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PROGRESS ON CONSTRUCTION AND COMMISSIONING OF THE SPALLATION NEUTRON SOURCE AT THE RUTHERFORD APPLETON LABORATORY

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ABSTRACT

This paper gives details of progress on the Spallation Neutron Source which is due to produce first neutrons in 1984. It updates similar reports given in ICANS-IV, V and VI. Since ICANS-VI the injector has been successfully commissioned to give 70 MeV H^- beams which have then been transported through the transfer line from the linac to the injection straight of the synchrotron.

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1. INTRODUCTION

This is an update of reports given by myself at ICANS-IV and D A Gray at ICANS-V and VI. The main parameters of the SNS are given in Table 1, with a layout in Fig 1. A full description of the project is given in Ref 1.

Since the last ICANS meeting the first SNS milestone has been achieved with successful commissioning of the 70 MeV H^- injector system during January 1983. Subsequently H^- ions have been transported through the transport line from the linac to the injection straight of the synchrotron.

2. FINANCE

The financial approvals for capital have been updated to £15.58M for the machine and target station, and £2.45M for the 7 approved instruments. The update is purely for inflation. This does not include costs for staff nor for design, research and development costs. The allocation to cover all costs for the SNS in the current year is £10.15M.

Approximately £13M worth of capital equipment has been ordered for the machine and target station, and £1M for the initial instruments. The money is consistent with the planned date for first neutrons in October 1984.

3. PROGRESS

3.1 Injector and Injection System

70 MeV H^- ions were successfully accelerated in the linac during January 1983 and subsequently the beam has been transported through the transfer line over the synchrotron and back to the entrance to the injection straight of the synchrotron (see Fig 2).

TABLE 1: MAIN PARAMETERS OF THE SNS

Proton design energy	800 MeV
Proton design intensity	200 μA
Nominal repetition frequency	50 Hz
Injection scheme	H^- charge exchange
Injection interval	376 μs
Injection energy (protons)	70.44 MeV
Injected protons/pulse	5×10^{13}
Emittance H^- ions	25×10^{-6} rad m
Mean radius of synchrotron	26.0 m
Number of superperiods	10
Dipole field at 70.44 MeV	0.1764 T
Dipole field at 800 MeV	0.6970 T
Betatron tune (Q_h, Q_v)	4.31, 3.83
Beam emittance at 70.44 MeV H	$540\pi \times 10^{-6}$ rad m
V	$430\pi \times 10^{-6}$ rad m
Number of RF cavities	6
Frequency swing (harmonic No = 2)	1.34 to 3.09 MHz
Vacuum chamber in magnet	Ceramic
Target material	Depleted Uranium
Fast neutron production rate	3×10^{16} n per sec
Neutron current from surface of moderator	$10^{15} - 10^{13}$ s^{-1} $ster^{-1}$ eV^{-1} (.01 eV - 1 eV)

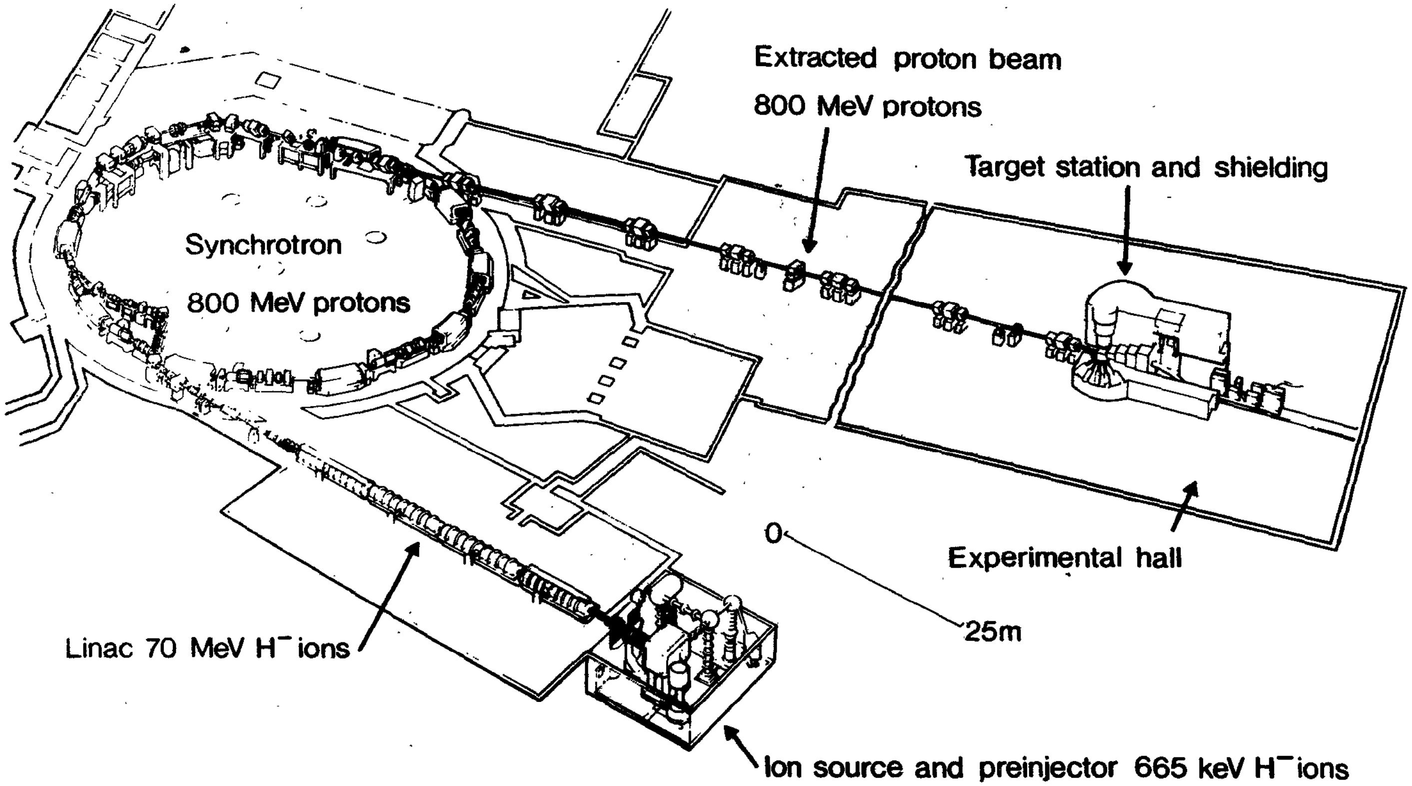

FIG 1 : LAYOUT OF THE SNS

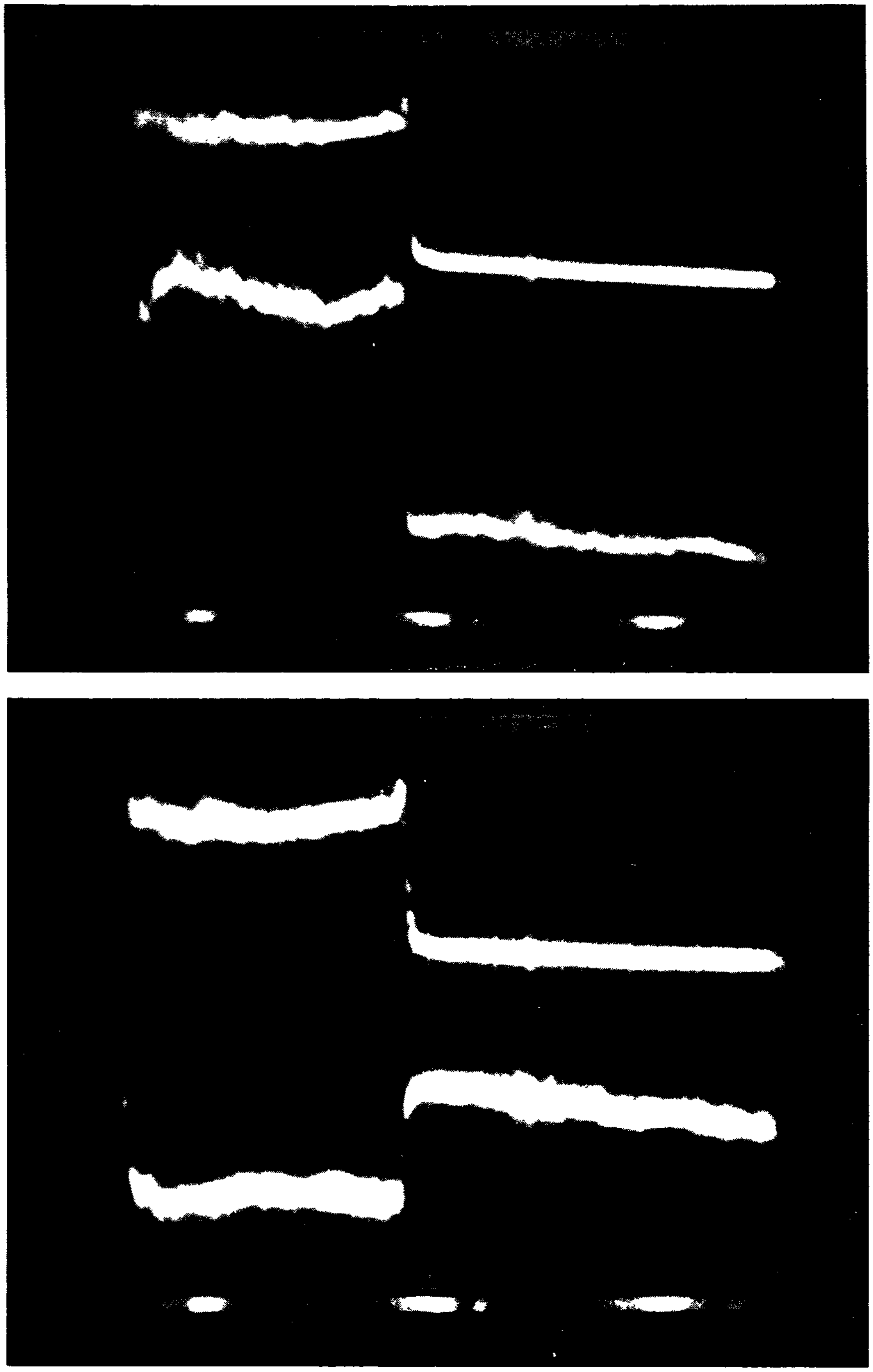

FIG 2 : FIRST 70 MeV H^- BEAM

Top trace - Input to Tank 1 4mA
Second trace - End of linac. 70 MeV foil out.
Third trace - Input to Tank 1
Bottom trace - End of linac. 70 MeV foil in.
Pulse length - 200 μs

The linac transmission is as expected with the buncher operational, viz 60%. The matching into the linac and the linac quadrupoles have been adjusted so that the beam loss is not measureable along the length of the higher energy part of the linac. To reduce induced activity levels in the 70 MeV beam stop the mean current during tests is kept to a maximum of 1 A (400 A mean is the design requirement). Pulsed currents of 3-4 mA have been used, the mean current is kept down by shortening the pulse length and reducing the repetition rate to typically 50/32 pps. The ion source arc is kept running at 50 pps. Ion source lifetime has been determined by the amount of caesium put into the caesium boiler. In one case 1 g of caesium lasted 120 hours of actual running. Another lasted 130 hours and is still working.

Emittances of the beam have been measured as follows for 99% of a 3 mA beam at 70 MeV:

	Horizontal	Vertical
Typical	12.5 π μmr	25.0 π μmr
Minimum measured	9.5 π μmr	10.2 π μmr
Specification (at 20 mA)	25.0 π μmr	25.0 π μmr

The linac is currently capable of producing enough 70 MeV beam to give about 30% of the design SNS high energy current.

Diagnostic devices in the linac and transfer line include toroids and 14 profile monitors using a scanning wire device to give horizontal and vertical profiles at each location.

The profile monitors are used for measuring emittance and steering and transfer matrix measurements in the transfer line and, by normalisation, can measure beam currents since the high vacuum quality toroids close to the synchrotron are not yet available.

A 'straight-through' branch of the transfer line at the final bending magnet is equipped with a scintillator and raster scan TV camera. The chopper, which will eventually be used to provide half-circumference length pulses in the synchrotron for injection studies, has been used to produce short pulses to prevent overheating of the scintillator. Beam has also been put down the third branch destined to be used, in collaboration with GSI, Darmstadt, for studies relevant to heavy ion fusion.

For the injection system, the septum magnet and its power supply are available. The 4 beam bump magnets have been installed in the injection straight. The power supply which supplies 14,000 A, 500 s long pulses at 50 pps is over a year late. It has passed its performance tests at the manufacturers and delivery is expected during August.

A batch of 5 stripping foils of the correct size have been successfully made. A further batch of 20 is being made.

It is planned to run a test of beam into a foil with the bump magnets powered some time during September.

3.2 Synchrotron ring

All components required for the next milestone, injection and trapping studies, are to hand except for the dipole magnets. The ring is expected to be ready for injection at the end of the year. Three of the 10 dipoles have been delivered and have successfully passed power tests. The effective magnetic lengths at both injection and extraction field levels were within ±0.5 mm as in the specification.

Supports for all synchrotron components are in position. Straight section components are being aligned without the aid of the bending magnet datum points. One straight section is completely installed with all vacuum joints made. A decision has been made that the ring will not be vacuum tested in sections following a satisfactory test on a section including the roughing line. Fitting together the modules especially those with RF shields and their associated capacitor rings requires careful work.

Trial fittings of the RF shield in the curved ceramic dipole vacuum vessel has been done to evolve the system for the production dipole installation.

Main ring diagnostic devices are installed in the ring, including position monitors, intensity monitors, profile monitors and a kicker magnet system for exciting betatron oscillation. Beam loss collectors will be installed initially for beam lost horizontally up to about 100 MeV. Ionisation chambers for beam loss detection will be installed around the ring (as well as along the injector and injection and extraction lines).

3.3 Magnet power supplies

Final wiring of the main magnet resonant power supply is in progress. The new make-up power supply consisting of a DC motor and singe phase alternator has been successfully run. The computer-controlled supplies for the trim quadrupole magnets are installed.

3.4 RF System

The next milestone requires 2 of the 6 RF systems for trapping studies. Two cavities have been installed in the synchrotron room. RF amplifiers have been built and are being installed. The 6 anode power supplies have been installed and tested into a dummy load. A potential problem of spikes into the mains from these supplies has been shown to be of no concern. Operation of the crowbar circuit of one supply does not trip another supply. Controls and ancillary supplies for two systems are ready for operation. The DC power supplies for the bias windings are installed. Trials on the prototype bias transistor regulator of about 50 kW showed a good frequency response. The first production regulator is installed. Sufficient low power RF equipment is available for the first system tests which are now in progress. Manufacture of the remainder of the four systems is proceeding well.

3.5 Services

Many raw water, demineralised water and chilled water systems have been installed and commissioned on systems as required.

3.6 Extraction

The extraction system consists of 3 kicker magnet systems with rise time of some 200 ns and a septum magnet to give a vertical deflection to the beam. Installation of the kicker power supplies is in hand. Each kicker is powered by two thyratron switched bumped delay lines. One complete system has been commissioned and is successfully powering one of the kicker magnets through the correct length of feeder. Boxes for the kicker magnets are being manufactured.

The septum magnet has been designed following work on a model to obtain field uniformity and sufficiently small fringe field into the working region of the synchrotron. The septum magnet power supply is installed but not yet wired up. The milestone date for extraction tests with 550 MeV protons is July 1984.

3.7 Extracted proton beam

The extracted proton beam takes the beam above and outside the synchrotron, back to target height through a shielded tunnel to the target.

The concrete plinths for supporting the beam components in the synchrotron room have been installed. The special bending magnet which comes after the extraction septum magnet to turn the beam horizontal has been manufactured and tested and is installed in the synchrotron room. Other components are being manufactured. The tunnel shielding walls have been installed and lined with concrete.

3.8 Target station

The progress on the target station will be reported in detail at this meeting by A Carne. Briefly:

i) Uranium target plates for 2 targets have been ordered.

ii) The target void vessel which contains the target, moderator, and reflector assembly is to be delivered in August.

iii) Target station main shield is being installed. Shielding wedges which support the neutron shutters have had a trial installation. Shutters are being delivered.

iv) The Remote Handling Cell and the Services area are being built up.

v) Refrigerators for the liquid hydrogen and liquid helium moderators have been ordered.

An important conclusion from the safety assessment is that the target plates will not melt, even if all cooling systems fail, provided the proton beam is turned off as soon as a fault condition is detected.

3.9 Controls

The controls system of 4 linked computers is being installed in a phased manner. The linac system has been used for the commissioning work on the linac. Many equipment designers are writing control programmes in the high level interpretive language 'GRACES'. Tuning of the system software has gone along in parallel.

4. SNS EXPERIMENTAL FACILITIES

Technical and scientific details of the first batch of SNS instruments were given at ICANS IV.

4.1 Liquids and Amorphous Materials Diffractometer (LAD) and High Throughput Inelastic Spectrometer (HTIS) - both LAD and HTIS are now in operation at the Harwell linac and will be transferred to SNS in the Spring of 1984.

4.2 High Resolution Powder Diffractometer (HRPD) - this is well advanced. The building is about half complete. The sample and detector tanks have been made, the glass guide tube sections have been delivered and the first octant of the scintillator detector is being tested. Completion is expected early in 1984 with final alignment of the guide in July 1984.

4.3 High Energy Transfer Spectrometer (HET) - the sample and detector tanks are nearing completion, the low angle ^{3}He counters have been delivered and a low cost, low background, scintillator detector module has been developed for use in the high angle bank. Completion is expected on the same time scale as HRPD.

4.4 Low Q Spectrometer (LOWQ) - a design change has recently been introduced, substituting a heavily shielded, supermirror bender for the in-shield nimonic chopper as a means of removing the high energy neutron background. Detailed design is just starting and completion of a 10 m long initial detector tank and part of the large scintillator detector is planned for Day One operation.

4.5 High Resolution Inelastic Spectrometer (IRIS) - the incident beam guide tube and disc choppers are being provided for Day One to serve a Be-Be window spectrometer being built by the Bhabha Atomic Research Centre (BARC) in India. IRIS itself will be provided in 1985.

4.6 In addition to the above, three development instruments will be built, viz: the polarised neutron spectometer POLARIS, using a polarising filter; an eV spectrometer using filter difference techniques and a single crystal diffractometer using an Anger Camera scintillator detector.

4.7 Development work on sample environment equipment such as cryofridges, sample changers etc is nearing completion and a batch of equipment for Day One operation has been specified.

A VAX 750 computer has been installed as a HUB computer together with the first three VAX 730's as Front End Mini Computers. Software development is now well under way.

5. FOREIGN PARTICIPATION

An agreement has been signed with BARC, India, for the supply of a beryllium window spectrometer for the High Resolution Inelastic instrument. In exchange, the BARC will have running time on this and other SNS instruments.

Instrument proposals have also been prepared by scientists from Italy (Constant-Q spectometer), Germany (inelastic crystal spectometer) and the Joint Research Centre Ispra (general purpose spectometer for radiation damage studies), and discussions are being held to define similar arrangements

Agreement has recently been reached with KFK, Karlsruhe, to provide a blockhouse and instrumentation for a neutrino experiment costing some 12 million DM. Engineering work on the foundations for the blockhouse and modifications to the experimental hall will start soon.

As part of a collaboration with KFA, Julich, six people from Julich are spending 6 months each working on the SNS. Also KFA and RAL are collaborating on studies of shielding of neutron lines at spallation sources.

6. OTHER USES OF THE SNS

A test beam for using secondary particles produced by high energy protons lost in the synchrotron is being installed.
An irradiation facility is being installed in the target void vessel for tests on materials where it is important to have a lower background of slow neutrons than in reactor irradiations.

A study has been made of a μSR facility derived from a transmission target in the extracted proton beam. This would be a very powerful facility. However funds are unlikely to be available initially for this. A simple test facility which will produce muons is being investigated.

7. DEVELOPMENT OF THE SNS

Until the SNS has run and it has been shown that losses in the synchrotron can be kept well below 1% at full energy, there is no point in a lot of work being done on increasing the SNS current using a new injector. Potentially bigger improvements to the SNS, particularly for lower energy neutrons, say at 4Å can be made by improving target arrangements. Two examples being studied in a collaboration between KFA Julich and RAL are a booster using a sub-critical target and a redesign of the existing SNS target system using fissile material. This will be reported in more detail at this meeting in a presentation by RAL/Julich.

8. CONCLUSION

The SNS is well on target to produce first neutrons in 1984 with some seven instrumental facilities. Foreign participation is welcome and is happening. There is good potential for an improvement to the SNS target arrangements which would be likely to yield up to a factor 10 improvement in useful neutron yields especially for slower neutrons.

9. ACKNOWLEDGEMENTS

I have reported here on the work of many people at RAL.

References

1. Spallation Neutron Source: Description of Accelerator and Target.
   B Boardman (Ed). RL-82-006, March 82.