Cryogenic Load on the ESR during the 12 Gev Era

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The 12 Gev upgrade Experimental Halls equipment compliment consists of the following items in the four Halls:

A) The existing pair of HRS spectrometers plus targets and sometimes the septum magnets.
B) The CLAS12 system consists of a new smaller SC Torus and a new SC Solenoid.
C) The SHMS and the existing HMS plus targets and sometimes the Moller.
D) The SC Solenoid is operated from a separate stand alone refrigerator that is twice the estimated solenoid load and will not be discussed further.

The combined steady state A+B+C heat load is estimated to be 151 % of the ESR and 175% of ESR when the effect of 15 K cryo targets is added. Clearly a very large supplement to the ESR will be required either from CHL or another source.

Hall's A, B and C are cooled at present by ESR with generous assistance from CHL. The ESR which is rated at 1450 Watts at 4.5 K. This load rating applies to a pure refrigeration load at 4.5 K with no targets at 15 K and no magnet current leads liquefaction load. The ESR performance as a 4.5 K refrigerator is degraded by 15 K target loads at a cost of 1 watt at 4.5 K for every 3 watts at 15 K. Each gram per second of current lead cooling costs a painful 150 watts of 4.5 K refrigeration. The usual cryogenic load situation in the Halls is to require the ESR (plus CHL) to provide 4.5 K refrigeration and magnet current lead cooling liquefaction and 15 K target cooling refrigeration simultaneously. Other devices are more rarely operated in the Halls that add to the above including Moller magnets, 6K helium targets, polarized targets and the septum magnets.

The expected 12 Gev Era load on the ESR **IS** considerably larger than the last summary published in 2003. The differences are due to the significant changes made since then in the 12 Gev Experimental Equipment Compliment. The Hall A load will not be different from the present average running situation because the equipment will be exactly the same. Hall B will be slightly higher considering that the new Torus and Solenoid have a combined load that is estimated to be slightly higher than the present much larger original CLAS and each magnet will have a pair of high current (~5KA) "burn out resistant" current leads and there will be a second distribution system in Hall B to accommodate the second magnet. Hall C represents a significant average load increase over past operation since two SC spectrometers (SHMS and HMS) will be required to operate simultaneously. This is different than the current situation with G0 and HMS where we only require one to operate and the other is either warm or at 80 K standby. Thus the ESR load will see an increase in Hall C due to the second spectrometer and its distribution system, the SHMS(2006) has 5 magnets while SHMS(2003) had 3 magnets, the SHMS magnets operate at higher current than HMS magnets and the use of "burnout resistant current leads" increases the lead cooling requirements.

A side consequence of the decision to remove the MAD spectrometer from the 12 Gev upgrade Experimental Equipment Compliment is that the offsetting decrease in Hall A helium consumption due to the mothballing of HRS(R) and substitution of the MAD (at potentially lower heat load) does not occur. Due to all of the above reasons there will be a substantial increase in the total baseline load (spectrometers) on the ESR compared to the present situation such that the total steady state(magnets & distribution) load will exceed the stand alone capacity of the ESR by 54 %. Adding 900 watts for 15 K ordinary H2/D2 cryotargets (one in A and 1 in C) adds an extra 300 watts at 4.5 K bringing the total load on ESR to 175 % of its capacity. Even today with the smaller 6 Gev program loads we operate with a continuous supplement from CHL except during stand down for CHL maintenance. Under these conditions today ESR can just maintain the entire system with no current in magnets and no power on targets.

The expected 4.5 K standby load (all magnets at no current) during the 12 Gev ERA is 1636 watts and will exceed the ESR stand alone capacity. This means that during CHL maintenance some Experimental Equipment would have to warm up so that ESR could maintain the load. The current beam delivery plan for the 12 Gev Era requires that only two Halls receive Beam if Hall D is getting beam. The Load on ESR can be reduced by taking the offline Hall to 80 K standby. The single case of taking Hall A offline leads to a reduction in the total operating load that is at 1425 watts (15 K target included) slightly below the total power that ESR can deliver.

There are several actions we can contemplate to reduce somewhat the heat load during the 12 Gev Era. Repairing or replacing the lossy Hall A delivery system was contemplated in 2003. If the present Hall A delivery system were replaced with one that had three times the efficiency the refrigeration savings would be ~ 200 watts at a cost of ~300 K$, a minimum 3 months Hall shut down and a large crew cost ~ 200 K$ for those three months. Most if not all the new SC magnets to be built for 12 Gev will use the surplus SSC cable. The value of the superconductor to be used is ~ 2.5 M$. A consequence of the use of this conductor is that some of the magnets will operate at currents that are higher than might otherwise be selected if new conductor were to be purchased and only magnet safety and cryogenic efficiency were considered. If the five new magnets that operate could be safely designed to operate at 2.5 KiloAmps instead of 5 KiloAmps then the savings in lead flow would be 1.5 grams/sec for a savings in 4.5 K watts of 225 watts at a cost of 2.5 M$ for new super conductor! The use of "burnout resistant" current leads costs 20 % more in current lead cooling than the use of regular commercial current leads. If all the new magnets had commercial leads instead of burnout resistant leads we could save 0.67 grams/sec of lead flow for a savings of 100 watts at 4.5 K at a cost of significantly reduced magnet safety. If all three of these somewhat drastic measures were taken it would save ~ 500 watts at a cost of up to 3 M$ but **would not** give the ESR a standalone capability for the total load with targets.

A brief summary of the expected 12Gev heat loads follows.

	QTY	current kA	Lead flow/mag [gm/sec]	total Lead Flow [gm/sec]	each 4.5KWatts	Total 4.5 KWatts	target 15KWatts
HallA/HRS							
Q1	2	3.5	0.44	0.88	15	30	
Q2	2	2	0.38	0.76	20	40	
Q3	2	2	0.38	0.76	20	40	
D	2	2	0.44	0.88	20	40	
Septum	0	1	0.10	0	34	0	
New Tl's+ Dist	1				30	30	
target	1					0	450
Dist Box	1				50	50	
TL's	1				120	120	
Unaccounted	1				100	100	
Total_A				3.28		450	450
HallB							
TORUS	1	5.00	0.6	0.6	70	70	
target + dewar	1				10	10	
Solenoid	1	5.00	0.6	0.6	50	50	
distribution	1				20	20	
TL	1				20	20	
Total_B				1.2		170	0
Hall C/HMS							
Q1	1	1.1	0.11	0.11	10.5	10.5	
Q2	1	1.1	0.11	0.11	11	11	
Q3	1	1.1	0.11	0.11	12	12	
HallC/SHMS							
D	1	3	0.32	0.32	60	60	
HB	1	1.5	0.18	0.18	20	20	
Q1	1	1.5	0.18	0.18	20	20	
Q2/Q3	2	5	0.6	1.2	20	40	
D	1	5	0.6	0.6	40	40	
Moller	0				10	0	
New Tl's+Dist	1				20	20	
Main target	0					0	450
Old TL+Dist	1				50	50	
Pol Target	0		0.33	0	10	0	
Total_C				2.81		284	450
ESR							
Dist+TL's	1				215	215	
Total				7.29		1119	900
4.5 K watts equivalent of leads & 15 K targets				1094			300
Total 4.5 K watts				2512			

		current	Lead flow/mag	Total Lead Flow	each	Total 4.5K	Target 15K
	QTY	kA	[gm/sec]	[gm/sec]	4.5KWatts	[Watts]	[Watts]
HallA/HRS							
Q1	2	3.5	0.44	0.88	15	**30**	
Q2	2	2	0.38	0.76	20	**40**	
Q3	2	2	0.38	0.76	20	**40**	
D	2	2	0.44	0.88	20	**40**	
Septum	0	1	0.1	0	34	**0**	
New Tl's+ Dist	1				30	**30**	
target	1					**0**	**450**
Dist Box	1				50	**50**	
TL's	1				120	**120**	
Unaccounted	1				100	**100**	
Total_A				**3.28**		**450**	**450**
HallB TORUS	1	5	0.6	0.6	100	**100**	
target + dewar	1			0.5	10	**10**	
Solenoid	1	5	0.6	0.6	70	**70**	
distribution	1				20	**20**	
TL	1				20	**20**	
Total_B				**1.7**		**220**	**0**
Hall C/HMS							
Q1	1	1.1	0.11	0.11	10.5	**10.5**	
Q2	1	1.1	0.11	0.11	11	**11**	
Q3	1	1.1	0.11	0.11	12	**12**	
D	1	3	0.32	0.32	60	**60**	
HallC/SHMS							
HB	1	4.5	0.55	0.55	20	**20**	
Q1	1	3.5	0.42	0.42	20	**20**	
Q2/Q3	2	4	0.48	0.96	40	**80**	
D	1	5	0.6	0.6	40	**40**	
Moller	0				10	**0**	
New Tl's+Dist	1				20	**20**	
Main target	0					**0**	**450**
Old TL+Dist	1				50	**50**	
Pol Target	0		0.33	0	10	**0**	
Total_C				3.18		323.5	450
ESR Dist+TL's	1				**215**	**215**	
Total				**8.2**		**1209**	**900**
				liquid He		refrigeration	Target
4.5 K watts equivalent				**796**		**1209**	**178**
Total 4.5 K equivalent watts *			**2182**				

* Using ideal liquifaction and refrigeration conversions