SSC DETECTOR SOLENOID DESIGN NOTE #22

TITLE: Cooldown of Magnet

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Historical Survey

The data given in Tables 1 and 2 was found in various documents describing the magnets. It is amazing that the goal was to cool the 1200-tonne MFTF coils in just 120 hours (5 days)!

Cooldown of the SSC Detector Solenoid

The cooldown rate depends, to a large extent, on how much money is spent for the cooldown equipment and how much the helium refrigerator is oversized. The frequency of cooldowns is a factor in the trade-off between cooldown time and equipment cost. The steady state 4.5 K heat load on the magnet system is presently estimated to be 350 W + 36 L/h (530 W equivalent), about 50 W of which is associated with non-magnet items.

Option 1. A helium refrigerator with a capacity of 2.4 kW at 4.5 K (refrigerator capacity ÷ expected heat load = 4.5), a separate cooldown refrigerator consisting of a LIN-He heat exchanger and a cooldown turbine (Fig. 1), and a dedicated compressor rated at 240 g/s. The cooldown flow rate is 240 g/s.

All eight coil/helium vessel modules would be cooled at the same time, so there would be a maximum flow through each of 30 g/s. The lines in the cooldown circuit are presently sized so that the pressure drop at this flow is negligible. The pressure drop through the 2-m coil module with a packing factor of 0.65 is estimated to be ~10 psi for either 60 g/s at 250 K or 100 g/s at 100 K. The LIN/He exchanger would be sized to cool 240 g/s of He by 100 K, approximately 125 kW. The turbine would be turned on when the return from the magnet reaches 180 K. It would cool 240 g/s from 80 K to 55 K by removing 30 kW at an efficiency of 67% Using this method, the modules would be cooled to 60 K in about 10 days. At this point the main refrigerator would be turned on and the remainder of the cooling will be provided by boiling LHe. With a production capability of 400 L/h (available for cooling after the heat leak is subtracted) the cooldown from 60 to 5 K should take an additional 7 days. The total LHe inventory in the coil modules and the two 5000-L storage dewars is ~21,000 L; it would take about another 2 days to fill them. The total time needed to cool and fill both 8-m modules with this method is 19 days. The maximum cooling rate, occurring near 150 K, is 1.5 K/h.

Option 2. Same 4.5 K refrigerator as Option 1, but with additional helium gas being drawn from the ring magnet refrigeration system during cooldown for a total of 400 g/s and a proportionately larger heat exchanger and cooldown turbine.

The turbine in this option is the same size and operates in the same temperature range as the 12 cooldown turbines in the SSC ring refrigeration system. With a flow of 50 g/s to each 2-m module the pressure drop is still quite low. The maximum cooling rate is about 2.4 K/h, which is probably OK from a thermal stress point of view. With this system the cooldown from 300 to 60 K would take 6 days. The time to reach 4.5 K and accumulate the inventory is the same as for Option 1, so the total time is 15 days.

Option 3. A 1600 W, 160 g/s, 4.5-K refrigerator, a cooldown refrigerator with LIN-He heat exchanger and two cooldown turbines, the second having an outlet gas temperature of 40 K. The cooldown flow rate is 400 g/s.

With this equipment the cooldown time from 300 to 45 K is 7 days, from 45 to 5 K is 4 days, and 3 days are needed to accumulate LHe: a total cooldown of 14 days. This option has the advantage that the main refrigerator is smaller, although the ratio of capacity to expected heat load is still 3, and therefore cheaper to purchase. It could cost $150k less per year to operate than the refrigerator in Option 1

Caveats

There are many combinations of the basic cooldown building blocks, the options considered here are illustrations only and are not presented as optimized solutions. We do want to point out the semi-obvious point that the coil design could have a effect on the cooldown time through the flow characteristics, i.e. pressure drop, of the windings. The MAWP of the helium vessel may/will also be important.

Summary

From the preliminary work done so far, it appears that both 8-m assemblies can be cooled to 4.5 K and filled with liquid helium in 2 to 3 weeks.

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SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: Table 2. MFTF vs SSC DS

NAME:

DATE: | REVISION DATE:

Magnet	Cold Mass m_c (tonnes)	Magnet Heat Load (Current off) $\dot{q}_m$ (W)	VCL (pairs)	$\frac{\dot{q}_m}{m_c}$ (W/tonne)
MFTF total	1200	1856	~20	1.54
SSC D.S.	800	~530	2	0.66

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SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: Table 1.

NAME:

DATE: REVISION DATE:

MAGNET	COLD MASS			LHe REFRIG.		COOLDOWN HEAT EXCHANGER	SEPARATE C.D. XKT FOR VESSEL	EXPCTD (SPEC) C.D.	MEASURED COOL DOWN TIME
	Conductor (tonnes)	Vessel (tonnes)	Total (tonnes)	Capacity L/h or W	Flow g/s			days	days
15 FT. B.C.	73	40	113	100 L/h	52	LIN & LH_2	No	8 1/2	40
UTSI (Dipole)	48	84	132	50 L/h or 200 W	~ 36	No	Yes	?	40
MFTF East Yin-Yang East refrig.	50	238	288	3100 W	?	LIN (50 kW at 100 g/s)	Yes	?	12.5 stand alone test, at least two cool downs
MFTF West refrig. West Yin-Yang	50	238	288	8000 W	?	LIN	Yes	5 w/ 125 g/s flow	One cooldown, ~45 days, flow control valve problem, flows lower than specified except for solenoids. "Solenoids cooled more rapidly."
solenoids	11 (2-coil module)	11 (2-coil module)	22 (2-coil module)				No	5 w/ 13-17 g/s flow	
other coils	—	—	—				?	5	
SSC detector solenoid both 8-m. modules	428	376	804	2.4 kW	240	LIN 125 kW @ 240 g/s	No	14 - 19	

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SECTION	PROJECT	SERIAL-CATEGORY	PAGE
Fig 1.			

SUBJECT	NAME
COOLDOWN HEAT EXCHANGER	
	DATE / REVISION DATE