Proceedings of the Tenth International Conference on Cyclotrons and their Applications, East Lansing, Michigan, USA

THE STATUS OF THE SOUTH AFRICAN NATIONAL ACCELERATOR CENTRE

A.H. Botha and H.N. Jungwirth for the NAC staff
National Accelerator Centre, CSIR, P.O. Box 72, FAURE, 7131, REPUBLIC OF SOUTH AFRICA

Summary

Two cyclotrons, an 8 MeV solid-pole injector cyclotron (SPC1) for light ions and a 200 MeV separated-sector cyclotron (SSC), are at present being constructed at the National Accelerator Centre. Beams of charged particles will be available for nuclear physics, isotope production and radiotherapy. Assembly of the injector cyclotron has been completed except for the extraction components. During December 1983 and January 1984 the first internal beams of protons were accelerated to 4 MeV, 6 MeV and 8 MeV. Three of the 4 sector magnets of the SSC have been assembled, and magnetic field measurements are now in progress. The two SSC resonators and power amplifiers have been completed and are now available for commissioning. Assembly of the transfer line is under way while many of the components for the high-energy lines have been delivered. Results of measurements on some components and the status of various subsystems are reviewed.

1. Introduction

The origin of the National Accelerator Centre (NAC), its aims and the lay-out of its facilities have been described before[1]. At the time of the previous conference the yoke of the SPC1 magnet and the first sector of the SSC had been assembled.

Since then the project has progressed to the stage where the injector has been completed, except for the extraction components, and the first three sectors of the SSC have been installed, with their vacuum chambers, main coils and trim-coils. The first of two SSC resonators and the two power amplifiers have been assembled. The transfer beamline, between SPC1 and the SSC, is now being put together.

The design of and progress with these and other components are reviewed in the following paragraphs, mainly with reference to recent photographs.

2. Injector Cyclotron

Fig. 1 shows a top view of SPC1. In the lower half of the figure can be seen (from left to right) the driving mechanism of a differential probe, the ion source drive, the vacuum system and a supporting structure for beam line components. Behind the magnet the quarter-wave co-axial resonators and two 25 kW power amplifiers are the most prominent components. Another differential probe drive is mounted between the two resonators.

Fig. 2 shows 7 circular trim-coils and their feedthroughs for water and power, welded onto a feedthrough ring, in the pole gap of the magnet. On the same frame as the trim-coils is bolted a set of harmonic coils, consisting of 8 coils on the lower pole.

Fig. 3 shows the vacuum chamber with the two conical sections, to which the outer conductors of the resonators are connected, and their copper liners. The top and bottom poles, together with the feedthrough rings, form the lids of the vacuum chamber. A bellows between the flange on which the resonator is bolted

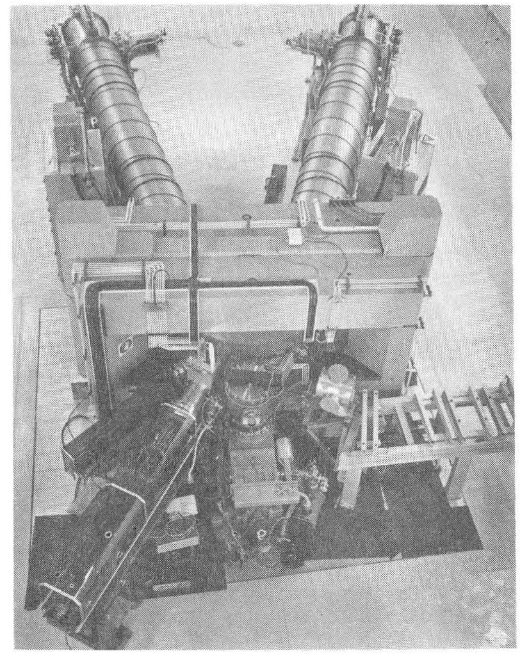

Fig. 1 A top view of SPC1 showing the magnet, the resonators and power amplifiers as well as the driving mechanism for probes and the ion source.

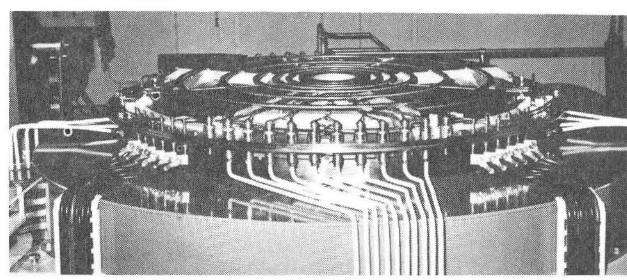

Fig. 2 The trim-coils of SPC1 mounted in the pole gap.

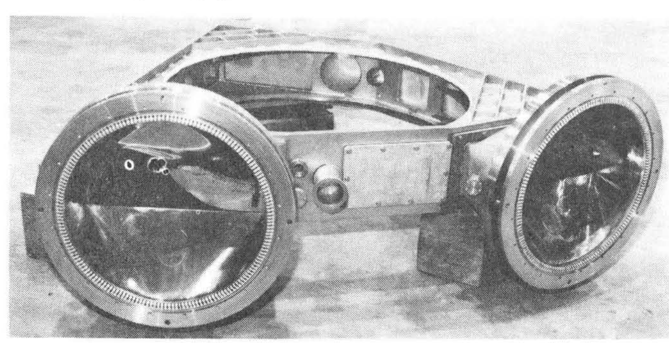

Fig. 3 The SPC1 vacuum chamber with the conical sections and their copper liners.

and a conical section allows adjustment of the inner and outer conductors of the resonator, independent of the vacuum chamber position.

In fig. 4 the two 90^{o}-dees and dummy dees, the ion source and one of the differential probes can be recognised. The ion source, which is based on the SIN source, has so far delivered currents of up to 900 µA for protons.

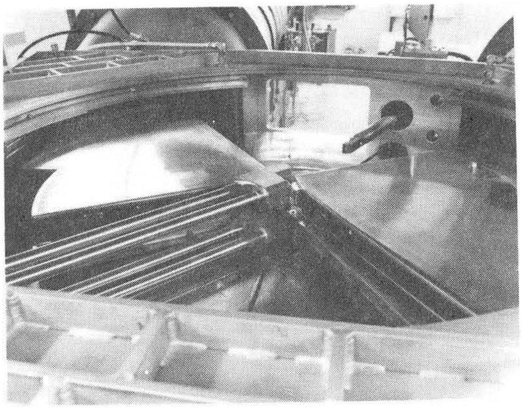

Fig. 4 A top view of the dees, dummy dees and ion source in the vacuum chamber.

A short-circuit plate in the process of being assembled is shown in fig. 5. Each plate consists of 9 segments on which 10 contact fingers are mounted on the inside. On the outside the number of contacts is 20. A dee voltage of 60 kV has been obtained at a phase- and amplitude stability of 0.1 degree and 10^{-3} respectively. Owing to residual inductance in the short-circuit plates, unexpected multipacting occurred between the plates and both the inner and outer conductors.

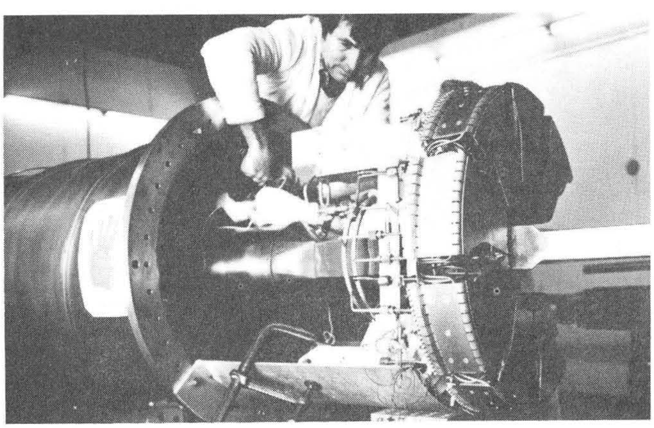

Fig. 5 A short-circuit plate in the process of being assembled on the inner conductor of a resonator.

Fig. 6 shows a radial beam distribution obtained by summing the finger currents of a differential probe for 8 MeV protons at a dee voltage of 41 kV. Except for the slots in the puller electrode no slits were then installed. The current on the probe body decreased from 500 µA near the centre of the machine to approximately 200 µA at the extraction radius.

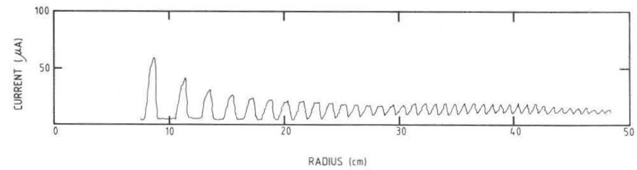

Fig. 6 Radial beam distribution for 8 MeV protons at 41 kV dee voltage.

One of the magnetic extraction channels can be seen in fig. 7. A radial gradient of 8 T/m at a current of 540 A can be obtained. The channel also acts as a steering magnet. A field increase or decrease of 0.1 T at a current of 224 A can be achieved. The channel is fitted with insulated water-cooled collimators. The second channel operates at a field gradient of 24 T/m for a current of 430 A through the coils.

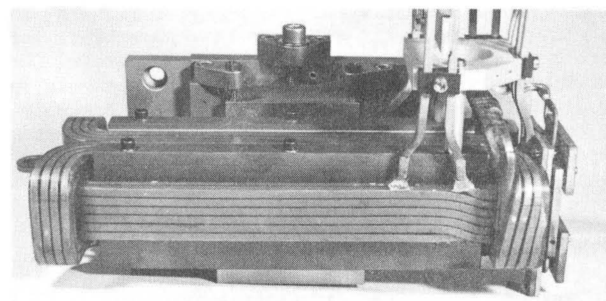

Fig. 7 Magnetic channel for SPC1. The channel steers and focusses the beam.

The central region, rf system, safety-interlocking system and results of magnetic field measurements are discussed in detail elsewhere in these proceedings.

3. Separated-Sector Cyclotron

The SSC is a four-sector machine with a sector angle of 34^{o}. Fig. 8 shows three sectors installed in the SSC vault with their vacuum chambers, trim-coils and main coils. A further set of coils around the central yoke pieces, providing up to 28 000 Ampere-turns on each magnet, is used to boost the average field, to generate first-harmonic components and to trim the field differences between the four sectors. A further advantage of these coils is the control over the field shape which they provide.

Fig. 9 shows a magnet vacuum chamber with a full set of trim coils on it. In total there are 29 coils each capable of carrying a current of 500 A. The trim-coils are insulated with a 0.35 mm Nylon coating, applied in the form of a powder after pre-heating the copper parts in hot air. Further insulation is added in the form of a 0.4 mm thick Melinex sheet on the vacuum chamber underneath the trim-coils, and a 0.05 mm sheet on the surface of each pole.

The vacuum chambers are supported from the poles by 48 studs on the top and bottom surfaces of each vacuum chamber. Field errors due to the presence of these studs and the holes in the pole plates have been compensated to within 0.23 mT by means of washers 0.46 mm thick and 19 mm diameter. It proved to be a surprisingly easy task to install the vacuum chamber in the pole gap and to position it in such a way that the 96 studs slipped into the holes in the pole plates.

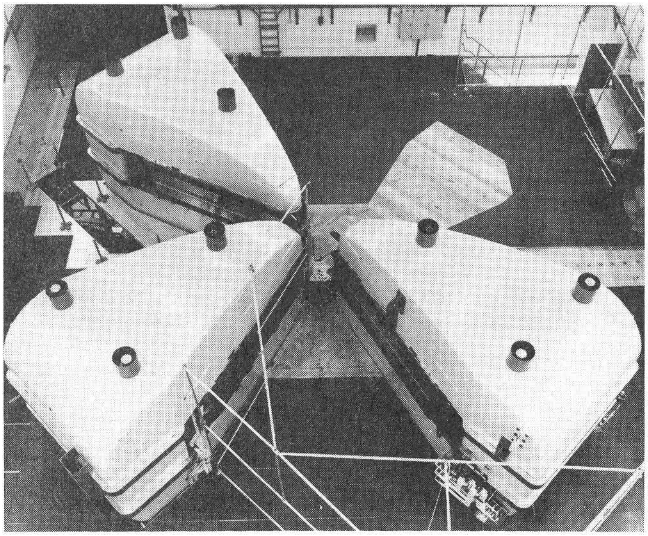

Fig. 8 Three of the four sector magnets installed in the SSC vault.

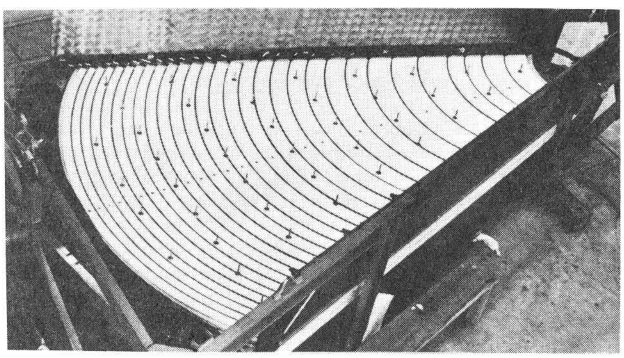

Fig. 9 A magnet vacuum chamber with a full set of trim-coils on the top surface.

Fig. 10 shows the magnetic field measuring system situated in the pole gap of a sector magnet. Field values are measured in the flying mode over a radial range of 3.7 m and stored at 20 mm radial and 0.25^{o} azimuthal intervals. The maximum statistical error is 0.3 mT at full excitation (1.25 T). The field falls off radially by 0.3% of the peak value at the extraction radius, and by 1% at the injection radius. A field difference of 20 mT can be obtained with a single trim-coil. Figures 11, 12 and 13 show results of field measurements. The various field distributions agree to within 1% of the maximum field value of 1.25 T with those calculated with computer programs POFEL3 and VEPO2[2].

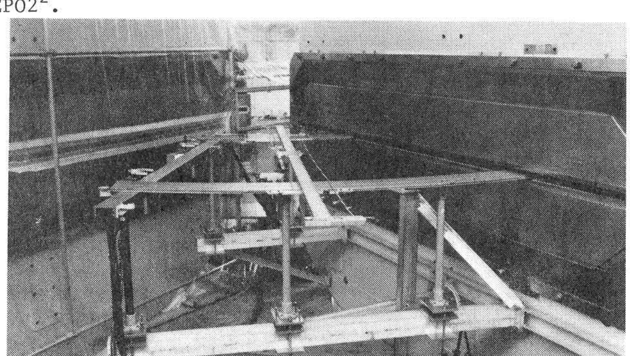

Fig. 10 The SSC magnetic field measuring system positioned in the pole gap of a sector magnet.

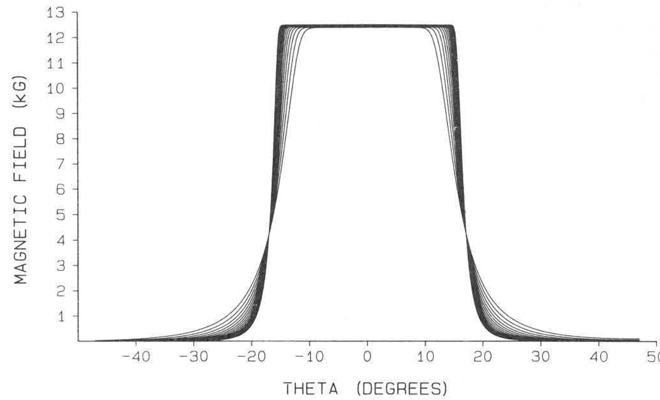

Fig. 11 The field of a sector magnet at full excitation.

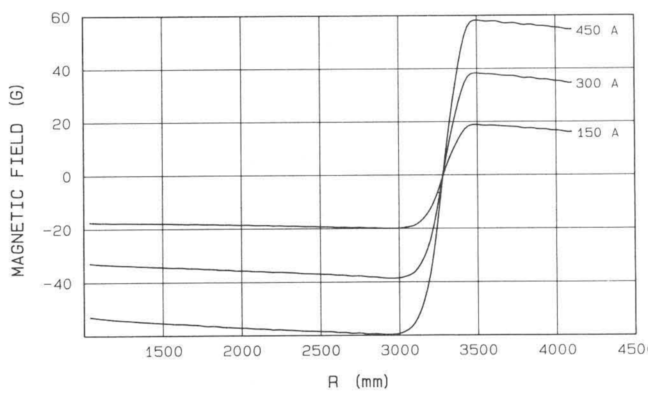

Fig. 12 Average field due to trim-coils 14 and 15.

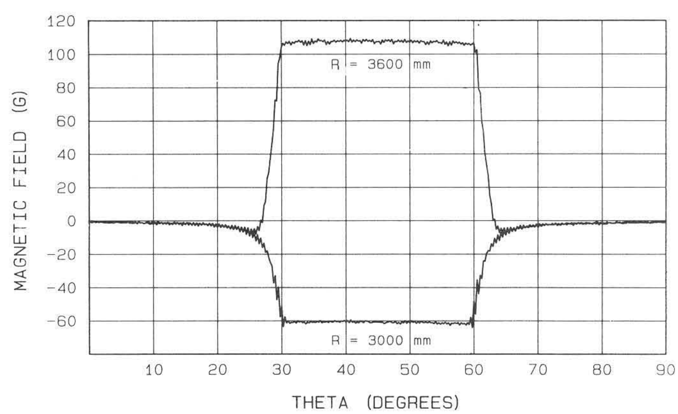

Fig. 13 Azimuthal field distribution due to trim-coil 15 at a current of 450 A.

The SSC resonators will operate at a dee voltage of 250 kV and can be tuned by means of short-circuit plates and variable capacitors over the frequency range 6 MHz to 26 MHz. Fig. 14 shows an assembled resonator. Above and below the outer triangular chamber, made from 40 mm thick copper-lined stainless steel plates, the two cylindrical co-axial resonators can be seen. Their inner conductors are connected to a triangular dee, as shown in fig. 15 for the lower half of the dee. The outer conductors are mechanically bolted to the stainless steel chamber and electrically connected to the copper liner. The copper surface of the dee is kept level by means of I-beams diverging radially from the junction of the dee and the inner conductor of the transmission line. For assembly, the dee splits in the median plane and the vacuum chamber separates at the top flange, which can be removed together with the outer conductor. Both resonators have been assembled and vacuum tested. The mechanical design of the short-circuit plates has been completed. Both power amplifiers have also been received. One of them has so far been commissioned. Each of these amplifiers can deliver as much as 150 kW to a resonator and can be tuned over the frequency range 5.5 MHz to 30 MHz. Tuning an amplifier to a particular frequency takes 25 seconds under control of a dedicated micro-processor.

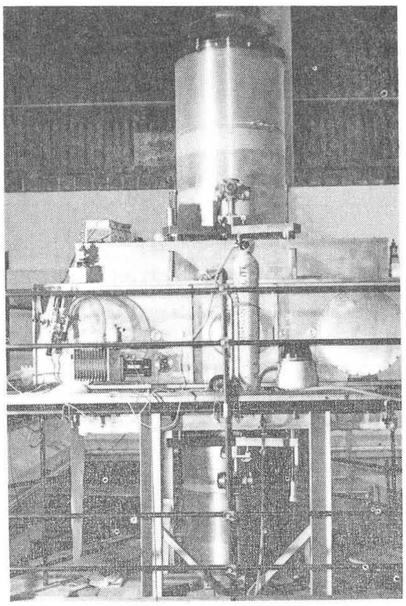

Fig. 14 An SSC resonator.

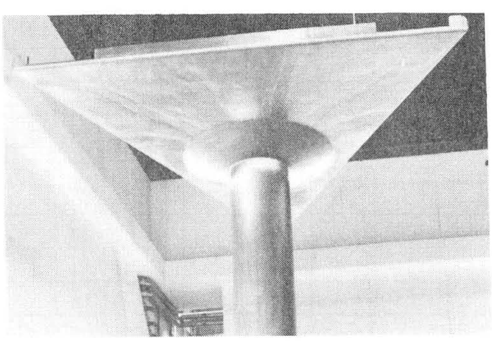

Fig. 15 The lower half of a triangular dee connected to the dee stem.

Two valley vacuum chambers, in many respects similar to the stainless steel chambers of the resonators, are on order. Ports on the top, bottom, front and back flanges make provision for installation of pumps, probes and injection and extraction components.

Some of the components of the injection system can be seen in fig. 16. There are two bending magnets with maximum attainable flux densities of 0.88 T and 1.69 T respectively, and two diagnostic chambers housing a harp, a scanner and a capacitive probe. Another component, not shown in the figure is the magnetic inflection channel situated in the pole-tip of a sector magnet. The field in the tip of the magnet is increased by 0.22 T at a current of 2400 A in the channel coils.

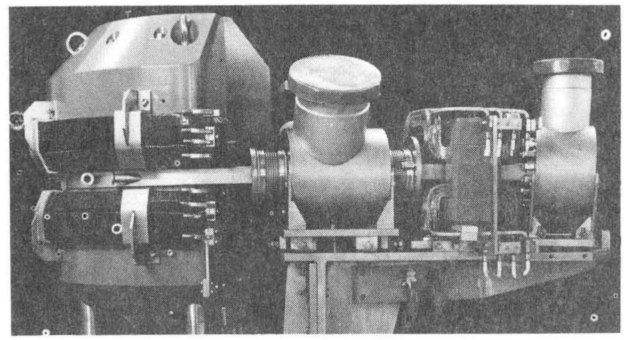

Fig. 16 The SSC injection system.

4. Beamlines

Assembly of the transfer beamline, between SPC1 and the SSC, has almost been completed. This line consists of 20 quadrupoles, 4 dipoles and 19 diagnostic chambers containing 37 diagnostic elements such as faraday cups, slits, capacitive probes, beam scanners and harps.

For the high-energy lines the quadrupoles and their power supplies as well as some diagnostic elements have been delivered. Orders have been placed for most of the dipole magnets.

5. Buildings and Services

The accelerator buildings as well as the vaults for nuclear physics, radiotherapy and isotope production have been completed. An office and laboratory building for isotope production is still under construction.

The transformer yard and the high-tension and low-tension switchgear have been installed and commissioned.

The central cooling system, consisting of 7 cooling towers and 4 chillers came into operation in 1983. Fig. 17 shows the pump and heat-exchanger room. Cooling water, at 20°C, is available on the secondary side of the heat exchangers.

Almost all the dc current-stabilised power supplies have been commissioned on site.

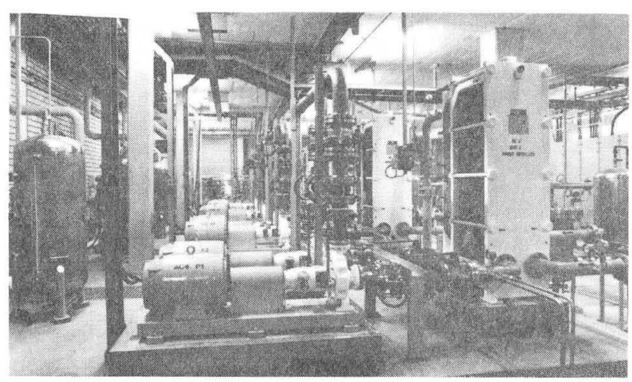

Fig. 17 The plant room of the central cooling system.

References

1. A.H. Botha, Proc. 9th Int. Conf. on Cycl. and their Applic. (Caen, 1981) p. 33.

2. H.N. Jungwirth and W.G. van der Merwe, Proc. 4th COMPUMAG Conf. on the Computations of Electro-Magnetic Fields (Genoa, 1983) to be published.