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Heat Pipe-based DEMO Divertor Target concept: high heat flux performance evaluation

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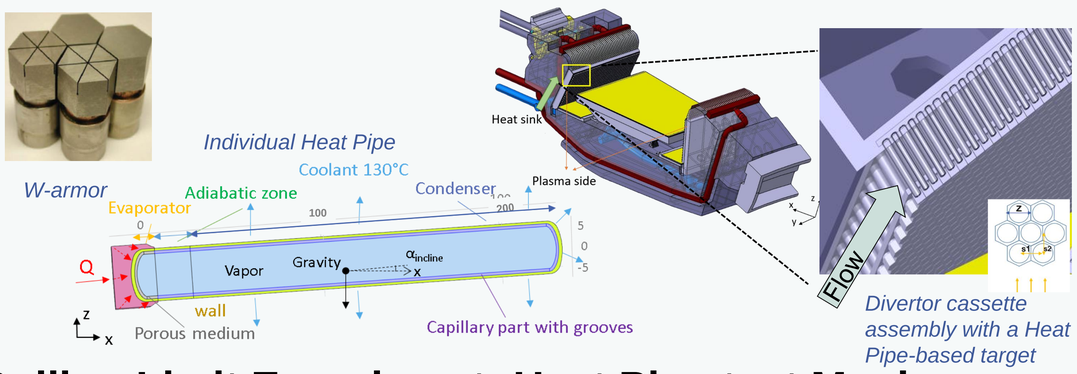
Objectives

- Evaluate the capability of a water-based HP designed for heat fluxes as high as 20MW/m² with focus on the heat transfer performances of the HP evaporator;
- Investigate the HP evaporator boiling limit experimentally for different porous structures and (water) filling conditions.

DEMO-Divertor Heat Pipe Concept (DIV-HP)

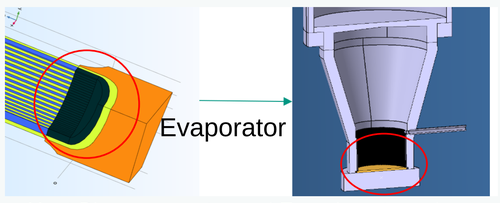
- Divertor Heat Pipe target is made out of 230mm long cylindrical Heat Pipes (HPs), which are installed parallel in a water cooling channel, forming a staggered structure .
- HP wick structure is combined with sintered porous and open grooves.



Divertor cassette assembly with a Heat Pipe-based target

Boiling Limit Experiment: Heat Pipe test Mock-up

- The capillary limit of DIV-HP is well above the operating power, the other critical limit, like boiling, need to be analyzed to prevent dry out.
- The experiment focus on the performances of evaporator with sintered porous structure subject to a high heat flux.

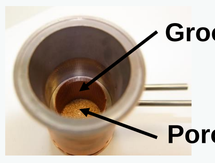


Demo Heat Pipe evaporator and Experiment mock-up model

Thickness: 2mm

Grooves width: 2mm
Grooves depth:1mm

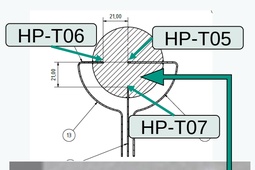
Condenser inside view



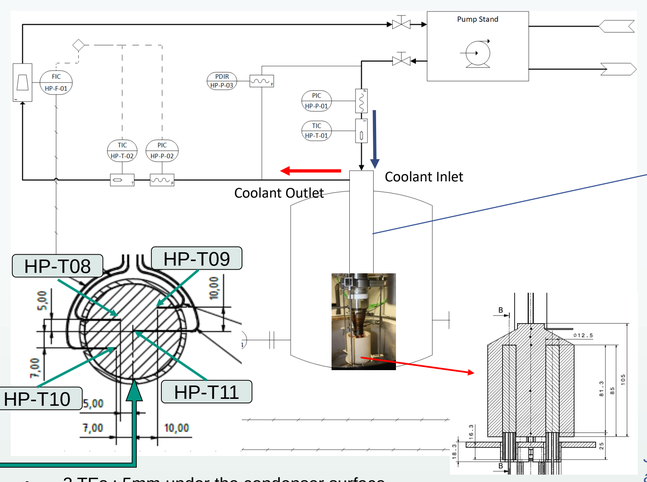
Evaporator inside view

Sintered porous structure: plain shape; with grooves

- 2 HP test mock-ups reproduce similar DIV-HP evaporator conditions.
- 2 evaporator porous structures having 800-900µm bronze grains:
  - a plain sintered porous structure
  - a porous structure with grooves as enhanced performance solution

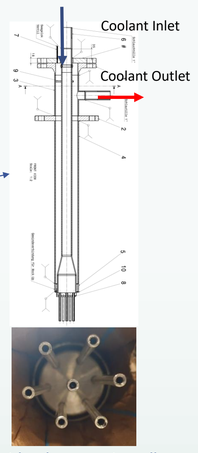


Mock-up with thermal sensors



- 3 TEs : 5mm under the condenser surface
- 2 TEs : in FHP body for vapor temperature
- 4 TEs : evaporator surface

Electric copper heater with inserted 6 heater rods



Jet impingement cooling at the condenser side

- Power evaluated calorimetrically on the (external) coolant side.
- Temperature variation of mock-up monitored by 9 thermocouples.

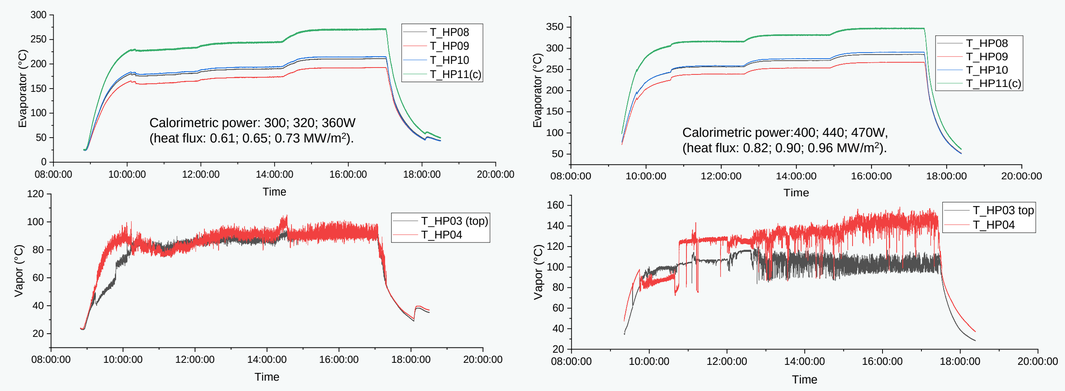
Experimental heat transfer performance evaluation

➢ Method

- Loading is applied using either an electric cooper heater (low power level screening) or a laser machine (high power level); power is increased stepwise from 0.4 MW/m^2 up to 20MW/m^2 until there are indications of dry-out;
- Liquid inventory inside set to 1.5ml (estimated max. heat flux ~1MW/m^2); in a second step it will be increased to 2.5ml (~20MW/m^2 max.);

➢ Experimental results

Temperature evolution for two power levels with liquid inventory for 1MW/m²



- At a specified (electrical) power level, the experiment is run until the temperatures, both on the mock-up and the electrically heated copper block temperatures stabilizes (120 to 150 minutes).
- For applied heat flux up to 0.7MW/m^2, the measured vapor temperatures (T_HP03 and T_HP04) are almost the same and increase with the applied heat flux;
- Starting from 0.8MW/ m^2 , the vapor temperatures become distinct, the one close to evaporator (T_HP04) becoming larger than the other one and increasing with the heat flux. Between 0.9 to 1.2 MW/m² both temperatures seem to stabilize themselves around 100°C for T_HP03 and 150°C for T_HP04. From 1.2MW/m² both temperature exhibit an increase, the gap between the two temperatures becoming smaller.

- The heat flux versus wall superheated ΔT curves at the evaporator indicate that, in the tested loading range (0.4 to 1.3MW/m²), the heat pipe operates still in nucleate boiling regime. Up to this heat loading level, the curves plotted considering each of the four temperature sensors separately, show no indication of a localized dry-out or partial film boiling.

Conclusions and future plans

- Up 1.3MW/m² the evaporator shows no sign of dry-out showing a better performance as expected. However, the wall temperatures are relatively high most probably due to the low conductivity of the evaporator that is made out of bronze.
- The experiments will continue with this mock-up until the dry-out is observed or other technological limit is reached. For comparison, the second mock-up will be tested afterwards, using the same filling level.

EUROfusion

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