction of deposited $I_2$ which resuspends over time.
- Converts the resuspended fraction to a filter efficiency.

## Assumptions

Assumption 1: The $I_2$ is reactive and will tend to plate out on surfaces in the drywell.

Justification: Elemental iodine is a gas at containment temperatures and is reactive with many materials [2]. It is well documented that it will tend to deposit on surfaces by chemical adsorption [3].

Assumption 2: The resuspended $I_2$ is converted to organic iodide.

Justification: According to Reference [3], resuspended $I_2$ can change its chemical form (conversion) to organic. For simplicity and conservatism, this conversion is assumed to be 100%.

## References

1. L. Soffer et al, "Accident Source Terms for light-Water Reactor Nuclear Power Plants," NUREG 1465, February, 1995.

2. "Handbook of Chemistry and Physics," 73rd Edition, 1992-1993.

3. J. Cline, "MSIV Leakage Iodine Transport Analysis," Prepared for the U.S. Nuclear Regulatory Commission under contract NRC-03-87-029, Task Order 75, March 26, 1991.

4. N. A. Fuchs, "The Mechanics of Aerosols," Dover Publishing, 1964.

5. "Aerosol Decay Rate (Lambda) in Drywell," Polestar QA Record PSAT 04001H.02, Revision 0, September 1, 1995.

6. "Design Data Base for Application of the Revised DBA Source Term for the TVA Browns Ferry Nuclear Power Plant, " Polestar QA Record PSAT 04000U.03, Revision 1, September 22, 1995.

7. D. McNeese and A. Hoag, "Engineering and Technical Handbook," Prentice Hall, 1963.

8. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," U.S. NRC, NUREG 0800, Section 6.5.2, Revision 0.

9. "Aerosol Decontamination Factor in Main Steam Line," Polestar QA Record PSAT 04002H.08, Revision 0, September 19, 1995.

## Calculation

### Calculation of Plateout Area of Aerosol vs. Plateout Area of Drywell Shell, Equipment, and Structural Surfaces

Per Assumption 1., the $I_2$ will tend to plate out on surfaces. This calculation is to determine the relative magnitude areas of potential plate out surfaces in the drywell.

The aerosol particle surface area is estimated as follows. From Reference [4], the mass fraction for aerosols of radius r is expressed by

$$f(r)dr = \frac{1}{\ln\sigma\cdot\sqrt{2\pi}}\exp\left\{-\frac{\left[\ln r-(\ln r_g+3\ln^2\sigma)\right]^2}{2\ln^2\sigma}\right\}d\ln r$$

$$=\theta(r)d\ln r$$

The subtotal of the mass for aerosols of radius r to r + dr is

$$\Delta m = Mf(r)dr = \frac{M}{\ln\sigma\sqrt{2\pi}}\exp\left\{-\frac{\left[\ln r-(\ln r_g+3\ln^2\sigma)\right]^2}{2\ln^2\sigma}\right\}d\ln r$$

$$=M\theta(r)d\ln r$$

where the total mass of aerosols is M.

The subtotal of the volume is

$$\Delta v = \frac{\Delta m}{\rho}$$

where the volume per particle is

$$v = \frac{4}{3}\pi r^3$$

Thus the number of particles in r to r + dr is

$$N(r) = \frac{\Delta v}{v}$$

where the surface area per particle is

$$A = 4\pi r^2$$

The subtotal of surface area for aerosols in r to r + dr is

$$S = N(r).A \;=\; \frac{\Delta v}{v} 4\pi r^2 \;=\; \frac{\Delta v}{\frac{4}{3}\pi r^3} 4\pi r^2 \;=\; \frac{3\Delta v}{r}$$

$$= \frac{3\Delta m}{\rho r} = \frac{3M}{\rho r}\theta(r) d\ln r = \frac{3M\theta(r)}{\rho r^2} dr$$

Using a total aerosol mass of 12.6 kg and a particle density $\rho$ of 3760 kg/m$^3$, the total surface area of the aerosol is

$$\int_0^\infty \frac{3M\theta(r)}{\rho r^2} dr = 1.87\mathrm{E}4 \text{ m}^2 \text{ for } r_g = 0.22\ \mu\text{m and } \sigma = 1.81.$$

These values of aerosol mass, density, and size distribution are taken from Reference [5] for the conditions existing at the start of the fuel release. This is very conservative with regard to aerosol mass and surface area since the peak aerosol suspended mass will be much larger after fuel release begins.

The drywell shell, equipment, and structural surface area is estimated by summing the following: (1) calculating the horizontal surface area of the drywell shell ($A_h$), (2) using a multiplicative factor based on a calculation by TVA to account for additional horizontal surface area (m), (3) calculating the vertical surface area of the drywell shell ($A_v$), (4) applying the same multiplicative factor to the vertical surface area, and (5) calculating the downward facing surface area of the drywell shell ($A_d$).

Using dimensional information from Reference [6], Item 7.5, $A_h$ can be calculated as follows:

$$A_h = (\pi)(67/2)^2 = 3526 \text{ ft}^2$$

The total horizontal surface area for sedimentation from Reference [6], Item 7.1, is 8138 ft$^2$. Thus the multiplicative factor is

$$m = 8138/3526 = 2.31$$

$A_V$ can be calculated as follows:

$$A_V = A_1 + A_2$$

where $A_1$ is the sidewall area of the cylinder (based on a height of 55 feet per Reference [6]), and $A_2$ is the sidewall area of the drywell sphere (based on a height of 50 feet per Reference [6]). From Reference [6],

$$A_1 = (38.5\pi)(55) = 6652\,ft^2$$

From Reference [7], the surface area of the sphere sidewall may be calculated as

$$0.5A_2 = \pi l^2 / 4 + \pi h^2$$

where l is the height of the sidewall and h is the distance which the sidewall projects out from the cylinder. From Reference [6], this is

$$0.5A_2 = (\pi / 4)(50)^2 + \pi(67/2 - 38.5/2)^2 = 2601\,ft^2$$

Thus,

$$A_2 = 5203 \text{ ft}^2$$

and

$$A_V = A_1 + A_2 = 11855 \text{ ft}^2$$

The downward facing area $A_d$ can be calculated from Reference [6] as

$$A_d = \pi(38.5/2)^2 = 1164\,ft^2$$

Thus, the total plateout area of drywell surfaces including equipment and structures is

$$A_{tot} = (A_h + A_V)(m) + A_d$$

Thus,

$$A_{tot} = 36694 \text{ ft}^2 \times 0.0929 \text{ m}^2/\text{ft}^2 = 3409 \text{ m}^2$$

The minimum aerosol surface area during fuel release is 18700/3409 = ~6 times that of the drywell surfaces. Thus, the $I_2$ will tend to plate out almost entirely on the aerosol.

A second consideration with regard to $I_2$ plateout on aerosol is the fact that the aerosol gradually is removed from the drywell and thus its effective plate out area decreases with time. However, the $I_2$ plateout rate constant ( $\sim 1.7\ hr^{-1}$ from Reference [8]) is significantly larger than the sedimentation rate constant of the aerosol (0.3 to 0.9 $hr^{-1}$ from Reference [5]). While the aerosol sweepout rate constant is somewhat larger, sweepout will remove both aerosol and $I_2$. Thus the $I_2$ will plateout on the aerosol much faster than the aerosol itself is removed from the drywell.

On the basis of the large aerosol surface area and the fact that the $I_2$ will plate out on the aerosol much faster than the aerosol itself will be removed, it is reasonable to assume that essentially all of the $I_2$ deposits on the aerosol and thus that the $I_2$ behaves as an aerosol up to the point that it deposits in the steam lines.

## Fraction of $I_2$ Resuspended from Steam Lines

Based on Reference [9], essentially all of the aerosol which leaks through the MSIVs and into the steam lines will deposit on the pipewalls. Thus the $I_2$ attached to this aerosol will also be deposited, and some fraction of this $I_2$ will resuspend. This fraction is estimated by comparing the rate constant for fixation with the rate constant for resuspension.

From Reference [3], the resuspension rate of $I_2$ (assumed to be resuspended as 100% organic per Assumption 2) as well as the fixation rate of $I_2$ varies with temperature of the steam line wall. Also from Reference [3], main steam line temperature varies from about 565 K to 400 K over the first few days after shutdown (see Exhibit 1). From Exhibit 1, it may also be seen that the average fixation rate over the first 3 days (260,000 seconds) is about 1E-5 $sec^{-1}$, and the average resuspension rate is about 8E-6 $sec^{-1}$. Thus the fraction which resuspends is something less than half of the total deposited. For conservatism, it is assumed that half of the $I_2$ resuspends. This resuspension will occur over a period of several days (i.e., about 90% of the resuspension occurs in the first 72 hours).

## Results

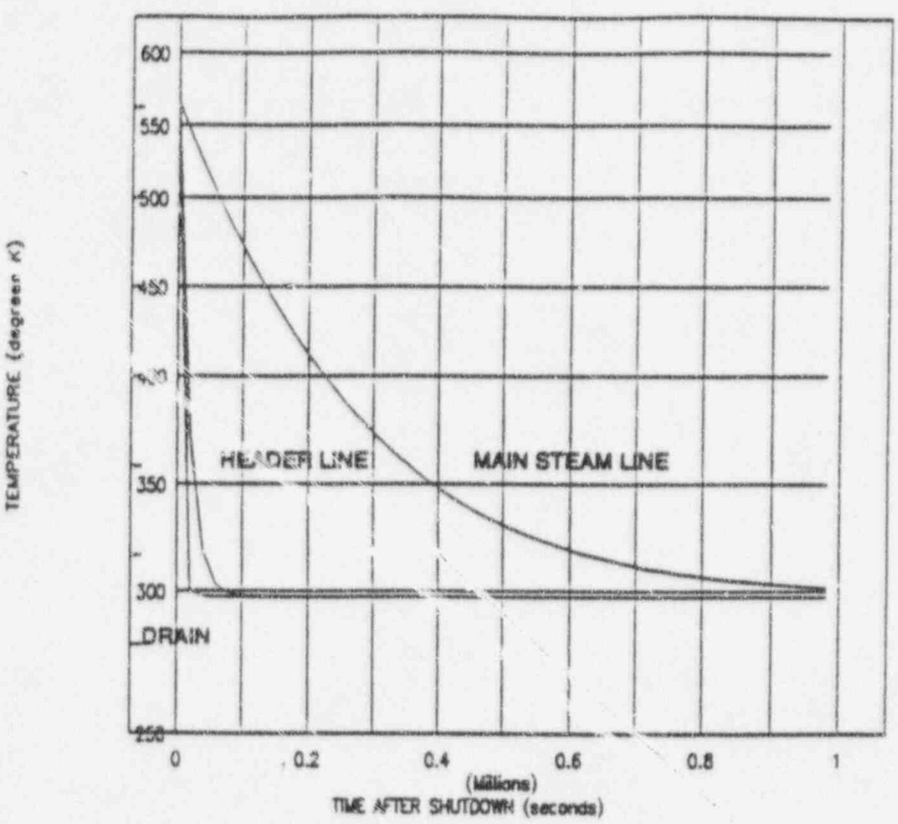
Treating the resuspension as a filtering process is conservative since the actual resuspension occurs over a several day period, whereas the filtering process assumes that the release is instantaneous at the time of deposition on the steam lines. The effective filter efficiency on the $I_2$ entering the steam lines is conservatively taken as 0.5. The unfiltered $I_2$ is then assumed to be released as organic iodide per Assumption 2.

## Conclusions

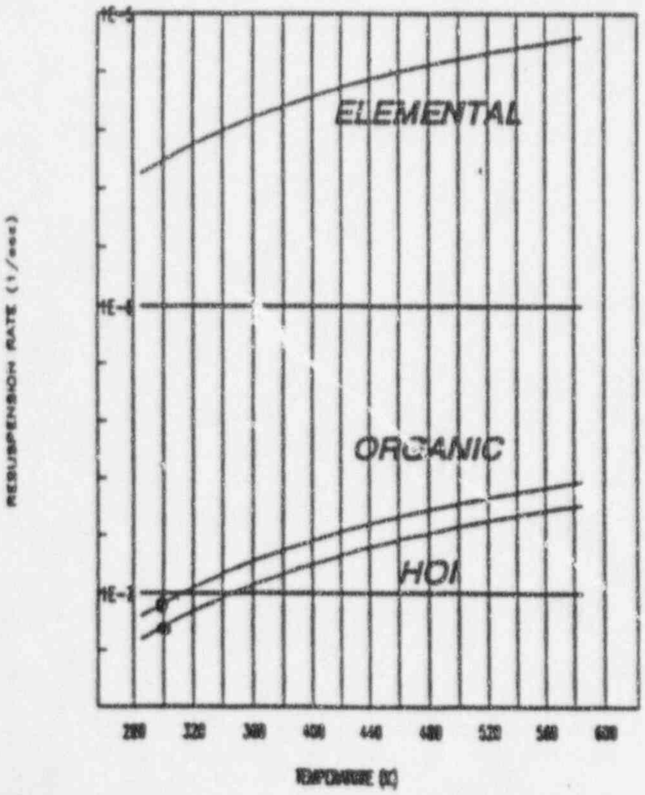
It is concluded that treating the elemental iodine as aerosol up to the point that it is deposited in the steam lines is reasonable, and that the elemental iodine entering the steam lines may be conservatively modeled with an effective filter efficiency of 50%.

Exhibit 1
(Taken from Reference [3])

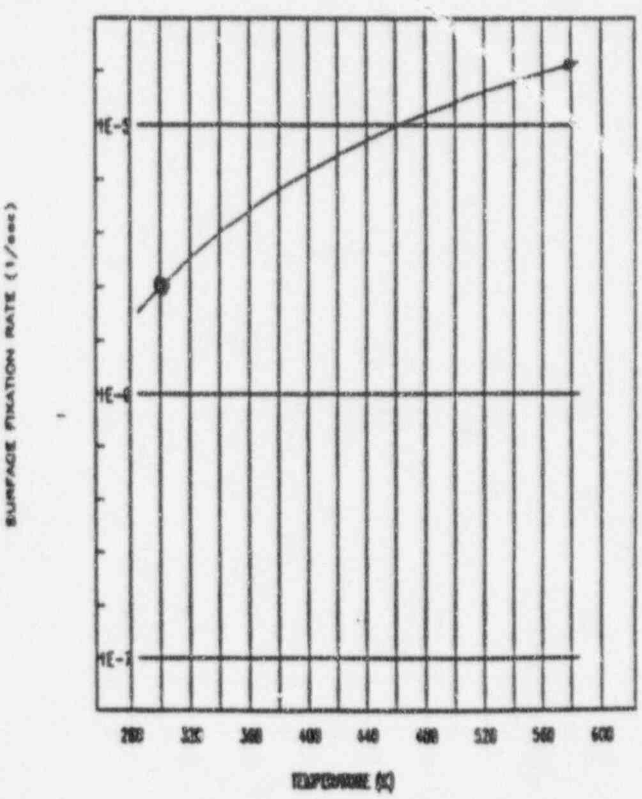
TEMPERATURES OF THE MSIV LEAKAGE LINES



RESUSPENSION RATE



SURFACE FIXATION RATE



# Attachment 12

Fax dated September 1, 1995 from Don McCamy (TVA Technical Contact) to James Metcalf (PSAT Project Manager) providing a reference for Item 3.28 of the Project Data Base

1 SEPT 95

To: Jim Metcalf
Fm: Don McCamy

Subj: Polestar BFN project data base

1. Per your FAX to me today, the following information is provided:

- Item 3.16 - The hardened wetwell vent leak path does not have a fraction which leaks to the stack base room.
- Item 3.28 - It is acceptable to use ≤ 250 SCFH combined MSIV leakage, with no one MSIV > 100 SCFH.
- Item 4.1 - The T/S filter efficiencies are provided as attachments to this FAX.

2. TVA has had an opportunity to review the project data base and generally agrees with the data. There remain some <u>areas</u> to be resolved, however.

appropriateness of references is the issue — Confirmed by telecon 9/1/9.

## Attachment 13

Notes of Telecon dated September 13, 1995 between James Metcalf (PSAT Project Manager)
and Don McCamy (TVA Technical Contact) providing concurrence
for time-shift of fumigation X/Qs (Item 5.1 of Project Data Base)

**Notes of Telecon between:**

Jim Metcalf (Polestar - Portsmouth) and Don McCamy (TVA - Browns Ferry)

**On:** September 13, 1995

**Regarding:**

Fumigation X/Qs

**Summary:**

I explained to Don that my 9/11 review of preliminary ABB-CE results indicated that there might be a significant increase in the containment leakage contribution to the thirty-day Control Room thyroid dose if the fumigation X/Qs were to occur during the last half-hour of the 2-hour release period rather than the first half-hour. Since the fumigation X/Q timing is essentially arbitrary, I recommended that it be assumed to be from t=1.5 hours to t=2 hours instead of from t=0 to t=0.5 hours. Don concurred.

Supplementary note: Preliminary results show that 2-hour Control Room thyroid dose from containment leakage (no MSIV leakage) with "old" X/Q timing was about 0.1 rem. With changed X/Q timing this becomes about 1 rem. Thirty-day Control Room thyroid dose with changed X/Q timing (containment leakage contribution only, no MSIV leakage, without charcoal credit for either SGTS or CREVS) is about 3 rem. Again, these results are preliminary. The contribution of containment leakage in the current design basis analysis is 4.4 rem (which includes credit for SGTS and CREVS charcoal).

cc: Dave Leaver - Polestar - Los Altos
Don McCamy - TVA - Browns Ferry
Ray Schneider - ABB-CE