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RHIC Warm-to-Cold Transition: Heat Load Analysis of the Placement on the Beam Tube of the Lug for the Braided Heat Sink Strap

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RHIC PROJECT

Brookhaven National Laboratory

RHIC Warm-to-Cold Transition: Heat Load Analysis of the Placement on the Beam Tube of the Lug for the Braided Heat Sink Strap

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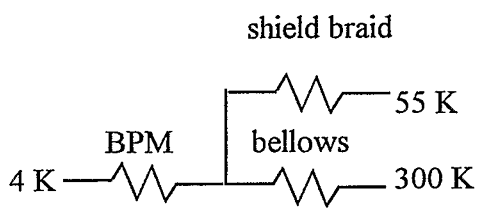
For the purpose of determining the optimum location for fixing the cold end of the RHIC standard braided heat sink strap (TCS Manufacturing, Inc., 1100 series aluminum, 152,408 circular mils, 7.5" length) on the Warm-to-Cold Transition (W/C) Beam Tube Assembly the following study was conducted. The geometry and construction procedure is such that there are two basic options for the "junction" location. The junction can be on either the cold side (option A) or the warm side (option B) of the bellows (RHIC drawing 01045029) of the Beam Tube Assembly.

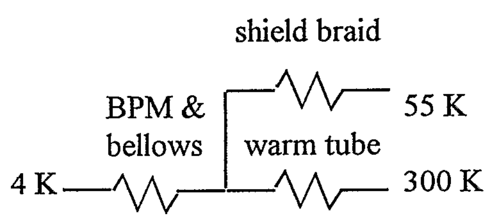
The term "junction" is appropriate when one considers the model of the system to be analyzed. There are three points stationed at three different temperatures (or potentials). Heat is conducted along each of three legs to a common node the temperature of which is unknown. This node is referred to here as the "junction" between the warm leg of the beam tube, the heat sink strap, and the cold leg of the beam tube (leading to the end volume). Where the beam tube penetrates the W/C vacuum vessel it will, of course, be at room temperature. At the end volume filled with liquid helium the temperature will be 4K. Where the strap fixes to the heat shield pipe it will presumably be at 55K.

We assume that there is sufficient MLI wrap on the beam tube where the tube to shield temperature difference is significant to ignore radiation affects. The conduction heat transfer problem then, is non-linear as the thermal conductivity varies greatly from 300K to 4K. Furthermore, we assume sectional properties of a length of tube is continuous; ConFlat flanges and BPM (beam position monitor) are treated as continuous with the average geometrical properties of the beam tube. Like wise, average geometrical properties are used for the bellows. Equivalently, the problem is one-dimensional.

Then by electrical analogy, the models to be compared are given in figure 1.



Option A



Option B

Abbreviations are given under <u>parameters</u>. A simple heat balance is taken at the junction to solve for the temperature there. Heat loads out of the junction to 4K (end volume) and 55K (heat shield pipe) follow. The thermal conductivity integrals are as given in Technical Note # 327 in the BNL Cryogenic Data Reference. The geometrical parameters are given. The equation to be solved is as follows (for option A):

$$\text{Qbt out} + \text{Qs out} = \text{Qb in} \quad \text{or}$$

$$(\lambda ss(T)-\lambda ss(4K))(Abt/Lbt) + (\lambda al(T)-\lambda al(55K))(As/Ls) = (\lambda ss(300K)-\lambda ss(T))(Ab/Lb)$$

Strap location A gives a 4 K heat load of 0.27 W and a 55 K heat load of 0.21 W. B gives a 4 K heat load of 0.20 W and a 55 K heat load of 11.53 W. Thus option A is optimal.

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Analysis of beam tube heat sink braid strap placement.

Option A: braid strap on cold side of beam tube bellows.

Temp K	lambda-SS W/cm	lambda-Al W/cm	Qbpm out Watts	Qs out Watts	Q out tot Watts	Qb in Watts
300	31.6	728				
260	25.2	618	3.2437008	18.155171	21.398871	0.1045846
230	20.8	558	2.6773403	15.723675	18.401015	0.1764865
200	16.7	508	2.1495954	13.697428	15.847023	0.243486
180	14.2	464	1.8277997	11.914331	13.74213	0.2843393
160	11.75	420	1.5124399	10.131234	11.643673	0.3243756
140	9.49	376	1.2215365	8.3481365	9.569673	0.3613071
120	7.37	330	0.9486538	6.4839895	7.4326433	0.3959507
100	5.4	284	0.6950787	4.6198425	5.3149213	0.4281431
80	3.58	232	0.4608115	2.5125459	2.9733574	0.4578844
70	2.76	202	0.3552625	1.2967979	1.6520604	0.4712843
60	2.01	170	0.2587238	0	0.2587238	0.4835403
50	1.36	134	0.1750569	-1.458898	-1.283841	0.4941622
45	1.08	115	0.1390157	-2.228871	-2.089856	0.4987377
40	0.83	96.2	0.1068362	-2.99074	-2.883904	0.5028231
35	0.617	77.3	0.0794192	-3.756661	-3.677242	0.5063038
30	0.437	59.2	0.0562499	-4.490163	-4.433913	0.5092452
27	0.345	42.4	0.0444078	-5.170982	-5.126574	0.5107486
24	0.267	34	0.0343678	-5.511391	-5.477023	0.5120232
20	0.179	27.6	0.0230406	-5.770751	-5.74771	0.5134613
13	0.0665	15.2				
10	0.0351	6.07				
8	0.0196	3.42				
6	0.00798	1.38				
4	0	0				

Temp at juntion (K)	Heat load to 4K (W)	Heat load to 55K (W)
61.599443	0.2741646	0.2074154

parameter	sect. area sq cm	length cm
bpm-beam pos mon	5.885	45.72
s-shield braid	0.772	19.05
b-bellow	0.653	39.96

Warm-to-Cold Transition May-96

Analysis of beam tube heat sink braid strap placement.

Option B: braid strap on warm side of beam tube bellows.

Temp K	lambda-SS W/cm	lambda-Al W/cm	Qb out Watts	Qs out Watts	Q out tot Watts	Qbt in Watts
300	31.6	728				
260	25.2	618	0.3599213	18.155171	18.515092	4.1848889
230	20.8	558	0.2970779	15.723675	16.020752	7.062
200	16.7	508	0.2385192	13.697428	13.935947	9.7429444
180	14.2	464	0.2028128	11.914331	12.117143	11.377667
160	11.75	420	0.1678204	10.131234	10.299054	12.979694
140	9.49	376	0.1355418	8.3481365	8.4836783	14.457483
120	7.37	330	0.1052627	6.4839895	6.5892522	15.843728
100	5.4	284	0.077126	4.6198425	4.6969685	17.131889
80	3.58	232	0.0511317	2.5125459	2.5636776	18.321967
70	2.76	202	0.0394199	1.2967979	1.3362178	18.858156
60	2.01	170	0.028708	0	0.028708	19.348572
50	1.36	134	0.0194243	-1.458898	-1.439473	19.7736
45	1.08	115	0.0154252	-2.228871	-2.213446	19.956689
40	0.83	96.2	0.0118545	-2.99074	-2.978886	20.120161
35	0.617	77.3	0.0088124	-3.756661	-3.747849	20.259439
30	0.437	59.2	0.0062415	-4.490163	-4.483921	20.377139
27	0.345	42.4	0.0049275	-5.170982	-5.166054	20.437297
24	0.267	34	0.0038135	-5.511391	-5.507578	20.488301
20	0.179	27.6	0.0025566	-5.770751	-5.768194	20.545843
13	0.0665	15.2				
10	0.0351	6.07				
8	0.0196	3.42				
6	0.00798	1.38				
4	0	0				

Temp at juntion (K)	Heat load to 4K (W)	Heat load to 55K (W)
175.67572	0.1952469	11.5288

parameter	sect. area sq cm	length cm
b-bpm & bellows	0.653	45.72
s-shield braid	0.772	19.05
bt-warm beam tube	5.885	9