Support and Possible In-Situ Alignment of ARIES-CS Divertor Target Plates

Presented by

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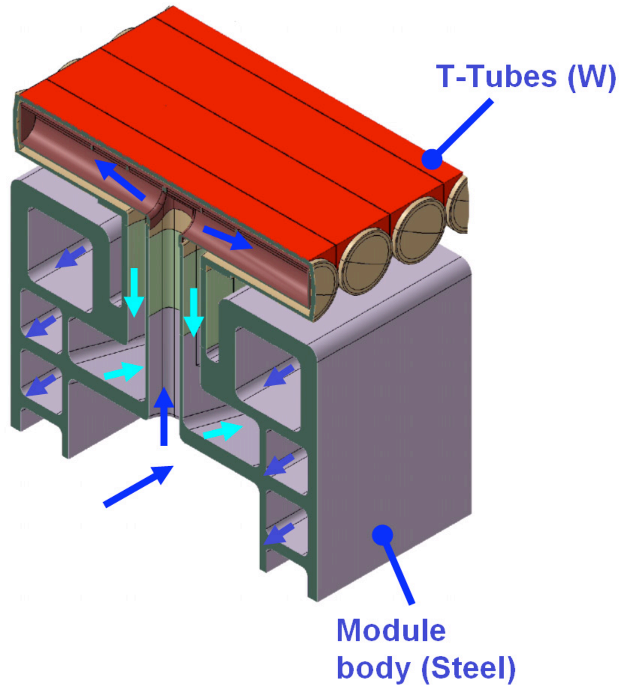
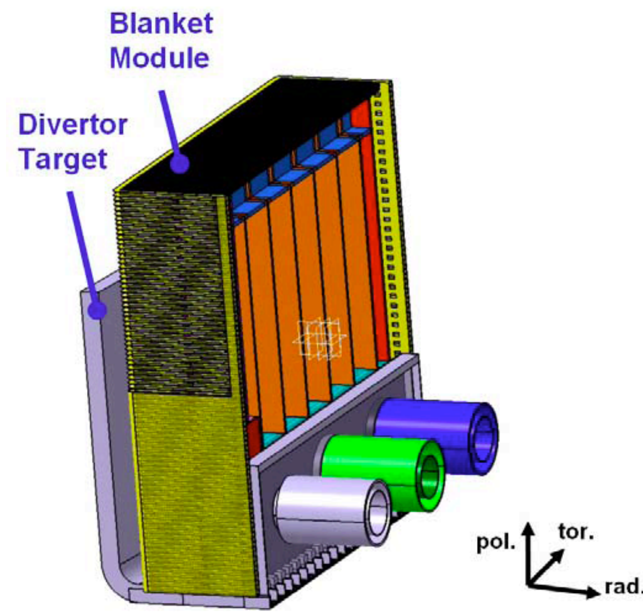
Initial Effort on Divertor Design and Support

- As part of the development of the divertor T-tube design, some preliminary thoughts were given as to how to support and feed the divertor target plates.
- One possibility was to integrate the plate with a blanket module and to include the divertor manifold as part of the blanket manifold region at the back.
- However, this concept was not studied in any detail.
- Some concerns exist, including the lack of space at the back for an additional divertor manifold running next to the blanket manifold and also the effect of the blanket module thermal expansion on the alignment of the divertor in this integrated configuration.
- We revisited this issue in more detail to try to come up with a more attractive solution.





Divertor Maintenance

- The divertor is subdivided into separate plates made up of a number of T-tube unit cells.
- Individual support and coolant feed are provided to each plate.
- The divertor plates will be exchanged through the same horizontal ports as the blanket modules.
- In analogy with the blanket, we assume one concentric coolant access pipe for each divertor plate with an outer pipe id of ~ 0.3 m (this would allow for removal of ~10 MW per divertor plate).
- For a total thermal load of ~240 MW on the divertor, this means that there would be about 24 such plates.
- The dimension of each plate would depend on the exact coverage of the divertor region but would be ~ 3 m^2 (e.g ~1.5 m poloidally by ~2 m toroidally). The port size should be able to comfortably accommodate such a plate dimension for maintenance.

Divertor Plate Attachment and Coolant Supply

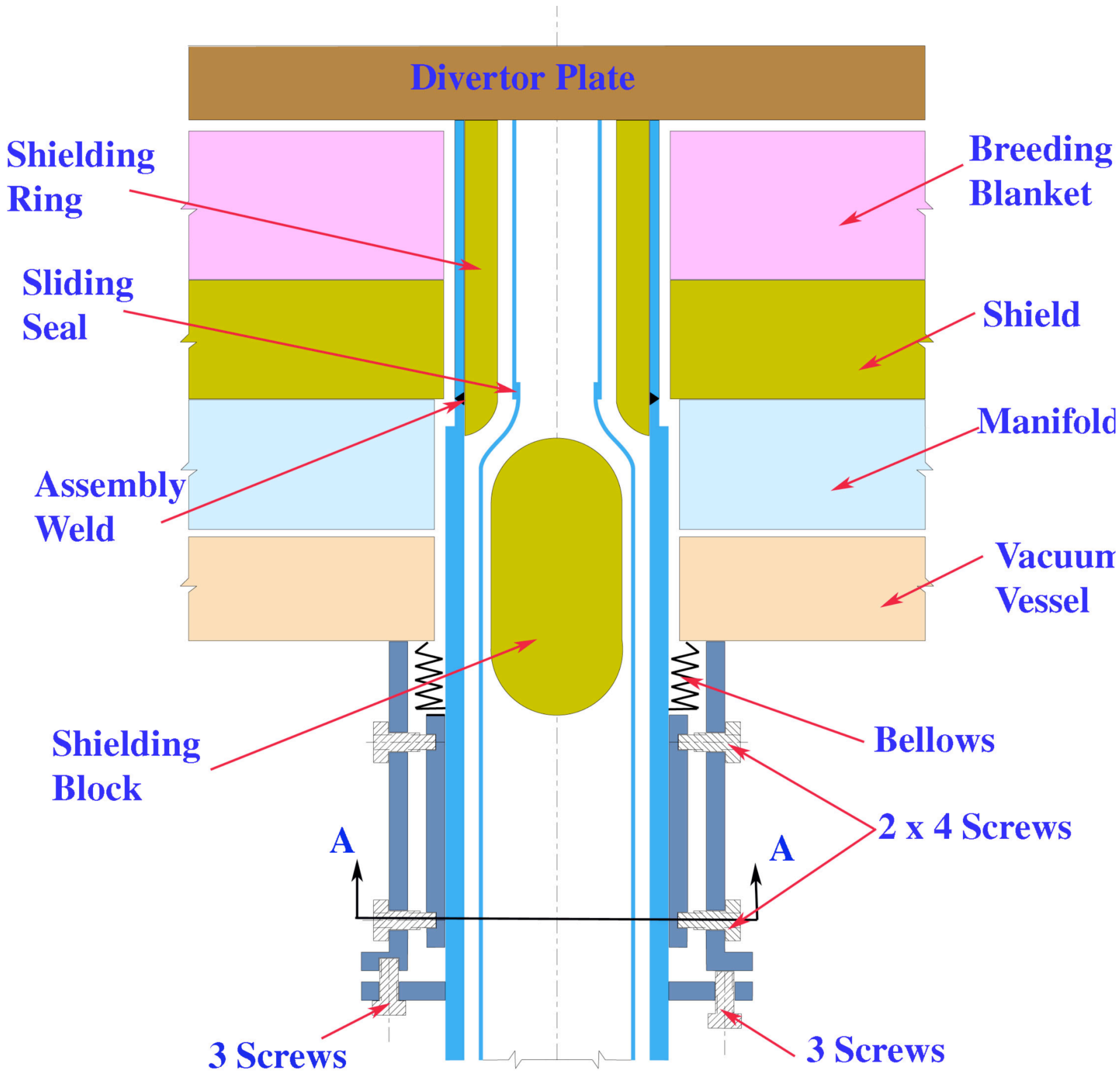
- **If the divertor is attached to the breeding modules (themselves attached to the "hot" shield + manifold ring which is attached at discrete points to the VV), the location of the divertor plate surface relative to the magnetic field would be influenced by the significant blanket/FW thermal deformation and movement relative to the VV.**

- **To avoid this large uncertainty, we considered attaching each plate directly to the VV, with the coolant supply tube/mechanical attachment penetrating the breeding modules and the hot shielding ring (breeding modules would have to be designed to allow this).**

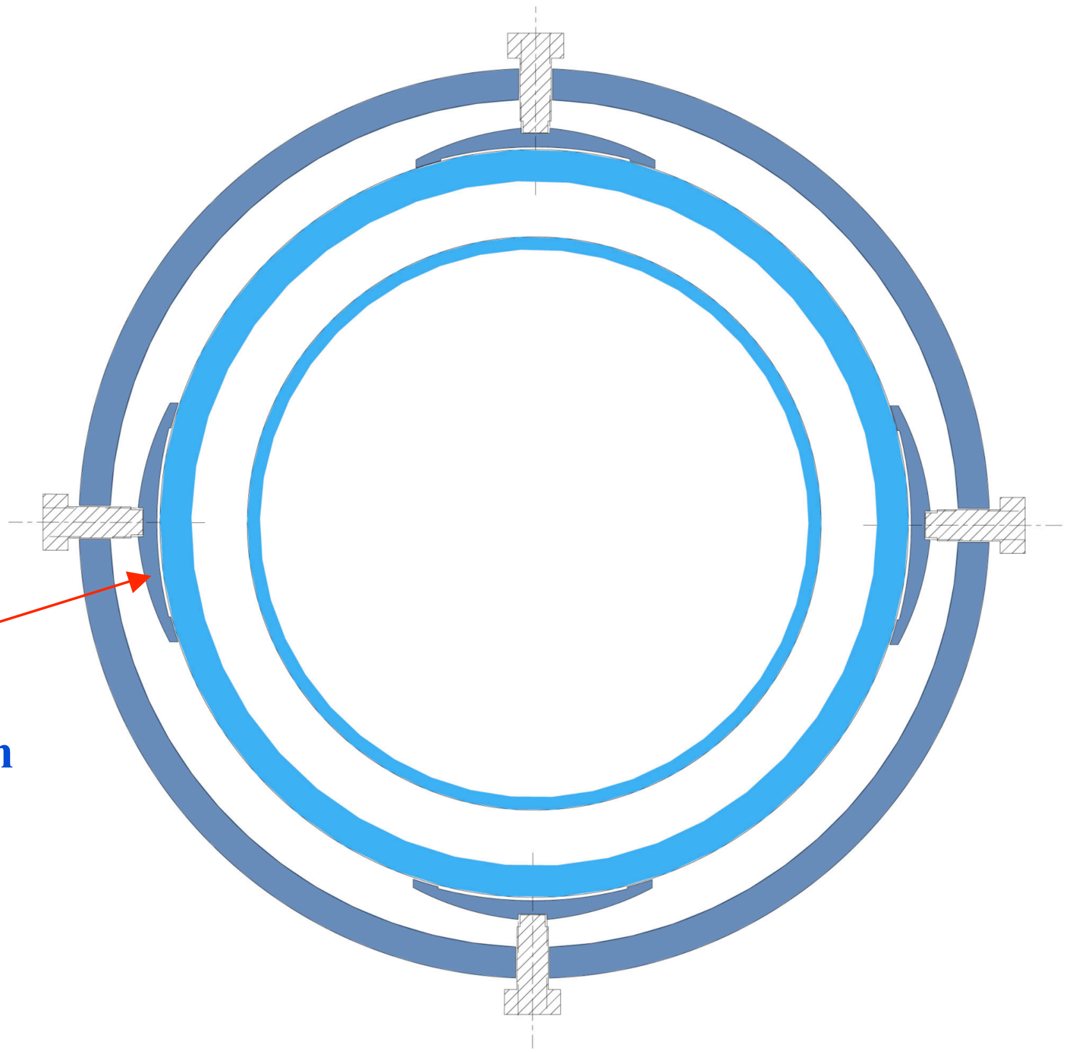
- **In this case the coolant pipes to each of the divertor plates are attachedat the back of the VV, and can be cut/rewelded with in bore tools inserted from the outside of the VV.**

- **Utilizing the coolant piping as structural support could also provide the possibility of in-situ divertor alignment if required.**
  - **The holes in the VV for the coolant access pipe can be made considerably larger than the outer diameter of the pipe (~60 cm), allowing in this way the desired alignment of the divertor plates relative to the magnetic field.**

Schematic of Divertor Plate Attachment and Coolant Supply Including Inner Shielding Blocks to Prevent Neutron Streaming



Details of Adjustable Divertor Support Patches



A-A Cross Section

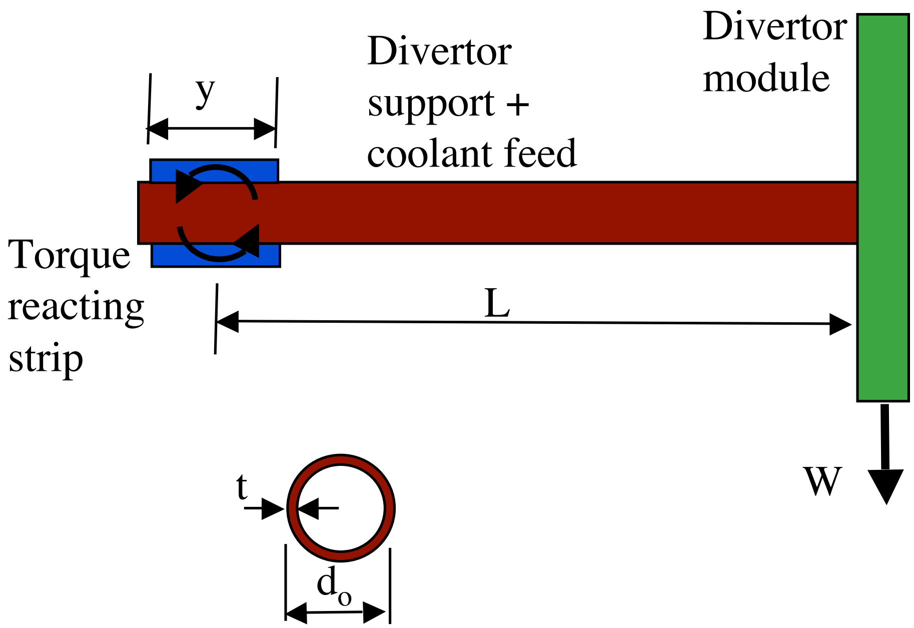
- **Support system designed to allow for some elastic deflection in case of differential thermal expansion between outer supporting ring and inner divertor tube support.**

“Cantilever” Divertor Support

- **Example parameters:**
  L ~ 2 m; W ~ 1-2 ton; d_o= 0.55 m; t = 0.025 m; y = 0.5 m

- **Maximum load on supporting screws = 2000 x 2/0.5=8000 kg**
  ~ 80 kN (moment) + 20 kN (static) = 100 kN

- **Static deflection at the end of the cantilever beam ~ 0.3-0.4 mm**



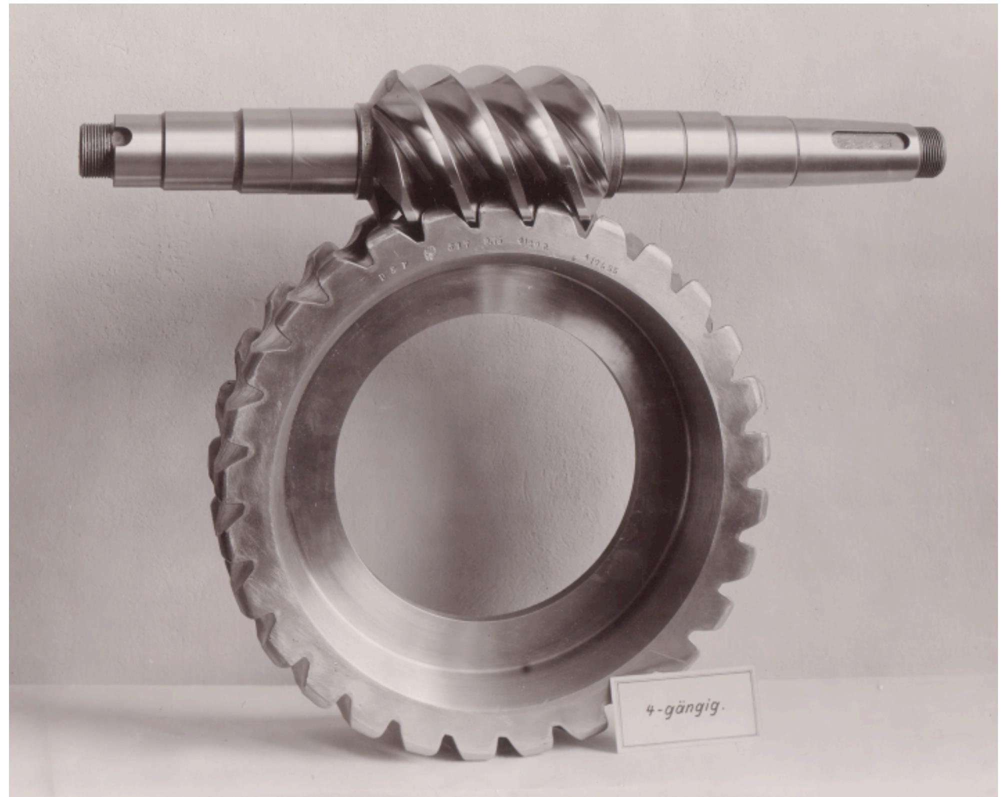
Provision for Precise Alignment of the Divertor Plates

- **Is in-situ PFC alignment required?**
  - **For the FW of the breeding blanket, no precise alignment is required as the SOL is assumed to be much larger than anticipated thermal deformation.**
  - **However, for the divertor any significant uncertainty in the location and alignment of the divertor plate with respect to the magnetic field lines (during operation) could lead to unacceptable local heat flux?**
  - **The magnetic field will probably be aligned prior to operation. Is this sufficient?**
  - **Or, would the possibility of in-situ alignment (~1mm?) for individual divertor plate be beneficial?**

- **Such an alignment provision could be included via a strong mechanical connection between access tube and VV; this connection would be aligned and fastened at the outside of the VV, thereby allowing for a certain range of adjustment of the divertor plate location and angle.**

Use of Roller and Worm Gear to Control Divertor Plate Alignment

- **Hydraulic or pneumatic motor to turn a screw via a roller-and-worm gearbox.**
- **Assume a gear ratio where 1 revolution of the motor results in 1/50 revolution of the screw (and, with h=5 mm, an axial motion of ~0.1 mm)**
- **Assume force on the screw~100 kN**
- **For a ~600 rpm motor, power required ~ 0.1 kW (100% efficiency)**
- **Motor power < 0.5 kW for efficiency >20%**



Hydraulic Motor Probably Available Off-the-Shelf

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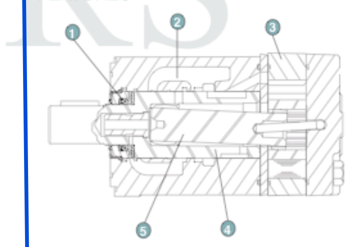

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RS Series motors are the most economical model in the White Hydraulics product line, but are not low-tech. Unlike competitive products using power robbing, two-piece rotor set designs with sliding contact points, RS Series motors utilize the patented Roller Stator® design. Seven precision rollers for the contact points reduce friction, providing more power and longer life for your application. Each output shaft is custom ground to maintain exact tolerances between the housing and shaft, producing high volumetric efficiencies. Industry standard mounting flanges and output shafts allow the RS Series motors to interchange with competitive designs.

SPECIFICATIONS

Code	Displacement (in^3/rev)	Max. Speed (RPM) - 1)Cont	Max. Speed (RPM) - 2)Inter.	Max. Flow (GPM) - 1)Cont	Max. Flow (GPM) - 2)Inter.	Max. Torque (lb-in) - 1)Cont	Max. Torque (lb-in) - 2)Inter.	Max. Pressure (PSI) - 1)Cont	Max. Pressure (PSI) - 2)Inter.	Max. Pressure (PSI) - 3)Peak
050	3.2	400	490	6	10	730	840	1750	2000	2250
080	4.6	460	540	10	12	1070	1230	1750	2000	2250
090	5.4	420	580	10	14	1300	1480	1750	2000	2250
100	6.3	510	570	14	16	1500	1725	1750	2000	2250
110	6.8	460	600	14	18	1630	1900	1750	2000	2250
125	7.7	410	530	14	18	1600	1850	1500	1750	2250
160	10.0	370	460	16	20	1970	2350	1500	1750	2250
200	12.5	300	370	16	20	2640	3050	1500	1750	2250
250	15.5	300	360	20	24	2540	3040	1250	1500	1750
300	17.9	300	310	20	24	2460	3100	1000	1250	1500
400	24.9	190	220	20	24	3350	4100	1000	1250	1500

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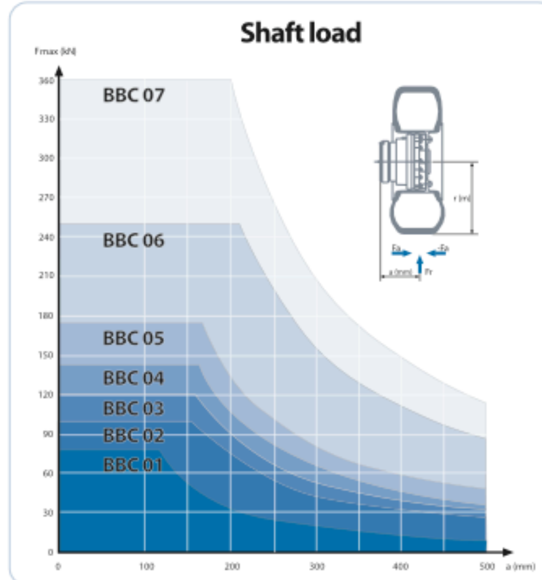
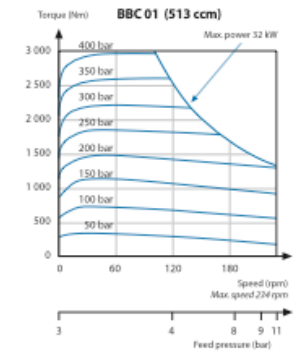
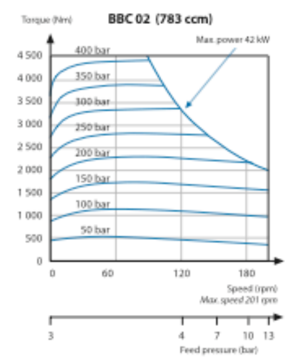
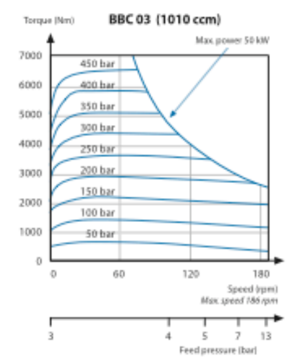


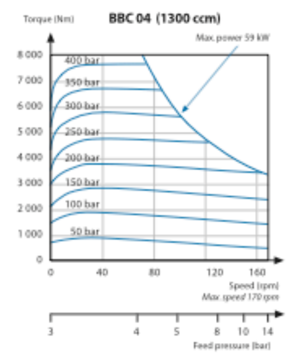
Performance curves

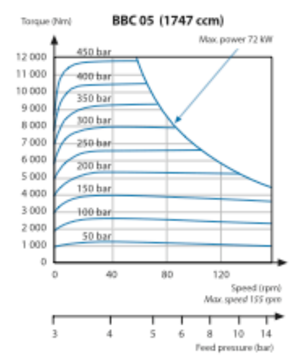
The performance curves are based on nominal displacement (100%) of each frame size. Also 90, 110, 120 and 130% displacements are available.
For more information, please contact us.

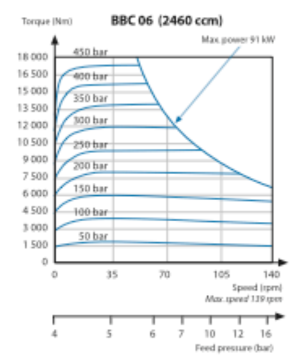


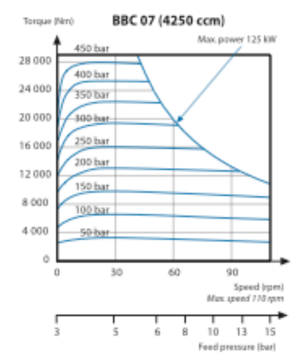












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Summarizing Trade-Off Study for Divertor Power Flow Assuming all Alpha Loss Power Goes to Divertor

Power Flow Diagram for Estimating Maximum Heat Fluxes on PFC's for ARIES-CS

- **Assume Combined Divertor/Alpha Modules**

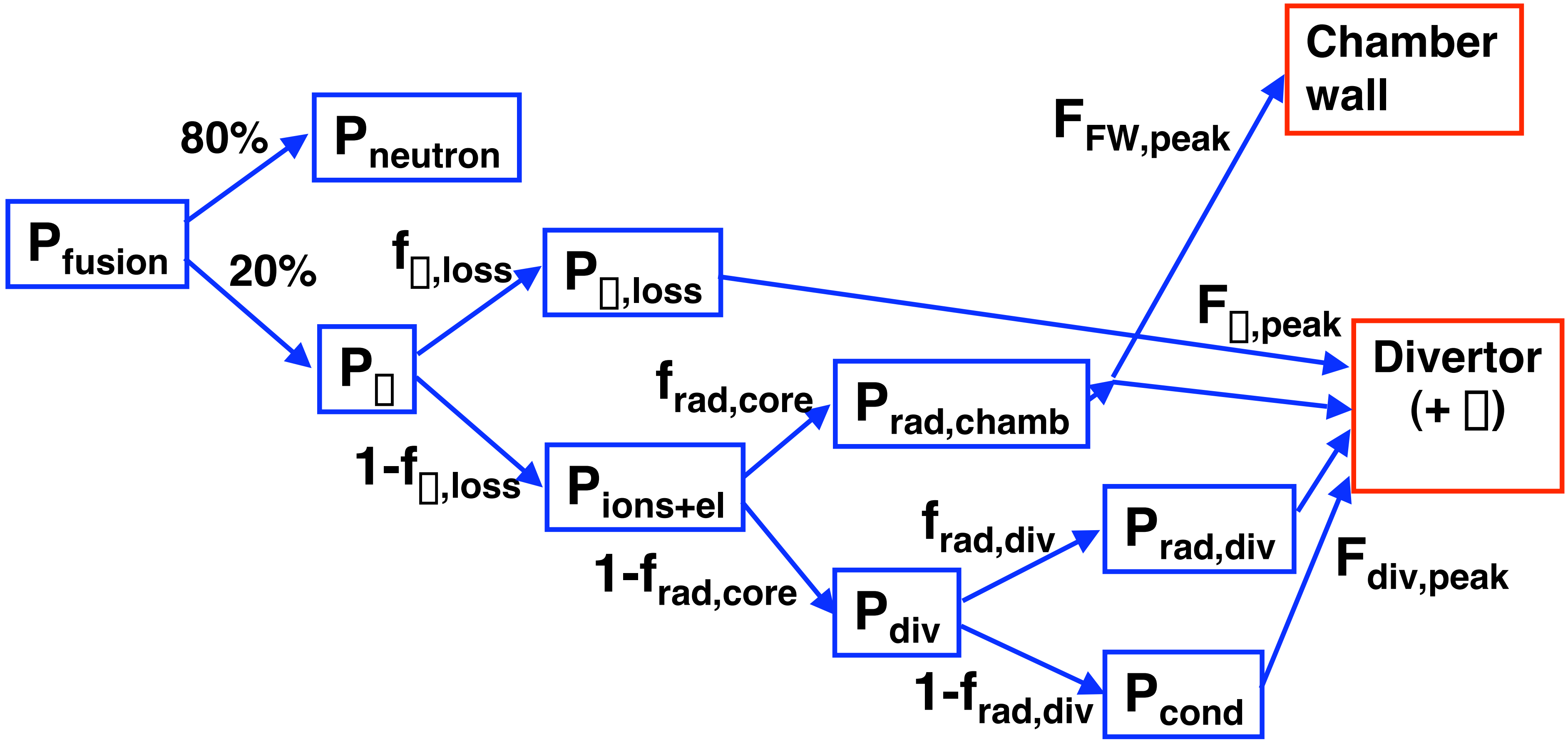

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Illustration of Requirements on Different Parameters for Combined Divertor and Alpha Modules

Example parameters required to maintain peak heat load on divertor = 10 MW/m²