Divertor cooling cost estimation

Sean Ballinger

May 13, 2017

Volumes are given in units of m^3.

1 Helium coolant

1.1 Material volumes

Rough surface area estimate for two X-point target divertors:

$$A = (4a)(2\pi R) \approx 25aR$$

Tungsten surface tiles have an average thickness of 6mm, giving a total volume of tungsten of

$$V_W = \boxed{0.15aR}$$

Each finger has a hexagonal surface with area $2.1 \times 10^{-4}\,m^2$, and assuming no wasted divertor surface area, the number of of assembles is $N = 120000aR$. The volume of WL-10 alloy used is then

$$V_{alloy} = (2\pi 0.016)(0.001)(0.018)N = \boxed{0.11aR}$$

Finally the amount of ODS EUROFER-97 steel including piping around the machine required is

$$V_{steel} = (2\pi 0.007)(0.001)(0.018)N + (2\pi 0.007)(4a/0.009)(2\pi R)(0.001)$$

$$= 0.095aR + 0.12aR = \boxed{0.22aR}$$

(number of distributor pipes assumed to be proportional to the cross section divertor surface length divided by the surface radius of a finger).

1.2 Coolant pump and plant

Flow rate 240 m/s.

Entirely arbitrary estimate based on ITER entire cooling system (water and H) cost of $400m in 2017 dollars: Helium loop, pump, and plant will cost around $50m.

2 FLiBe coolant

3 Material volumes

3 mm tungsten (or TZM) thickness:

$$V_W = \boxed{0.075aR}$$

12 mm FLiBe cooling channel:

$$V_{FLiBe} = \boxed{0.3aR}$$

4 cm inconel:

$$V_{inconel} = \boxed{aR}$$

3.1 Coolant pump and plant

According to ARC survey: 1.5 MW fluid pumping power required, flow rate 2 m/s.

Another arbitrary estimate based on ITER entire cooling system cost: because we would have a FLiBe system shared with blanket, cost of a FLiBe divertor might be around $25m.