COOL DOWN OF THE COMET SUPERCONDUCTING COILS AT PSI

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The new COMET cyclotron was delivered to PSI in March 2004. The assembly of the cyclotron started immediately and the cryogenic system began its operation at the end of April. The superconducting coils were cooled down to liquid helium temperature and the six cooling machines were switched on. They maintain the cryostat temperature without an external supply of liquid helium. The cryostat and its subsystems were tested and met our expectations.

INTRODUCTION

The first cool down and powering up of the COMET cyclotron was performed at the workshop of the manufacturer ACCEL in Germany in December 2003 [1] and a field map, which is needed for the fine-tuning of the field by shimming the iron poles, was measured. After this first test, the superconducting coil was warmed up and the cyclotron dismounted for transportation to PSI in March 2004. Only five weeks after delivery, the cyclotron assembly was advanced so far that the cryogenic system was ready to cool down again.

Fig. 1: Mounting of the coil cryostat in the iron yoke at PSI.

COOLING SYSTEM

The autarkic cooling system of the COMET cyclotron consists of two connected cryostats [1]. The coil cryostat, which holds the superconducting coils, and the supply cryostat, which holds the infrastructure connections together with the four reliquifier cooling machines (Fig. 2). These cooling machines, each with a cooling power of 1.5 W at 4.2 K, are able to recondense evaporated helium gas and thus no liquid helium from outside is required during routine operation. To keep the heat load of the cryostat low, an isolation vacuum and a copper radiation shield between the inner helium tank and the outer tank of the cryostat are implemented. The shield reduces the radiated heat to the helium tank and is separately cooled to 60–80 K by two additional cooling machines (Fig. 3).

COOL DOWN PROCEDURE

The total cold mass of 2.5 tons has to cool down from 290 to 4.2 K. The standard way of cooling down is to fill up with liquid nitrogen until the cryostat is full and cooled down to the liquid nitrogen boiling temperature of 77 K. Liquid nitrogen is used because of the 10 times higher evaporation enthalpy of nitrogen compared to helium.

Fig. 2: One of four reliquifier two-stage Gifford-McMahon cold heads (SHI Sumitomo Heavy Industries).

Fig. 3: One of two single stage Gifford-McMahon shield cooler cold heads (Helix CTI).

After completing the liquid nitrogen cooling procedure, the nitrogen is pumped out and the cooling process continued with liquid helium until 4.2 K is reached and the cryostat is full. To control the cool down more than 20 temperature sensors are placed in the cryostat.

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This cool down procedure with liquid nitrogen cooling started on April 29th, in close cooperation between the manufacturer ACCEL and PSI (Fig. 4). In order to avoid a temperature gradient higher than 80 K in the coil, the cooling velocity was controlled by the temperature sensors and slowed down if necessary. During the cool down process, the mechanical forces at the 12 coil attachments have to be adjusted to avoid strong forces due to thermal shrinking of the coil mandrel. On May 3rd, the cooling with liquid nitrogen was completed and had required about 1400 litres of liquid gas. Before the liquid helium cooling started, the liquid nitrogen was pumped out and special heaters used to evaporate the remaining liquid nitrogen.

Fig. 4: Cooling down using liquid nitrogen.

After purging with helium gas, the liquid helium cooling started. All cooling machines (four reliquifiers and two shield coolers) were switched on. The cooling process finished on May 5th and took 1200 litres of liquid helium. After the cooling down, the cryostat was sealed and a feedback heater inside the cryostat, which keeps the absolute gas pressure constant at the specified 1040 mbar, was switched on and its proper functioning demonstrated. This slight overpressure prevents contamination from the surrounding air.

FIRST EXPERIENCES AFTER COOL DOWN

The power dissipation of the feedback heater is a direct measure of the cooling power of the four reliquifier cooling machines. The heat load (radiation and conduction losses) of the cryostat was expected to be 2.2 W. The cooling power of the reliquifiers is 1.5 W each, which leads to an expected heater power of 3.8 W. Values of 4.2 - 4.5 W were measured, so that the performance of the cryostat was a slightly better than expected. With one reliquifier switched off, the heater power was measured 2.7 – 3.1 W.

Two cooling machines (Fig. 3) and the first cooling stage of the four reliquifier cold heads cool the copper radiation shield in the isolation vacuum of the cryostat. It took roughly one week for the radiation shield temperatures to reach their lowest static temperature of 50 – 80 K.

The first powering of the coils took place on May 13th. During this first powering, the forces at the 12 coil attachments have to be monitored very carefully. If the coil is not at the right position, mechanical forces arise. By adjusting the coil position, these forces were kept low and the nominal current of 160 Amps was reached. Fig. 5 shows the NMR measurement of the field in centre of the cyclotron at the first powering.

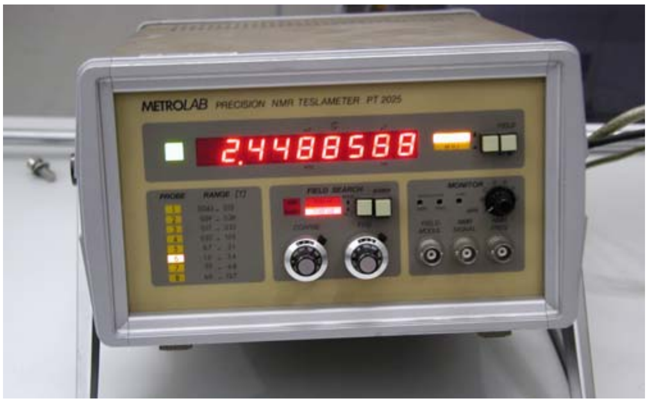

Fig. 5: NMR measurement of the magnetic field in the centre of the cyclotron at the first powering at PSI.

FIELD MAPPING AND SHIMMING

In a successive process during the following month, whereby ACCEL measured and shimmed the field map of the cyclotron with a specially designed machine based on moving coils, the field was trimmed to the design values within 2 Gauss accuracy.

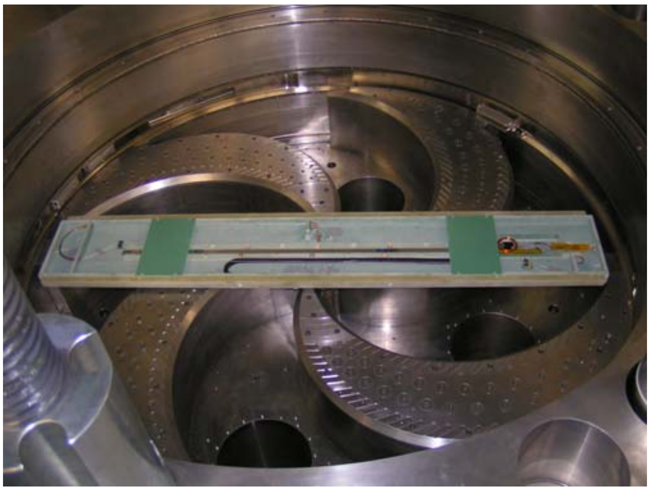

Fig. 6: Field-measuring machine built by ACCEL.

CONCLUSION

The COMET cyclotron shows the expected operation values for the cryostat and the magnet system after the cool down at PSI. The optimised magnetic field is ready for commissioning.

REFERENCES

[1] M. Negrazus, J. Duppich, M. Schippers, *Cooling down and first powering of the COMET superconducting coils*, PSI Scientific Report 2003, Volume VI.