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OPERATING EXPERIENCE WITH THE HEUB SUPERCONDUCTING DIPOLES*

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SUMMARY

Four large aperture superconducting dipole magnets have been installed in the High Energy Unseparated Beam at the Brookhaven AGS. This beam services the Multiparticle Spectrometer (MPS) facility. The upstream two magnets are mounted on a sliding base so that they can also be used as part of beam A3. These two magnets have been in use since the fall of 1976 and all four magnets were in operation by the end of that year. The magnet power supplies are computer controlled by the same system that operates the conventional beam line magnets. In this paper the operating experience with these magnets, their refrigeration system and the associated instrumentation is summarized.

INTRODUCTION

The magnetic design and construction details of the dipoles have been covered elsewhere.[1-3] For convenience some of the principal parameters are recapitulated in Table I. Operational information is contained in a departmental technical note.[4]

TABLE I. Magnet Parameters

Inner diameter of windings	24.8 cm	(9.75")
Inner diameter of warm bore tube	20.0 cm	(7.875")
Length of magnet core	254 cm	(100")
Magnetic length	229 cm	(90")
Total weight	11×10^3 kg	(25 000 lbs)
Magnetic constant (unsaturated core)	15.14 G/A	

The general physical dimensions of each unit are shown in Fig. 1.

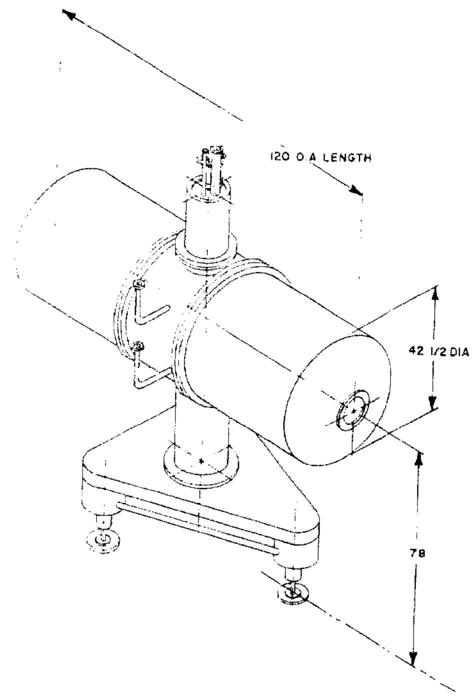

Fig. 1. Physical dimensions of the HEUB dipoles (in.).

MAGNET PERFORMANCE

All four magnets reached or exceeded the design field of 4.0 Tesla after a few quenches as shown in Fig. 2. While the training observed was somewhat greater than that exhibited by smaller cross section coils of similar design,[5] it was modest for such large, high current density coils.

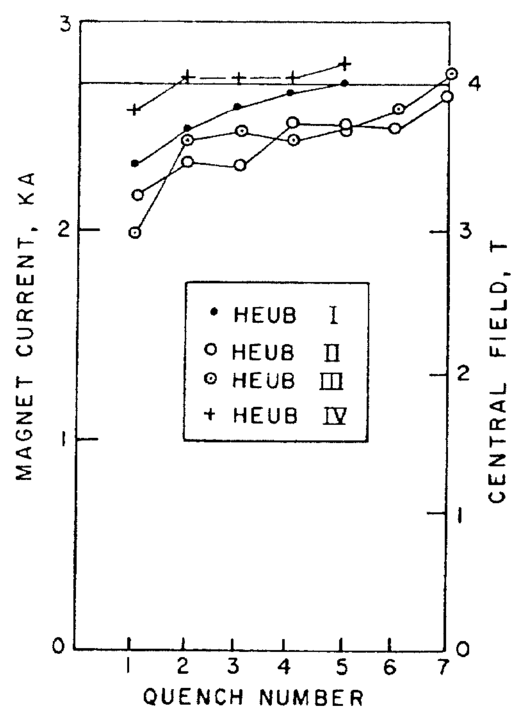

Fig. 2. Training history of the four HEUB magnets.

The magnetic field measurements have been presented previously.[3,4] The coils are designed so that the sextupole component which arises from the partial saturation of the iron core is compensated for by the sextupole field due to the coil ends at 4 Tesla. At lower fields the integrated sextupole component can be adjusted by an independently powered trim coil. A trimming coil is also provided for the next allowed harmonic, the decapole term. In actual operation it is possible to reduce the integral sextupole component to less than $4 \times 10^{-5}/cm^2$ at all field levels. The two downstream magnets are shown in Fig. 3 in the MPS beam.

REFRIGERATION SYSTEM

The refrigerator is the largest model 4000 CTi unit built to date and has a capacity of 1500 W at 4.5 K with liquid nitrogen precooling. Without precooling the capacity is reduced to 900 W. It is equipped with two expansion engines but can operate at full capacity with only one engine. The other engine can be serviced while

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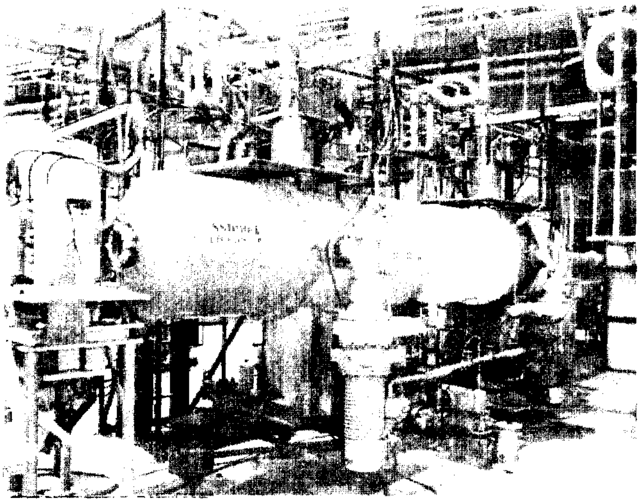

Fig. 3. The two downstream magnets in the MPS beam.

the machine is running. A large liquid storage vessel (4000 ℓ) is situated next to the refrigerator cold box. In the normal operating mode liquid is supplied from this tank to the magnets and the refrigerator maintains a constant level in the buffer tank. Liquid is supplied to the magnets in a single line 83 m long. There are two helium return lines so that any magnets can be cooled down while the others are full and under power. These lines were vendor fabricated in 12 m sections and shipped with the insulating space evacuated. The measured heat leak for both supply and return lines was approximately 0.25 W/m. The refrigerator control panel is shown in Fig. 4.

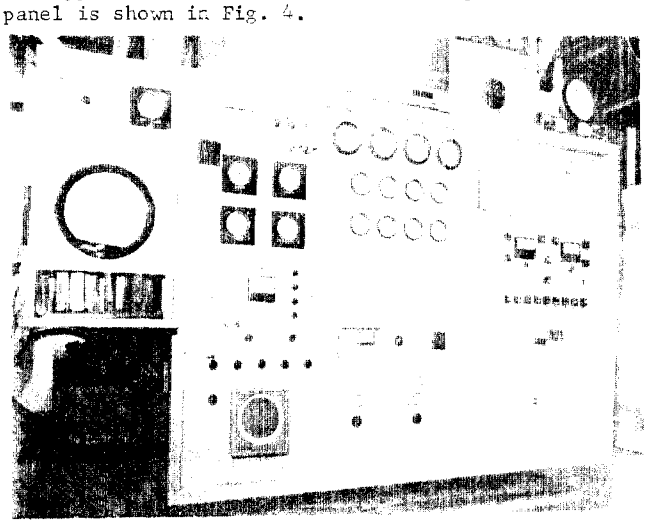

Fig. 4. Control panel for the HEUB refrigerator.

INSTRUMENTATION

The electronic monitoring system is designed to control the system over long periods of unattended operation. All important magnet and cryogenic variables are alarmed to indicate any malfunction. A few critical alarms are interlocked with the power supplies and will shut off power if tripped. The magnets are clamped with room temperature power diodes so that they will discharge slowly in the event of a power failure. Each magnet has sensors for helium level, main current lead voltage drop, lead cooling gas temperature and cryostat pressure. The low liquid level sensors and lead monitors are interlocked with the power supply. The positions of the sensors on the magnet assembly are shown in Fig. 5. A large number of other variables such as dewar vacuum, seal pressure and refrigerator engine speed are also connected to the alarm system. The control and monitoring panel is shown in Fig. 6 with the alarm indicators on the right.

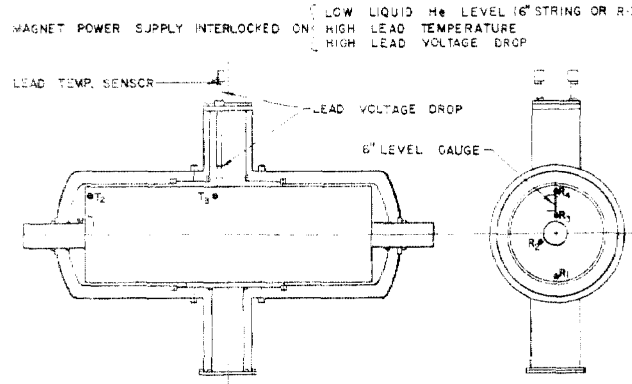

Fig. 5. The location of the instrumentation sensors on each magnet.

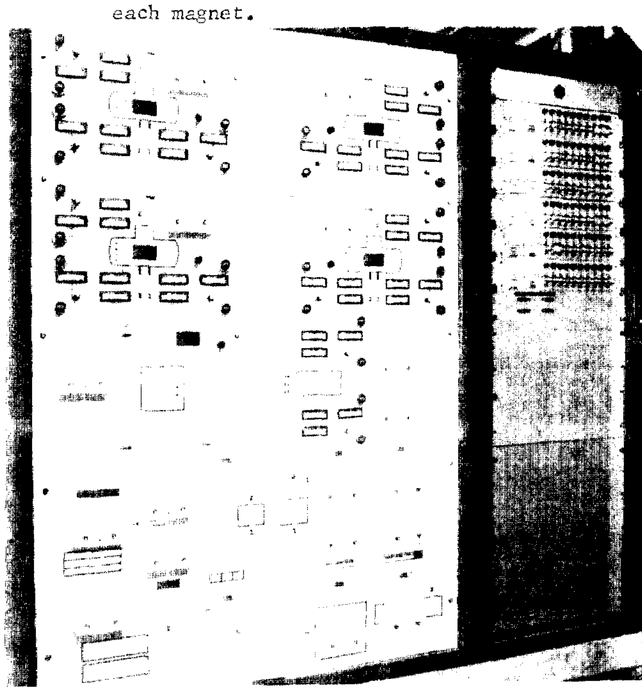

Fig. 6. The magnet monitoring and alarm panel.

OPERATING EXPERIENCE

The refrigeration system acceptance tests were performed in March 1976 and since that time it has logged more than 3500 h without major difficulties. The first two dipoles were installed in August and first operated in beam A3 in September. The second pair of magnets were first energized in December 1976. Some difficulties were encountered with the cryostat vacuum of the last magnet which was assembled from the "remaining" pieces of the four "identical" units. While the quality of the vacuum in this dewar is not nearly as good as that achieved in the other vessels it is stable and does not contribute significantly to the heat load. The total heat load seen by the refrigerator under normal conditions is approximately 550 W at 4.5 K. Of this, the magnets represent about 400 W (100 each) and the transfer lines and storage dewar, the remaining 150 W.

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