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**Preliminary Heat Load Estimates of Some
Cryogenic Components for ESS**

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The aim of this note is to carry out preliminary heat load estimates of some cryogenic components for ESS, including the main cryogenic transfer line for the linac, the jumper connections and the transfer line side valve boxes for the cryomodules.


Our assumptions are listed below:

1. The length of the main cryogenic transfer line is 500 m. The transfer line consists of four tubes (5 K supply, 8 K return, 40 K supply and 80 K return) within one vacuum shell.
2. There are totally 59 cryomodules (14 spokes, 15 medium beta and 30 high beta) and the related jumper connections and valve boxes.
3. The length of one jumper connection is 5 m and also consists of four tubes in one vacuum shell.
4. One vacuum barrier is used to separate the main transfer line vacuum from that of each cryomodule.
5. One valve box serves one cryomodule. The heat load sources of one valve box basically include two 5-8 K and two 40-80 K cryogenic valves, 5 safety valves (one for each tube plus one for the cavities), one 40-80 K shield (assuming the valve box is 1 m in diameter and 1 m height, so that a shield area of 6.3 m² is obtained) and others like support posts, instrumentation and cables, etc.
6. Some empirical values for heat load estimates are given in Table 1.
7. To calculate the 4.5 K equivalent power of refrigeration, the following approximations are used [1].

Approximate equivalencies

- » 2 K heat load x 3 = 4.5 K equivalent
- » 5 K - 8 K heat load x 0.75 = 4.5 K equivalent
- » 40 K - 80 K heat load / 14 = 4.5 K equivalent

The results are given in Table 2. The conclusion is, that the total 4.5 K equivalent of these cryogenic components is about **1 kW**. The equivalent refrigerator power should be **1.5 kW** at 4.5 K, considering the reasonable assumption of an overcapacity margin of 1.5. It should be noted that the results here are very rough estimates and more accurate results can only be obtained on the basis of a full P&ID of the ESS cryogenic system and a real design of these components.

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References

1. Cryomodule heat load estimates converted to 4.5 K equivalent cooling power, Tom Peterson, Fermilab, Beijing TTC meeting, 6 December 2011.

Table 1 Empirical values for heat load estimates

	5-8 K	40-80 K
Cryogenic Valve	1 W/Valve	1 W/Valve
Safety valve	0.5 W/Valve	0.5 W/Valve
Shield	0.1 W/m ²	2 W/m ²
Transfer line	0.2 W/m single pipe	2 W/m transfer line
Vacuum barrier	5 W/each	15 W/each

Table 2 Heat loads estimates of some cryogenic components for ESS

Related to one Cryomodule				Related to 59 Cryomodules		
	q 5-8 K, W	q, 40-80 K, W	Remarks	Numbers	Q 5-8 K, W	Q, 40-80 K, W
Jumper connections	2	10	L=5 m	59	118	590
Vacuum barriers	5	15	N=1	59	295	885
Cryogenic valves	2	2	N=4	59	118	118
Safety valves	1.5	1	N=5	59	88.5	59
Shields		13	A=6.3 m ²	59		741
Others	3	10		59	177	590
Main transfer line	L=500 m				200	1000
Total, W					997	3983
4.5 K equivalent, W	5-8 K heat load X 0.75=4.5 K equivalent 40-80 K heat load / 14 =4.5 K equivalent (T. Peterson)				747	285
Total 4.5 K equivalent, W						1032
For refrigerator sizing, W	Safety factor=1.5					1548