SUPERCONDUCTING BEAM-TRANSPORT MAGNETS AT THE 200-BeV ACCELERATOR

Seminar Presented

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Super magnets are still in an early state of development and many improvements can be expected in the future. This is in contrast to the case of copper and iron magnets whose potentialities are well understood and whose technology has plateaued. If super magnets are adopted at NAL, then it is probable that many unforeseeable improvements will occur. Nevertheless, our immediate and first task is to prove feasibility within a short time on the basis of what is known now. Within a year or so we should be able to show that bending magnets with fields $\approx$ 40 kG and quadrupoles with gradients $\approx$ 15 kG/in. can be reliably engineered on a mass-production basis. If feasibility and acceptability for the job can be proved, and the decision is made to move ahead in this direction, the succeeding years are sure to lead to profitable development work in exploring new materials, obtaining higher and better-quality fields, and improving reliability and fabrication techniques.

There is very little experience on the construction of magnets of this type and virtually none on large-scale helium refrigeration systems. One has to be very cautious about extrapolating from experience at small scale to the very large scale of the mature 200-BeV areas. I believe that this can be done fairly well for the utilities systems, but unfortunately, the superconducting art is still poorly enough understood that full-scale magnets of several varieties must be constructed to be sure that they will work.

These considerations are reflected in work that has been going on at LRL for a couple of years. Experience at BNL with NbSn ribbon during the last several years is also relevant. During the next year or so, programs at LRL, ANL, and BNL are expected to yield engineering information of great practical value for the design of 200-BeV areas.

First, I would like to draw attention to a few reports that are available in the Summer Study file that give background information on the LRL and European work.[1-7] The three main areas of attack being explored at LRL are:

1. Cryogenic-Refrigeration System. The main requirement of the cryogenic-utilities system is to supply liquid helium coolant to the magnets. Many possible schemes were explored with the help of NBS about two years ago. More recently, a joint LRL-ADL study has examined a small number of the most likely candidates in

considerable detail.[2] A summary of the five major examples is shown schematically in Fig. 1. The cheapest system in capital cost is Example 1, where a central liquifier makes liquid helium which is transported by cart in large dewars around the experimental areas. Magnets could be topped up, say, every day. The large amount of labor involved makes the operational cost very high and the need for full access of carts to every magnet location would be a disadvantage. Most attractive are Examples 3, 4, and 5, in which a refrigerator is mounted on or near a magnet and, depending on its size, may refrigerate one or more neighboring magnets. This system takes best advantage of the natural clustering of magnets in a beam line (doublets, triplets, etc.). The bulkiest part of the system, the compressor, can be located to one side of the experimental area and the utility runs are minimal, consisting of two warm-gas lines, one at 20 atmospheres, the other at 1 atmosphere.

A feature of this recent study which interacts with the cryostat design is that heat losses can be quite high (≈ 5 W per magnet) and that liquid nitrogen can be eliminated entirely.

2. Magnet Coil and Cryostat Construction. Here the main emphasis is on developing fabrication techniques that lend themselves to inexpensive mass-produced magnets. A dipole and quadrupole are under construction using square NbTi conductor wound in pancakes to give current distributions in an "intersecting circles" geometry. A

warm-bore horizontal axis magnet and cryostat has been made and is operating in a beam line;[3] it simulates a 200-BeV transport element in many respects (stored energy, current density, field, weight, forces, etc.), except for the winding configuration, and has already yielded valuable information. Construction of several full-scale dipoles and quadrupoles during the next year or two is needed to understand magnet and cryostat costs, static heat loads, dynamic heat loads, performance in experimental beams, ease (or otherwise) of operation in ganged configuration from a single refrigerator, the power-supply requirements, etc.

3. Fundamental-Design Parameters. There is a number of small miscellaneous programs at LRL that have a direct bearing on the main utilities and magnet programs. The disturbing unpredictability of certain of the superconducting materials has necessitated the study of their behavior in coils of different sizes at different fields. This behavior is not yet understood, and it is too costly and time-consuming to build full-scale magnets simply for materials testing. In addition, there are studies of the minimum needs for ventilation and insulation since we are interested in obtaining high bulk current densities ($\approx 20,000\ \mathrm{A\,cm^{-2}}$). AC heating phenomena are also being examined for multifilament conductors as they determine how rapidly the magnet current can be changed.[4] Finally, a

small helium refrigerator is being installed to simulate a subassembly of a group of transport magnets fed by a single refrigerator, and also to study transfer-line losses.

REFERENCES

[1]M. A. Green, Superconducting Material, April 30, 1968.

[2]M. A. Green, G. P. Coombs, and J. L. Perry, Refrigeration for Superconducting Magnets in the 200-BeV Accelerator, Weston, Illinois, June 1, 1968.

[3]R. B. Meuser, W. H. Chamberlain, and R. E. Hintz, Solenoid Having a Horizontal Axis and a Room-Temperature Aperture, Lawrence Radiation Laboratory UCRL-18179, April 1968.

[4]W. S. Gilbert, R. E. Hintz, and F. Voelker, AC Loss Measurements in Superconducting Magnets, Lawrence Radiation Laboratory UCRL-18176, April 1968.

[5]R. B. Meuser, Superconducting Bending and Focusing Magnets--Notes and Sketches, 1968.

[6]D. Keefe, Program Aims for the Superconducting Experimental Areas at NAL, AS/Experimental/01, May 22, 1968.

[7]D. Keefe, Summary of ECFA Work on Superconductivity Applications, AS/Experimental/06, UCID-10201-X, July 21, 1967.

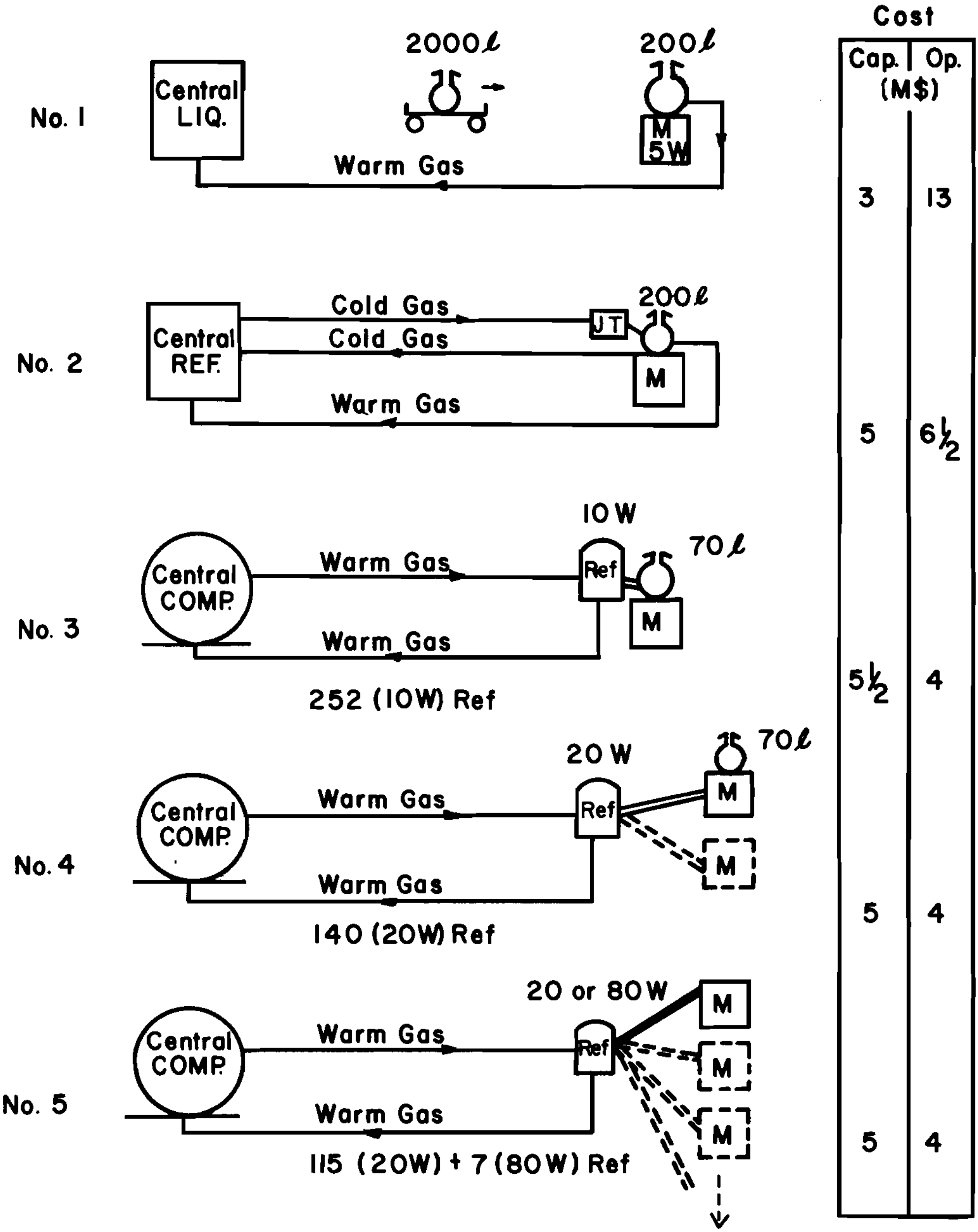

Fig. 1. Schematic summary of five different refrigeration systems discussed.