A RELATIVE COMPARISON OF A CONTACT COOLED VS. POOL BOILING SOLENOID FOR THE FERMILAB COLLIDING DETECTOR FACILITY*

Comparison Area	Contact Cooled Coil	Pool Boiling Coil
Sources for Quenches	a) A small defect in the superconductor would cause local heating leading to a quench this might limit the maximum operating field of the magnet.	a) A normal zone can only occur if the conductor is not covered by LHe.
	b) A hot spot, such as near the supports, could cause the superconductor to exceed its critical temperature. This could also limit the field of the magnet. In general a contact cooled coil is extremely sensitive to the 4.2K heat load.	b) A variation in line voltage could trip interlocks, but these could be quickly reset.
	c) A small heat pulse from conductor motion may cause the critical temperature to be exceeded.	c) A pool boiling coil is relatively insensitive to the total 4.2 K heat load.
	d) A relatively minor interruption in the helium flow would cause the magnet to quench.	
	e) A variation in line voltage could trip the quench detection system. The resulting rapid discharge would quench the coil.	

*Prepared by the CDF Magnet Design Group, 11/20/81, R. Kephart, et al.

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Implications of a quench	a) If, for example, the magnet temperature reaches approx. 77K 1800 L of LHe is required to recool the magnet. The recovery takes 6 hrs at a flow rate of 300 L/hr.	a) In the very unlikely event that a large normal zone is detected a 45 sec discharge is initiated where the maximum temperature is <250 K. Even if no helium is present in the coil. A large volume of LHe is however vaporized.
	b) A rapid discharge of the magnet (τ = 30 sec) produces forces on nearby components.	b) The fast discharge voltage is 200 volts.
	c) The discharge voltage across the leads ≅ 400 volts.	
	d) An extended training period could create problems.	
Refrigeration System	a) The magnet heat load is ≅ 56 L/hr. The helium pump will add about another 10 L/hr.	a) The heat load is also ≅ 56 L/hr.
	b) A helium pump or refrigerator is required to circulate liquid helium.	b) The magnet will operate for ∿ 24 hrs with only its local storage dewar. Additional LHe can be Added to this dewar from any of several sources. This dewar also provides refrigeration during the move from the assembly hall to the collision hall.
	c) The pump and refrigerator are critical components which require back-up power or redundant system.	

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	d) Special provisions for refrigeration are required during the magnet move or the magnet must be allowed to warm up.	
Eddy Currents During Charge.	a) Bore tube heating may limit the charge rate to more than 10 min. (For example, TPC and CELLO charge in about 40 min.).	a) The charge rate is currently limited by the power supply to 10 min.
	b) 15 to 20 liters of LHe is vaporized during a 10 minute charge.	b) Charging the magnet vaporizes 26 liters of helium.
Eddy Currents During Discharge	a) A normal discharge (τ = 300 sec) vaporizes 17 liters of helium and generates a maximum eddy current power of 300 W.	a) A normal discharge (τ = 300 sec) vaporizes 26 L with a maximum power of 450 W.
	b) A fast discharge (τ = 30 sec) vaporizes 175 liters of helium with a maximum power of 30 kW. Note that the coil would quench under these circumstances, and therefore requires a total of 1800 L.	b) A fast discharge (τ = 45 sec) vaporizes 176 L with a peak power of 20 kW. The cryostat requires adequate venting to prevent over-pressurization. this design includes.

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Helium Pressure Vessel	a) The pressure vessel containing the helium consists of an aluminum tube and thus is simple. Leak checking the tube should be easy.	a) The pool boiling coil requires a leak tight pressure vessel fabricated of aluminum. Leak checking and welding of aluminum is more difficult than stainless.
	b) The tube must withstand high internal pressures during a quench.	b) Over-pressures must be prevented with a large (≅ 8") diameter exhaust stack and reliefs.
	c) The helium inventory around the coil is about 60 liters.	c) The liquid helium inventory around the coil is about 800 L.
		d) The helium vessel requires a central rib for mechanical strength.
Vacuum Shell	a) The vacuum shell is identical for both designs.	a) SAME
LN_2 Shields and Superinsulation	a) The physical thickness of the shields are identical in both designs.	a) SAME
	b) The end shroud of the shield must be very effective in blocking thermal radiation.	b) The pool boiling coil is relatively insensitive to thermal radiation for successful operation.

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Chimney and Power Leads	a) The exit from the coil can be made about 6" in diameter.	a) The exit from the coil is about 12" in diameter.
	b) Two cold and electrically insulating power lead feed-throughs are required.	b) No cold feed-throughs are required.
	c) Standard current leads can be used on both magnets.	c) SAME
	d) The contact cooled coil requires a complicated control dewar with a heat exchanger, pump, valves, high pressure rating, etc.	d) The local storage dewar is simple but must withstand ≅ 75 psi.
	e) The relief valves can be made relatively small.	e) Several large burst disks and relief valves are required.
Mechanical Supports	a) Both magnets create the same loads and require identical stiffness.	a) SAME
	b) The supports probably require a LHe intercept.	b) A LHe intercept is not required.
Thickness	a) The physical thickness is between 9 and 12 inches	a) The physical thickness is about 10 inches.
	The radiation and absorption lengths are the same for the proposed Japanese design.	

Comparison Area	Proposed Contact Cooled Coil	Proposed Pool Boiling Coil
	λ_r	λ_r
Vacuum shell and shields	0.329	0.329
Bobbin	0.14	0.267 } (outer shell included)
Conductor	0.358	0.232
Banding	0.169	0.169
Insulation	0.046	0.046
Cooling Pipe	0.003	---
TOTAL	1.05	1.04

Both coils are ∽ 0.24 absorption lengths thick.

Conclusion: On the basis of this information, we conclude the contact cooled design presently offers no significant advantages. A more aggressive design approach could produce a design with enough advantages to justify the increased risk associated with contact cooled coils.