Opinions on Key Liquid Wall Issues

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Presented at the APEX Project Meeting
November 1-4, 1999
UCLA, Los Angeles, California

The following three issues will be discussed in this presentation

1. 3-D MHD effects
2. Maximum liquid velocity
3. Tritium recovery/confinement.

3-D MHD Effects

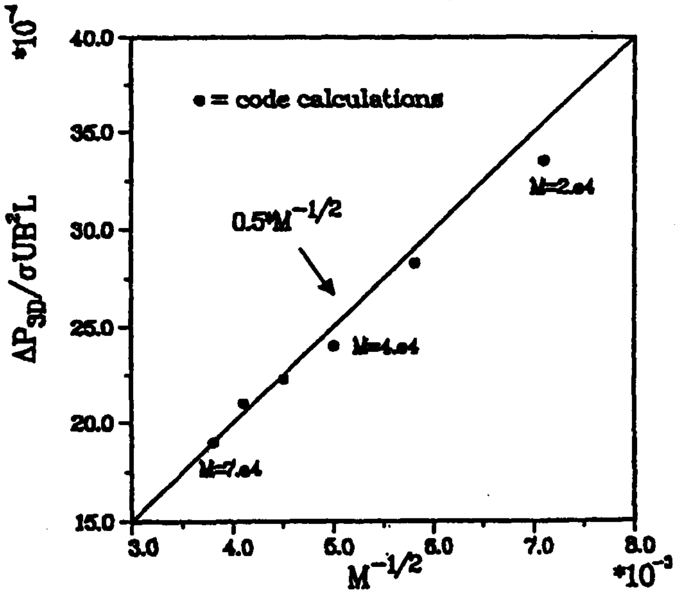
- The liquid velocities required are between 10 to 15 m/s.
- This liquid flow will have to go through the space between the TF coils.
- The magnetic field will increase from zero from outside of the magnets, to ~ 15 Tesla at the IB of the blanket.
- This change of the VXB will cause 3-D MHD effects, which will have large pressure drop.
- The insulating coating will not have effect on the MHD effect.

QUESTION

- How large is this MHD pressure drop?
- Is this pressure drop acceptable?
- How can we reduce this pressure drop?

3-D Pressure Drops in Insulated Round Ducts

For a transverse magnetic field varying rapidly in the flow direction



Reference

T.Q. Hua and J. s. Walker, Three-dimensional MHD flow in insulating circular ducts in non-uniform transverse magnetic fields, Int. J. Eng. Sci. 27 (1989) 1079

How Large is the 3-D MHD pressure drop

- Assuming Velocity is 10 m/s
  Magnetic field is 15 Tesla
  The Hartman number is 100,000
  The flow length is 3 m.
- The coolant is lithium.
- The 3-D MHD pressure drop is 30 Mpa.

Comparing the 3-D MHD pressure drop to Hartman pressure drop

- 3-D MHD pressure drop

$$\Delta P_{3D} = 0.5\ [M^{-1/2}]\ \sigma v B^2\ l$$

- Hartman pressure drop in a conducting wall is

$$\Delta P_{Ha} = v B^2\ l\ t_w\ \sigma_w / a$$

- The ratio of the pressure drops are

$$\Delta P_{3D} / \Delta P_{Ha} = 0.5\ M^{-1/2}\ \sigma a / \sigma_w\ t_w$$

Since the wall conducting ratio is usually about 100, while the Ha number is usually about 10^5, this pressure drop ratio is about 1.

- Based on this assessment, the 3-D MHD pressure drop is very large.

Impact on the reactor system by the coolant flow rate

- Since there is a limitation on the maximum coolant velocity, the coolant flow rate will have a significant impact on the primary loop design.
- If the volumetric coolant flow rate is large, the cross-sectional area for the coolant piping will also increase.
- The cost of the coolant piping is a significant large fraction of the total reactor system cost.
- With possible using of the advanced structural material, the cost of the piping will be even larger.
- Therefore, the reactor coolant DT has to be large enough to limit the cost of the primary loop.
- Also, as the coolant flow rate increases, the number of the piping in the primary heat exchanger will also increase. This will reduce the reliability of the primary heat exchanger.

Velocity Limitations

Those are suggested limits on local velocity limitations to avoid excessive erosions:

• For bismuth	< 3 m/s
• For water or sodium	< 12 m/s
• For steam	< 90 m/s
• For sluries	< 7 m/s

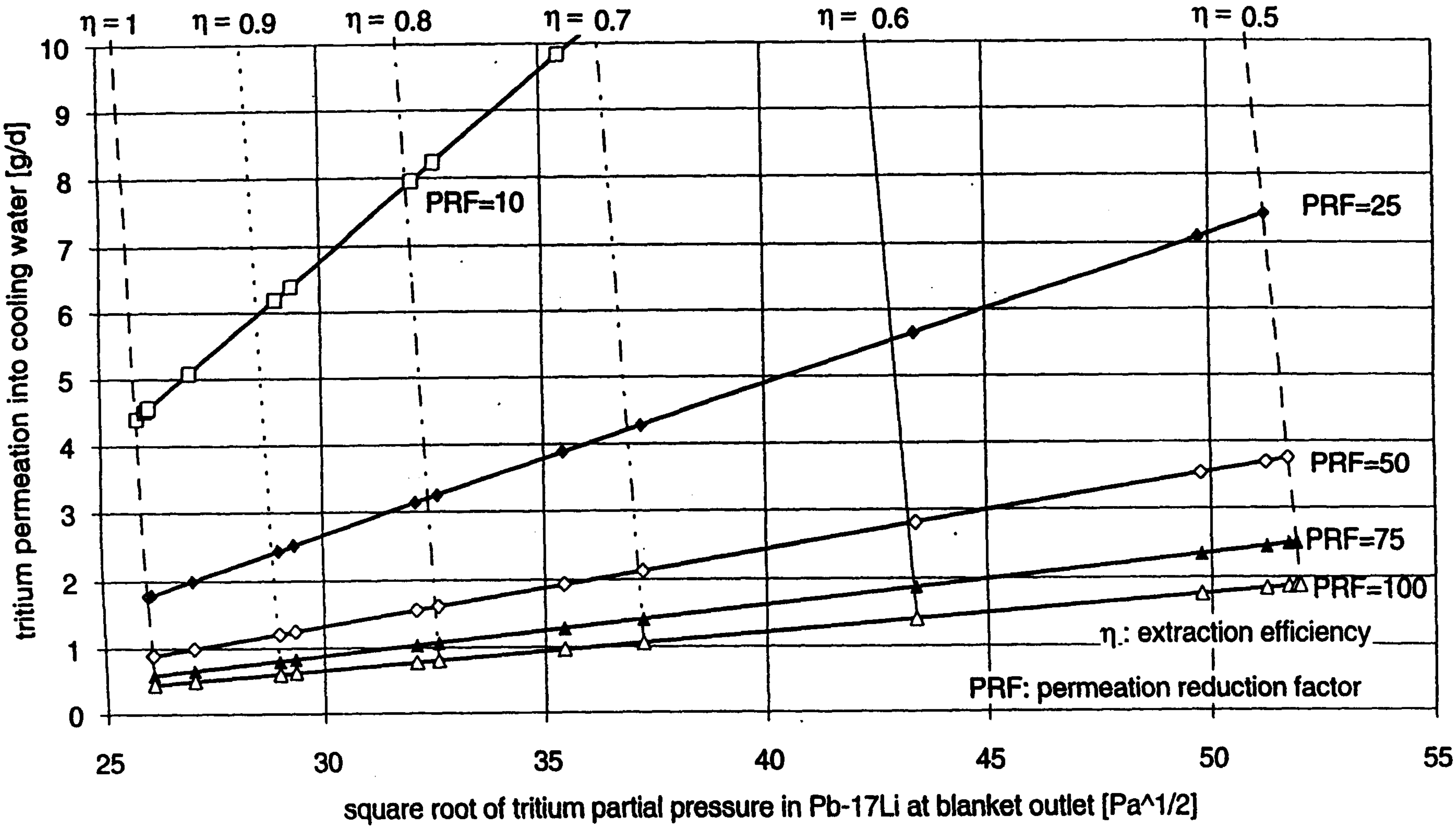
(T. J. Thompson, The Technology of Nuclear Reactor Safety, Volume 2, p. 297)

- The coolant velocity in the reactor system needs to be limited to a value similar to this.

Tritium Recovery/containment

- The tritium inventory in the breeding material has to be limited to a value consistent with safety requirements. (<200g)
- The tritium leakage rate will also be limited to a value consistent with safety requirements. (< 10 Ci/d)
- There is strong confidence that the tritium inventory goal can be reached.
- However, the tritium leakage goal is much more difficult to reach.
- The problem is even more severe for a high temperature system.

Tritium permeation from Pb-17Li into cooling water (without FW contribution) as a function of extraction efficiency and permeation reduction factor [7.9]



Comments

- TSTA lost 0.7 Ci tritium and was shut down for 6 months.
- Dave Patti suggest that 10 Ci/d will not be acceptable. We may have to set the limit at 1 Ci/d.
- As we go to higher temperature systems, both the tritium partial pressure and the permeability increase exponentially with temperature.
- Tritium containment will be one of the most important issues for the D-T fusion system.
- Not enough attention has been paid on this issue.

Tritium Parameters for flibe

- The tritium concentration increase per coolant pass is 0.92 ppbm.
- The tritium partial pressure increase per coolant pass is 440 Pa.
- If a steam generator is used, and the temperature is 500°C, the tritium partial pressure at the steam generator has to be 10^{-7} Pa, if there is no tritium diffuse barrier.
- Even with a very efficient tritium diffuse barrier, many orders of magnitude reduction of tritium partial pressure will need to be achieved.

Methods to reduce tritium diffusion

- Develop tritium diffusion barrier.
- Develop a very efficiency tritium recovery method.*
- Design an intermediate loop.
- Design a double-walled heat exchanger.
- Select structure materials with low tritium diffusivity.
- Develop a non-water power conversion system.
- Some combination of the above.

*As suggested by R. Moir. Two stages of disengager will be used. Each stage has 99.7% efficiency.

Summary

- There are many issues that have to be resolved.
- Some of those issues are particularly sensitive because of the APEX design parameters, such as
    - Coolant velocity
    - Coolant flow rate
    - System temperature
- The impact of those parameters to the entire system have to be evaluated.