RECONSTRUCTION OF THE BEAMLINE SECTION IN THE CENTRE OF THE 590 MEV CYCLOTRON

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There is a need for higher neutron fluxes at the spallation source SINQ. The increase of the proton beam current requires shorter repair and maintenance times in order to reduce the dose load of the personnel. In the 2002 shutdown, the 30-year-old beam line section in the centre of the 590 MeV-cyclotron was reconstructed: (i) By installation of two vacuum valves at the entrance and exit of the beam line section, the cyclotron is no longer ventilated if the vacuum in the beam line has to be broken. (ii) The new support structure of the beam line components, together with the design of the supply lines for the cooling water and electrical connections, improves the accessibility. (iii) In order to reduce the time needed to mount and dismount the injection beam line bending magnets, the electrical and cooling water connections were made pluggable and the adjustment feet replaced by pre-adjusted positioning pins. The vacuum connections were also replaced with expandable, easy-to-remove, units.

INTRODUCTION

In order to meet the requirements of more intensive neutron fluxes at the spallation neutron source SINQ, the proton beam current at the production target has to be increased. With the present accelerator facility, this can only be accomplished up to 2 mA. Over the medium term, a further increase of the beam current demands new, more powerful accelerator cavities, which will successively be installed, starting in 2004. The larger size and weight of the new cavities was taken into account in the design of the reconstruction, and corresponding preparatory work was included in the shutdown program.

Higher beam currents cause more activation of the beam transport system environment and the dose load of the service personnel is likely to become more severe than at present. Therefore, a better accessibility, longer times between failures as well as shorter repair and maintenance times have been important goals of the reconstruction design.

The reconstruction included the following tasks:

INDEPENDENT VACUUM SEGMENT

An independent vacuum segment shortens the down time considerably when the repair or maintenance work necessitates opening of the beam pipe, because the ring cyclotron does not have to be ventilated. The cyclotron pump down time is an important factor due to the large surfaces inside the vacuum chambers and cavities. Furthermore, the functioning of critical components, such as the electrostatic devices, can be adversely affected following ventilation.

By the installation of two valves, VND5 and VND6, at the entrance and exit of the beam line section ventilation of the cyclotron can be avoided. A pipe of 40 mm diameter from the beam pipe to the backing vacuum station of the ring cyclotron provides the connection to the vacuum pump. The valve VRZ1 that is inserted in the pipe is actuated by the control system of the backing vacuum station. A Pirani pressure gauge installed in the beam pipe provides a pressure signal to the vacuum control system.

Operational concept of the vacuum segment

(1) Beam is not allowed if the valves VND5 and VND6 are closed. Two interlock signals are generated, “VND5 not open” and “VND6 not open”. The valves close automatically if the pressure in the ring cyclotron, as measured by the gauge GR5, rises beyond the limit of 1 mbar.

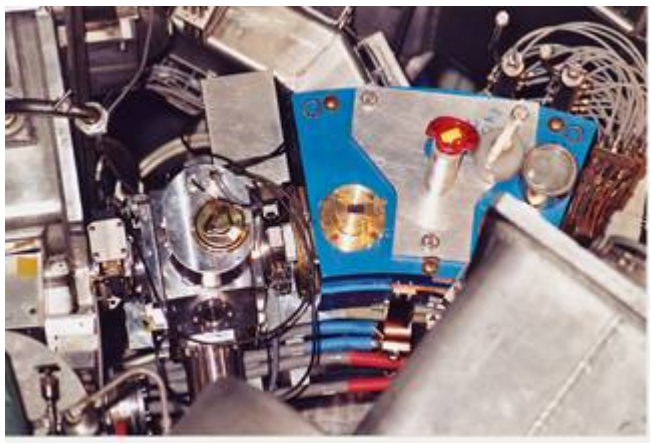

Fig. 1: Beam line section at the entrance of the ring centre. On the left of the magnet, a profile monitor and the valve VND5 can be seen. At the top, the console that is fixed to sector magnet SM6 is partly visible.

(2) The valves can be opened at the vacuum control station if the pressure in the beam pipe is better than 10^{-2} mbar and the electrostatic beam septa EIC and EEC are turned off.

(3) In the evacuation stage, the valve VRZ1 closes automatically when the backing vacuum pressure is reached.

(4) In the main control room, the status of the valves VND5 and VND6, “open”, and “not open”, is displayed. There is also a “busy” signal in case the valve opening is delayed due to the priority management of the vacuum control.

IMPROVEMENT OF THE ACCESSIBILITY

A better accessibility, a clear overview and more freedom of movement diminish the risk of accidents and raise the efficiency of maintenance work. This was achieved by (i) removing redundant equipment, (ii) modifying the service platform, (iii) installation of a new support structure for the beam line components and (iv) redesigning the supply lines for the cooling water and electrical connections.

Modification of the service platform

The supports of the service platform have been a major obstacle to efficient service work. To improve the situation, the size of the platform was reduced to a minimum. This allowed the platform to be simply attached to the existing support column in the centre and the posts at the corners to be removed.

Support structure of the beam line section

The support structure of the beam line section is designed to carry the beam line components and to serve as space-saving conduits for the cooling and electricity supply lines. There are two major support units. The first is a console with a girder that is attached to the yoke of sector magnet SM 6. It carries the first part of the beam line section in the ring centre including the bending magnet ANC. The second unit is a console attached to sector magnet SM2. It carries the bending magnet doublet AND01 and AND02 that inject the beam into the first orbit of the cyclotron.

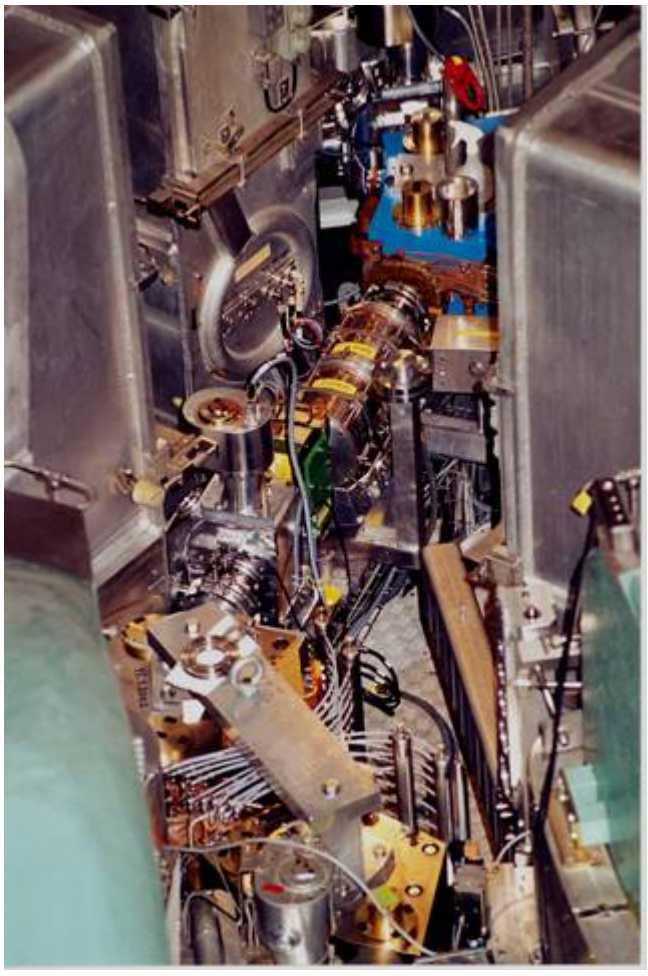

Fig. 2: Beam line section in the ring centre. The beam enters in front of the magnet at the top and leaves via the two magnets at the bottom.

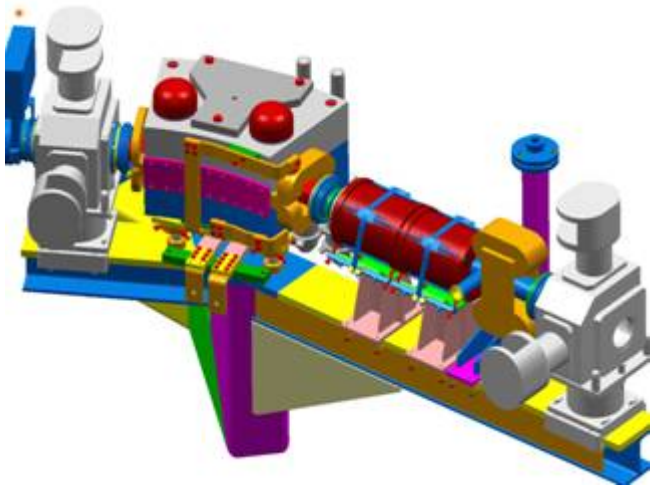

Fig. 3: Support unit of the first segment of the beam line. The new girder is extended to the magnet AND01 and also carries the profile monitor in front of AND01.

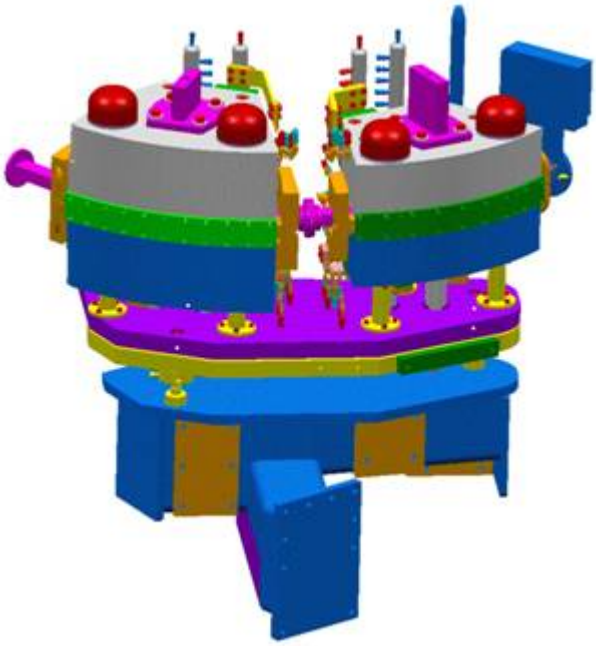

Fig. 4: Support console of the magnet doublet AND01 and AND02.

RAPID REPLACEMENT OF THE MAGNETS

The main ring injection beam line bending magnets ANC, AND01 and AND02 run under extreme conditions with high current density and consequent high velocity water-cooling. As an example, we can look at AND02 where we are feeding 1200 Amps into a 5 mm copper conductor. These magnets are therefore more liable to fail than most of the other magnets in PSI and we must be prepared for occasional breakdowns in such a way that the unavoidable radiation exposure of personnel and the lost beam time are kept to an absolute minimum. Before the modification, disassembly

involved removal of heavy copper cables, large water pipes and complicated vacuum connections under cramped conditions in a radiation environment. Following the modification, it is possible for one person plus a crane operator to complete the removal and subsequent replacement with a spare unit within a remarkably short time, measured in minutes rather than hours.

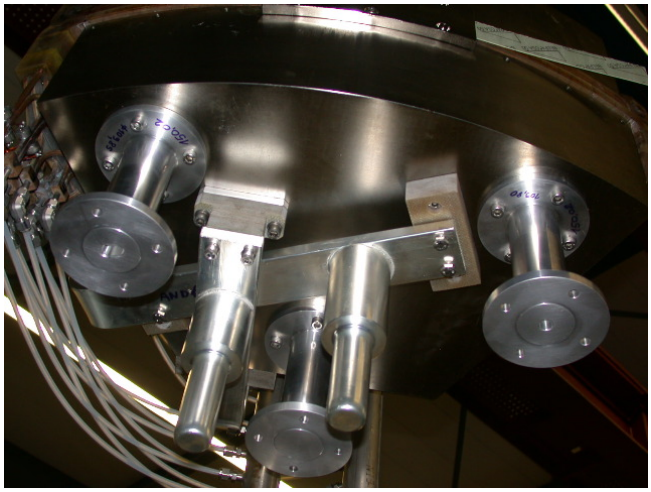

Fig. 5: The AND02 magnet fitted with electrical connectors and fixed feet ready for mounting on the base plate.

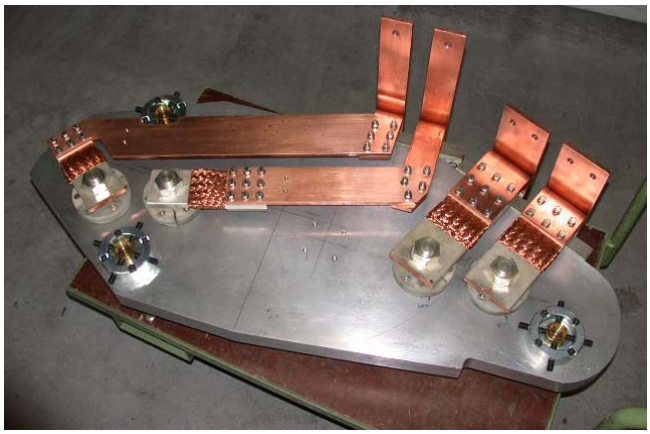

Fig. 6: The underside of the AND fixed plate showing the electrical connections from the flexibly mounted receptacles to the lugs where the supply cables will be attached, together with the supporting adjustable feet.

Plugs, connections and pins

The new electrical connections are made using commercially available “Multicontact” plugs suitably mounted using glass-epoxy clamps. The connection is made automatically during the magnet module assembly. Removing one standard plug by hand disconnects all the temperature switch cables. The cooling water connections are made using commercially available “Walther” connectors fitted with extra handgrips and special O-rings. Release just takes a moment and the supply pipe settles into its holder. These connectors also seal off the water passage on both sides.

The vacuum chambers are held in position with respect to the magnet yokes using welded pins (Fig. 11). This allows the use of expandable vacuum connection units, one on the entrance side of the AND01 vacuum chamber (Fig. 10) and one on the exit side of the AND02 vacuum chamber (Fig. 9). After removing the compressed air, the deflated units can be removed. The unit at the exit of AND02 replaced the existing bellows system and the space gained could be used to insert the vacuum valve VND6 mentioned above.

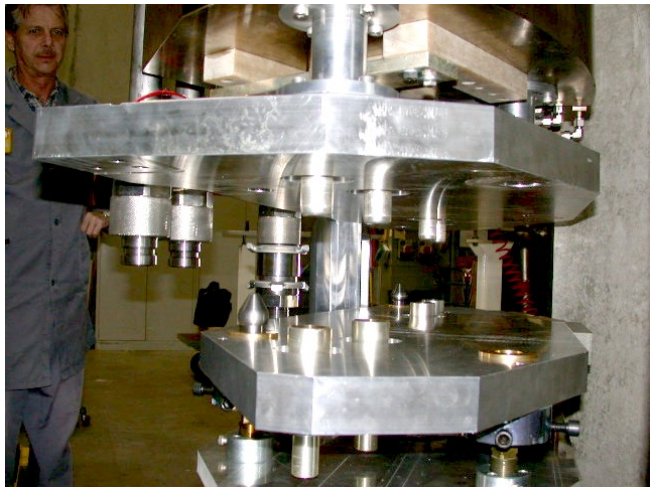

Fig. 7: The AND module in the connection plane. The electrical and water supply connectors as well as the positioning pins can be seen. The upper plate with the electrical contact pins and positioning holes and slots is the module base plate. The lower plate, with the receptacles for the electrical connectors and the mechanical positioning pins, is fixed. A duplicate serves as parking plate when the magnets must be removed from the centre for repair under reduced radiation exposure conditions or for preparation and pre-adjustment of the replacement magnets.

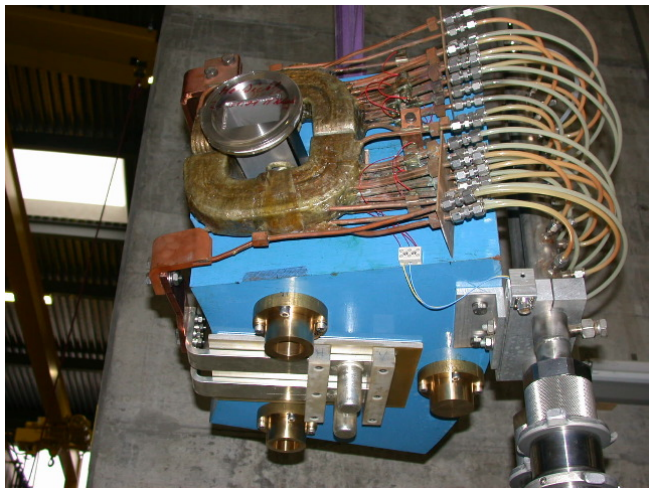

Fig. 8: The ANC magnet ready for assembly. The water supply manifolds, the electrical contact pins, the thermo-switch connection socket and the positioning attachments can be seen. The crane is attached at one point above the centre of gravity.

The module is then attached to the crane and can be removed in a controlled way. For the AND module (Figs. 5, 7, 12), the first motion is upwards, steered by vertical pins. The second motion involves a guided rotation about the main guide pin, to clear the protruding cavity, followed by a further vertical movement to a position where the module is free. The ANC (Fig. 8) module can simply be lifted vertically.

Fig. 9: The expandable vacuum connector together with its compressed air quick coupler ready for use.

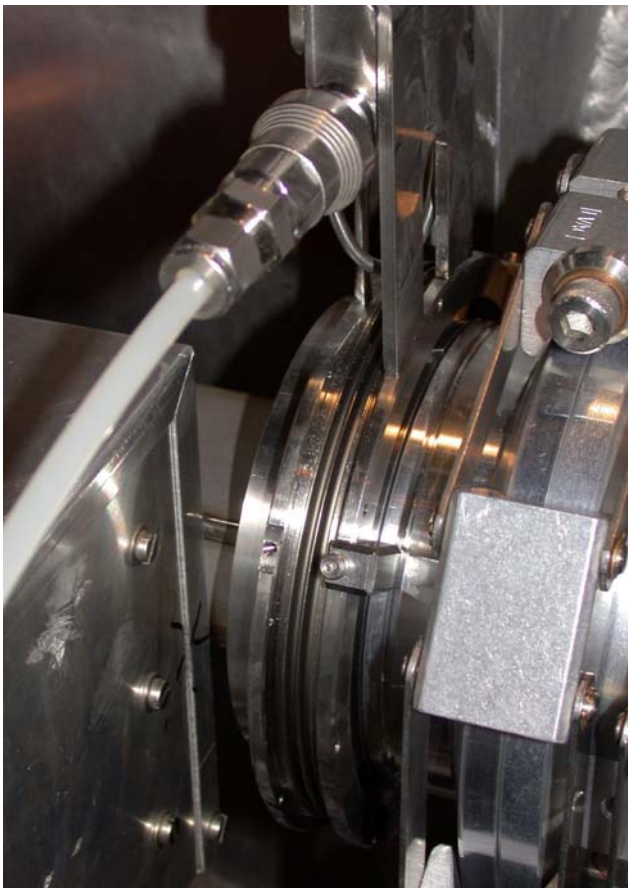

Fig. 10: One of the expandable vacuum connectors inserted at the entrance of the AND01 vacuum chamber.

ACKNOWLEDGEMENTS

It would have been never possible to accomplish the reconstruction of the beam line section in the ring centre without the valuable contributions with helpful ideas and the assistance of many colleagues involved in the project.

Fig. 11: The AND02 vacuum chamber with its welded positioning pins. The integrated bellows (left) enables the connection to the AND01 vacuum chamber to be made in a minimum of space using a standard chain fastener together with an aluminium seal.

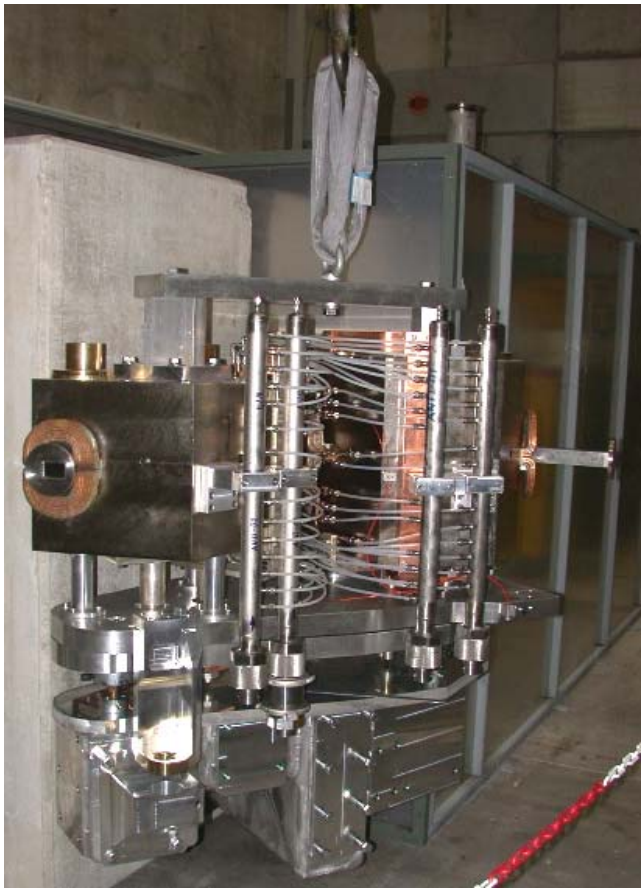

Fig. 12: The AND module during test assembly. One of the water supply manifolds is fitted with a quick coupler. The crane is attached at one point above the centre of gravity of the module. The main guide pin (front left) is not yet mounted.

We like to thank the infrastructure groups for the redesign and reconstruction of the supply lines for the cooling water and electrical connections, especially A. Weber, M. Strittmatter, W. Fichte, and T. Scherer. For the reconstruction work on the magnets and for their contribution during the installation of the magnets we like to thank W. Däppen and P. Pabst. We thank R. Erne for the important contribution to the reconstruction and installation of the beam line section and R. Knecht for the realisation of the independent vacuum section. The AMI division has supported us during the design, especially R. Ehrat, and the workshop, headed by H. Blumer