

PIP-II Cryomodule Static Heat Load Estimates

T. Nicol

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The static heat load in a cryomodule is the sum of heat flowing from several sources summarized below.

- input coupler
- mechanical support structure
- magnet current leads
- thermal radiation and residual gas conduction
- cold-to-warm transition

Each represents some form of connection between cryomodule components and the environment. In the case of the input coupler, support structure, current leads, and cold-to-warm transition, they are mechanical connections to the vacuum vessel with intermediate heat intercepts at 70 K and 5 K. The heat loads to 70 K, 5 K, and 2 K are determined by the temperature dependent thermal conductivities of the materials making up the structures, their lengths and cross-sectional areas. The current leads have an additional source in joule heating of the leads when the magnets are powered. The heat loads below assume the maximum current in each of the leads. Thermal radiation and residual gas conduction are forms of heat transfer to various temperatures through the multi-layer insulation (MLI) and are estimated to be 1.5 W/m^2 to 70 K and 0.15 W/m^2 to 2 K where the effective area is the surface area of the insulating layer.

Tables 1 through 4 show the heat loads from each static source for each style of PIP-II cryomodule, SSR1, SSR2, low beta 650, and high beta 650. Table 5 is a summary of all the static loads for all cryomodules. In table 5, the values for the half-wave resonator (HWR) cryomodule are taken from the reference design report. Dynamic heat loads are not included.

Table 1. SSR1 static heat loads (8 cavities, 4 solenoids)

	Each cavity (W)			Multiplier	Total per CM (W)		
	70 K	5 K	2 K		70 K	4.5 K	2 K
Input coupler (static)	5.4	2.8	0.5	8	43	23	4
Support post	0.4	1.8	0.0	12	5	22	0
Current leads	21.4	10.9	1.5	4	86	44	6
MLI	30.5	0.0	1.4	1	31	0	1
Cold to warm transition	0.7	0.1	0.0	2	1	0	0
Total static (per CM)					165	88	12

Table 2. SSR2 static heat loads (5 cavities, 3 solenoids)

	Each cavity (W)			Multiplier	Total per CM (W)		
	70 K	5 K	2 K		70 K	4.5 K	2 K
Input coupler (static)	5.4	2.8	0.5	5	27	14	3
Support post	0.4	1.8	0.0	8	3	14	0
Current leads	21.4	10.9	1.5	3	64	33	4
MLI	30.5	0.0	1.4	1	31	0	1
Cold to warm transition	0.7	0.1	0.0	2	1	0	0
Total static (per CM)					126	61	9

Table 3. LB650 static heat loads (3 cavities, 0 solenoids)

	Each cavity (W)			Multiplier	Total per CM (W)		
	70 K	5 K	2 K		70 K	4.5 K	2 K
Input coupler (static)	4.4	1.8	0.2	3	13	5	1
Support post	0.4	1.8	0.0	6	2	11	0
MLI	30.6	0.0	1.5	1	31	0	1
Cold to warm transition	0.7	0.1	0.0	2	1	0	0
Total static (per CM)					48	16	2

Table 4. HB650 static heat loads (6 cavities, 0 solenoids)

	Each cavity (W)			Multiplier	Total per CM (W)		
	70 K	5 K	2 K		70 K	4.5 K	2 K
Input coupler (static)	4.4	1.8	0.2	6	26	11	1
Support post	0.4	1.8	0.0	12	5	22	0
MLI	53.3	0.0	2.6	1	53	0	3
Cold to warm transition	0.7	0.1	0.0	2	1	0	0
Total static (per CM)					86	32	4

Table 5. PIP-II Cryomodule Static Heat Load per CM (W)

	No. CM	70 K	5 K	2 K
HWR	1	250	60	14
SSR1	2	165	88	12
SSR2	7	126	61	9
650 low-B	11	48	16	2
650 high-B	4	86	32	4
Total static (all CM)		2334	975	139