5.3 Beam Diagnostics for Beamlines

Summary: The beam diagnostic components for both the transfer and the high-energy beamlines perform well except for some of the scanners whose noise pick-up has become a problem, especially at low beam intensities. This noise pick-up is primarily due to deterioration of the bearings in the scanner. At some locations in the high-energy beamlines, scanners were replaced by harps as the scanners proved to be practically useless for the low-intensity beams required in the experimental areas.

The slits in the low-energy beamline, which are not water-cooled, have to be repaired at regular intervals because of vacuum leaks. Overheating causes the ceramic feedthroughs to deteriorate resulting in the vacuum leaks. Water-cooled slits have been ordered to replace the existing slits which will later be used in the beamlines associated with the second injector cyclotron SPC2.

Diagnostic components for the rest of the proposed high-energy beamlines as well as the new low-energy beamlines have been ordered and should be delivered later in the year.

The current-measurement system, which presented us with some spurious readings, will be slightly modified and should then be much more reliable.

5.3.1 Beam diagnostics for the transfer beamline

The main problems encountered with the beam diagnostic components of the transfer beamline were due to vacuum leaks on some of the slits. The leaks are caused by overheating of ceramic vacuum feedthroughs which are required for current measurements from the jaws of the slits. Although the tantalum slit-jaws themselves can withstand these very high temperatures, the heat from these jaws is conducted by the electrical wire connecting the jaws to the feedthrough, thus heating the ceramic feedthrough, melting the solder and causing a vacuum leak. We have thus decided to replace these slits with a slightly modified, water-cooled version, to overcome this problem. The slits are on order and should be delivered later in the year. The existing slits will later be installed in the beamlines associated with the second injector cyclotron SPC2, where the beam intensities will be lower.

As in the case of the slits, the Faraday cups in the low-energy beamlines are cooled mainly by heat radiation. As a result of the very high temperature reached when a high-intensity beam is interrupted by such a Faraday cup, unreliable current readings are obtained from these cups. This is due to thermal electron emission from the Faraday cups which is interpreted by the measurement system as beam current. We have thus decided to replace these cups with a water-cooled version to overcome this problem. These new cups are on order and should be delivered later this year.

Owing to the very high intensity of the beam at extraction from SPC1, the harp in the first diagnostic chamber was moved to the third diagnostic chamber i.e. after the extracted beam has been trimmed by a pair of slits. However, it was found that overheating of the harp was still a problem at this location and the harp was thus later replaced by a scanner, which performs satisfactorily.

The logarithmic current-measurement system has become more reliable since a software bug was eliminated during the year, resulting in reliable operation of the watch-dog monitor.

Apart from the overheating problems of the various components at high intensity, the beam diagnostic system of the transfer beamline performs well. The overheating problems should, however, be minimized once the new water-cooled Faraday cups and slits have been installed.

5.3.2 Beam diagnostics for the high-energy beamlines

The beam diagnostic equipment on all the existing high-energy beamlines performs well with the exception of some of the scanners, mainly owing to deterioraton of the bearing, causing noise pick-up. This renders them virtually useless for low-intensity beams. As a result we have replaced scanners with harps at several locations where diagnostic information from the scanners was insufficient for proper beam transportation.

We have designed, manufactured and installed two water-cooled collimators in the beamline for protection as well as for diagnostic purposes, one in the isocentric neutron therapy unit and the other in front of the switcher magnet in the isotope beamline.

Beamline D has been completed (refer to figure 1) and the lines P2, S and N are currently under construction. Beam diagnostic chambers for these beamlines have been delivered and the diagnostic components are on order and should be delivered before the end of the year.

5.3.2.1 Scanners and scanner electronics

The scanners have been used extensively during beam transportation adjustments and perform well at higher beam intensities. However, at low beam intensities, noise pick-up has become a problem on scanners owing to deterioration of bearings. Replacement of these bearings is a lengthy and difficult task, but will have to be performed on a routine basis. Owing to this problem, we have replaced some of the scanners with harps and plan to install only harps in all future beamlines, (beam-intensity permitting).

Noise levels of the scanners were, however, slightly reduced by not earthing the current measurement cable at the beamline itself, thus eliminating earth loops. An experiment to reduce scanner noise by reducing scanner rotational speed by a factor of ten, and consequent reduction of the bandwidth, was inconclusive in respect of profile jitter. Other options to reduce the noise levels are being investigated. A strobe light was used to check the consistency of the speed control of the scanners, which was suspect, and it was found to be sufficiently constant not to cause a problem.

5.3.2.2 Harps and harp electronics

A second set of harp electronics to serve up to eight harps has been delivered and installed in the high-energy electronics area. To date four harps have been installed and connected to this system and are fully controllable from the control console. Harps required for the rest of the proposed high-energy beamlines have been delivered. In general the harps and harp electronics perform very well and the maintenance required is minimal.

5.3.2.3 Pneumatic actuator control electronics

A fourth pneumatic actuator control cardframe has been completed and installed in the high-energy electronics area. It is used to control the harps and Faraday cups which have since been added to the existing beamlines, and will also be used to control actuators still to be installed in future beamlines. This cardframe has been connected to the safety-interlock system and via CAMAC to the control console.

5.3.2.4 Faraday cups

Improvements made to the Faraday cups in an effort to prevent water leaks which occurred from time to time are not quite satisfactory, and a new design for the layout of the flexible water supply tubes is being contemplated. At present the flexible tubes are coiled in a spiral in a cylinder to allow for the up and down movement of the Faraday cup when it is inserted and extracted from the beam. This movement causes deterioration of the tube, especially at the interface where it is connected to the stiff copper tube. This eventually leads to a split in the pipe and a water leak. The proposed improvement will allow the movement to be taken up outside the constraints of the cylinder, thus permitting a much larger loop in the flexible tube. This will not only increase the life expectancy of the tube but will facilitate visual inspection and simplify maintenance. A prototype of this design has been implemented on a Faraday cup which will be installed and tested before this modification is implemented sequentially on the others.

5.3.2.5 Beamline collimators

Two new collimators have been designed, manufactured in our workshop and installed in the beamlines. One is used for protection and diagnostic purposes at the entrance to the 160° bending magnet of the isocentric unit in the neutron therapy vault. This water-cooled, electrically-isolated collimator in effect replaced a short section of beamline, between the coils of the magnet, linking the vacuum chamber of the magnet to the rest of the beamline. In addition to the current measurement from the main collimator body, four individual electrically insulated segments protruding slightly from the body are used to measure beam current and thus provide indication of possible beam misalignment. The layout of this collimator is shown in figure 2.

The other new beamline collimator is installed right in front of the switcher magnet in the isotope production beamline. This collimator is also designed in such a way that it replaces a short section of beamline. 'O'-rings which are used as vacuum seals, perform the additional task of providing electrical insulation of the main body of the collimator from the rest of the beamline. This water-cooled copper body also supports four electrically insulated tantalum sections protruding slightly at the back of the body, to provide diagnostic indication of a misaligned beam. The layout of this design is shown in figure 3.

5.3.2.6 Current-measurement electronics

Progress has been made during the last year in uncovering remaining bugs in the current-measurement system, but fault conditions still arise from time to time.

A new input card has been designed for the current-measurement electronics and will be used in all the future systems to be installed. The prototype has been tested and mass production should commence soon. The power supply for this system has also been redesigned to take care of problems encountered with the resetting and monitoring of the system, and will shortly be built and tested.

We are still busy with the upgrading of the microcomputer software to run on an IBM-compatible type machine, as well as with the BITBUS software to be able to use the new BITBUS firmware.

5.3.2.7 The beam phase measurement system

The existing software for the beam phase measurement system has been extended to provide new features. Relative phase measurement, repeatable within approximately 0.1 degrees from day to day, is performed without intervention to make adjustments of any kind. Time-of-flight energy measurement making use of the five transfer beamline capacitive phase probes (CPPs) is similarly automated. Non-destructive current measurement on any given CPP is also possible after calibration of the detected CPP signal level against beam current observed on a nearby Faraday cup; medium term drift ot second-harmonic signal level so detected remains to be investigated.

The CPP electronics bases its amplitude and phase measurement upon the measured second-harmonic content in the capacitively-induced beam pulse train. Ever since this same harmonic frequency of the accelerating RF was chosen with which to drive the buncher, we anticipated that the transfer beamline CPPs would detect an unwanted second-harmonic directly from the buncher resonator situated on the transfer beamline. The level of this interference was quantified by measurements made recently, whereupon a test was also made for presence of the unwanted third harmonic with a view to performing phase and amplitude measurements on this harmonic instead. Interfering third harmonic was found to be present on the transfer beamline, and so to be unavoidably detected by these CPPs. Its level was found to be 40 dB lower than the unwanted second harmonic and still 30 dB higher than thermal noise in the final system bandwidth of 25 Hz, in which phase and amplitude measurements are made by the system at the second intermediate frequency (i.f.) of 1.5 KHz. Unless this interfering third harmonic presented to the transfer beamline CPPs can be reduced by at least 30 dB, the potential of the system to resolve phase within 0.1 degrees at beam currents down to 10 nA will not be achieved on this beamline.

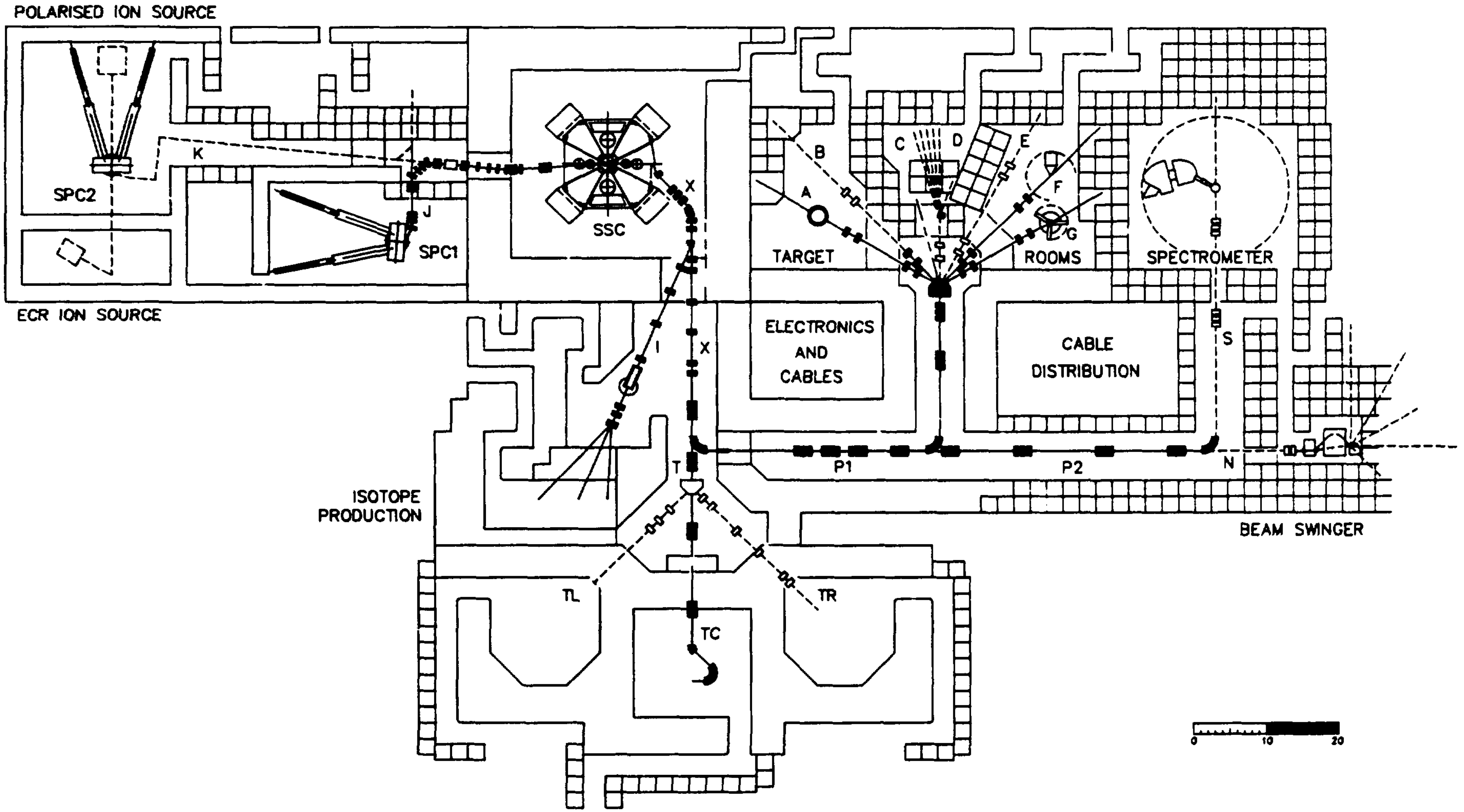

Fig. 1 Layout of beamlines within the shielded areas. Magnets already in position are coloured black.

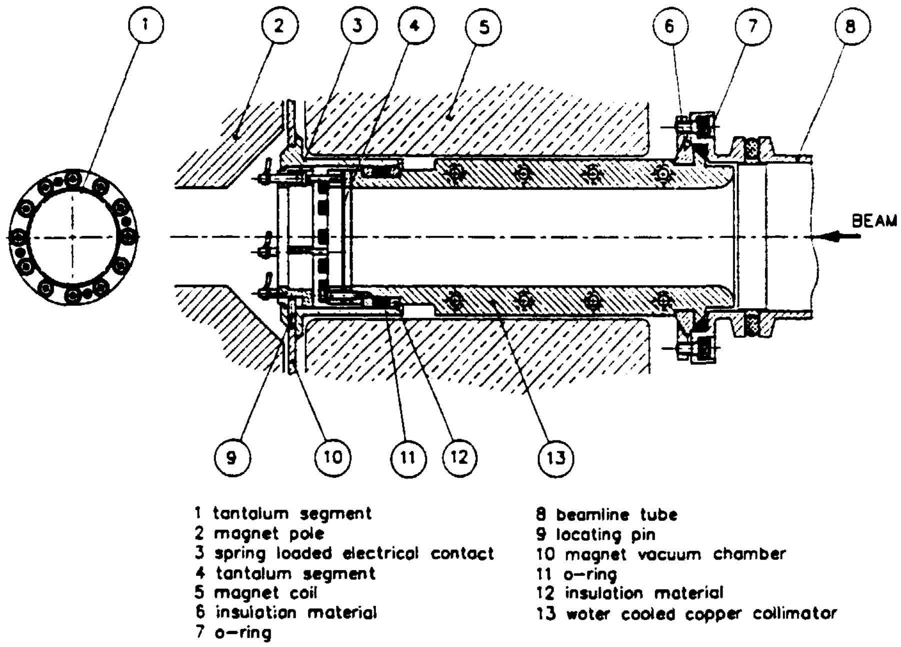

Fig. 2 The beamline collimator installed at the entrance to the 160° bending magnet of the isocentric unit in the neutron therapy vault.

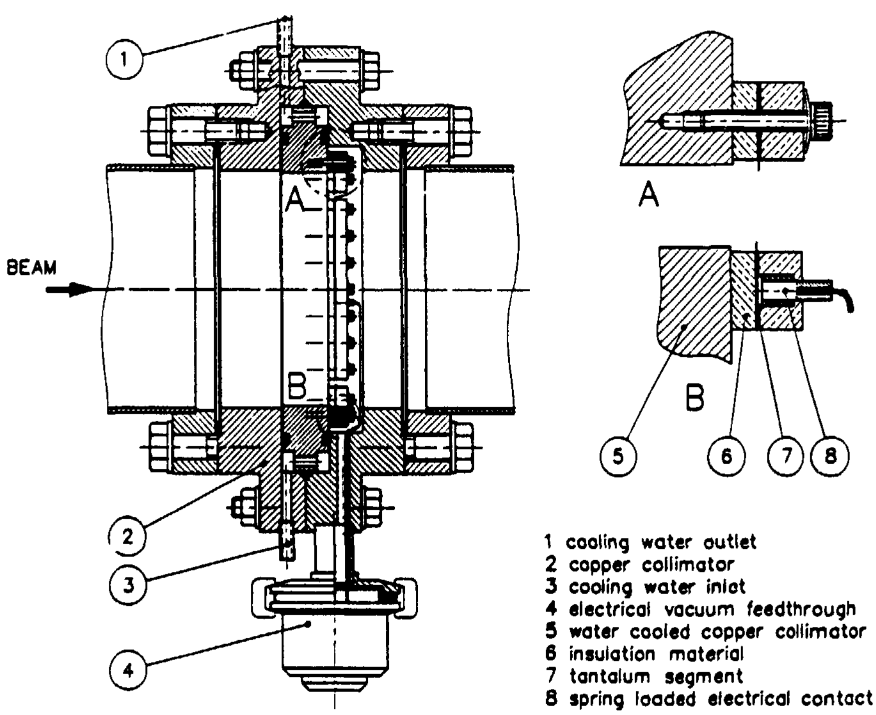

Fig. 3 The beamline collimator installed in front of the switcher magnet in the isotope production beamline.