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Calculation of SY Tank Annulus Continuous Air Monitor Readings After Postulated Leak Scenarios

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The objective of this work was to determine whether or not a continuous air monitor (CAM) monitoring the annulus of one of the SY Tanks would be expected to alarm after three postulated leak scenarios. Using data and references provided by Lockheed Martin's Tank Farm personnel, estimated CAM readings were calculated at specific times after the postulated scenarios might have occurred. Potential CAM readings above background at different times were calculated for the following leak scenarios:

- Leak rate of 0.01 gal/min
- Leak rate of 0.03 gal/min (best estimate of the maximum probable leak rate from a single-shell tank)
- Leak of 73 gal (equivalent to a ¼-in. leak on the floor of the annulus).

The equation used to make the calculations along with descriptions and/or explanations of the terms are included below, as is a list of the assumptions and/or values used for the calculations.

According to one of the reviewed references on annulus flows (Powell, 1989), in some situations, the CAM may not be expected to alarm even after a leak occurs. These cases would include situations where the radioactivity that is airborne is insufficient to raise the integrated count rate on the CAM above the alarm set point. This might occur (a) if the material dried on the bottom of the annulus or side of the primary tank and was not resuspended, (b) if the leak was very small and/or consisted of a small source term, or (c) if the material evaporated due to increased temperature and radioactive particulate material was not resuspended into the annulus space. In these cases, a visual check would have a higher potential of finding a leak than the CAM. However, several examples provided in the same report also showed how a CAM could alarm after different leak scenarios and how the distribution and level of exhaust flow in the annulus could affect the alarm capability of the CAM.

The calculations below include best estimates and conservative values. The actual average measured value for the exhaust airflow velocity was used, as was the most conservative radioactive activity concentration of the three tanks. Other "correction" factors for potential particle line loss and filter characteristics were also employed.

Equation to Estimate CAM Minimum Leak Detection Capability

The following equation was used to calculate the minimum leak detection capability of the CAM:

- Airborne release rate: $\left(\frac{4E-7}{hr}\right)$
- Conservative Activity Concentration: $\left(\frac{350\ \mu Ci}{ml}\right)$
- Gross Beta Counting Efficiency: $\left(0.2\ \frac{cpm}{dpm}\right)$
- CAM Flow Rate: $\left(5E+4\ \frac{ml}{min}\right)$
- 10% Particle Line loss: (0.9)
- 10% Filter Correction Factor: (0.9)
- Annulus volume: $(21{,}900\ ft^3)$

$$A(cpm) = \frac{[\text{Source Term (ml)}]\left(\frac{4E-7}{hr}\right)\left(\frac{350\ \mu Ci}{ml}\right)\left(2.2E+6\ \frac{dpm}{\mu Ci}\right)\left(0.2\ \frac{cpm}{dpm}\right)\left(5E+4\ \frac{ml}{min}\right)(0.9)\ (0.9)}{\left(\frac{60\ min}{hr}\right)(21{,}900\ ft^3)\left(\frac{2.83E+4\ ml}{ft^3}\right)}(t\ (min))\left[\frac{(1-e^{-rt})}{r\ (min^{-1})}\right]$$

Note:

1. Source Terms: 73 gal, (0.03 gal/,min)t, (0.01 gal/min)t; liquid
2. r = Annulus ventilation removal rate = Annulus exhaust flow rate / Annulus volume $= 300\ ft^3/min\ /\ 21{,}900\ ft^3 = 0.0137\ min^{-1}$
3. Annulus space build-up factor = $1-e^{-rt}$
4. Airborne release rate taken from DOE-HDBK-3010-94, *Airborne Release Fraction / Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, 1994
5. It was assumed that airborne material becomes evenly dispersed throughout annulus space over time.

Assumptions / Values Used

- Annulus exhaust rate = 300 ft^3/min (actual data)
- Annulus volume = 21,900 ft^3
- A conservative activity concentration of 350 µCi/ml was used; this is for gross beta (241-SY-102 Tank).
- An airborne release rate of 4E-7/hr was used. This is for indoors, on heterogeneous surfaces (e.g., stainless steel or concrete), and for low airspeeds up to normal facility ventilation flow (taken from DOE-HDBK-3010-94, 1994).
- A gross beta counting efficiency of the detector of 20% was used.
- A CAM flow rate of 50 l/m was used.
- A CAM alarm set point of 2000 cpm is currently used.
- The leaks are assumed to be liquid (supernatant). If sludge or solids are part of the leak scenario, then the CAM readings would be expected to decrease – perhaps to levels below the alarm set point because less material would become airborne (if larger particle sizes are involved). The time to alarm would be dependent on the particle size and the amount of material resuspended.
- A 10% particle line loss was used; this is conservative. Information taken from WHC-SD-WM-TI-392 (1989) discussed particle size data from the aging waste off-gas sampling downstream of the 241-A-401 condensers. Most of the beta/gamma activity was concentrated in the smaller aerodynamic diameter size range of 0.4 to 0.05 micron. Some larger diameter beta distribution was seen with 2-micron particles. No line loss would be seen with the smaller particles; some, but fairly insignificant, line loss may be seen with the 2-micron particles.
- A 10% filter correction factor was used. This is conservative; it compensates for collection efficiency and beta energy absorption.
- The 0.03 gal/min leak rate represents a 95%/95% confidence level. We would be 95% confident that at least 95% of the population of single-shell tanks will have a leak rate less than 0.03 gal/min (taken from RHO-ST-34, 1981).

Results

Table 1 represents the calculations of the potential CAM readings after the three postulated leak scenarios:

Table 1. Estimated SY Tank Annulus CAM Readings after Postulated Leak Scenarios

	CAM Reading Above Background (cpm)		
Time (min)	0.01 gal/min	0.03 gal/min[1]	73-gal leak[2]
2	<1	<1	70
10	2	10	1700
20	20	50	6500
30	60	170	14,000
60	400	1100	46,000
90	1100	3200	86,000
120	2200	6500	130,000
180	5500	16,000	220,000

(1) Best estimate of maximum probable leak rate from single shell tank (RHO-57-34, 1981).
(2) 1/4-in. spill on floor of annulus.

Conclusions

- The CAM could be expected to alarm if the liquid materials introduced into the annulus became airborne at the levels and rates proposed.

- The time to alarm depends on the location and magnitude of the leaks but is estimated to be less than a few hours for the postulated leaks. Even if other parameters came into effect, many potential leaks should be seen within 24 hours.

- The two postulated leak rates are not considered to be excessive. A leak as small as 0.01 gal/min could be seen within the above stated time.

- The CAM is expected to alarm before the conductivity monitor alarm does for leaks of less than 73 gallons (total volume) if the assumptions used are valid.

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