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Heat Pipe technology based Divertor Plasma Facing Component concept for European DEMO

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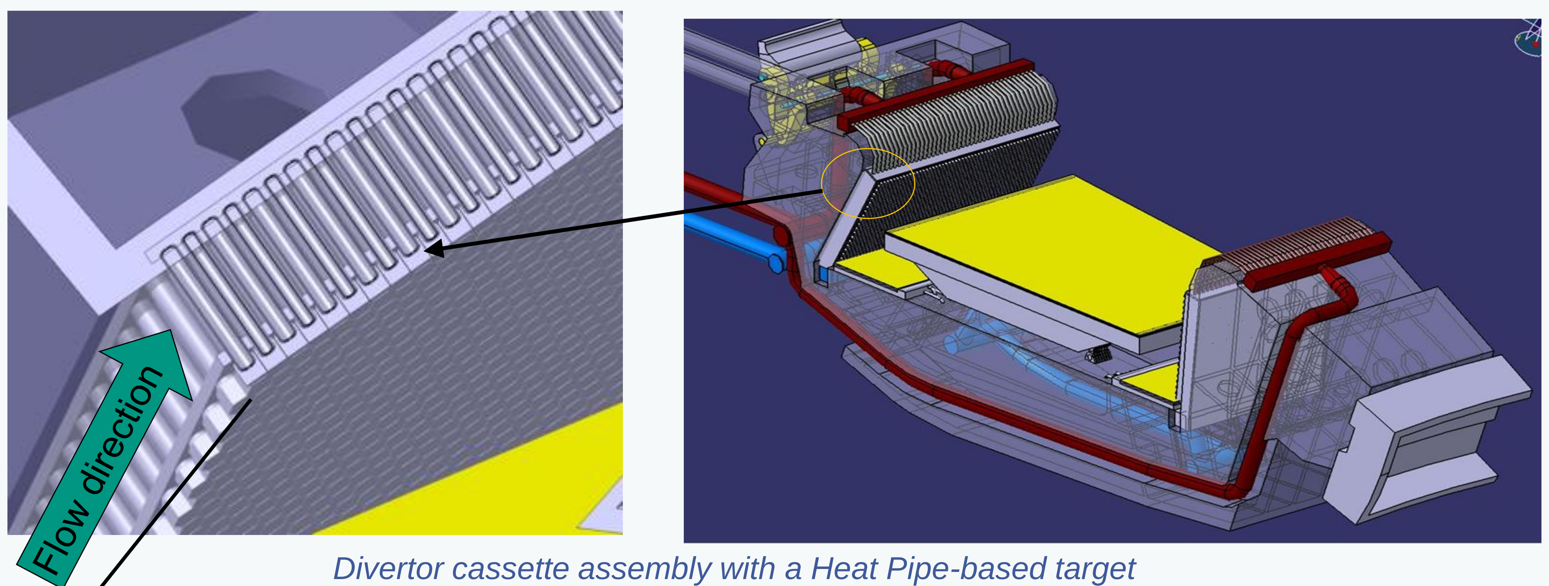
Objectives

Investigate the possibility of using water-based heat pipes in conjunction with a new divertor concept including:

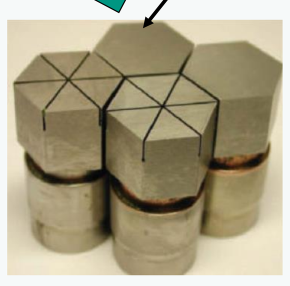
- dimensioning a variable conductance heat pipe that should be capable of dealing with heat fluxes as high as (at least) 20MW/m^2
- analysis the integration of the HP in the divertor target

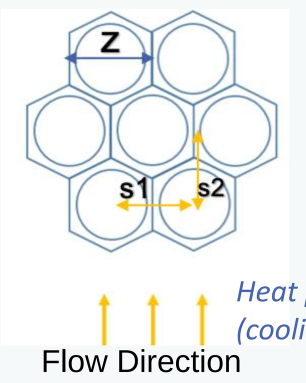
Basic Concept

- Divertor target made out of parallel cylindrical Heat Pipes installed in a water cooling channel. The HP rods form a staggered structure (HP condenser).
- The Heat Pipes penetrate the plasma facing side of the cooling channel, having a hexagon W-armor at that particular end (HP evaporator side).

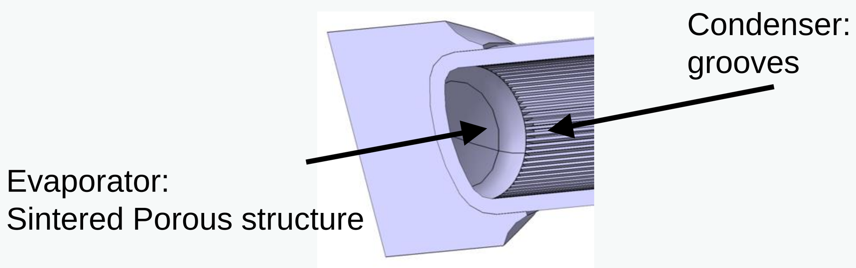


Divertor cassette assembly with a Heat Pipe-based target


W-armor

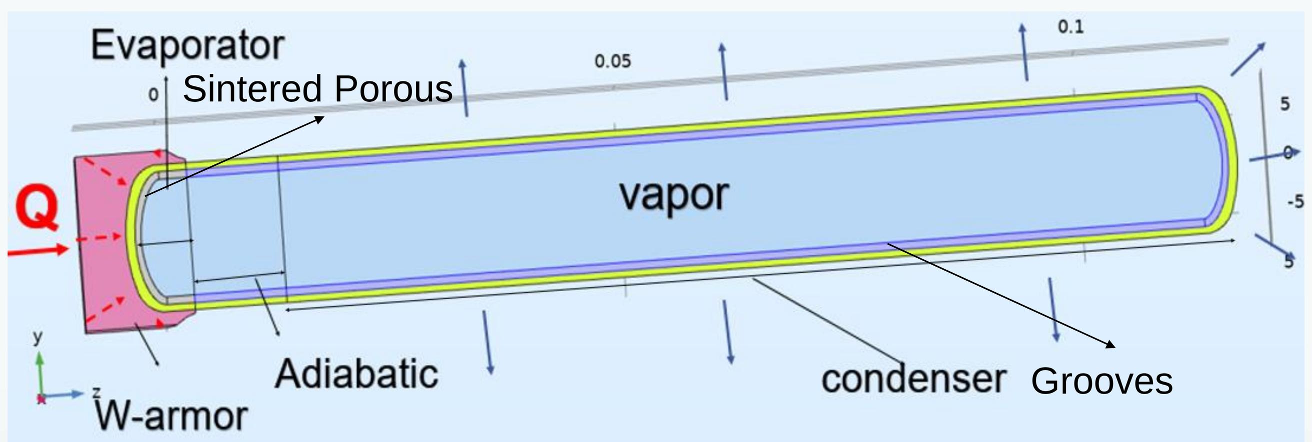


Heat pipes arrangement (cooling channel side)



HP Evaporator end with porous

- HP has cylindrical body with outside diameter 15mm, while the vapor space is 12mm in diameter;
- HP material: CuCrZr
- HP total length is 230mm, the length of the evaporator and adiabatic part being 7mm and, respectively 23mm.
- Orientation 7.8º depends on divertor target.



Individual Heat Pipe

Design Studies

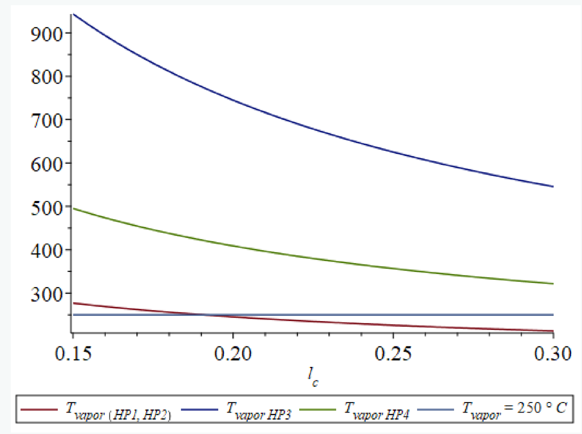
Power removal system: assumed to have the same mass flow rate and conditions (**4MPa, 130°C**) as the EU-DEMO divertor baseline.

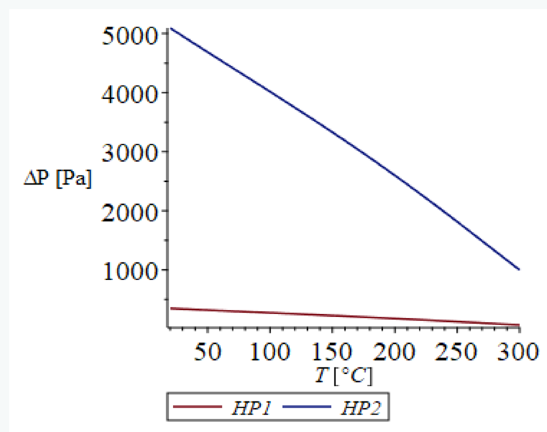
HP working medium is **water**: design that has a vapor temperature around 200°C (best performance for water-based heat pipes) and does not exceed 250°C (rapid fall of performance).

➢ **Find the optimal condenser length (l_c)**

Four options for the capillary structure have been considered:
-HP1: grooves for condenser and adiabatic zone and mesh for the evaporator
-HP2: grooves for condenser and adiabatic zone and sinter porous material for evaporator
-HP3: mesh for capillary structures inside
-HP4: sinter for capillary structures inside

Design option	HP1	HP2	HP3	HP4
Number of grooves N_a	80	80		
Width of groove w [mm]	0.3	0.3		
Height of groove h [mm]	1	1		
Mesh/Wire Diameter d_m [mm]	0.1		0.1	
Mesh width w_m [mm]	0.5		0.5	
Sinter particle radius r_p[mm]		0.05		0.05
Porosity ε	0.74	0.5	0.74	0.5


Temperature levels (in °C) needed to transfer 5.6kW into the cooling circuit (l_c with unit m)



Variation of the maximum driving capillary pressure difference with temperature levels

- **HP1** and **HP2** options can operate at vapor temperatures below 250°C when condenser length is more than 200mm
- **Capillary limit**: HP2 has lager driving capillary pressure against pressure losses allowing for higher operational power.
- **Entrainment limit:** using open groove it limits the power level; adding mesh screen between groove and vapor increases that limit.

l_c [mm]	Vapor Temperature [°C]	Capillary limit [kW]		Entrainment limit HP1/HP2 [kW]	
		HP1	HP2	No mesh screen	With mesh screen
150	277	1.6	5.57	5.7	16
200	245	2.2	7.5	5.7	16
220	234	2.5	7.9	5.6	15.6
250	226	2.6	8.3	5.4	15.2
300	212	2.8	8.5	5.1	14.5

Conclusions

- **Solution:** A water based heat pipe **230mm** long made out of CuCrZr, from which the condenser should be at least 200mm long, should be capable for peak heat flux of 20MW/m^2.

Futures works

- The operating limits here using engineer formulas need to be validated experimentally.
- The first experiment focus on evaporator is under preparation.

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