TD Note 99-041

Backup Documentation for the Installed Cryogenic Capacity Requirement included in the LHC Inner Triplet Functional Specification, rev 1.0

J. Kerby, 1 November, 1999

This note collects the information used to generate table 5.0-1 in the LHC Inner Triplet Functional Specification. It is expected that the cryogenic requirements will change as the design of the system becomes more refined, for instance as the DFBX design is updated. As appropriate, the table and the Functional Specification release will be updated to show these changes. This note is simply to summarize the current inputs used in the creation of the table, such that a baseline is available for comparison when future changes are included. Rob vanWeelderen, Tom Peterson, and Nikolai Mokhov, among others, have provided inputs and checks important to completing the table.

Needless to say, this is not 'publication' quality, instead a note such that we can recreate the trail a year from now when we need to.

Reference documents, locations and files include:

Rob's heat load web site, http://home.cern.ch/~vanweeld/heatload/hlmagnets.html, the printed version of which went into this table is included here.

Nikolai's most recent dynamic heat load calculation for the high luminosity IP's.

Tom's summary of the heat load in the triplet, and cooling through the collars and iron yoke to the cryo system, a current version of which is included.

Jim's excel file for the heat load per ½ of each IR, and the file which calculates the installed capacity per LHC Note 140, and generates the table which has the calculated numbers rounded up and displayed to the nearest integer. The files can be found on the tdpc59 C: drive in the TripletFS folder.

IP1or5_Q1_LorR Heat Load

calculation results obtained from hlmagnets.cgi
author: R. van Weelderen
date: Wed Aug 25 15:33:09 CEST 1999

source files: LHCparameters.src, hlcryostat_stat.src, IP1or5_Q1_LorR.src, hlIP1or5_Q1_LorR_dyn.src

** Breakdown for **IP1or5_Q1_LorR**,
values based on local photon flux information available on June 1999,
values in [W/m], for two beams,
Ib=beam intensity, SR=synchrotron radiation

	nominal-field region	**ultimate-field region**	**nominal-field free region**	**ultimate-field free region**	
Synchrotron radiation	0.0952	0.1421	0.0952	0.1421	~Ib; (0.6W+0W/col
Image currents	0.249	0.555	0.249	0.555	~Ib^2<=>noı ~ARCbeamscreen-diameter/b increased by 20% to t the beam offset from the ce pumping slots 0.025 fract
Beam-gas scattering	0.06	0.06	0.06	0.06	beam vacuum im
Photoelectron	0.032	0.11	4.762	15.85	~Ib^3;nominal, ~p discriminate between (SR & field)

http://home.cern.ch/~vanweeld/heatload/hlmagnets.html

email to Taka

** Breakdown for **IP1or5_Q1_LorR,**
default configuration
operating temperature: 1.9 K,
actively cooled beam screen: no

values either in [W] or in [W/m], for two beams,

	50-75 K	4.5-20 K	4.5 K	1.9 K
static heat loads, [W]:				
Support posts	32.500	2.250	0	3.000
Thermal shield (50-75 K)	18.693	0	0	0
Radiation to cold mass	0	0	0	1.402
Resitive heating (splices)	0.016	0.027	0	0.345
BPM	0.000	0.880	0	0.130
Instrument feed through	0	0	0	0.000
Cold warm transition	0	0	0	0.831
QQS	0.410	0	0	0.030
1/2 jumpers	0	0.000	0	0.000
sum static nominal [W/m]:	7.364	0.450	0.000	0.819
F **sum static nominal [W]:**	51.622	3.155	0.000	5.741

	50-75 K	4.5-20 K	4.5 K	1.9 K	
dynamic heat loads, nominal [W/m]:					
Synchrotron radiation	0	0	0	0.0952	
Image currents	0	0	0	0.249	
Beam gas scattering	0	0	0	0.06	
Photoelectron field region	0	0	0	0.032	
Photoelectron field free region	0	0	0	4.762	
TAS	0	0.7114	0	0	
Secondaries	0	0	0	5.9914	5.24
A **sum dynamic nominal, field region [W/m]:**	0	0.711	0.000	6.428	5.68
B **sum dynamic nominal, field free region [W/m]:**	0	0.711	0.000	11.158	10.41
sum dynamic nominal, field+field free region [W/m]:	0	0.711	0.000	6.907	
C **sum dynamic nominal, field region [W]:** A x (L=6.3 m)	0	4.479	0.000	40.496	35.78
D **sum dynamic nominal, field free region [W]:** B x (L=0.71 m)	0	0.505	0.000	7.922	7.39
E **sum dynamic nominal, field+field free region [W]:** C+D	0	4.984	0.000	48.418	43.17
sum static and dynamic heat loads, nominal, field region [W/m]:	7.364	1.161	0	7.247	
sum static and dynamic heat loads, nominal, field free region [W/m]:	7.364	1.161	0	11.977	
sum static and dynamic heat loads, nominal, field region [W]:	46.393	7.314	0.000	45.656	
sum static and dynamic heat loads, nominal, field free region					

sum static and dynamic heat loads, nominal, field free region [W]:	5.228	0.824	0.000	8.504	
sum static and dynamic heat loads, nominal, field+field free region [W]: E + F	51.622	8.138	0.000	54.160	48.9

		50-75 K	**4.5-20 K**	**4.5 K**	**1.9 K**	
	dynamic heat loads, ultimate [W/m]:					
	synchrotron radiation	0	0	0	0.1421	
	image currents	0	0	0	0.555	
	beam gas scattering	0	0	0	0.06	
	Photoelectron field region	0	0	0	0.11	
	Photoelectron field free region	0	0	0	15.85	
	TAS	0	1.062	0	0	
	Secondaries	0	0	0	8.945	13.10
A	**sum dynamic ultimate, field region [W/m]:**	0	1.062	0.000	9.812	13.97
B	**sum dynamic ultimate, field free region [W/m]:**	0	1.062	0.000	25.552	29.71
	sum dynamic ultimate, field+field free region [W/m]:	0	1.062	0.000	11.406	
C	**sum dynamic ultimate, field region [W]:** A × 6.3	0	6.691	0.000	61.816	88.01
D	**sum dynamic ultimate, field free region [W]:** B × 0.71	0	0.754	0.000	18.142	21.09
E	**sum dynamic ultimate, field+fieldfree region [W]:** C + D	0	7.445	0.000	79.958	109.1
	sum static and dynamic heat loads, ultimate, field region [W/m]:	7.364	1.512	0	10.631	
	sum static and dynamic heat loads, ultimate, field free region [W/m]:	7.364	1.512	0	26.371	
	sum static and dynamic heat loads, ultimate, field region [W]:	46.393	9.526	0.000	66.975	
	sum static and dynamic heat loads, ultimate, field free region [W]:	5.228	1.074	0.000	18.723	
	sum static and dynamic heat loads, ultimate, field+field free region [W]: E + F	51.622	10.600	0.000	85.698	114.8

IP1or5_Q2_LorR Heat Load

calculation results obtained from hlmagnets.cgi
author: R. van Weelderen
date: Wed Aug 25 15:26:49 CEST 1999

source files: LHCparameters.src, hlcryostat_stat.src, IP1or5_Q2_LorR.src, hlIP1or5_Q2_LorR_dyn.src

** Breakdown for **IP1or5_Q2_LorR**,
values based on local photon flux information available on June 1999,
values in [W/m], for two beams,
Ib=beam intensity, SR=synchrotron radiation

	nominal-field region	**ultimate-field region**	**nominal-field free region**	**ultimate-field free region**	
Synchrotron radiation	0.06333	0.0945	0.06333	0.0945	~Ib; (0.8W+0W/col
Image currents	0.199	0.444	0.199	0.444	~Ib^2<=>nor ~ARCbeamscreen-diameter/be increased by 20% to t the beam offset from the ce pumping slots 0.025 fract
Beam-gas scattering	0.06	0.06	0.06	0.06	beam vacuum im
Photoelectron	0.017	0.06	2.609	8.68	~Ib^3;nominal, ~p discriminate between (SR & field)

** Breakdown for **IP1or5_Q2_LorR,**
default configuration
operating temperature: 1.9 K,
actively cooled beam screen: no

values either in [W] or in [W/m], for two beams,

	50-75 K	4.5-20 K	4.5 K	1.9 K
static heat loads, [W]:				
Support posts	65.000	4.500	0	6.000
Thermal shield (50-75 K)	33.688	0	0	0
Radiation to cold mass	0	0	0	2.527
Resitive heating (splices)	0.076	0.126	0	1.642
BPM	0.000	0.000	0	0.000
Instrument feed through	0	0	0	0.000
Cold warm transition	0	0	0	0.000
QQS	0.000	0	0	0.000
1/2 jumpers	0	0.000	0	0.000
sum static nominal [W/m]:	7.818	0.366	0.000	0.805
F **sum static nominal [W]:**	98.765	4.624	0.000	10.170

	50-75 K	4.5-20 K	4.5 K	1.9 K	
dynamic heat loads, nominal [W/m]:					
Synchrotron radiation	0	0	0	0.06333	
Image currents	0	0	0	0.199	
Beam gas scattering	0	0	0	0.06	
Photoelectron field region	0	0	0	0.017	
Photoelectron field free region	0	0	0	2.609	
TAS	0	0.7114	0	0	
Secondaries	0	0	0	5.3827	3.63
A **sum dynamic nominal, field region [W/m]:**	0	0.711	0.000	5.722	3.97
B **sum dynamic nominal, field free region [W/m]:**	0	0.711	0.000	8.314	6.58
sum dynamic nominal, field+field free region [W/m]:	0	0.711	0.000	5.954	
C **sum dynamic nominal, field region [W]:** A × 11.5	0	8.176	0.000	65.803	45.66
D **sum dynamic nominal, field free region [W]:** B × 1.133	0	0.806	0.000	9.420	7.455
E **sum dynamic nominal, field+field free region [W]:** C+D	0	8.982	0.000	75.223	53.11
sum static and dynamic heat loads, nominal, field region [W/m]:	7.818	1.077	0	6.527	
sum static and dynamic heat loads, nominal, field free region [W/m]:	7.818	1.077	0	9.119	
sum static and dynamic heat loads, nominal, field region [W]:	89.907	12.386	0.000	75.061	
sum static and dynamic heat loads, nominal, field free region					

sum static and dynamic heat loads, nominal, field free region [W]:	8.858	1.220	0.000	10.332	
sum static and dynamic heat loads, nominal, field+field free region [W]: E + F	98.765	13.606	0.000	85.393	63.3

		50-75 K	**4.5-20 K**	**4.5 K**	**1.9 K**	
	dynamic heat loads, ultimate [W/m]:					
	synchrotron radiation	0	0	0	0.0945	
	image currents	0	0	0	0.444	
	beam gas scattering	0	0	0	0.06	
	Photoelectron field region	0	0	0	0.06	
	Photoelectron field free region	0	0	0	8.68	
	TAS	0	1.062	0	0	
	Secondaries	0	0	0	8.036	9.07
A	**sum dynamic ultimate, field region [W/m]:**	0	1.062	0.000	8.695	9.728
B	**sum dynamic ultimate, field free region [W/m]:**	0	1.062	0.000	17.315	18.348
	sum dynamic ultimate, field+field free region [W/m]:	0	1.062	0.000	9.468	
C	**sum dynamic ultimate, field region [W]:** A × 11.5	0	12.213	0.000	99.993	111.88
D	**sum dynamic ultimate, field free region [W]:** B × 1.133	0	1.203	0.000	19.618	20.79
E	**sum dynamic ultimate, field+fieldfree region [W]:** C+D	0	13.416	0.000	119.611	132.67
	sum static and dynamic heat loads, ultimate, field region [W/m]:	7.818	1.428	0	9.5	
	sum static and dynamic heat loads, ultimate, field free region [W/m]:	7.818	1.428	0	18.12	
	sum static and dynamic heat loads, ultimate, field region [W]:	89.907	16.422	0.000	109.250	
	sum static and dynamic heat loads, ultimate, field free region [W]:	8.858	1.618	0.000	20.530	
	sum static and dynamic heat loads, ultimate, field+field free region [W]: E + F	98.765	18.040	0.000	129.780	142.84

IP1or5_Q3_LorR Heat Load

calculation results obtained from hlmagnets.cgi
author: R. van Weelderen
date: Wed Aug 25 15:27:08 CEST 1999

source files: LHCparameters.src, hlcryostat_stat.src, IP1or5_Q3_LorR.src, hlIP1or5_Q3_LorR_dyn.src

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** Breakdown for **IP1or5_Q3_LorR**,
values based on local photon flux information available on June 1999,
values in [W/m], for two beams,
Ib=beam intensity, SR=synchrotron radiation

	nominal-field region	**ultimate-field region**	**nominal-field free region**	**ultimate-field free region**	
Synchrotron radiation	0.0590	0.0881	0.0590	0.0881	~Ib; (0.5W+0W/co
Image currents	0.199	0.444	0.199	0.444	~Ib^2<=>no ~ARCbeamscreen-diameter/b increased by 20% to t the beam offset from the ce pumping slots 0.025 frac
Beam-gas scattering	0.06	0.06	0.06	0.06	beam vacuum im
Photoelectron	0.027	0.09	4.110	13.68	~Ib^3;nominal, ~ discriminate between (SR & field)

** Breakdown for **IP1or5_Q3_LorR,**
default configuration
operating temperature: 1.9 K,
actively cooled beam screen: no

values either in [W] or in [W/m], for two beams,

	50-75 K	4.5-20 K	4.5 K	1.9 K
static heat loads, [W]:				
Support posts	32.500	2.250	0	3.000
Thermal shield (50-75 K)	22.587	0	0	0
Radiation to cold mass	0	0	0	1.694
Resitive heating (splices)	0.019	0.032	0	0.417
BPM	0.000	0.880	0	0.130
Instrument feed through	0	0	0	1.590
Cold warm transition	0	0	0	0.000
QQS	0.410	0	0	0.030
1/2 jumpers	0	0.000	0	0.000
sum static nominal [W/m]:	6.554	0.373	0.000	0.810
F **sum static nominal [W]:**	55.512	3.159	0.000	6.861

	50-75 K	4.5-20 K	4.5 K	1.9 K	
dynamic heat loads, nominal [W/m]:					
Synchrotron radiation	0	0	0	0.0590	
Image currents	0	0	0	0.199	
Beam gas scattering	0	0	0	0.06	
Photoelectron field region	0	0	0	0.027	
Photoelectron field free region	0	0	0	4.110	
TAS	0	0.7114	0	0	
Secondaries	0	0	0	6.1393	5.57
A **sum dynamic nominal, field region [W/m]:**	0	0.711	0.000	6.484	5.915
B **sum dynamic nominal, field free region [W/m]:**	0	0.711	0.000	10.567	10.00
sum dynamic nominal, field+field free region [W/m]:	0	0.711	0.000	7.048	
C **sum dynamic nominal, field region [W]:** A × 7.3	0	5.190	0.000	47.333	43.18
D **sum dynamic nominal, field free region [W]:** B × 1.17	0	0.832	0.000	12.363	11.70
E **sum dynamic nominal, field+field free region [W]:** C+D	0	6.022	0.000	59.696	54.88
sum static and dynamic heat loads, nominal, field region [W/m]:	6.554	1.084	0	7.294	
sum static and dynamic heat loads, nominal, field free region [W/m]:	6.554	1.084	0	11.377	
sum static and dynamic heat loads, nominal, field region [W]:	47.844	7.913	0.000	53.246	
sum static and dynamic heat loads, nominal, field free region					

sum static and dynamic heat loads, nominal, field free region [W]:	7.668	1.268	0.000	13.311	
sum static and dynamic heat loads, nominal, field+field free region [W]: E+F	55.512	9.181	0.000	66.557	61.74

		50-75 K	**4.5-20 K**	**4.5 K**	**1.9 K**	
	dynamic heat loads, ultimate [W/m]:					
	synchrotron radiation	0	0	0	0.0881	
	image currents	0	0	0	0.444	
	beam gas scattering	0	0	0	0.06	
	Photoelectron field region	0	0	0	0.09	
	Photoelectron field free region	0	0	0	13.68	
	TAS	0	1.062	0	0	
	Secondaries	0	0	0	9.166	13.93
A	**sum dynamic ultimate, field region [W/m]:**	0	1.062	0.000	9.848	14.61
B	**sum dynamic ultimate, field free region [W/m]:**	0	1.062	0.000	23.438	28.20
	sum dynamic ultimate, field+field free region [W/m]:	0	1.062	0.000	11.725	
C	**sum dynamic ultimate, field region [W]:** A x 7.3	0	7.753	0.000	71.890	106.67
D	**sum dynamic ultimate, field free region [W]:** B x 1.17	0	1.243	0.000	27.422	33.00
E	**sum dynamic ultimate, field+fieldfree region [W]:** C+D	0	8.996	0.000	99.312	139.66
	sum static and dynamic heat loads, ultimate, field region [W/m]:	6.554	1.435	0	10.658	
	sum static and dynamic heat loads, ultimate, field free region [W/m]:	6.554	1.435	0	24.248	
	sum static and dynamic heat loads, ultimate, field region [W]:	47.844	10.476	0.000	77.803	
	sum static and dynamic heat loads, ultimate, field free region [W]:	7.668	1.679	0.000	28.370	
	sum static and dynamic heat loads, ultimate, field+field free region [W]: E+F	55.512	12.155	0.000	106.173	146.52

Heat Load and Temperature Summary for the LHC Interaction Region Final Focus Superconducting Magnets

Tom Peterson
21 September 1999

Heat loads in Table 1 come from Jim Kerby's 10 Sep 99 summary spreadsheet (IRCryoCapacityKerby990910.exe). Base heat loads in Kerby's spreadsheet are taken from Tom Peterson's interaction region summary table (IRSysHeatload990830.exe, 30 Aug 99) updated for Mike Lamm's splice heat calculation (total change -0.6W to 1.9K)

Tom Peterson's baseline heat is based on Rob Van Weelderen's heat load website (http://home.cern.ch/~vanweeld/heatload/hlmagnets.html). The major difference is in total dynamic load (using the Mokhov updated calculation, Table 4, for heat from secondaries) and scaling to ultimate using 2.5.

Static heat loads are 2nd estimates by Jim Kerby, 10 Sep 99. D1 and DFBX (draft2) inputs are updated in Jim Kerby's summary spreadsheet.

Current lead flow assumes 0.079 g/s per kA for CERN HTS leads and for conventional leads (difference is conventional lead flow comes from 4.6 K rather than 20 K). 1 pair 8 kA HTS leads plus 1 pair 5 kA HTS leads plus 5 pair 600 A conventional leads plus 7 pair 60 A conventional leads.

Table 1. Estimated inner triplet heat loads (30 m)

	70K	4.5K-20K	1.9K	RVW 9/24	4.5K Static	1.9K Static
	J Zb rev 9/24					
IP1 Nominal	530 ~~784.9~~	168.7	~~181.4~~	181.8	117.8	26.8
IP1 Ultimate	530 ~~784.9~~	202.1	~~416.9~~	417.9		
IP2 Nominal	588 ~~842.1~~	128.3	58.4		122.6	34.0
IP2 Ultimate	588 ~~842.1~~	139.0	~~93.3~~	94.0		
IP5 Nominal	530 ~~784.9~~	168.7	~~181.4~~	181.8	117.8	26.8
IP5 Ultimate	530 ~~784.9~~	202.1	~~416.9~~	417.9		
IP8 Nominal	588 ~~842.1~~	122.5	65.7		122.6	34.0
IP8 Ultimate	588 ~~842.1~~	122.5	~~111.6~~	114.1		

Table 2. Helium flow rates for nominal heat at IP5 at each temperature level. 50 K – 75 K flow assumes a 66 K to 75 K temperature rise. 4.6 K – 20 K flow is heat divided by 17.7 J/g (vaporization of 1.4 bar liquid). 1.8 K flow is heat divided by 20 J/g.

Temperature levels	50 to 75 K (actually 66 to 75 K rise)	4.6 K – 20 K	1.8 K (in heat exch)	Current lead flow (g/s)
Standby (static) flow (g/s)	~~16.7~~ 11.3	6.7	1.3	
Additional dynamic flow (g/s)	0	0.5	7.9	
Total flow (g/s)	~~16.7~~ 11.3	7.2	9.1	2.6

Below, in Figure 5, is the output from a spreadsheet that calculates temperature drops through the inner triplet system from the center of the holes in the iron yoke to the end of the pumping line at the DFBX. The input is the heat load profile shown above in Figure 1 for IP5, nominal heating, totaling 181.4 W, and the use of four 60 mm holes in the iron yoke. Other pipe dimensions are as indicated in the figure. This spreadsheet includes an estimation of the location of the "neutral plane" from which heat flows to the Q1 magnet ends in each direction, as described above.

The chart shows a comparison with an "internal" heat exchanger consisting of two heat exchange tubes, in two of the four holes in the iron yoke. One can see that for the internal heat exchanger, the benefit of not having a temperature drop through the superfluid channels is approximately offset by the pressure drop of the smaller tubes.

Figure 5. Temperature drops with estimated heat loads to 1.9 K

Summary of estimated temperature drops from the center of the holes in the Q1 iron yoke to the end of the pumping line at the DFB

DT1: from the Q1 magnet thermal center to the end within pressurized He II thru holes in the iron yoke, 4 x 60 mm holes

Q (W) = 181.4

DT2: within the connecting pipe, L=125 cm, D=11 cm.

DT3: between connecting pipe and He II heat exchanger, L=15 cm and D=11 cm.

DT4: within the pressurized He II side of He II heat exchanger, L=450 cm, D_in=9.6 cm, D_out=16 cm.

DT5: across the He II heat exchanger wall.

DT6: due to the vapor pressure drop.

	External HX	Internal HX
	1 X 85/96 mm	2 X 49/57 mm
DT1 (mK)	1.1	0.0
DT2 (mK)	4.2	0.0
DT3 (mK)	1.7	0.0
DT4 (mK)	0.6	0.0
DT5 (mK)	21.8	18.4
DT6 (mK)	4.5	18.3
tal DT (mK)	34.0	36.6

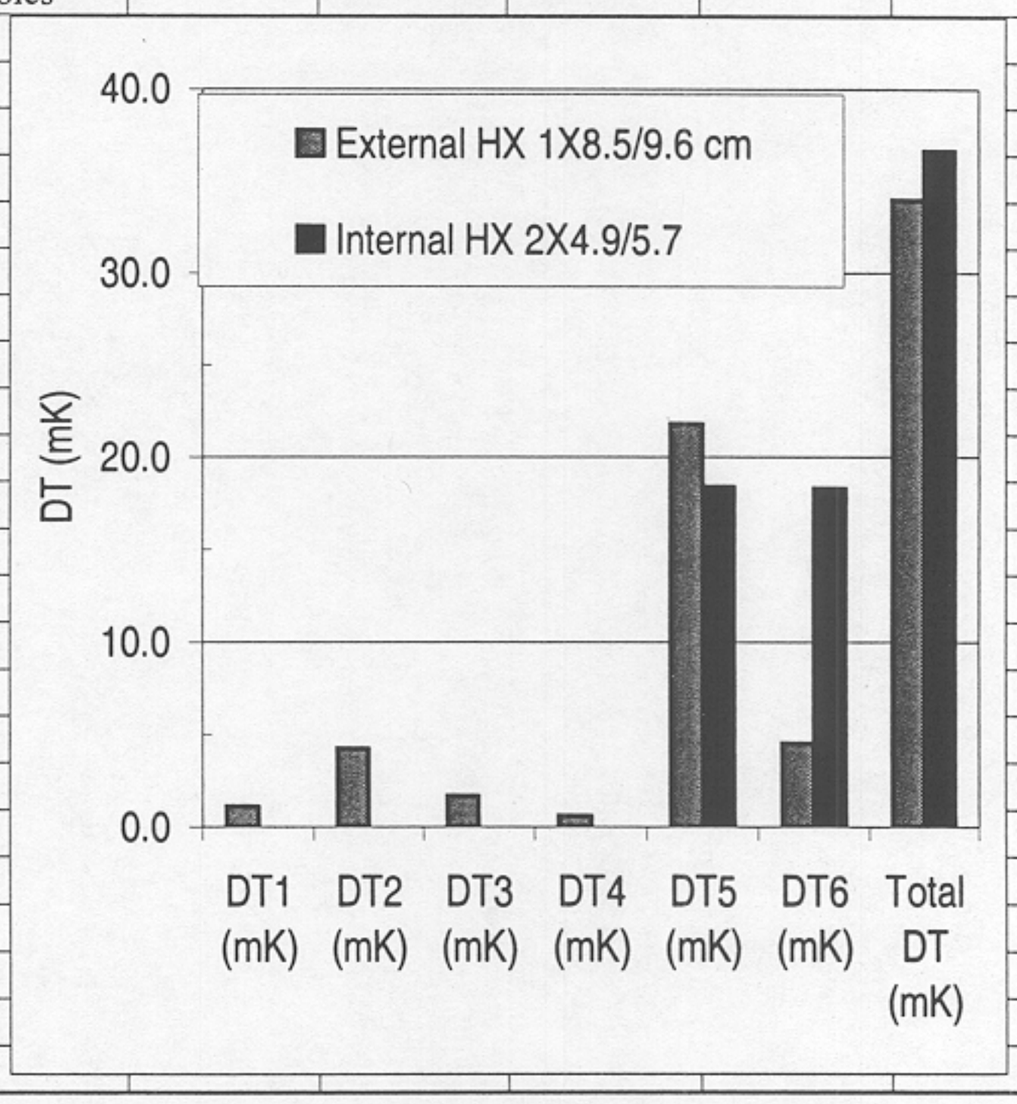


Figure 6 is a summary of estimated temperature drops from the center of the holes in the Q1 iron yoke to the end of the pumping line at the DFBX in IR5 with the entire heat load (static plus dynamic, used in figure 5) scaled up by 1.5 to 272 W total.

Figure 6. Temperature drops with 1.5 times estimated heat loads to 1.9 K.

Summary of estimated temperature drops from the center of the holes in the Q1 iron yoke to the end of the pumping line at the DFB

DT1: from the Q1 magnet thermal center to the end within pressurized He II thru holes in the iron yoke, 4 x 60 mm holes

Q (W) = 272.1

DT2: within the connecting pipe, L=125 cm, D=11 cm.

DT3: between connecting pipe and He II heat exchanger, L=15 cm and D=11 cm.

DT4: within the pressurized He II side of He II heat exchanger, L=450 cm, D_in=9.6 cm, D_out=16 cm.

DT5: across the He II heat exchanger wall.

DT6: due to the vapor pressure drop.

	External HX	Internal HX
	1 X 85/96 mm	2 X 49/57 mm
DT1 (mK)	3.8	0.0
DT2 (mK)	14.3	0.0
DT3 (mK)	5.7	0.0
DT4 (mK)	2.2	0.0
DT5 (mK)	32.7	27.5
DT6 (mK)	9.1	37.2
tal DT (mK)	67.8	64.7

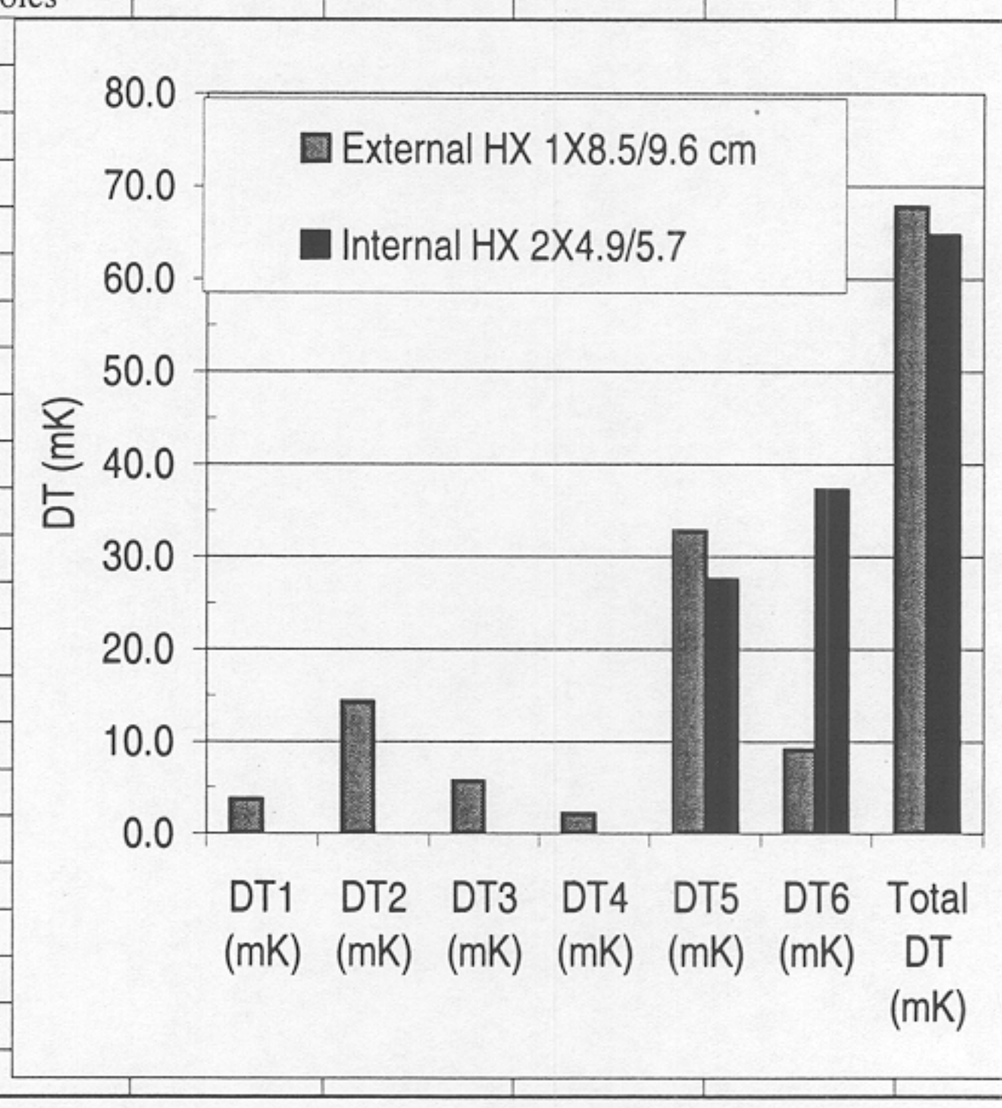
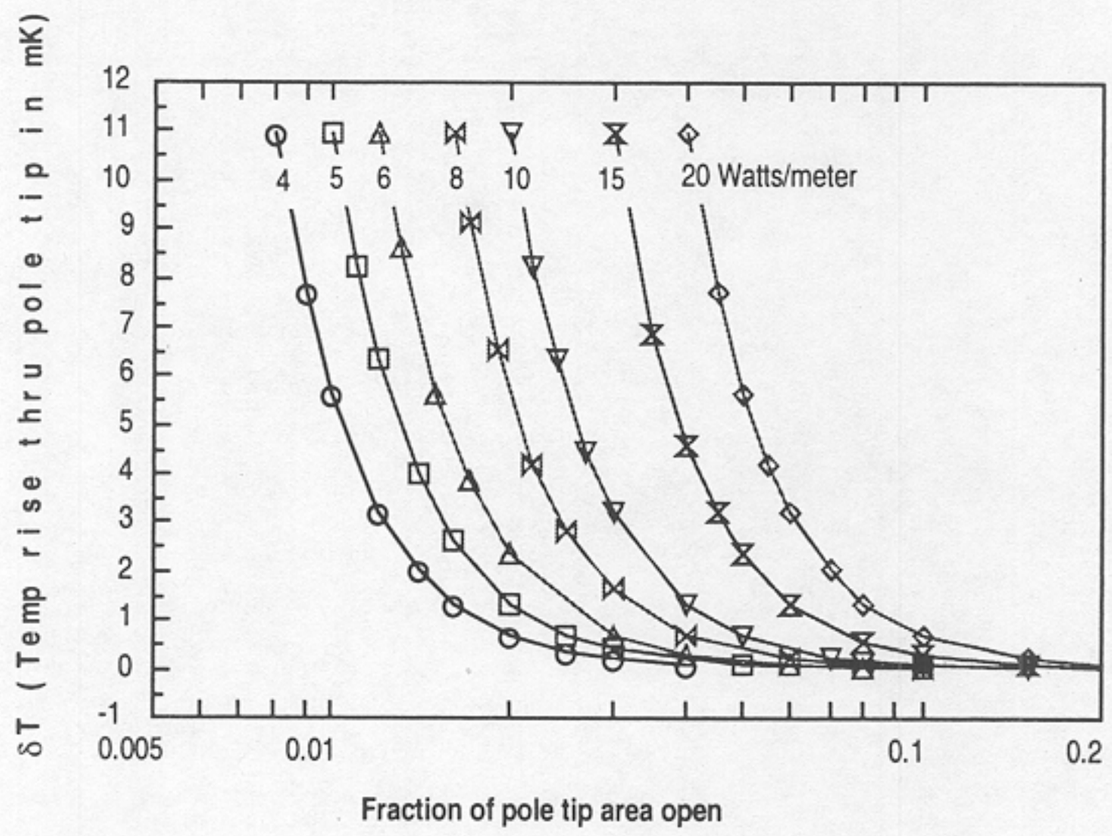


Figure 12. Plot of delta-T through the collar pole tip region
versus fraction of pole tip area open for heat transport



∴ Should have 4-5% open

Figure 12 assumes (like figure 8) a 0.7 cm wide pole tip and 1.6 cm distance for heat transfer radially outward. In order to have only a 3 mK temperature rise through the collars in Q1, where the local heat load could be between 15 and 20 W/m, one can see from Figure 9 that the pole tip area must be 0.06 open, or 6% open.

Figure 13. Heat carried axially along the MQX beam pipe with 1 mK delta-T

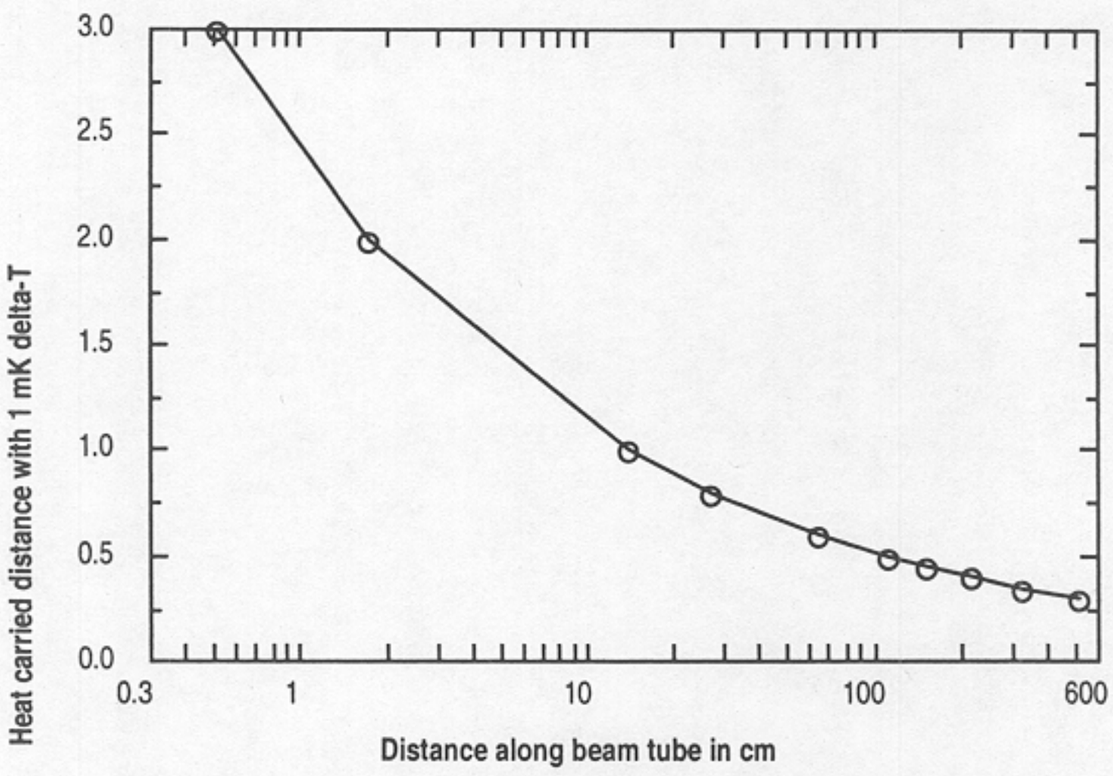


Figure 13, above, assumes a 1.2 mm annular space around a 62 mm tube. Heat is plotted which can be carried with a 1 mK delta-T over a given distance. This plot shows that a local "spike" of 2 Watts will not spread axially very far, but "spikes" of 0.5 Watts or less will be spread over a meter or more.

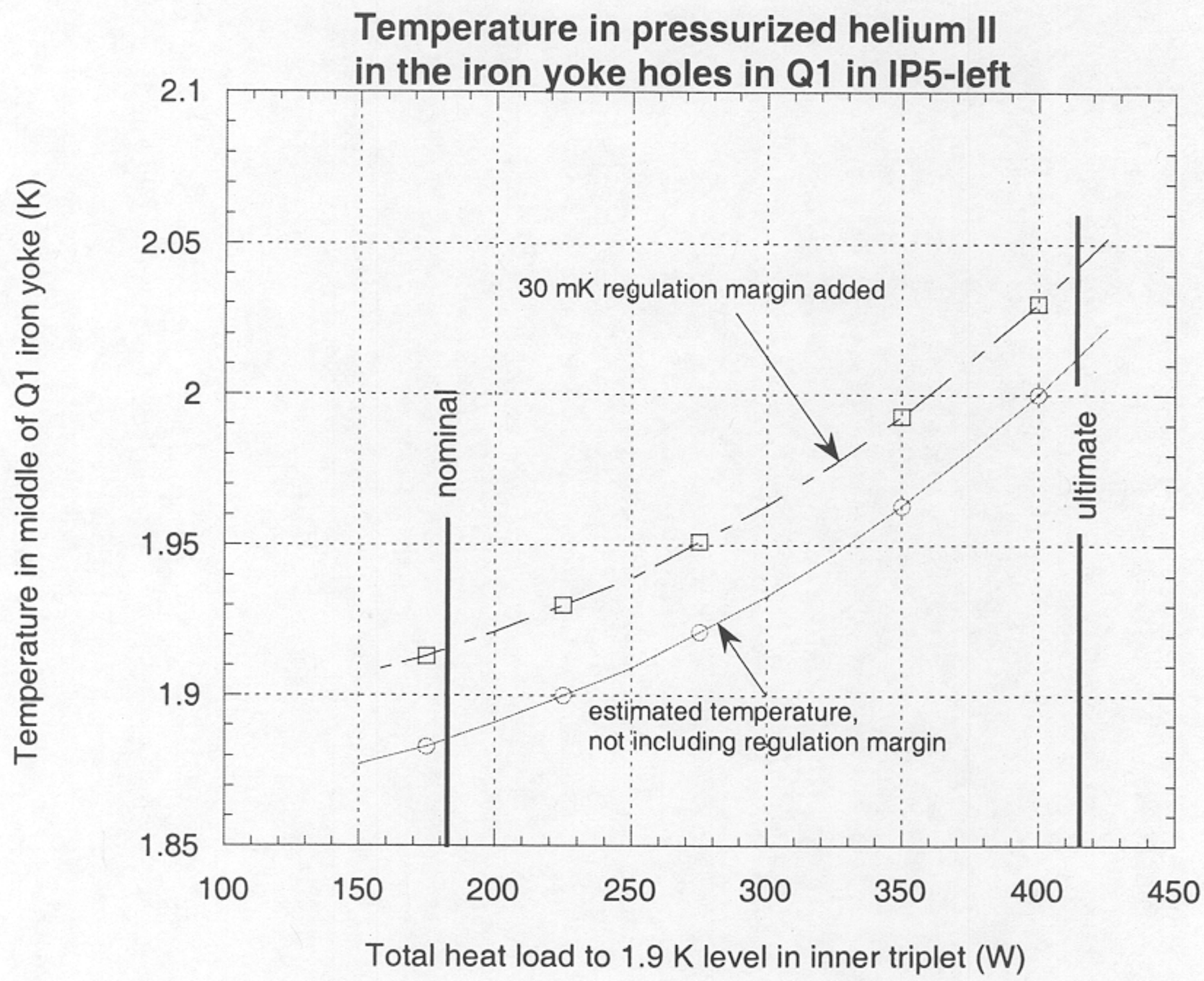
Below, in Table 4, is a summary of all the delta-T's through the cryogenic system from the pressurized superfluid around the magnet beam tube, in contact with the magnet bore, to the cold compressor. Heat load is 272 W, 1.5 times nominal for IP5. Note that this does not include delta-T's inside the magnet coil.

Table 4. Temperatures and pressures from magnets through transfer line to cold compressor

System temperature or pressure location	Pressure (mbar)	Temperature (K)
Pressure at cold compressor (flow through header B is nominally at 3.5 K; saturation temperature corresponding to pressure is shown in parentheses)	15.0	(1.776)
Pressure at tunnel feedbox after adding the pressure drop due to flow through header B in the 3.3 km of transfer line	18.6	(1.836)
Pressure at tunnel feedbox after adding the pressure drop due to elevation change through header B in the 3.3 km of transfer line	19.2	(1.845)
Pressure and temperature in saturated He II at the feedbox end of the triplet after adding the pressure drop through the JT heat exchanger	19.6	1.851
Pressure and temperature in saturated He II at the Q1 end of the triplet after adding the pressure drop through the corrugated pipe along the inner triplet (DT6)	19.9	1.860
Temperature in the pressurized He II after adding the temperature drop across the heat exchanger wall to the saturated He II (DT5)		1.893
Temperature in the pressurized He II in the iron yoke after adding the temperature drop through the pressurized He II from the magnet center to the He II heat exchanger (DT1+DT2+DT3+DT4)		1.919
Temperature in the pressurized He II around the beam pipe, in the magnet bore, after adding the temperature drop through the collar and yoke laminations. Based on 1-inch spacing of pole tip gaps in collar laminations and 96% packing factor in yoke laminations.		1.923
Temperature in pressurized He II at warmest point along the bore tube in Q1, including regulation margin		1.953

Figure 14, below, illustrates the bottom line of the above table versus various total inner triplet heat loads.

Figure 14. Temperature in the pressurized helium II at the warmest position in the iron yoke holes in Q1 in IP5-left versus total inner triplet heat load to 1.9 K.



Conclusion.

Assuming the gaps around the beam tube and through the collars and yoke to the holes in the iron add only a few more mK to the total delta-T, the temperatures shown above in Figure 14 are approximately the temperatures between the beam tube and coil at the warmest point in Q1. The question is then what temperature is required to support heat transfer out of the coil and prevent quenching. We know from our tests of magnets in the vertical dewar that the magnet quench performance is fine in a 1.90 K bath. This corresponds, however, to just the heat load for nominal luminosity with no safety factor. We will try some tests at 1.95 K, which corresponds to the magnet temperature at 1.5 times the estimated heat load for nominal luminosity, and at other temperatures in order to define more precisely our temperature limits.

Subject: **[Fwd: Update on heat load to the IP5 components]**
Date: Tue, 24 Aug 1999 11:35:03 -0500
From: kerby@fnal.gov (James Kerby)
Organization: Technical Division, Fermilab
To: Peterson Tommy <tommy@fnal.gov>

FYI. I think we scale for ultimate (see bottom).

-------- Original Message --------
Subject: Update on heat load to the IP5 components
Date: Tue, 24 Aug 1999 11:12:30 -0500 (CDT)
From: Nikolai Mokhov <mokhov@fnal.gov>
To: Jim Kerby <kerby@fnal.gov>
CC: strait@fnal.gov, lamm@fnal.gov, tnicol@fnal.gov,Tanaji Sen <tsen@fnal.gov>, Bill Turner <wcturner@LBL.gov>,Ranko Ostojic <Ranko.Ostojic@cern.ch>, Nikolai Mokhov <mokhov@fnal.gov>

UPDATE ON POWER DISSIPATION IN THE LHC IP5 COMPONENTS
DUE TO PP-COLLISIONS AT THE BASELINE LUMINOSITY
OF 10^34 CM^-2 S^-1

N. Mokhov
August 24, 1999

Component	P(W)	Peak (W/m)	Peak location/averaging
TAS-1 1.7<r<25 cm	205.6		
Q1 r>2.35 cm	36.67	9.98	Last meter
TAS-2 2.5<r<6 cm	10.46	7.58	Full 1.38 m
Vessel	0.47		
Q2A r>3.0 cm	17.84	4.79	First meter
MCBX-1	1.99		
Q2B r>3.0 cm	26.04	5.47	Last meter
TAS-3 3.0<r<6.05 cm	4.74	3.31	Full 1.43 m
Other stuff between Q2B and Q3	10.59		
Q3 r>3.0 cm	32.77	7.17	First meter
MCBX-1	3.85		
DFBX	11.60		

Rob Nikolai
2.5 x Nikolai

42 W / 7.01 m
36.7 / 7.01 m = 5.24 W/m nom
13.10 W/m ult.

68 W / 12.633 m
45.9 W / 12.633 m = 3.63 W/m
9.07 W/m ult

52 W / 8.47 m
47.2 / 8.47 m = 5.57 W/m
13.93 W/m ult

Say 3.5 into 1.9K
~~x 2.5 = 29.0~~
x 2.5 = 8.8
so add 5.3 to Jon's 7.5 W total

*) Scale linearly to the 'ultimate' luminosity
**) Disregard the '98 numbers of the previous message.

Inner Triplet + Heat Load Summary

30-Aug-99

Operation - Nominal Beam Current

IR1 (incl DFBX spec, Rev 2)	70K	4.5K-20K	1.9K	Vapor flow 20K leads	Vapor flow 5K leads	5K excess to line D
Warm to Cold Transition	102.0	8.0	0.3			
Inner Triplet	205.9	30.9	173.9			
Q1	51.6	8.1	*48.9*			
Q2	98.8	13.6	*63.3*			
Q3	55.5	9.2	*61.7*			
TAS2/3	0.0	*18.8*	0.0			
DFBXA	375.0	103.0	7.5	2.2	0.3	3.0
Warm to Cold Transition	102.0	8.0	0.3			
TOTAL	784.9	168.7	182.0	2.2	0.3	3.0

IR2 (incl DFBX spec, Rev 2)	70K	5K	1.9K	20K leads	5K leads	5K excess to line D
Warm to Cold Transition	102.0	8.0	0.3			
Inner Triplet	205.9	10.9	43.9			
Q1	51.6	3.2	11.8			
Q2	98.8	4.6	17.6			
Q3	55.5	3.2	14.5			
DFBXB	375.0	92.8	8.3	3.1	0.3	1.2
D1	57.2	8.6	6.3	Actively cooled beam screen		
Warm to Cold Transition	102.0	8.0	0.3			
TOTAL	842.1	128.3	59.0	3.1	0.3	1.2

assumed for IR 2+8 in final table

IR5 (incl DFBX spec, Rev 2)	70K	5K	1.9K	20K leads	5K leads	5K excess to line D
Warm to Cold Transition	102.0	8.0	0.3			
Inner Triplet	205.9	30.9	173.9			
Q1	51.6	8.1	*48.9*			
Q2	98.8	13.6	*63.3*			
Q3	55.5	9.2	*61.7*			
TAS2/3	0.0	*18.8*	0.0			
DFBXA	375.0	103.0	7.5	2.2	0.3	3.0
Warm to Cold Transition	102.0	8.0	0.3			
TOTAL	784.9	168.7	182.0	2.2	0.3	3.0

IR8 (incl DFBX spec, Rev 2)	70K	5K	1.9K	20K leads	5K leads	5K excess to line D
Warm to Cold Transition	102.0	8.0	0.3			
Inner Triplet	205.9	10.9	45.2			
Q1	51.6	3.2	12.1			
Q2	98.8	4.6	18.2			
Q3	55.5	3.2	14.9			
DFBXB	375.0	92.8	8.3	3.1	0.3	1.2
D1	57.2	2.8	12.1			
Warm to Cold Transition	102.0	8.0	0.3			
TOTAL	842.1	122.5	66.3	3.1	0.3	1.2

	Installed Capacity Required (W)		
	70K	4.5K-20K	1.9K
IP1 Nominal	785	170	182
IP1 Ultimate	785	205	417
IP1 Installed Capacity	1180	300	424
IP2 Nominal	845	130	59
IP2 Ultimate	845	140	94
IP2 Installed Capacity	1265	240	102
IP5 Nominal	785	170	192
IP5 Ultimate	785	205	417
IP5 Installed Capacity	1180	300	424
IP8 Nominal	845	130	59
IP8 Ultimate	845	140	94
IP8 Installed Capacity	1265	240	102

Table 5.0-1 in rev 1.0

Installed cryogenic capacity for 1 side of each IR (per LHC Project Note 140)
Base heat loads taken from TomP interaction region summary table; 30 Aug 99-->updated for M Lamm splice calc (total change -0.6W to 1.9K)
"-->agreement w/ Heat Load web site (Rob vanW) good, major difference in total dynamic load (Mokhov updated calc) and scaling to ultimate->use 2.5
>Static heat loads are 2nd estimates by jsk, 10 Sep 99-->D1 and DFBX (draft2) inputs are updated

Fov	1.5
Fun	1.25

70K: Cap = max (Fov * Qnom, Qult)
lower T: Cap = max (Fov * (Fun * Qstatic + Qdynamic,nom) , Fun * Qstatic + Qdynamic, ult)

	70K	4.5K-20K	1.9K	4.5K Static	1.9K Static
IP1 Nominal	784.9	168.7	181.4	117.8	26.8
IP1 Ultimate	784.9	202.1	416.9		
IP1 Installed Capacity	1177.4	297.2	423.6		
IP2 Nominal	842.1	128.3	58.4	122.6	34.0
IP2 Ultimate	842.1	139.0	93.3		
IP2 Installed Capacity	1263.2	238.4	101.8		
IP5 Nominal	784.9	168.7	181.4	117.8	26.8
IP5 Ultimate	784.9	202.1	416.9		
IP5 Installed Capacity	1177.4	297.2	423.6		
IP8 Nominal	842.1	128.3	58.4	122.6	34.0
IP8 Ultimate	842.1	139.0	93.3		
IP8 Installed Capacity	1263.2	238.4	101.8		

FOR COMPARISON ONLY: INSTALLED CAPACITIES NOT CALCULATED---

LHC Project Note 140	70K	4.5K-20K	1.9K
IP1 Nominal	421.5	108.0	206.5
IP1 Ultimate	421.5	161.0	456.5
IP2 Nominal	509.5	110.0	67.5
IP2 Ultimate	509.5	158.0	100.5
IP5 Nominal	421.5	108.0	206.5
IP5 Ultimate	421.5	161.0	456.5
IP8 Nominal	509.5	110.0	67.5
IP8 Ultimate	509.5	158.0	100.5

Deltas - "Current" - Note 140

	70K	4.5K-20K	1.9K
IP1 Nomina	363.4	60.7	-25.1
IP1 Ultimat	363.4	41.1	-39.6
IP2 Nomina	332.6	18.3	-9.1
IP2 Ultimat	332.6	-19.0	-7.2
IP5 Nomina	363.4	60.7	-25.1
IP5 Ultimat	363.4	41.1	-39.6
IP8 Nomina	332.6	18.3	-9.1
IP8 Ultimat	332.6	-19.0	-7.2

% Change from lhc Note 140

70K	4.5K-20K	1.9K
86%	56%	-12%
86%	26%	-9%
65%	17%	-13%
65%	-12%	-7%
86%	56%	-12%
86%	26%	-9%
65%	17%	-13%
65%	-12%	-7%