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AN ASSESSMENT OF PROBLEMS ASSOCIATED WITH TRITIUM CONTAINMENT*

by

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Preventing tritium leakage across a large heat transfer area at high temperature is one of the most difficult problems associated with a D-T fusion reactor design. One of the most efficient methods to reduce the mobility of tritium is to convert it to tritiated water. Most solid breeder systems use a purge gas and assume tritium will be oxidized into the water form. For 17Li-83Pb system, a double-walled steam generator is used. Tritium is assumed to be oxidized across the gap in between the two walls. However, if tritium cannot be oxidized efficiently, the tritium containment problem can become critical.

The allowable tritium partial pressure before the last barrier to the steam generator can be calculated by

$$P = \left[\frac{\dot{M}}{At}\left(\frac{1}{P_m/\delta} + x\,\frac{\delta_o}{\delta}\right)\right]^2$$

*Work supported by the Office of Fusion Energy/U.S. Department of Energy.

Some of the possible methods to provide a large reduction factor are:

1. Oxidation. If tritium can be oxidized into water form, the driving force of tritium permeation will be greatly reduced. However, oxidation process, though favored thermodynamically, may be slow kinetically. In the pressure region of 10^{-9} Torr, no experimental information is available.

2. Diffusion Barrier. An oxide barrier can provide a barrier factor of a few hundred, which is helpful but not enough. Structural materials used in fusion are not effective barriers (316 SS, Inconel).

3. Isotopic Effect. In theory, introduction of large amounts of protium to a tritium stream will result in a diffusion rate of tritium proportional to the first order of tritium partial pressure instead of square root. This has to be experimentally verified.

As a part of the Blanket Comparison and Selection Study (BCSS), a special task group is formed to assess the problems associated with tritium containment. The subjects to be investigated are:

1. Tritium diffusion and release model in solid breeders.
2. Tritium cleanup in helium and Li/LiPb.
3. Tritium oxidation kinetics in helium.
4. Tritium permeation model and the effect of oxygen and isotopes.
5. Interaction of tritium and molten salt.
6. Limit of tritium leakage to water.

This paper reports the analysis and conclusion of this task group.

in which P is allowable tritium pressure

P_m is the permeability of the base material

A is the surface area

t is time

δ is wall thickness

x is the experimentally measured oxide barrier factor

δ_o is the wall thickness in the experiment

$\dot{M}$ is the allowable tritium leakage rate.

For a typical steam generator parameters and assumes an oxide factor $\left(x\frac{\delta_o}{\delta}\right) = 100$, the allowable tritium partial pressure is ~10^{-9} Torr if the allowable tritium leakage rate to the environment is limited to 10 Curie/day.

To illustrate the severity of the problem, the typical tritium partial pressures of the breeding materials are

$P = 10^{-4}$ Torr (17Li-83Pb)

$P = 6 \times 10^{-9}$ Torr (lithium at 1 wppm)

$\Delta p = 10^{-6}$ to 10^{-2} Torr/pass* (solid breeders)

For 17Li-83Pb or solid breeders, a reduction factor in the between 10^3 to 10^7 is needed between the tritium concentration in the source (breeding material) and the sink (last barrier before the water). For lithium, the reduction factor needed is less and should be achievable.

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*10^{-6} Torr/pass assumes $V_{purge} = V_{coolant}$ and 1% of the tritium in the form T_2, 10^{-2} Torr/pass assumes $V_{purge} = .01\ V_{coolant}$ and 100% of the tritium in T_2 form.