Tritium and the Implications of Zero Liquid Discharge Policies

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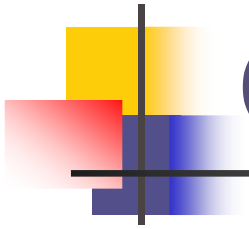

Challenging Perception: *I*

"The time has come," the Walrus said,
"to speak of many things…"
"Of shoes and ships and sealing wax,
of cabbages and kings…"
"Of why the sea is boiling hot,
and whether pigs have wings".

Lewis Carrol

Challenging Perception: *II*

Eliminating Liquid Discharges Eliminates Liquid Dose

in other words…

Adopting Zero Discharge is ALARA!

(or is it??)

Tritium Characteristics

- Half-life: 12.28 years … buildup
- β^- emitter: 18.6 keV max., 5.7 keV avg.
- Decays to chemically-inactive helium… implications to ionic bonds
- ALI: 8E+4 uCi
- DAC: 2E-5 uCi/mL air
- DCF: 6.4E-2 mrem/uCi EDE

Tritium Production

- Ternary fission… 3rd fission fragment
  - 1-2% fissions are ternary, 10% of which yield ^{3}H
- $^{2}H\ (n,\gamma)\ ^{3}H$ … heavy water reactors
- $^{2}H\ (D,p)\ ^{3}H$ … heavy water reactors
- $^{6}Li\ (n,\alpha)\ ^{3}H$
- $^{7}Li\ (n,n\alpha)\ ^{3}H$
- $^{10}B\ (n,2\alpha)\ ^{3}H$
- $^{10}B\ (n,\alpha)\ ^{7}Li\ (n,n\alpha)\ ^{3}H$
- BWRs: Control Rods; PWRs: Li, B

Tritium Chemical Forms

- Elemental/H_2/'Gaseous': H-T, D-T, T-T
  - Most elemental tritium will quickly oxidize, forming 'liquid' form
- Oxide/HOH/ 'Liquid': H-O-T, D-O-T, T-O-T
  - Vapor form of liquid "acts" like gas
  - Limited reactivity… won't ion exchange
- Hydroxide: OH^- … NaOH
- Hydride: H^- … CaH_2
- Hydrate: •HOH … $CuSO_4$•5HOH, concrete

Implications of Chemical Form

- Predominant form is water
  - Zen… the tritium and coolant are one!
  - Can't be removed by ion exchange
- Chemical & physical stability of hydroxides, hydrides, hydrates
  - β^- decay may break ionic bonds
  - Implications to chemical reactivity of products, mechanical stability of solidification
  - Hydrate form (e.g., concrete) likely most stable

Liquid Source Term Reduction

- BWRs: limit Li and B in coolant
  - Good control rod performance
  - Effective cleanup of Li, B
- PWRs: optimize Li and Boron use for pH, reactivity
- CANDU Reactors: reduce deuterium--*Good Luck!!*
- Won't exchange out, concentration will only continue to increase
  - Implications to License Extension
  - May show up in places not observed before… IE80-10, storm drains, REMP

Airborne Source Term Reduction

- Minimize steam leaks
- Reduce spent fuel pool (SFP) temperature
- Reduce air temperature over SFP
- Dehumidify SFP ventilation before discharge
- Optimize air exchange over SFP
- All airborne source term reduction efforts ***WILL*** exacerbate buildup of H-3 concentrations in coolant!

Reduce SFP Water Temperature

- Lower evaporation by lowering vapor pressure
  - Evaporation is a complex balance of water temperature, air temperature, air humidity, and air movement; proportional to vapor pressure
- Vapor pressure vs. temperature:
  - 100°F: 65.3 millibars
  - 70°F: 25.0 millibars
- Reduce evaporation 62% by lowering fuel pool temperature by 30°F, reducing H-3 in air
  - Implications to DAC, worker dose

Reduce Air Temperature over SFP

- Lower water-holding capacity of air by lowering temperature of air
- H-3 in water vapor in air reaches equilibrium with H-3 in SFP water

Temp °F	g H_2O/mL air	uCi H-3/mL air	Ci/yr Released*
100	4.55E-5	4.55E-7	67.7
70	1.84E-5	1.84E-7	27.4

*Assumes 1E-2 uCi H-3/mL water, 100% RH, 10,000 cfm ventilation

Dehumidify SFP Ventilation

- Direct relationship… reducing relative humidity by 20% will reduce H-3 release by 20%
- Air above SFP can approach 100% RH, depending on ventilation
- Need to 'treat' condensed liquid
  - Effectively "recapturing" vapor as liquid, ultimately contributing to buildup of H-3!

Optimize Ventilation Over SFP

- Direct relationship… reducing ventilation rate by 20% will reduce H-3 release rate by 20%
- Evaluate what air exchange is really necessary, optimize to minimum allowable level
  - Consider implications to buildup of airborne radioactivity levels… DAC
  - Consider dynamics of buildup of humidity

“Treatment” Options

- ‘Conventional’ disposal as solid waste
  - Impractical… can’t ion exchange, concentrate, remove, place into solid form
- Release as Effluent
  - Liquid: may not be an option if your plant has committed to zero liquid discharge!
  - Gaseous: the “preferred” method, used by most plants
  - Need to evaluate cost and dose… ALARA!

Effluent Dose Impact

- As seen at Pilgrim Station… your mileage may vary!
- Liquid Release: 310,000 gpm dilution
  - 9.5E-7 mrem/Ci released over 1 year
- Gaseous Release
  - 300 ft Stack: 1.0E-4 mrem/Ci released
  - Ground-level: 1.6E-3 mrem/Ci released
  - Accounts for 95+% of airborne PIT dose
- Gaseous dose 100X to 1000X ***higher*** than liquid… can we justify gaseous discharge over liquid?

Adequacy of RG-1.109 Models

- Operation of TMI evaporator indicated majority of HTO 'falls out' onsite, even from an elevated release
  - Doesn't get offsite to expose public
  - 'Standard' χ/Q used in RG-1.109 models may not accurately predict H-3 in environment
  - Need for new/revised χ/Q specific to H-3 to account for atmospheric losses?

Implications to REMP

- RG-1.109 models may not accurately predict concentrations in media and food products
  - Increase environmental sampling for H-3 in water samples… localized 'fallout' could contaminate groundwater (TMI saw this!)
  - Expand REMP to look for H-3 in other media? Expensive!
  - Calculate doses from H-3 *observed* in media, instead of concentrations *predicted* by RG-1.109

Summary

- No effective means to remove H-3 from coolant… concentrations ***will*** increase through time
  - Implications to License Extension
  - Implications to worker dose, IE80-10, storm drains, REMP
- Limit ***production*** of H-3
  - Control blades, Lithium, Boron Optimization
- Limit mechanisms of release
  - Most likely form is liquid/vapor… manage temperature, humidity, air exchange

Summary (continued)

- Chemical changes from beta decay
  - Implications to chemical reactivity and physical/mechanical stability
- Airborne dose > Liquid Dose
  - It may be preferable (***ALARA***), to release in liquid effluent stream rather than gaseous effluent stream
  - May need to revisit/revise airborne dose assessment models… χ/Q methods, transport in environment, buildup in media

Summary (continued)

- Plants were designed, constructed, and licensed to release radioactivity in liquid and gaseous effluents
  - Should still attempt to ***minimize*** releases, but ***elimination*** may be impractical
  - The only way to achieve true zero ***release*** is to have zero ***production*** of radioactivity… shut down the reactor!

Summary (continued)

- Evaluating and comparing plants on the basis of liquid volume/activity discharged ***may*** …
  - Lead to unfounded and erroneous ***competition*** for top quartile or top decile performance
  - Lead to cost-prohibitive practices
  - Be counterproductive
  - Increase dose to workers
  - Increase dose to the public

Challenging Perception: *III*

Zero Liquid Discharge Is

NOT

ALARA