Muon Cryosystem Design Note 14

SUBSYSTEM [X] CCM [ ] CVM [ ] Cryoplant

TITLE: Operating History of Cryostable Magnets

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OBJECTIVE OF NOTE

To demonstrate, by considering the operating history of several large, cryostable magnets, that the likelihood of a failure of the CCM liquid helium level gauging system is extremely small.

HISTORICAL SURVEY AND DATA

In order to pull together information regarding the operating history of a number of large, long-running cryostable, pool-boiling superconducting magnets, the questionaire given in Appendix A was mailed to the individuals listed in Table 1. The data received in the responses is presented in Table 2.

DISCUSSION OF DATA

The cold operating time of the seven magnets can be fairly well documented. However "power-on" time is known only for the Fermilab and CERN bubble chambers. BEBC appears to have been kept cold almost all the time, with a low power-on/cold duty factor, whereas the 15-ft chamber magnet was energized 70% of the time that it was cold. I feel that the "max est" power-on time is more representative of the duty factor of a typical magnet and so will use it in the analysis.

The notes to Table 2 summarize the three reported incidents of low liquid helium level. In no case could low liquid level be attributed to a failure of the level gauging circuit. In the 15-ft and 12-ft/SLAC incidents administrative decision or operator error was the direct cause of low level. The incident with the 12-ft at Argonne occurred during the initial commissioning in 1968. The initial cold gas return line was inadequate for the actual boil off and caused the liquid level to be lower at the inlet to this line than at the level gauge. This difficulty was overcome by installing four equally spaced exhaust pipes of the same conductance[1].

Low liquid level does not always result in a section, or all, of a cryostable coil going normal. In fact the consequences of the three low level incidents were quite different. The 12-ft/SLAC incident did not result in any normalcy and the 12-ft/ANL incident caused only one pancake (the one in gas) to go normal. The initiation of a fast dump with low helium level caused the entire 15-ft magnet to quench. It is not my intent to use this bubble chamber magnet experience to estimate the likelihood of a normalcy being initiated in the CCM coil, nor to predict the consequences of a normalcy.

CALCULATION OF FAILURE PROBABILITY

I assert that the design specifications for the liquid helium level gauging systems for those magnets which use an AMI or other superconducting wire are sufficiently similar that the cumulative operating experience can be used to estimate the probability that the CCM gauging system will fail. Since none of these six gauging systems have failed in 1.24×10^5 hours of power-on operation the failure probability estimated from this experience is less than 0.8×10^{-5} per hour.

CONCLUSIONS

The superconducting-wire based liquid helium level gauging systems are very reliable, with a failure probability $\sim 10^{-5}$ per hour.

REFERENCE

1. "The Superconducting Magnet System for the Argonne 12-foot Bubble Chamber," P.G. Marston, ed., Argonne National Laboratory Report ANL/HEP 6813 (1968).

REVIEWED BY

D. P. Smith 3/27

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Table 1. Sources of Historical Information

Magnet	Institution	Source
"4 FT"	Fermilab	R. Fast
CCM	Fermilab	R. Dachniwskyj
15 ft B.C.	Fermilab	J. Kilmer
U-25	ANL-USSR	R.P. Smith R. Niemann
12 ft B.C. - Vert Field	ANL	M. Derrick
12 ft B.C. - Horiz Field	SLAC	R. Watt
LASS	SLAC	R. Watt
BEBC	CERN	G. Harigel

Table 2. Summary of Historical Data

Magnet \ Parameter	Stored Energy (MJ)	Active or Retired	Lifetime	Cold Run Time (h)	Power-on Time: Actual (h)	Power-on Time: Max Est[2] (h)	Power-on Time: Min Est[3] (h)	LHe Level Sensor	Number of failures of level gauging system
"4 FT" - Fermilab	2.2	R	1975-85	30000	---	21000	9000	AMI-superconducting wire	None
CCM - Fermilab	26	A	1981-pres	4400	---	2800	1300	AMI-superconducting Wire	None
15 ft B.C.-Fermilab	400	A(?)	1972-pres	42000	29000	29000	29000	AMI-superconducting wire	None - See Note 1
U25 - ANL/USSR	34.2	?	1976-?	1300[1]	---	900	400	AMI-superconducting wire	None
12 ft B.C. Vert field - ANL	80	--	1968-79	43400	---	30000	12500	Superconducting wire	None - see Note 2
12 ft B.C. Horiz field - SLAC	80	A	1980-pres	21600	---	15000	6200	Superconducting wire	None - see Note 3
LASS - SLAC	34	R	1976-83	27400	---	18900	8000	Differential pressure transducer	Not applicable
BEBC - CERN	740	R	1973-84	86500	25000	25000	25000	Superconducting wire	None
					25660	142600	91400		
					229200 w/o LASS	123700 w/o LASS	83400 w/o LASS		

Footnotes
1. Average of two estimates: 600 and 2000 h
2. Applying 15 ft B.C. duty factor (69%) to all but BEBC
3. Applying BEBC duty factor (29%) to all but 15 ft B.C.

Note 1
LHE level was once administratively allowed to fall below top of coil. Some coil pancakes were in gas. A dump initiated a quench of entire coil. No permanent damage.

Note 2
During initial commissioning inadequate gas return line once caused a local depression of LHe level, exposing a portion of top pancake. Only top pancake went normal.

Note 3
Through operator error LHe level once fell several feet below top of coil. Coil did not go normal or quench.

Appendix A

Pool-Boiling, Cryostable Superconducting Magnet Questionaire

Magnet

Institution

Stored energy (MJ)

Is the magnet still-- ▱ used ▱ or retired

Lifetime -- 19 ____ to 19 ____

Total running time to date-------------------------------- ____ hours (approximately)

Type of LHe level measuring circuit*

Low LHe level protection ------------------------------ ▱ Manual ▱ Automatic

Number of running hours magnet was
unprotected due to failure of level
circuit or to administrative decision.

or

Number of scheduled running hours ------------------------ ____ hours
that magnet was inoperable due to
failure of level circuit.

Number of magnet quenches to date. ----------------------- ____ quenches

Cause of quenches.

Remarks

Name/Date

Return to: R.W. Fast, MS 219, Fermilab, P.O. Box 500, Batavia IL 60510 (USA)

*For example:

AMI = American Magnetics superconducting wire type
SWT = other superconducting wire type
CR = carbon resistors
DPT = differential pressure transducer

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