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Modification of the Existing Magnet Exciting Coil in the ANL-NAL 30" Hydrogen Bubble Chamber to Operate in the Superconducting Mode

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Introduction

The existing ANL-NAL 30" Hydrogen Bubble Chamber operates at a field of 32.5 kG requiring 4 x 10^6 ampere turns. The present exciting coils consist of 200 turns of 1 7/8" x 1 7/8" copper with a 1" water coolant hole and operate at 20,000 amperes dc. Total system demand considering the power supply, power factor, etc. is approximately 7250 kVA. This is the single largest load on the Neutrino line and taxes the installed system capacity.

A concentrated effort is being made to study the feasibility of replacing the existing Magnet Coils with Superconducting coils. This Technical Memo submits an alternative proposal wherein the existing coils are modified in such a manner that they serve as the Helium Vessel and Heat Sink as well as the support structure for the superconductor.

Recent experience by W. Fowler, D. Richied, P Vander Arend et al in the Pump Loop for the Energy Doubler program has proven the feasibility of pumping Liquid Helium thru relatively long lengths of tubing at negligible pressure drop and temperature rise.

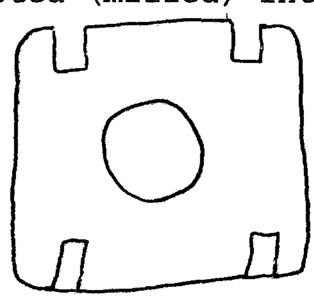
Superconducting wire and cable of dimensions 0.150" by 0.050" has been rpocured for the Doubler program and will carry about 4000 amperes in a field of 4 Tesla at about 80% of short sample. The cable type superconductor may be obtained in greater size with corresponding current carrying capabilities.

Approach

The first step in evaluating the modification would be to establish the outer dimensions of the cryostat to house the modified coils. Herein one must balance the refrigeration costs due to suspension heat leaks versus cryostat size. The forces are easily calculated and are not small. It is obvious from ANL Drawing 03-1112-2 that at least one layer must be removed from each of the coil packages and an inner and outer turn from each of the coils proper. This leaves one with 84 turns per coil package requiring approximately 25,000 amp vs. the present 20,000. The physical size of the superconductor would be relatively small if one were to use four square cables imbedded with soft solder in grooves rooted into the existing copper. This gives contact on three sides to the superconductor with the 4.2^{O}K heat sink.

Fabrication

The coils would be removed and the insulation stripped as per the existing techniques used on the Main Ring magnets. The coil pancakes would be split into single layers and the inner and outer turns removed. The separated layers would have four slots rooted (milled) into the copper as shown.



A new cross-over would need to be fabricated for the inner turn and it is at this point that splicing of the superconductor would occur thru double slot width. The entire coil layer would be heated to approximately 100^{O}F less than the flow point of the soft solder to be used in the imbeddment of the superconductor into the copper. The superconductor would be imbedded into the copper with a torch-roller technique.

Two layers would be assembled with the new cross-over welded. The four superconducting "cables" would then be spliced at this point. This is relatively straight forward. It should now be noted that we have a well stabilized coil with a very high copper to superconductor ratio.

"Scotch-ply" "batts" would be introduced into the voids between turns and layers and the five layers firmly taped. Interconnections between the layers would be made by welding with superconductor attached to the jumpers in the proper ratio.

It should be noted that one lead will have to come from the inside out. This design problem is not insurmountable.

Metalized ceramic tubes are soft soldered to the leads for Liquid Helium feed and return.

The entire coil package is now vacuum impregnated and we are left with a single input and output lead with four superconductors in parallel per copper conductor (Helium Vessel).

The Electrical Insulation (Scotch-ply and spoxy) serves two purposes. It is the turn to turn insulation and also serves to consolidate the 84 turn package into a sound monolithic structure. It also serves to act as a heat barrier to the exposed side of the superconductor.

A thin honeycomb structure would support an LN_2 shield. It is anticipated that this would be plumbed to the existing LN_2 system.

A support structure must be deivsed to distribute the magnetic forces from the coil to the vacuum can and hence to the yoke. As mentioned before, herein is where the heat leak vs. refrigeration must be balanced off.

<u>Cryogenic and Electrical Hook-up</u>

Optimized current leads typically require one liter of LHe per hour per 1,000 amps. Therefore we would like to provide a superconducting loss between the two coil packages.

Cryogenic header boxes will be incorporated into the cryostat. Since we are not talking of great pressure differentials, it may be feasible to simply slip fit the ceramic LHe feed and return tubes into these header boxes. Bellows must exist at some point to take up misalignment and movement during cool down.

It is anticipated that we will operate at a positive pressure in the helium loop[1] with subsequent recool in a heat exchanger after the pumping. This will prevent the formation of gas pockets.

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[1]"Pump Loop Test Program" by Peter Vander Arend, January, 1974.

Risers and level gauges must be provided to prevent other possible gas pockets in the feed and return headers.

Instrumentation will be provided as per the Doubler Program. This has proven simple and adequate.

Refrigeration Requirements

If we are to run at 25,000 amps, we need 50 liters per hour of LHe. Extremely pessimistic estimates would indicate that cryostats could be built requiring no more than 25 liters per hour.

Costs

1. All coil modifications done on site (including cable	$150,000
2. Refrigeration - equivalent to 3 - CTi 1400's	$200,000
3. Cryostats	$ 50,000
4. Recovery system	$ 10,000
5. Operating budget as per usual	
6. All labor to come out of operating budget	
7. Contingency 25%	$100,000
Total	$500,000

Time Scale

1. Three months of Engineering and Planning prior to shut down.
2. Twelve months shut down to turn on.

Economic Considerations

1. Capital Cost

Years to construct and install - 1
Operating cost (construction and installation)
Equipment cost (construction and installation)
AIP cost (construction and installation)

Total Cost $500,000
(Capital and Operating)

2. Useful Calendar Life - 10 years

3. Additional Operating Costs

MY/Yr and $/Yr - 0. Bubble chamber crew would operate magnet also as for 15-ft.

5. Energy Saving

a. Operating power for old device (MW)	6.0
b. Operating power for new device (MW)	0.8
c. Energy saving per year (GWHr)	23.7
d. Power cost saving per year	$230,000

6. Years to Amortize

a. Base rate - 2.0
b. 2 x Base rate - 1.0

7. Physics Gain

Bubble chamber could continue to operate without being a major drain on Laboratory power.