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Progress report on the construction of the Spallation Neutron Source at the Rutherford & Appleton Laboratories

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Abstract

This report is an update of the report given by G Manning at ICANS IV, KEK, in October 1980. The proceedings of that meeting give details of the specifications for the SNS and the financial and programme expectations for the project.

The SNS programme is proceeding well. Although there have been delays in producing some of the equipment, these do not appear to prejudice the time-scale being aimed for.

1. INTRODUCTION

This report is an update of the report given by G Manning at ICANS IV, KEK, in October 1980. The proceedings of that meeting give details of the specifications for the SNS and the financial and programme expectations for the project.

2. FINANCE

The financial approvals for capital have been updated and are now £14.405M for the machine and target station and £2.179M for the first seven instruments, all at 1.10.80 prices. The update is purely for inflation; no real extra cost is involved. This money does not include money for staff or for research and development items. The allocation to cover all costs for the SNS for the current financial year is £7.42M. This is about £0.5M less than that indicated in G Manning's last report. We aim to try to keep to the programme.

Approximately £6.2M worth of capital equipment has been ordered for the machine (out of £11.4M) and £0.25M on the target station (out of £3.0M). Only £150K has been committed on the instruments.

3. PROGRESS

An outline of progress on different parts of the facility is given below.

3.1 Civil Engineering and Services

All civil works for the synchrotron room and for the RF power supply have been completed on schedule. This work included the filling of a trench and provision of supports for the foundations for the ring and the provision of a flat floor inside and outside the ring to provide easy access for maintenance.

The mechanical services, such as cooling and ventilation, formerly used on Nimrod are being refurbished and installation of services in the ring building has started. Components for the electrical distribution system, eg transformers and switchgear, already available are being installed in places to meet their new task.

3.2 Injection

Updating of the cooling systems on the 4 tanks of the 70 MeV linac has been completed. Tank 1 has been fed with full RF power at 50 Hz using the new modulator feeding the original RF power tube. Conditioning was very quick. Presumably the improved vacuum conditions resulting from using the installation of turbomolecular pumps rather than diffusion pumps provide the reason why problems with multipactoring did not recur.

Tanks 1 and 4 and the drift tubes in them have been realigned.

The pre-injector voltage polarity has been reversed together with that of the 'bouncer' which compensates for voltage droop during the pulse.

Work on the ion source has concentrated on obtaining reproducible and reliable results at close to full duty cycle. Currents of 33 mA of H^- have been regularly produced. This work is discussed in the Accelerator session by P Gear. We aim to have a 655 kV H^- beam by September.

Good progress has been made in the development of the stripping foil as C Planner reports in the Accelerator session. Foils of 12 cm x 3 cm with 50 $\mu g/cm^2$ thickness of Alumina with one 12 cm edge unsupported have been produced.

3.3 Synchrotron ring magnets

As reported in October, all magnets for the 10 superperiods are on order. The 20 doublet quadrupoles have been delivered. There is good coincidence of the magnetic centre with the geometric centre. The trim quadrupoles which permit shift of Q-value during injection and acceleration have been tested and are also within specification.

The prototype singlet quadrupole is expected soon. The prototype dipole magnet will probably be one year late. There have been problems of gluing together the laminations into wedge-shaped blocks which are then put together to form the top and bottom yokes. The method so far used has been to coat the laminations with a wedge of epoxy resin which is then cured to B-stage using ultra-violet light. The laminations are then dry-stacked into a jig where they are heated and the end shape controlled under pressure. There have been problems with obtaining the correct heating so that the outer epoxy does not cure before the inner has softened and also with uneven pressures.

An alternative method is being investigated which would use laminations with dimples to obtain the wedge with vacuum impregnation of resin. The prototype coils and the first base are available.

3.4 Magnet power supplies

The choke and capacitors for the main ring resonant power supply have been installed. The DC bias supply has been delivered. The make-up supply will use a DC motor driving an alternator. Control of the speed through the DC motor will enable operation either locked to the mains at 50 Hz or a fixed frequency, eg 53 or 47 Hz. This later mode may be necessary for the operation of linked choppers for fine shaping of the neutron pulse.

3.5 Main ring vacuum

Following the successful testing of the 3 different prototype ceramic chambers, production is in full swing. The manufacturer of the ceramic sections has delivered all the components for the 2 types of quadrupole chamber including flanges. Six of the 10 3m chambers for the doublet and trim quadrupole module have been glued up using the glass-bonding technique. One chamber in the middle of the production run cracked for a reason not ascertained. Otherwise the production has gone well. The first production set of sections for the 36^o 5m chamber for the dipole magnet is available at the manufacturers. We shall change over to making this type of chamber to prove that the successful prototype was not just a fluke. The smaller chambers for correction magnets have been ordered as have the metal sections of chamber not subjected to magnetic fields.

All vacuum pumps have been delivered.

3.6 RF shields

Detailed design of the RF shields which fit inside the ceramic chambers is in hand. These present a low RF impedance to the beam to reduce destructive RF voltages seen by the beam. Final dimensions for beam size and aperture have been determined which take into account the expected shape of the fall-off of magnetic field at the edge of the dipole magnets.

3.7 Main ring RF system

A complete prototype RF system has now been built up and is ready for testing. The cavity itself was somewhat delayed by late delivery of the initial batch of copper discs for cooling the ferrite. There was also some delay in delivery of ceramic-metal components forming the two accelerating gaps in the cavity. The prototype RF amplifier which is removable as a unit and plugs into the cavity is ready for test into a dummy load.

As far as the production RF components are concerned, the 6 anode power supplies and the bias supplies are being manufactured. All the ferrite for the cavities has been delivered and properties measured. All is within specification. The properties will determine the position in the ferrite stack. All the cooling rings have also been delivered.

The design of the low power RF is proceeding well. Six more prototypes remain to be made of the 50 or so circuits required.

3.8 Diagnostics

The position monitors have been designed. The electronic head units for these have been completed. The mechanical components will be ordered in a few months. The special co-axial cable required will be ordered very soon.

A prototype intensity monitor is under construction. The measurement of beam profile presents a very difficult problem. A method based on measuring ions produced by the proton reaction with residual gas molecules has been evolved. To measure the betatron frequency of the circulating protons the protons will be perturbed transversely and the resultant oscillations measured. A prototype system has been successfully built and tested.

The design of special diagnostics required in the injection straight have yet to be integrated with the injection straight design.

3.9 Extraction

Significant progress has been achieved since the last report. The kicker magnet rise time has now been reduced to below the 220 ns spacing between the 2 bunches.

3.10 Beam loss protection

A full description of the scheme was given in the last report. Development of the hardware is proceeding.

3.11 Extracted proton beam line

The DC septum magnet design is being developed using existing magnets powered from the final power supply which is already installed. Design of the second vertical bending magnet is continuing. Part of the shielding for the EPB tunnel has been installed.

3.12 Target station

A description of the target station was given by A Carne in the ICANS-IV proceedings. As indicated in that paper, there were difficulties in obtaining satisfactory cladding of the uranium target plates with Zircaloy-2. An order has now been placed for work which will use the hot isostatic pressure bonding technique.

The decision to have a 20°K moderator has been reconfirmed. In addition, there will be two ambient temperature moderators and one at 77°K.

The target assembly is mounted in a cylindrical vessel 3.2 m diameter by 3.8 m high which provides a contained helium atmosphere at reduced pressure. The detailed engineering design is about 70% complete. The target vessel has 18 double skinned aluminium windows for the neutron beams. The design of these windows and their remote handling equipment has been carried to the proof-of-feasibility stage.

The energy deposition in the shutter system has been calculated to be 13 kW. This heat will be removed by flowing air, to be exhausted via the extracted beam line shielding enclosure into the magnet hall. Design of the shutters proceeds and the vertical movement will be provided by mechanical jacks.

The outer bulk shielding will contain 75% iron and 25% concrete. The iron will be in the form of large blocks of former Nimrod shielding. A large milling machine has been installed in Hall 3 for machining the blocks to the required shape. The bulk shield will contain inserts, fabricated from steel plate, which contain apertures in which the neutron beams will be mounted. The order for the inserts has been placed.

The target station plinth provides shielding under the target and a stable common foundation for the bulk shield and remote handling facility. It consists of a reinforced concrete tank with a waterproof membrane and contains 3 layers of Nimrod magnet sectors and pole pieces and on top a 0.18 m reinforced concrete plate. A double-walled stainless steel drain has been installed to connect eventually the void vessel to the underground shielded dump tanks. Steel plates which form the base for the shutter system have been manufactured and are currently being installed, together with a central survey pillar.

Major dimensions of the remote handling cell have been determined and design of the interior is continuing. The main areas of study have been use of the manipulators (the first pair of which has been delivered), design of the target storage wells, recess doors and ventilation.

A mock-up remote handling cell has been built to study in detail the problems of handling the components of the target assembly. Prototype components and handling fixtures have been made.

The first of the two zinc bromide windows for the remote handling cell has been ordered. This window will be used firstly in the mock-up cell.

A first draft of the Target Station Safety Assessment has been prepared for discussion purposes. In addition to satisfying the more conventional requirements the assessment has aimed to show that:

a) The overall target station design takes proper account of the principal hazards, ionising radiation and radioactivity, and that we are able to meet our statutory obligations under Radiation Protection legislation.

b) Under extreme fault conditions, such as a target melt-down, the release of radioactivity will be contained in a closed volume.

c) The release of activity into the raw water supply (and hence dispersal to the environment) would require the breaking of three physical barriers. This is backed up by continuous monitoring of activity levels and the ability to safely isolate the target.

3.13 Controls

Work on both the software and hardware continues. The satellite computer for the injector system has been installed and will be used for the 665 keV beam commissioning in September.

3.14 Experimental instruments

The SNS project provides for 15 instruments, 14 of which have been identified and 7 have received approval for construction. Of these 7, the Liquids and Amorphous Materials Diffractometer (LAD) and the High Throughput Inelastic Spectrometer (HTIS) are being built for installation on the Harwell linac. The main shielding tank for LAD has been delivered and all other components are on order. It should be installed at the linac in the summer of 1981. Detailed design is complete for HTIS and the majority of the components ordered, in particular the beryllium for the filter. The latter will not be delivered before the autumn of 1981 and is on the critical path for the project, which will be completed in the Spring of 1982.

Detailed design is complete for the following 3 instruments:

1. High Intensity Powder Diffractometer
2. High Resolution Powder Diffractometer
3. High Energy Transfer Spectrometer

Manufacture of these now awaits provision of funding.

No further work has been done yet on the remaining 2 of the 7 approved instruments; the Low Q Diffractometer and the quasi-elastic instrument IRIS.

The state of the remaining 7 instruments is as follows:

1. Small Angle Neutron Diffractometer for Liquid and Amorphous Samples (SANDALS) - outline design and cost estimates are complete.

2. Medium Energy Transfer Spectrometer (MET) - outline design is at an early stage.

3. Single Crystal Diffractometer (SCD) - completion of outline design awaits experience on the linac which will decide the type of detector.

4. Polarised Neutron Spectrometer (POLARIS) - the major components of this instrument, two polarising filters, are being funded by the NBR Programme. One filter is well proven and the dilution refrigerator for the second has been commissioned. Final design of the SNS instrument awaits experience on the linac.

5. Constant Q Spectrometer (CONQ) - design of the SNS instrument will depend on experience gained with the existing linac instrument.

6. High Symmetry Spectrometer (HYSYM) - design awaits the results of a test experiment on the linac.

7. eV Spectrometer (EVS) - again, the design of the SNS instrument will use experience gained from experiments on the linac.

Work has begun on the scientific specification of SNS beam collimators and beam stops.

A technical trawl was carried out early in 1980 of possible suppliers for the PUNCH Computing System for instrument control, data collection and data reduction. No further work will be done until funds are available.

4. OTHER USES OF THE SNS

There is interest in other uses of the SNS. The status of these is given below:

4.1 Intermediate Target Station in the EPB

The design of the system that transports the proton beam to the SNS Target Station has been made so that an intermediate focus can be produced 22m upstream of the SNS target. If no target is placed at this focus the full beam will be delivered to the SNS target with no deterioration.

If a target of 5 cm of carbon is placed at the intermediate focus 12% of the protons will interact in the target and the rest will be delivered to the SNS target with a slight increase in the beam divergence and a slight decrease in energy - the neutron yield would be reduced by 15%. Adequate shielding must be provided around the intermediate target to reduce radiation to below the tolerance levels for biological and experimental purposes.

Secondary beams can be formed from particles produced at this intermediate target. Two such beams are a pion beam for biomedical experiments and a muon beam for either muon spin rotation experiments for use in condensed matter research or for studies of rare muon decays.

A proposal has been made to the Medical Research Council and SERC for the construction of a pion beam for biomedical research at an estimated cost of £1.2M. The MRC has agreed to pay half of the £78K required to carry out work on the construction of the shielding for the EPB and the beam transport equipment to keep open the option for the construction of the pion beam and the muon beam. The SERC has agreed to provide the other half of the money.

4.2 Neutrino Facility

A cavern has been constructed below floor level adjacent to the SNS Target Station.

A Letter of Intent has been produced proposing to construct a detector and to carry out neutrino experiments using the SNS. A group from Karlsruhe is also considering a proposal to undertake neutrino experiments on the SNS and this may involve increasing the size of the neutrino cavern.

The neutrino experiments are completely compatible with neutron experiments and will in no way interfere with the requirements of the neutron beam exploitation.

4.3 Irradiation Facilities

An investigation has been made of the possibilities of using the 70 MeV beam from the linac for isotope production. The cost of these studies was covered by the Radiochemical Centre at Amersham. They have decided not to request us to proceed with the implementation of the resulting plan at this stage. Further possibilities of using the small neutral beam formed when the H^- beam passes through the stripping foil, or other parasitic possibilities, may be investigated at a later stage.

There is also the possibility of providing fast neutron irradiation facilities close to the SNS target. This is of interest to study radiation damage of materials relevant to fusion and/or fission energy sources. The Energy Committee of the SERC has agreed to provide £30K for the provision of an access tube in the Target Station to permit the option for an irradiation facility to be kept open.

If this facility is provided it will be compatible with the neutron beam use of the SNS.

4.4 Charged Particle Test Beam for HEP

A study is in hand to provide a charged particle test beam in Hall 1 for use by high energy physics teams. The beam will be formed using particles produced by beam lost in the SNS Machine Room during acceleration or extraction.

Every attempt will be made to minimise the beam lost and under no circumstances will beam be deliberately lost to increase the test beam intensity. The requirements of the test beam are not stringent and it is virtually certain that there will be no difficulty in meeting the needs - it is not possible to be completely certain until we operate the SNS.

The Nuclear Physics Board of SERC will pay for any expenditure required for this test beam and the facility will be parasitic on normal SNS operation.

4.5 Use of the SNS for accelerator studies relevant for heavy ion fusion

Many groups throughout the world have been investigating the possibility of achieving controlled fusion as an energy source by using beams of energetic heavy ions to compress hollow pellets of dimensions of a few millimetres containing deuterium and tritium. The studies indicate that the ions need to be singly charged uranium of 10-20 GeV energy. These particles have the same velocity as protons of about 70 MeV. These paper studies indicate that beams have to be produced that are very intense and have to be tightly compressed in time and space. The space charge effects are very large and experimental verification is needed to prove that the required compression can be achieved. The cost of a suitable 10-20 GeV heavy ion accelerator is extremely high ($\gg$ £10^8) and hence it is necessary to make studies using a suitable scaled model. The SNS with the 70 MeV injected beam is a perfect model and is uniquely suitable for all the existing or planned accelerators.

RAL has recently held an international Workshop to consider the possibilities of using the SNS for these model studies relevant for heavy ion inertial confinement. RAL proposed a programme costing about £1.6M over a period of about 5 years. The Workshop supported the proposed programme and many laboratories expressed interest in participating.

The requirements for the SNS are believed to be compatible with normal SNS use but require about 12 days per year of dedicated use of the SNS. It is unlikely that normal SNS operations will be able to use all of the available time because of financial constraints so it is probable that the dedicated time could be given without conflicting with normal SNS utilisation.

It is intended to develop this programme as a formal proposal.

5. CONCLUSION

The SNS programme is proceeding well. Although there have been delays in producing some of the equipment, these do not appear to prejudice the time-scale being aimed for.