P3-006

Design of the EU DEMO Tritium Extraction System mockup based on Permeator Against Vacuum technology

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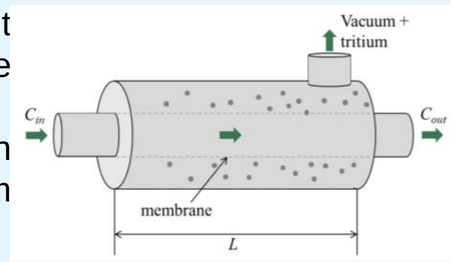
Introduction

- The Helium Cooled Lithium Lead (HCLL), Water Cooled Lithium Lead (WCLL) and Dual Coolant Lithium Lead (DCLL) Breeding Blankets foresee the use of flowing lead lithium as breeder material;
- One suitable technology for the Tritium Extraction Removal Systems is the Permeator Against Vacuum (PAV):
  - Simple operating principle
  - Claimed larger efficiency than other technologies
  - Minimize Tritium losses



Aim of the work

Design of the mockup for the PAV which will be tested in ENEA Brasimone TRIEX-II Facility

- Sizing and mechanical analyses
- Preliminary CFD/TH analysis
- Development of a new surface-limited permeation model and comparison with diffusion-limited model

Preliminary sizing

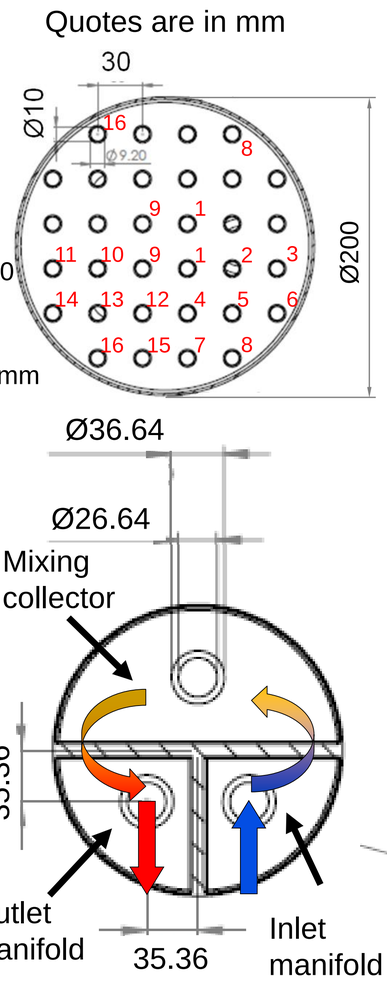
$SF = \frac{P_{cr}}{P_{env}} = 2$ [standard ASME VIII Div.1]

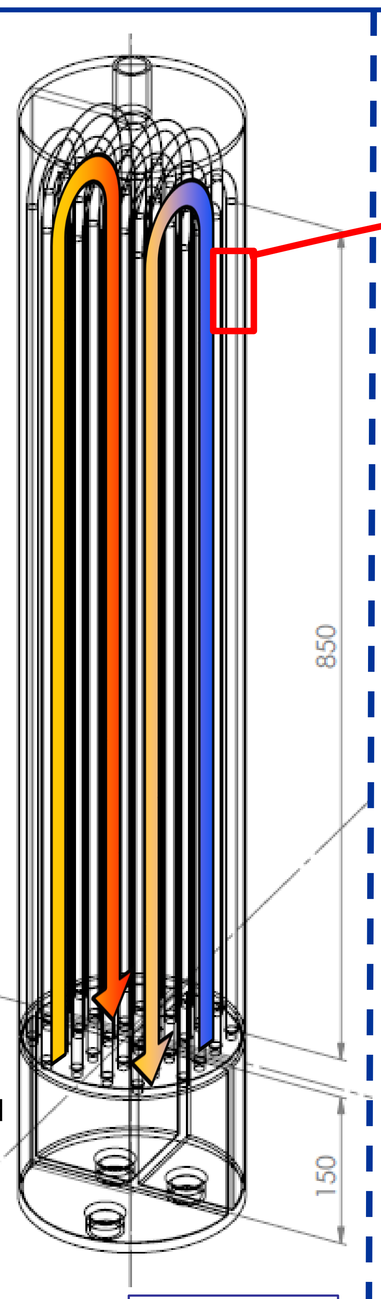
$P_{cr} = \frac{E}{4(1-\nu^2)}\left(\frac{s}{R}\right)^3$

Vessel material: 10CrMo910

$\sigma_{lim} = 108\ MPa$

→ Vessel thickness = 1.62 mm
→ Plates thickness = 8 mm





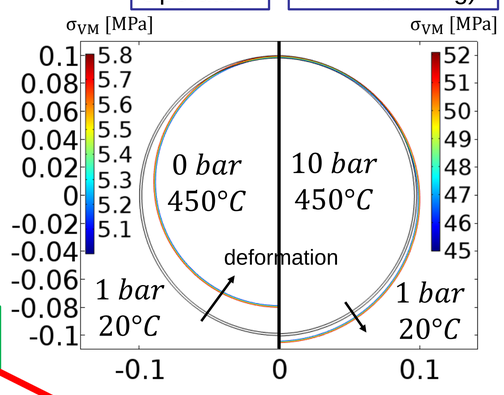
- 2 sets of 8 Nb U-pipes with 2 passages in vacuum
- Pipe height ~0.9 m × 4 passages → total length ~3.5 m

- Pressure drop < 0.5 bar
- Flow velocity ~ 0.5 m/s

Design assessment

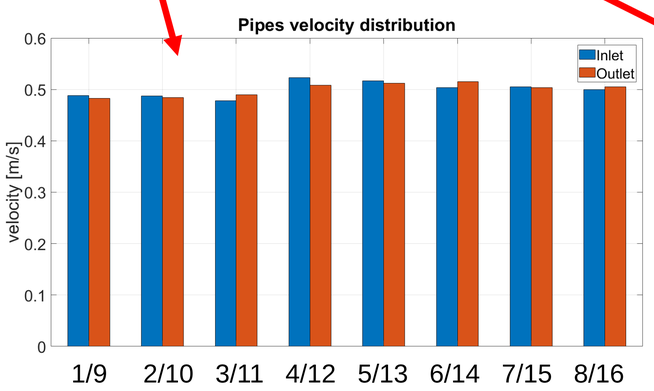
- **FEM thermo-mechanical analyses**
  - Thermal gradient;
  - Different pressure conditions
  - → Von Mises stress < limit
  - Weldings to be assessed

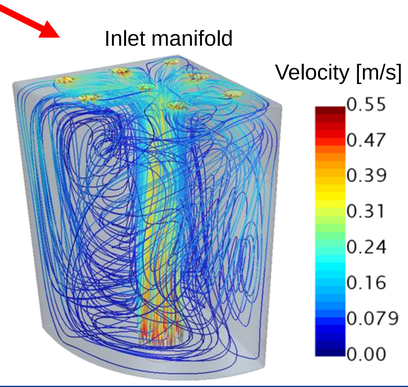
Operation | Test (during commissioning)



- **Preliminary CFD analysis**
  - Inlet mass flow ~ 2.6 kg/s

→ dm/dt well distributed among the pipes
→ ~uniform speed





Tritium extraction efficiency

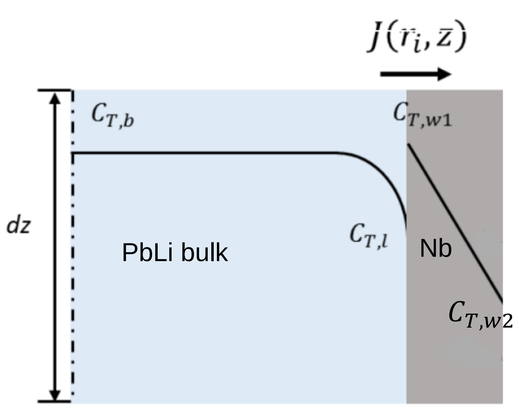
Permeation model

Diffusion Limited Model (DLM)

- Neglect surface effects
- Major resistance on PbLi side: mass transport coefficient

Depends on:
- Pipe geometry
- PbLi properties
- Velocity of PbLi

$h_t \propto Re^{0.913}$



$J = D_s \frac{\Delta C}{\Delta x}$

Permeated flux

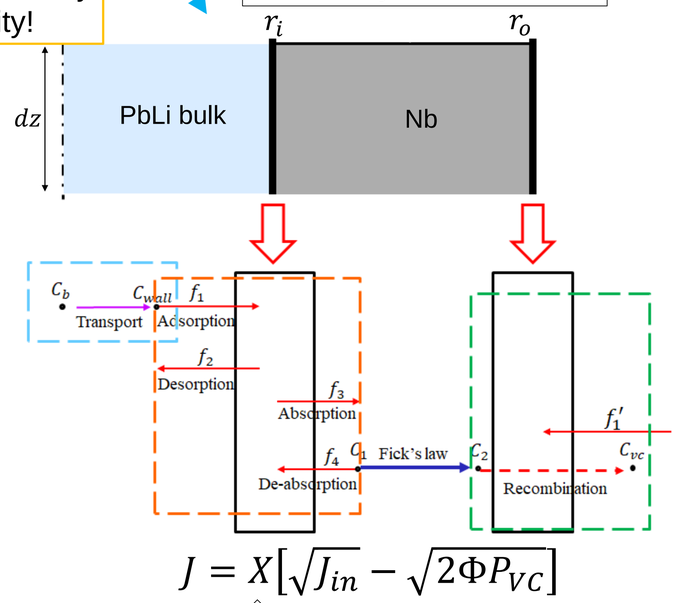
1D PbLi and Tritium advection along the pipe axis accounted for

Concentration along z is always influenced by mass flow velocity!

Surface Limited Model (SLM)

Resistance influenced by:
- Membrane properties (surface effects)
- Mass transport coefficient

Depends on:
- Pipe geometry
- Nb surface properties (unknown)
- Velocity of PbLi

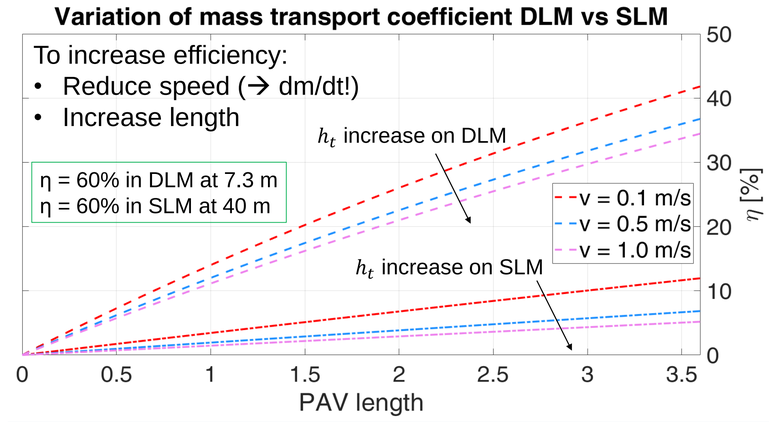


$J = X\left[\sqrt{J_{in}} - \sqrt{2\Phi P_{VC}}\right]$

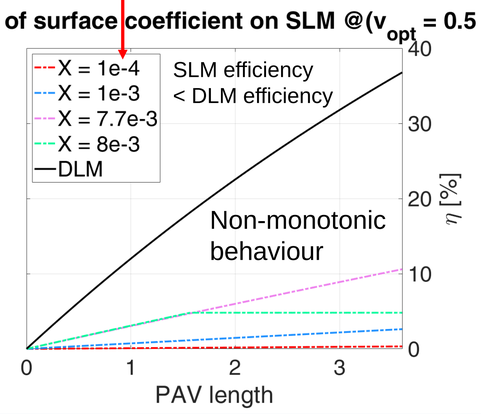
Surface coefficient

Results

Variation of mass transport coefficient DLM vs SLM



Variation of surface coefficient on SLM @(v_{opt} = 0.5 m/s)



Conclusions and perspective

- EU DEMO Tritium Extraction System mock-up design completed
- Detailed design assessment ongoing (CFD / thermo-mechanics)
- New, surface-limited permeation model developed / compared with diffusion-limited one
  → dedicated tests on Nb pipe to measure surface coefficient are envisaged
- Next step: mockup tests for design qualification and permeation model validation

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