BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division
Magnet Note

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Topic: Cryogenics for Magnet Testing and Measuring

Title: Cryogenic Test Results for DESY GO 1 Magnet

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Cryogenic Test Results for DESY GO 1 Magnet

Force flow cooling of the DESY GO #1 magnet was carried out in the MAGCOOL horizontal facility from May 16 through 19, 2000. This technical note describes the cryogenic test and presents the pressure drop and heat load of GO1.

Flow Diagram

The flow diagram for cooling the GO magnet is given in Figure 1. The magnet is connected to the lead tower and the feed can. Three flexible transfer lines are used to provide connections for the supply helium, return helium and liquid nitrogen flow. The magnet is cooled by helium from the MAGCOOL supply header. After cooling the magnet and lead tower, helium returns to feed can. In the feed can, a by-pass valve is installed to divert some flow to the return and control helium flow through the magnet.

In this test, the beam tube is cooled by liquid nitrogen from the feed can. The nitrogen also flows through the connecting tube and the lead tower as heat shield.

A venturi flowmeter with a differential pressure transducer is installed for measuring the flow through the magnet. A second differential pressure transducer is used to determine the overall pressure drop. A temperature sensor (TC3) is installed for determining the inlet temperature. Unfortunately, TC3 does not work in the test. Two temperature sensors (TC1 and TC2), installed in the magnet, are used to determine the heat load. Nine flowmeters are installed for the current leads and instrumentation feed through.

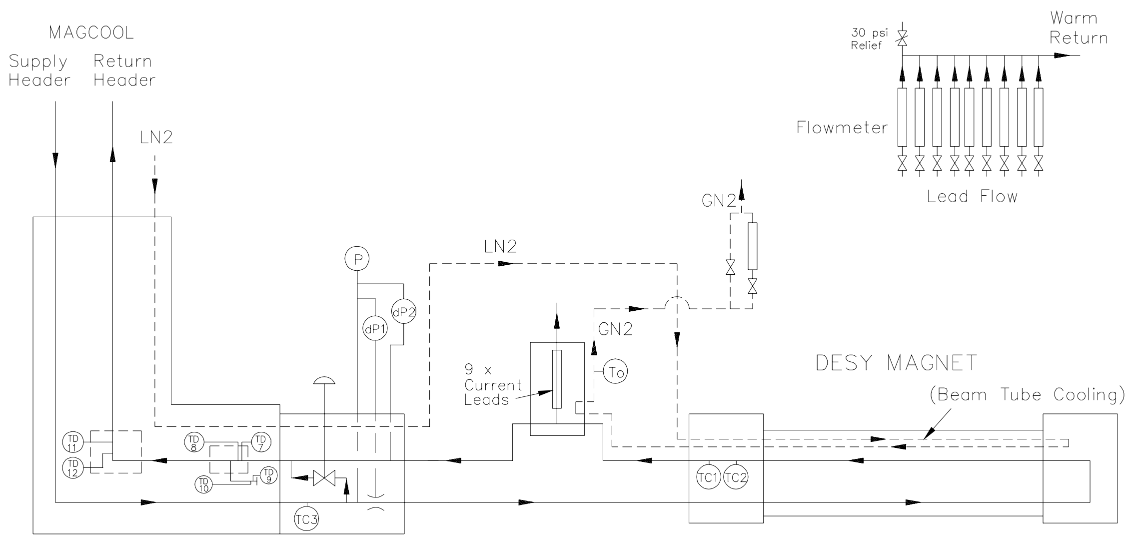

Figure 1 Flow diagram for testing DESY magnet

Test Conditions

In the two-day period (May 18 – 19), the cryogenic system provides stable temperature helium to cool the magnet. The by-pass valve is used to create three groups of flows through the magnet as shown in Figure 2. These three groups are approximately 0 - 16, 16 - 32 and 32 – 40 hours. Data are taken at ten minutes interval.

The pressure in the magnet is maintained steady between 3.5 and 4.5 atm as given in Figure 3. Note in Figure 3, a correction factor of 0.55/0.60 is applied on the raw data because we found the pressure readings taken during the test were not properly scaled. The magnet is kept between 4.7 and 5.0 K as shown in Figure 4. The differential pressure (dP1) for the venturi flowmeter is given in Figure 5. We have verified both dP1 and the differential pressure transducer dP2 are accurate for all practical purpose after the test. Temperature in the beam tube is between 80 and 100 K. During the test, the insulating vacuum is in the 10^{-5} Torr range. Temperature on the outer surface of the cryostat appears normal except in those locations corresponding to the internal supports. Four icy spots were observed.

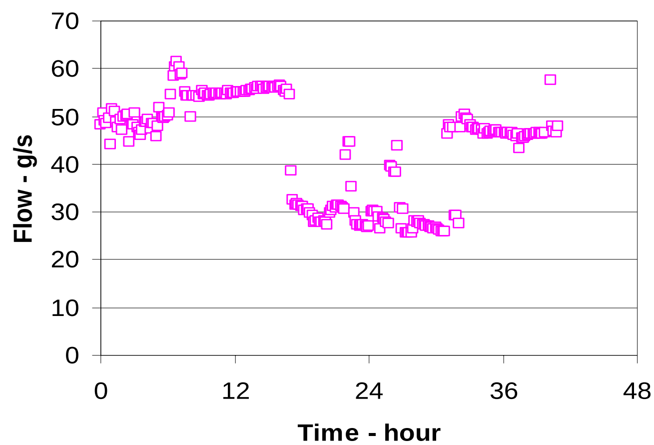

Figure 2 Flow rate through the DESY GO magnet

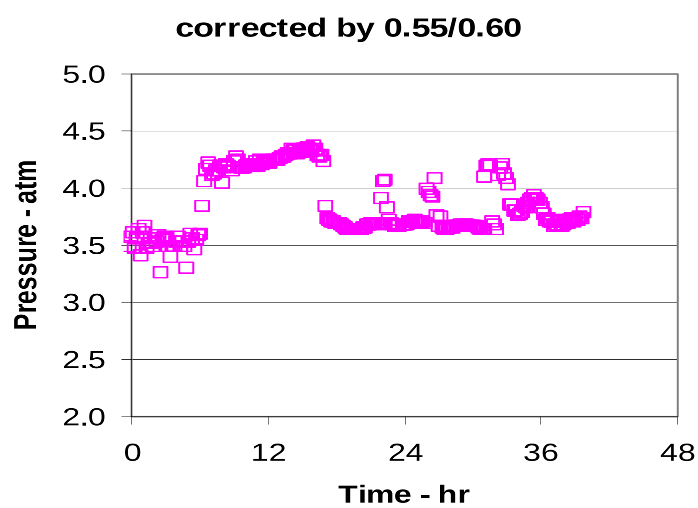

Figure 3 Pressure in the DESY GO magnet during the test

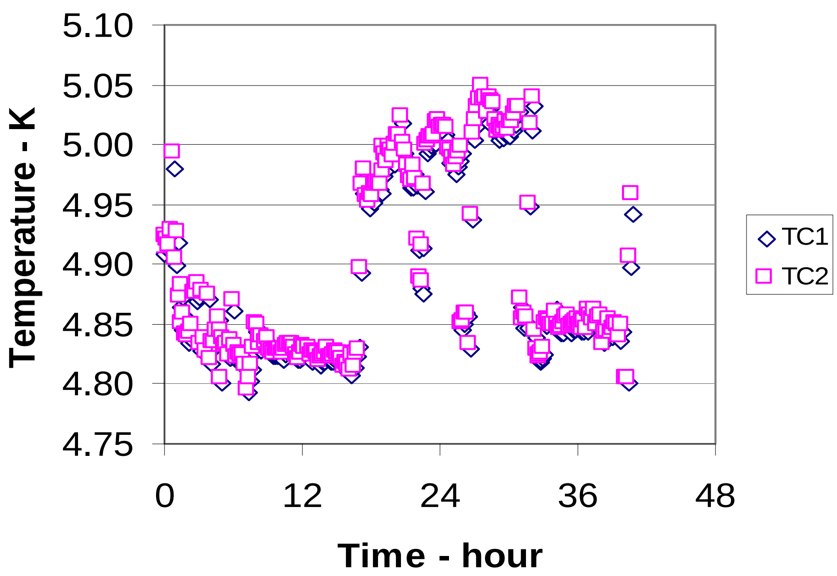

Figure 4 Temperature at the return of DESY GO 1 magnet

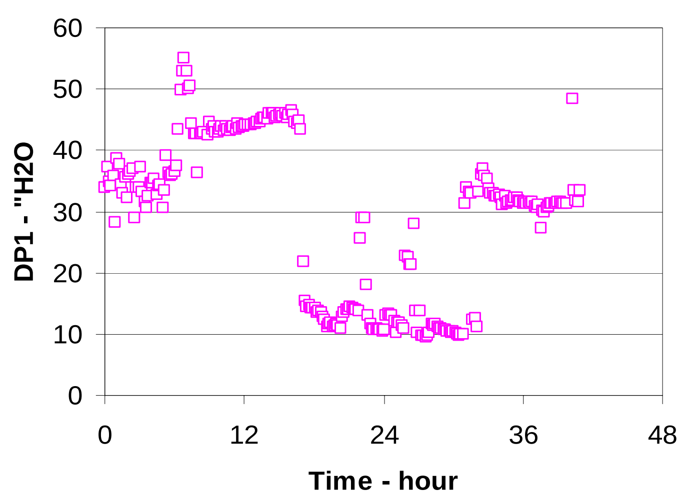

Figure 5 Differential pressure dP1 for the flowmeter

Overall Pressure Drop

In this test, we measure the overall pressure drop (dP2) including a supply line from the feed can, GO magnet, transfer tube to lead tower, lead tower and a return line to the feed can. The pressure drop as a function of time is given in Figure 6. A comparison of the overall pressure drop to the differential pressure developed on the venturi is given in Figure 7. As one can see, dP2 and dP1 correspond to each other. The ratio for dP2/dP1 is about 4.8 as shown in Figure 8. The pressure drop as a function of flow rate is given in Figure 9. Overall pressure drops are about 0.17 and 0.43 atm for 30 and 50 g/s flow respectively. Pressure drop through GO magnet equals overall pressure drop minus that from the transfer tube, the lead tower and the two flexible transfer lines.

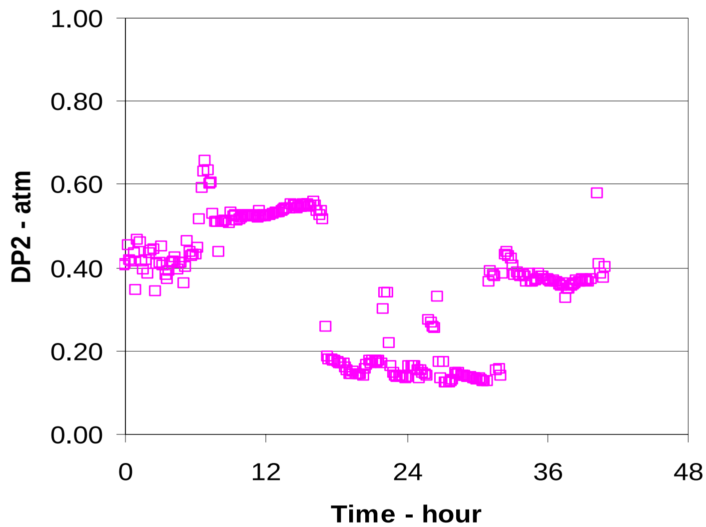

Figure 6 Overall pressure drop dP2 as a function of time

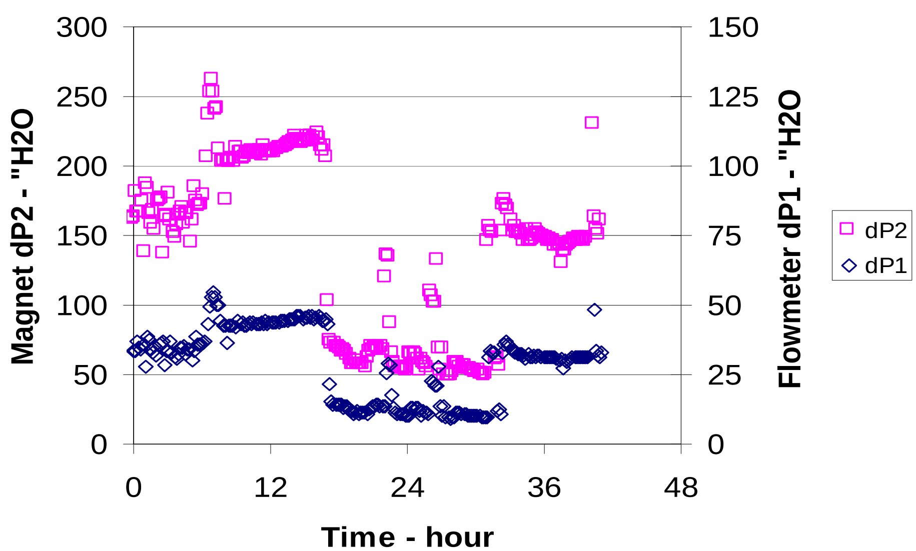

Figure 7 Comparison of overall pressure drop dP2 to dP1

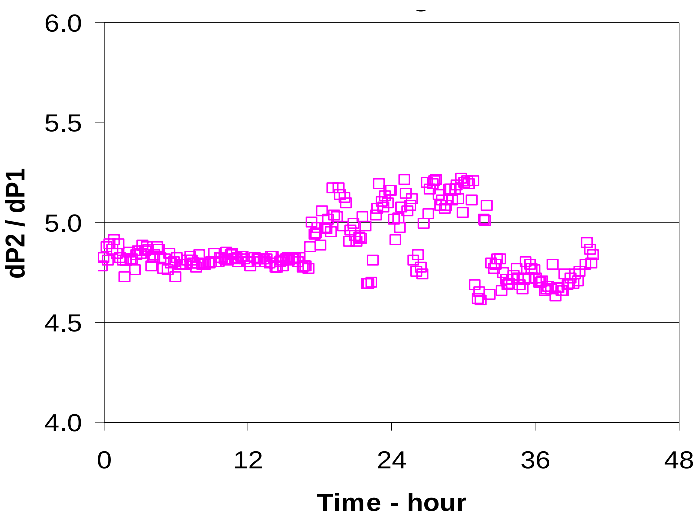

Figure 8 Ratio of dP2 to dP1

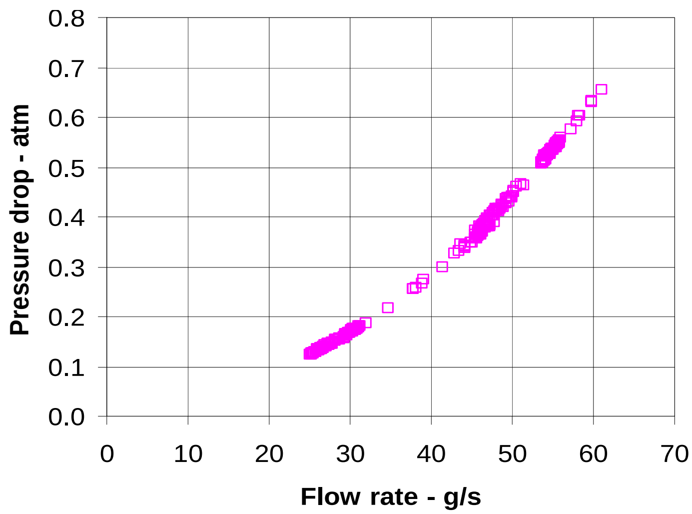

Figure 9 Overall pressure drop as a function of flow rate

Heat Load

The heat load of a system cooled by a steady fluid flow is given by equation 1. In this test, the heat load includes that of the magnet, the supply line and part of piping in the feed can. The heat load does not include the lead tower and the magnet-tower connecting tube.

$$\dot{Q} = \dot{m} \times C_p \times (T_o - T_{in}) \qquad (1)$$

For a typical cryogenic system, the temperature difference is often too small for determining the heat load accurately. In the present case, the inlet temperature sensor does not even work. Luckily, our cryogenic system was able to maintain constant inlet temperature through the test. Therefore equation 1 is rewritten in the following form.

$$T_o = T_{in} + \frac{\dot{Q}}{C_p} \times \frac{1}{\dot{m}} \qquad (2)$$

The exit temperature varies linearly with the reciprocal of mass flow. The slope is Q/Cp and the intersect equals Tin. The magnet temperature as a function of flow and reciprocal of flow are given in Figure 10 and 11. As one can see, the exit temperature decreases with flow. In Figure 11, the straight line is obtained using least square fit of the data. The heat load is estimated at 50 watts assuming Cp is 4.9 j/g-K. The inlet temperature is found to be 4.65 K which is consistent with the operating condition of the cryogenic system.

Heat load of the magnet equals 50 W minus that of the supply transfer line and part of the feed can. The magnet heat load will decrease when the beam tube is operated at 40 K instead of 80 K.

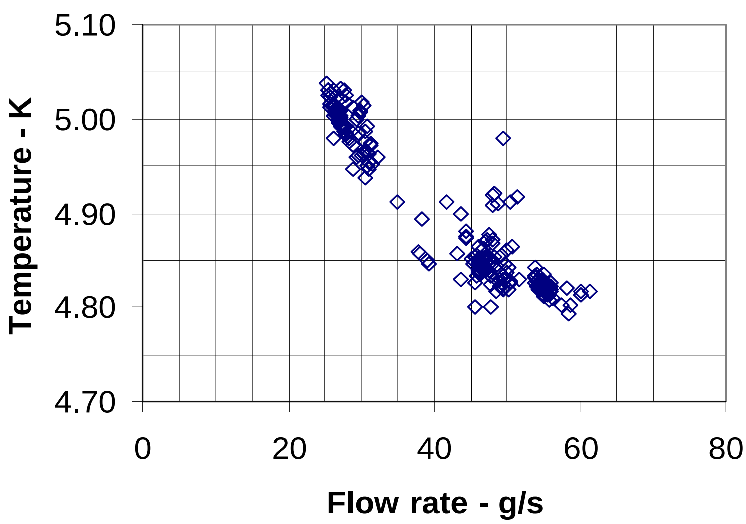

Figure 10 Temperatue at the return end of GO as a function of cooling flow

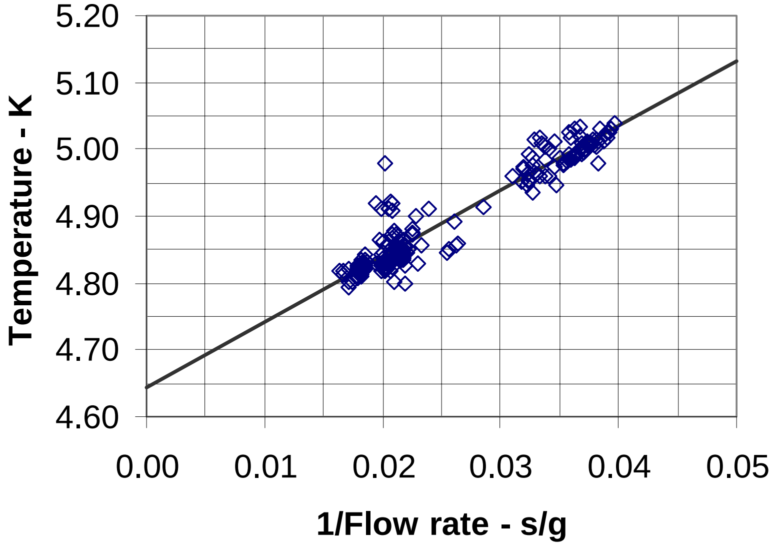

Figure 11 Temperature at return of GO vs reciprocal of cooling flow

Flow Calculation

The flow rate is calculated according to the following simplified formula for venturi flowmeter

$$\dot{m} = 22.6 \times \sqrt{Density \times dP_1} \qquad (3)$$

In equation 3, the units are g/s for mass flow, g/cc for density and inch of water for dP1. Density of helium is assumed to be 0.134 g/cc (4 atm and 4.8 K) for all cases.