A Common Cryogenics System for Two Superconducting Wigglers on the Daresbury SRS

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Abstract

Daresbury Laboratory has operated a 5 Tesla superconducting magnet for a number of years and has recently commissioned a new 6 Tesla magnet of a different design. Both of these are operated simultaneously from a single cryoplant. This paper describes the experiences of operating two cryogenically dissimilar superconducting magnets from a single cryogenic plant.

1. INTRODUCTION

The 5 Tesla superconducting wiggler magnet[1][2] has been operating in the SRS since 1982 and supports seven experimental stations. These are heavily over subscribed with the demand for synchrotron radiation in the energy range 10-50 KeV. On the basis of these needs and those of users seeking higher energies, funding was approved for the 6 Tesla superconducting wiggler[3][4] magnet in 1989. The new wiggler magnet was designed and manufactured, to a Daresbury specification, by Oxford Instruments, a British company specialising in cryogenic magnet technology. During the summer of 1992 the 6 Tesla wiggler magnet and associated synchrotron radiation beam ports were installed in the SRS and the magnet commissioned with the cryogenic system. The radiation will support a further five experimental stations, one of which is commissioned and the remainder are under construction.

2. WIGGLER MAGNET SPECIFICATIONS

The 5 and 6 Tesla superconducting wiggler magnets are situated in the Daresbury SRS on opposite sides of the storage ring. Key parameters for the magnets are shown in Table 1. They are supplied with liquid Helium from a Sulzer cold box via coaxial transfer lines of 12 and 45 metres in length.

The magnet cryostats comprise a liquid Helium filled inner stainless steel vessel, housing the magnet and iron shielding, a liquid Nitrogen cooled radiation shield and a stainless steel containment vessel. All services to both magnets are through turrets mounted on top of the containment vessels.

The 5 Tesla magnet was designed to operate with a continuously functioning cryoplant and hence the liquid Helium capacity was minimised and the system buffer sized to recover all the Helium at ambient temperature. In the case of the 6 Tesla magnet a conscious decision was made to have the option of operating the magnet independently of the cryoplant, initially through excess liquid Helium and further by transferring Helium to the cryostat from a Dewar. Due to this the Helium containment philosophy was abandoned and the cryostat was not designed to operate at high pressure. This has increased the complexity of operation of the two magnets and in the event of failure of the cryoplant the 6 Tesla magnet must be isolated from the system, to prevent over pressurisation. Careful control is also necessary during the early stages of cool down, with high gas flow and pressure, to prevent over pressurisation and subsequent Helium loss.

Table 1
Key Parameters for the 5 and 6 Tesla Wiggler Magnets

Peak Magnetic Field	5 Tesla	6 Tesla
Manufacturer	Rutherford Appleton Lab	Oxford Instruments
Year of Manufacture	1980	1991
Stored Energy	300 K Joules	256 K Joules
Liquid Helium Capacity	30 litres	200 litres
Helium Usage	5.0 litres/hr.	5.1 litres/hr.
Liquid Nitrogen Capacity		95 litres
Liquid Nitrogen Usage	2 l/hr	negligible
Max. Operating pressure	10.7 Bar abs.	2 Bar abs.
Endurance	1 hr.	10 hrs.

3. CRYOGENIC SYSTEM

The cryoplant is a Sulzer TCF100 system comprising of a K105D twin cylinder oil free compressor, a 10m^3 Helium gas buffer vessel operable to 10.0 Bar gauge, a cooled carbon purifier and cold box. Helium gas is delivered to the cold box where it is cooled through 5 heat exchangers, expanded through two turbines and a Joule-Thompson valve to produce liquid Helium at 4.2K and 1.3 Bar absolute. The liquid and gas are separated in a pot in the cold box and the liquid transferred to the magnets via coaxial transfer lines. A proportion of the magnet boil off gas is used to cool the magnet current leads before returning directly to the compressor at ambient temperature. The bulk is returned to the cold box to cool the forward flowing gas. Liquid Nitrogen is used to cool the first heat exchanger in the cold box and hence the forward flowing gas to achieve the desired capacity. The liquid Nitrogen is fed from a bulk storage tank through vacuum insulated lines to a phase separator local to the cold box. In addition this feeds the radiation shields on the Helium transfer lines and cryostats via analogue control valves. The system pressure is minimised to give good flow control and avoid large emissions of flash gas.

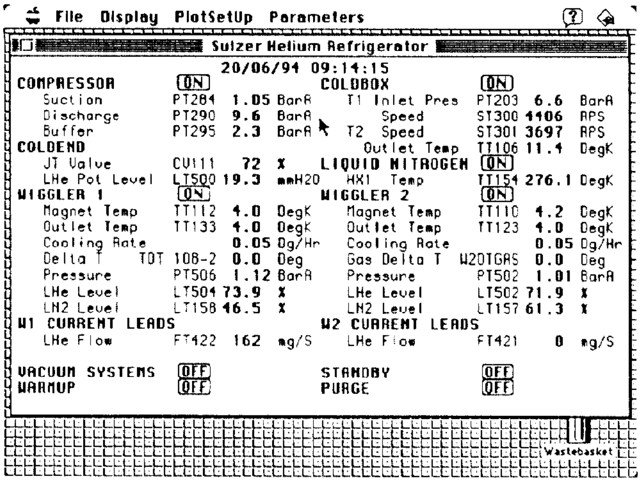
4. CONTROL SYSTEM

The 5 Tesla wiggler magnet and refrigeration system were controlled from 1982 by a Diogenes Process Controller produced by Rosemount Inc. By 1990 this was suffering from reliability problems, obsolescence and the capacity planned for the second magnet had been otherwise utilised. It was therefore decided to upgrade the system to resolve these problems and achieve the following objectives: To achieve single button cool down of any combination of magnets and to integrate control of all ancillary systems, liquid Nitrogen and vacuum. A commercial system was tendered for and the accepted solution was from Sulzer Brothers Ltd. The upgraded system uses a SattCon 31-50 Programmable Logic Controller (PLC) which provides the usual logical functions associated with PLCs together with good processing of analogue data and integrated PID control loops. The system input and output capacity is detailed in table 2.

Table 2
Cryogenic system control PLC Hardware Capacity

Hardware capacity	Available Channels	Utilised Channels
Digital Input	160	126
Digital Output	112	68
Analogue Input	56	52
Analogue Output	28	27
Serial Interface RS232/422	3	3

The control system supports an operator terminal local to the control PLC in the cryoplant compressor house. This provides a user interface to the system where key parameters can be monitored and system changes made. A second interface, for monitoring only, is available in the Main Control Room of the SRS. This consists of an application developed in house to run on a Macintosh Computer, see Figure 1. It provides a full graphical user interface to key parameters, the logging of parameters, the plotting of parameters and a graphical representation of the PID controllers. The data logged can be loaded into a Microsoft Excel spread sheet which allows easy access and analysis.



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                Sulzer Helium Refrigerator
                    20/06/94 09:14:15
COMPRESSOR          [ON]            COLDBOX            [ON]
   Suction          PT284  1.05 BarA   T1 Inlet Pres   PT203  6.6  BarA
   Discharge        PT290  9.6  BarA        Speed      ST300 4406  RPS
   Buffer           PT295  2.3  BarA   T2   Speed      ST301 3697  RPS
COLDEND                                  Outlet Temp   TT106 11.4  DegK
   JT Valve         CV111   72  %      LIQUID NITROGEN [ON]
   LHe Pot Level    LT500 19.3  mmH20    HX1  Temp     TT154 276.1 DegK
WIGGLER 1           [ON]            WIGGLER 2          [ON]
   Magnet Temp      TT112  4.0  DegK   Magnet Temp     TT110  4.2  DegK
   Outlet Temp      TT133  4.0  DegK   Outlet Temp     TT123  4.0  DegK
   Cooling Rate            0.05 Dg/Hr  Cooling Rate           0.05 Dg/Hr
   Delta T     TDT  108-2  0.0  Deg    Gas Delta T   W2DTGAS  0.0  Deg
   Pressure         PT506  1.12 BarA   Pressure        PT502  1.01 BarA
   LHe Level        LT504 73.9  %      LHe Level       LT502 71.9  %
   LN2 Level        LT158 46.5  %      LN2 Level       LT157 61.3  %
W1 CURRENT LEADS                    W2 CURRENT LEADS
   LHe Flow         FT422  162  mg/S   LHe Flow        FT421     0  mg/S

VACUUM SYSTEMS      [OFF]           STANDBY            [OFF]
WARMUP              [OFF]           PURGE              [OFF]
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Figure 1. Control System Monitor Summary Screen

The control software as commissioned by Sulzer supported the refrigeration system and the 5 Tesla wiggler with provision for a second wiggler of a similar characteristic. During the installation of the 6 Tesla wiggler magnet the ancillary systems, liquid Nitrogen and vacuum were integrated into the control PLC. In order to cope with the specified cooling rates of dissimilar magnets and the integration of the ancillary systems a major re-write of the control software was necessary. With this complete all parameters were under one controller making possible, for the first time, fully automated cool down from ambient to 4K.

5. OPERATIONAL EXPERIENCE

The cool down from ambient of any combination of wiggler magnets has been achieved in the minimum cool down time without any operator intervention. However this is the simplest situation in that all temperatures are approximately equal at the start. There are other situations which are not fully automated. The cool down of the cold box from ambient with the magnets at some temperature between 4K and 80K (Maintained by the liquid Nitrogen radiation shield) involves operator intervention to bring the magnets on line at the appropriate time, when the temperatures are matched. The cool down of one magnet from a temperature greater than 30K with the other magnet at 4K has not been possible while maintaining the cold magnet. The process has involved warming up the cold box, cooling the warmer magnet and recovering the cold magnet during the cool down. A process that involves operator intervention at the appropriate time. The recovery of the 6 Tesla magnet can be problematic when the refrigeration system is cold and making liquid Helium. A consequence of bringing it back on line is for a trapped volume of Helium gas at approximately 80K (liquid Nitrogen temperature), in the 45m long transfer line, to be pushed through the liquid Helium of the cryostat. This in turn causes boiling and pushes 4K Helium gas back to the cold box disturbing the operating point and under some conditions is sufficient to trip off the cold box, on the turbine gas temperature.

The requirement to cool the 6 Tesla magnet without the cryoplant provides for cooling the magnet down to 80K with liquid Nitrogen, through a pre-cooling circuit, and from 80K to 4K by transferring liquid Helium. To date this has not been commissioned due to the availability of the cryoplant, the manual nature of the process and the cost of cooling down to 4K with liquid Helium. The ability to maintain the magnet at 4K by transferring Helium from a Dewar has been commissioned, but proved to be wasteful, about 50% efficient by volume transferred. However by filling the 6 Tesla wiggler from a Dewar after a cryoplant shut down the recovery time is reduced by two days; the time required to make the liquid Helium. It is not envisaged that this process would be used to sustain the magnet for a long period, greater than a few days, because of the cost of Helium, the manual nature of the process and the restrictions on storage ring access.

The recovery of the cryoplant after a site electricity failure is now well proven and problems such as slow vacuum recovery on the Cold Box have been addressed through a higher performance pumping system. The recovery time is however a factor of six longer than the off time, highlighting the importance of a rapid system start up. The automation of this, as originally planned, has not been implemented. This is primarily due to the distributed nature of the plant and the implications the auto recovery has on safety together with realising a guaranteed recovery procedure.

6. CONCLUSIONS

Further to our experience with these cryogenic magnets it is advantageous to have both magnets as similar as possible. This simplifies operation, control and recovery.

The cryostat construction should be such that the volume of Helium needed to cover the magnet assembly is minimised, to facilitate rapid recovery. Any excess Helium should be above the magnet to provide endurance. The ideal solution is a small volume surrounding the magnet with a large volume above the magnet.

In consideration it would be advantageous to increase the compressor capacity relative to the size of the cryoplant. This would ease the handling of high transient gas boil off rate without disturbing the suction pressure and operation of the Cold Box.

7. REFERENCES

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