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Session P5

Analysis of Heat Transport and Pipe-routing Considerations for Blanket to Steam Generator for a Fusion Reactor

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ABSTRACT

- A Program has been developed to calculate the hydraulic parameters for Helium cooled blankets for three reactor configurations.
- These parameters will form the basis for detailed engineering calculations (thermal hydraulics).

ASSUMPTIONS

- Average blanket module area is 1.4 m^2.
- Helium pressure is 8 MPa.
- Inlet/Outlet temperature of Helium coolant is 300/500 °C.
- A common Ring Header (RH) collects hot helium from all the blanket modules distributed on 18 main manifolds and sends it to the Steam Generators (SG). RH diameter is an input.
- Number of channels is an input. Channel diameter and spacing within the blanket module is chosen in such a way that structure temperature at the geometric center of a '4-channel lattice' is does not exceed 560 °C.

Table 1: Thermal Hydraulic Parameters for Three Reactor Configuration

Parameters	Units	Reactor A	Reactor B	Reactor C
Fusion Power	MW	500	2500	3000
Q (Assumed Fusion Gain)		30	50	50
P_AUX	MW	17	50	60
P_Alpha	MW	100	500	600
Major Radius R	m	6.2	7.5	3.2
Minor Radius a	m	2	2.5	2
Elongation (Kappa)		1.85	1.85	3.4
Plasma Surface Area (A_PL)	m^2	697	1054	555
Volume (V_PL)	m^3	905	1710	858
Radiation from core (40%)	MW	47	220	264
Surface Heat Flux	MW/m^2	0.07	0.21	0.48
Average Blanket Module Area	m^2	1.5	1.5	1.5
NB (Number of Blanket Modules)		465	702	370
Neutron load on Blanket Module	MW	0.86	2.85	6.48
He Mass flow rate per BB	(kg/s)	0.93	3.04	6.93
Number of Steam Generators (SG)		2	4	4
Mass flow rate in Ring Header (RH)	kg/s	215	534	641
Ring Header Diameter	m	1	1.5	1.5
Velocity in RH	m/s	58	64	77
Number of Manifolds (NM)		18	18	18
Mass flow in Manifolds	kg/s	24	119	143
NB per Manifold		26	39	21
Per Blanket Mass Flow	kg/s	0.93	3.04	6.93
Diameter of Blanket Pipe	m	0.065	0.11	0.15
Number of coolant Channels (Nc) in the Blanket		80	80	120
mass flow per channel	kg/s	0.0116	0.0380	0.0578
Dia. of the channel	mm	7.3	12.7	14.2
Channel spacing	mm	6.0	6.0	6.0
Heat Extracted Per Channel	W	12018	39502	59968
Heat transfer coefficient	W/m^2-K	4168	3985	4482
Length of the channel	mm	2503	4989	5987
n_rad (Channels in Radial)		5	5	5
n_pol (Channels in Poloidal)		16	16	24
Fraction occupied by the channels		1.209E-02	7.168E-02	1.632E-01

DESCRIPTION

- A sketch of the overall scheme for all the three configurations has been shown in Fig. 1. The supply ring header (SRH) connects the SG to the 18 sectors (shown as circles) from where the extracted heat is taken to the SG by the return-ring-header (RRH). Each sector will itself have a manifold to connect all the BM within that sector by a sub-header.
- Table 1 shows the parameters for the 500 MW (Configuration A), 2500 MW and 3000 MW ST reactor scenario (Configuration B and C).
- The diameters of the different headers have been evaluated in order to keep the velocity ~ 70-100 m/s (well below the 10% of the sonic speed).
- The length of the pipes from BM to RRH and from RRH to SG are considered as ~40m and ~20m respectively.

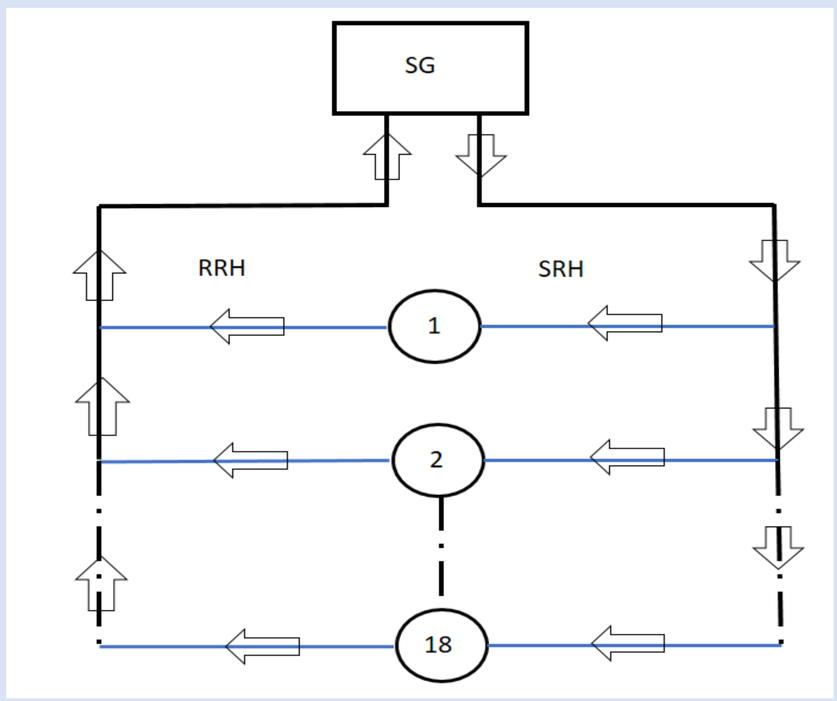

Fig 1: Overall Scheme of helium coolant flow

CONCLUSION

- For conventional assumptions of helium coolant of 8 MPa and 300/500 C inlet outlet temperature, the number of channels in a blanket module and the volume occupied by them seems reasonable (no significant replacement of blanket material by helium/void fraction from the neutronics point of view).
- For compact reactor, this volume fraction is about 16-20 % of the blanket volume.