THE DESIGN AND MANUFACTURE OF THE FAST KICKER MAGNET FOR THE ULTRA COLD NEUTRON FACILITY (UCN)

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The proposed new type of ultra cold neutron source to be built and installed at PSI requires the full intensity 590 MeV proton beam to be switched onto the spallation target, located at the centre of the UCN facility, for about 8 seconds every 15 minutes. For this purpose, a fast kicker magnet (rise-time ≤ 1 ms) with a ceramic vacuum chamber has been installed just in front of the existing DC-splitter device (EHT). This report describes the design and manufacture of this device.

INTRODUCTION

The specifications for the UCN fast kicker magnet were defined following discussions with our colleagues from beam optics [1] and from the power supply section [2]. During the switching pulse, the proton beam cannot be switched off and therefore briefly hits everything in its path. Our aim was therefore to provide the shortest possible switching time to reduce activation of the beam line between the kicker magnet and the UCN facility. The proton beam line in front of the kicker could be rearranged to provide 40 cm of space, which was considered to be sufficient.

CERAMIC VACUUM CHAMBER

The vacuum chamber has to be made using insulating material to avoid eddy currents, which would increase the switching time. The vacuum requirements in this region are determined by the neighbouring high voltage electrostatic EHT splitter. The glass-epoxy system as used for Gantry 1 could therefore not be used here and ceramic was the only viable alternative.

A Scottish ceramic company agreed to provide 70 mm diameter metallised round tubes at a reasonable price. By integrating the neighbouring bellows into the chamber, it was possible to provide space for a 36 cm ceramic tube. The PSI design department constructed a flange and bellows system which was then brazed onto the ends of the tube in the PSI central workshop. Fig. 1 shows the completed chamber.

SPECIFICATIONS

In order to minimize the inductance of the magnet, a window frame design was chosen. Provisional design parameters were passed on to the power supply section and it was agreed to use 18 turns per coil. (We regretted this decision during the manufacturing phase.)

Since the duty cycle of the magnet is less than one percent, the actual amount of power to be cooled is minimal and water cooling was not necessary. The copper of the coil is heated during the 8 second pulse and is air-cooled during the following 15 minutes. It was only necessary to provide an optimal copper cross section. However, eddy currents can also occur in the coil conductor leading to extra resistance and heating, and magnetic field disturbances. To minimize these effects, the conductor was arranged in vertical 1 mm sheets parallel to the magnetic field direction. This winding pattern provides a further advantage for the inter-turn insulation. During the switching, 350 Volts is applied to the magnet. Since there are a total of 36 turns, the maximum induced voltage between neighbouring turns is only about 12 Volts.

Fig. 1: UCN vacuum chamber with integrated bellows.

COIL MANUFACTURE

The novel design used to manufacture the coil consisted of computer cutting the 18 different single turns out of flat copper sheet, including tabs for inter-turn and external electrical connections, which are then precisely bent into their final form, as shown in Fig. 2. This work could be given to a local company.

The next phase was to insulate each turn by hand using sticky glass tape. The turns could then be stacked and the inter-turn connections made by soft soldering. Finally, a glass tape ground wrap was applied and the coil could be vacuum impregnated in a mould using epoxy resin.

Fig. 2: One of the 18 different turns ready for insulating.

THE MAGNET YOKE

The yoke of a window frame magnet is very simple and consists of a rectangular block with a rectangular hole through it as shown in Fig. 3. Again, the material is chosen to avoid eddy currents and either laminated iron or soft ferrite could be used. Since the magnetic field strength is very low and ferrite has excellent remanent field properties, soft ferrite was the preferred material. This material has already been successfully used for the SINQ kicker in the 870 keV Injector 2 beam line and the same American manufacturer provided the relatively large ferrite blocks which were required.

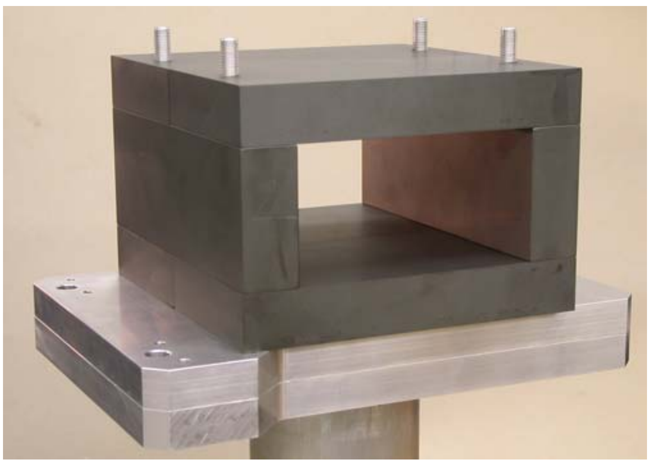

Fig. 3: The ferrite yoke attached to the aluminium base plate.

The yoke is made out of 6 blocks fixed to an aluminium base plate using precise locating holes as shown in Fig. 3.

MAGNET ASSEMBLY AND TESTING

Due to the simple form of the magnet, it can be assembled around the vacuum chamber, which was installed during the 2002 shutdown. The blocks and coils are simply stacked up and the electrical connections made. Fig. 4 shows the magnet ready for testing.

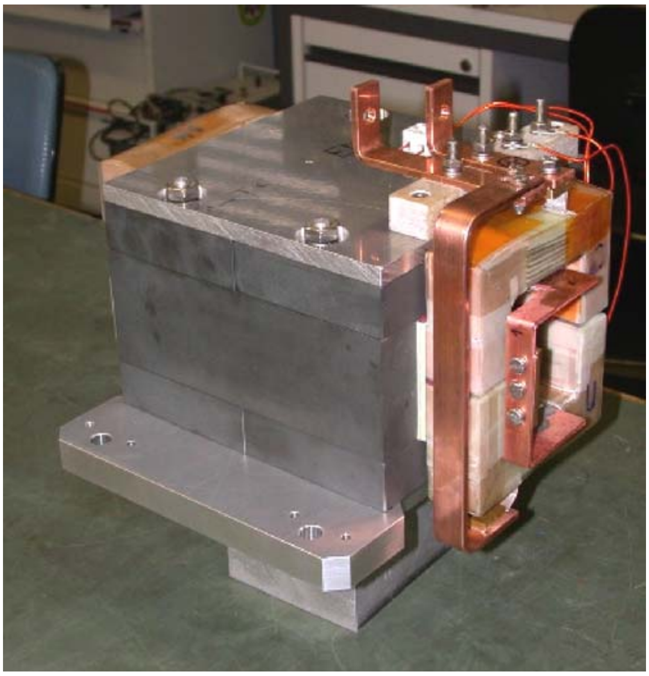

Fig. 4: The UNC kicker magnet ready for testing.

The tests confirmed the magnet parameters and that the integrated field was of good quality. Analysis of the measurements predicted a nominal excitation current of 153.1 Amps. After connection to the tuned power supply, a switch-on time of 0.5 ms and a switch-off time of 1 ms could be observed [2].

Heating tests showed that our conservative assumptions about the heat balance were too pessimistic and that, in fact, the coil does not heat up as much as predicted, presumably because the insulation also absorbs some heat and not just the copper. Together with the confirmation that the maximum design current of 200 Amps will not be required, this would permit the use of a longer pulse.

INSTALLATION AND COMMISSIONING

The magnet was installed on November 27th and successfully tested with a 20 µA test beam [1].

REFERENCES

[1] U. Rohrer et al., *First beam tests with the fast kicker magnet for the ultra cold neutron facility*, PSI Scientific Report 2002, Volume VI.

[2] F. Jenni, *Ein schnelles, präzises Speisegerät für den UCN-Kicker*, LOG Jahresbericht 2002.