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OPERATION OF SUPERCONDUCTING MAGNETS IN FERMILAB EXTRACTED BEAMS

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Summary

We discuss the design and layout of the refrigeration, transfer, and magnet systems. We also present data on heat leaks and beam losses.

Dual Dipole

The Fermilab has installed a pair of 30 in. superconducting dipole magnets in our external proton beam line 50 ft. downstream from the main ring extraction channel. The coils use a medium grade of Nb Ti superconductor with a short sample limit of 1850 A at 27 KG field in the gap and a copper to superconductor ratio of 2. The coils were used in the first successful test magnet in the energy doubler program and built in 1973.[1] The original cryostat was not suitable for remote operation and cool down; so a new one was built which also reduced the heat leak by a factor of 3. The dual dipole is a warm iron magnet with both coils in a single pool boil cryostat which uses the boil off to cool a 20° shield as well as the vapor cooled leads.

The cryogenics consist of a CTI 1400 He liquifier which produces two phase liquid into a dewar where the gas separates and returns to the liquifier heat exchangers. The liquid leaves the dewar at a pressure of 3.0 PSI and enters a 100 ft. transfer line which runs through a 6 in. cable penetration into the Transfer Hall. The transfer line is N^2 shielded and is connected both to the dewar and magnet with .200 in. ID u-tubes. The dewar U-tube contains a shut off valve and check valve; while the magnet U-tube contains the automatic fill valve.[2] The automatic fill valve is controlled by a liquid level gauge in the magnet lead stack and maintains the level to within 2 cm limits. The lead flows are maintained with commercial Freon temperature controlled valves. The excess boil off gas and the transfer line heat leak gas are used to first cool the shield and then to intercept heat leaking down the stack. The gas then returns to the gallery where the flows are monitored and then into the low side of the compressors. The magnet pressure is 2.7 PSI while the compressor pressure is 2.0 PSI. The simplified flow diagram is shown in Figure 1.

The purpose of this installation is to discover the problems associated with the remote operation of magnets in a high radiation area. The magnets are powered to 20 KG with a beam intensity of 10^{13} protons per pulse at 380 GeV. The heat leak into the liquid He is 3 watt for the transfer line and 6 watt for the magnet.

We ran a brief experiment to see what beam losses would be required to quench the dual dipole. Inserting SWIC's and scanning targets in the extraction channel had no effect on the magnets. We then dumped $1.5\cdot10^{12}$ protons per pulse in the extraction channel which only caused violent boiling. With a 10 sec. cycle time the boiling would stop before the next pulse. We then targeted the beam 25 ft. upstream from the magnets. Table 1 gives the loss monitor on the Dual Dipole as a function of current in the magnets. The spread between the quench and nonquench data points was limited by the resolution in setting the extraction power supply. We are now installing a variable thickness target so that we can continuously vary the losses. We are also working on an absolute calibration for the loss monitor.

The losses required for a quench at a 1000 A were a factor of 1000 higher than normal at the magnet. All quenches occurred in the upstream magnet which suggests a small low energy beam shield may be useful downstream from an injection or extraction area.

B12 Energy Double

In the B0 straight section a 100 GeV extraction and transport system has been installed and operated. The extraction system is the same design as the 500 GeV A0 system except that the number of magnets in the extraction channel itself is greatly reduced. The 100 GeV was chosen because the system could be built mainly with the existing spare parts from the A0 system.

During the normal acceleration cycle we fire 1.6 μsec kicker when the beam energy reaches 100 GeV. The kicker is synchronized with the beam so that only one of the 13 booster bunches in the main ring starts to resonate; as the horizontal amplitude increases, it enters the extraction channel. The other 12 bunches are extracted during flattop at A0 in the normal mode.[3]

In April, 1975 we plan to run a prototype Energy Doubler magnet system at B12. The first run will be with a single magnet; as more magnets are built they will be added until we reach the limit of the B12 refrigeration system.

In contrast to the Dual Dipole at A0 this is a forced slow system.[4] The refrigerator produces liquid in the same mode but at a higher pressure which means a higher temperature, about 4.8°K. The liquid then enters the transfer line and flows through the inner of two coaxial He pipes. This connects to the inner cryostat which contains the magnet coils; at the end of the string of magnets there is a remotely controlled JT valve which gives us a variable pressure drop. This pressure drop gives us two phase He at a lower temperature, about 4.4°K. The two phase returns in the outer shell of both the magnet and transfer line, making the entire system a heat exchanger which eliminates any gas in the inner coil vessel.

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For the first several runs with less than 30 ft. of magnets the two phase is returned to a second return port in the refrigerator. As more magnets are added a He pump will be used and the two phase will be returned to the dewar where the liquid will separate. We also have a 20° loop which is used for shield cooling as well as a heat intercept on the suspsensions.

The power for the magnets is carried into the tunnel by a superconducting bus located in the single phase pipe of the transfer line. Cool down for the magnet coils and power bus uses a 60°K port on the refrigerator. Both the liquid and 20° loops have a cooldown return line from the JT box to the low side of the compressors.

References

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3. "Operation of the NAL Main Ring Extraction System", E.J. Bleser, et al, 1973 Particle Accelerator Conference.

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LOSS MONITOR VS DUAL DIPOLE CURRENT

CURRENT	MAX. NONQUENCH LOSS	MIN. QUENCH LOSS
250A	12.3V	21.4V
500A	6.5V	8.3V
1000A	4.4V	6.2V

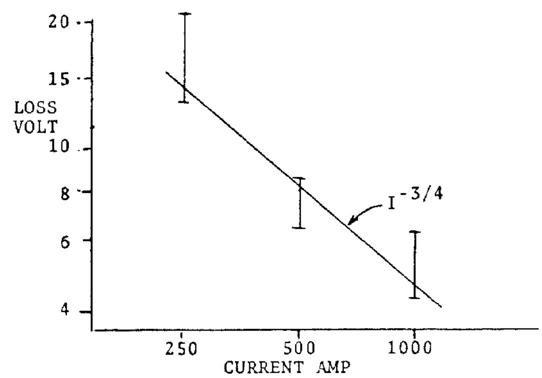
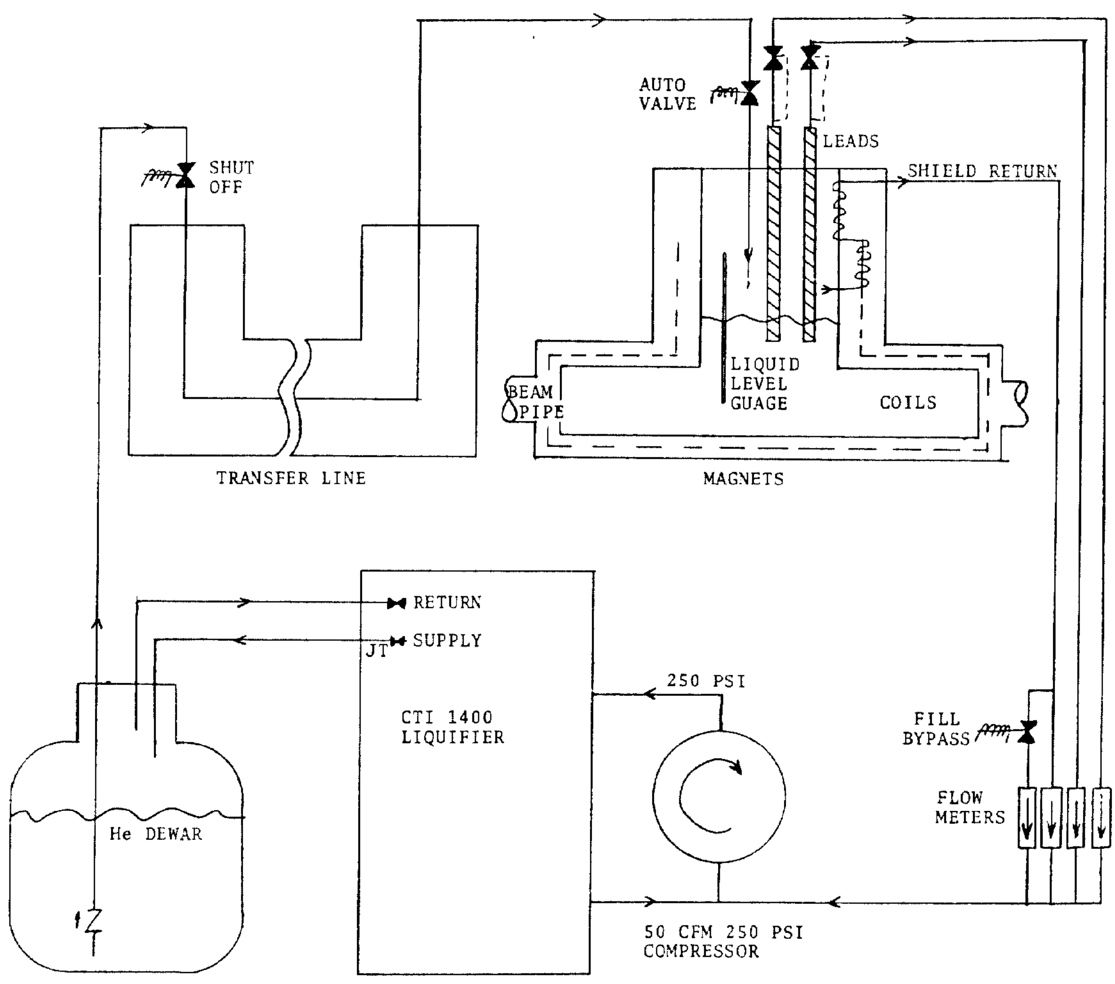
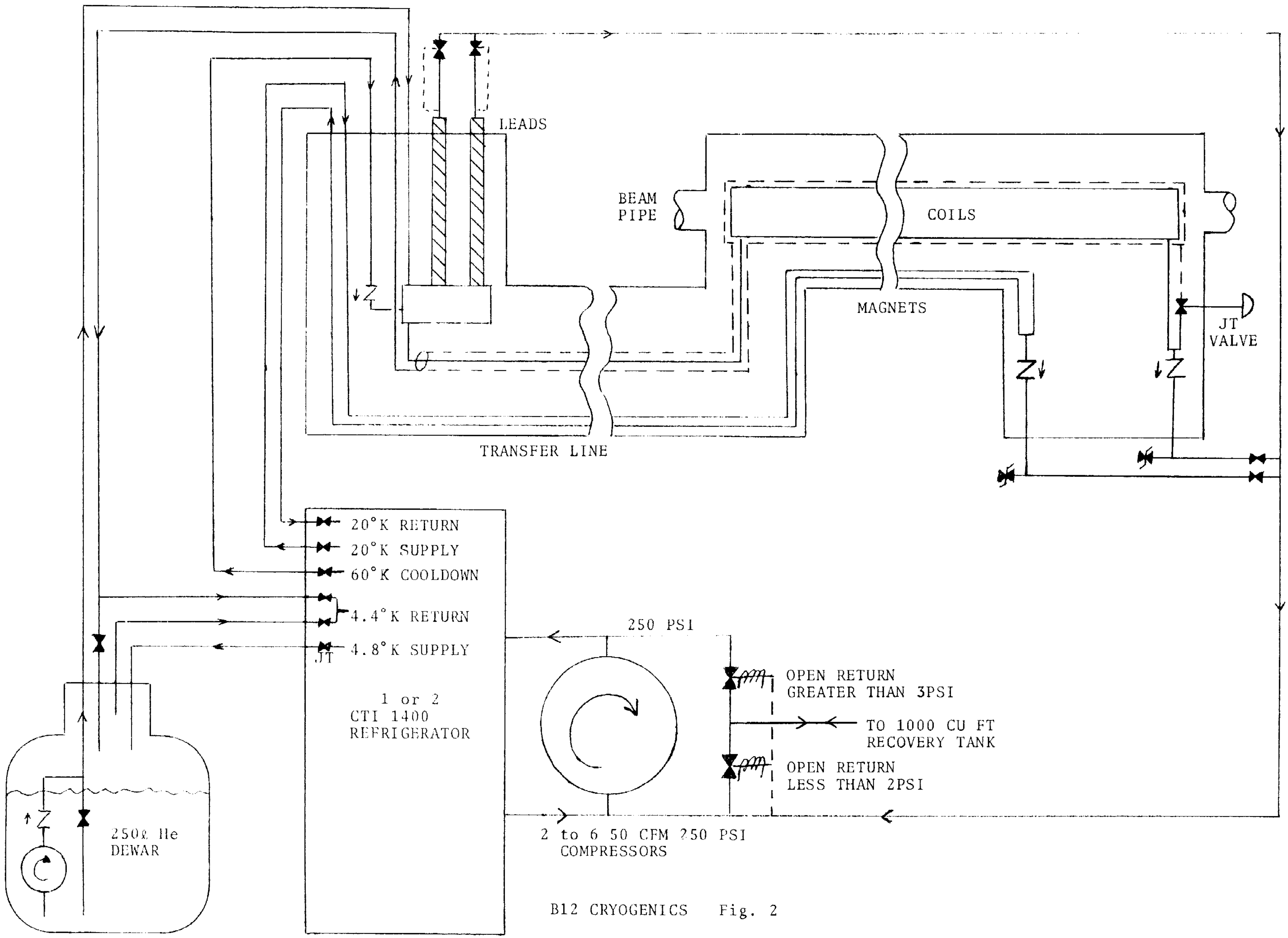


Table & Graph 1



DUAL DIPOLE CRYOGENICS Fig. 1



B12 CRYOGENICS Fig. 2