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RTNS-II NEUTRON SOURCES: STATUS REPORT

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INTRODUCTION

The Lawrence Livermore Laboratory has recently completed construction of a 14 MeV neutron irradiation facility for materials research in support of the fusion energy program. This facility, called the Rotating Target Neutron Source-II (RTNS-II) facility, contains two independent neutron sources, each consisting of an air-insulated 400 kV deuteron accelerator and a tritium target assembly which rotates at 5000 rpm. The accelerators are designed to deliver a 150 mA, 400 keV D^+ beam to a 1 cm spot on the titanium-tritide target. Neutron source strength produced at this current is 4 x 10^{13}n/s; irradiation samples may be placed within 3 mm of the beam spot where the flux is 1 x 10^{13}n/cm^{2}s.

During the course of the construction project, one accelerator was assembled temporarily in an unshielded enclosure for tests with H^+ and H_2^+ beams. Based upon the results of those tests, some modifications in design were made and incorporated in both accelerators when installed in the new building. This paper discusses the experience with both the prototype accelerator and the first accelerator operated as a neutron source. Other portions of the project, e.g. target system, tritium systems, etc. are described in detail elsewhere[1].

ACCELERATOR DESIGN

Details of the deuteron accelerator design have been given previously.[1,2] Briefly, the high voltage terminal contains a multi-aperture reflex-arc ion source followed by a 90° double-focussing magnet to separate the D^+ component from molecular species produced by the ion source. A solenoid lens following the separation magnet is used to match the D^+ beam into a low gradient (15 kV/cm) acceleration column. Two 10 cm aperture quadrupole triplet lenses and a single steering magnet are used to transport the beam to the target position approximately 4 m from the accelerator.

Design of the transport system assumed complete space charge neutralization of the beam in the low energy and high energy drift spaces. The quadrupole triplet field strengths are adequate to compensate for up to 50% residual charge on the beam. Normalized emittance assumed in the transport calculations was 2.5 mm-mrad.; measured emittance for the multi-aperture source used has been as low as 1 mm-mrad.

PROTOTYPE ACCELERATOR

Contracting authorization for the RTNS-II project was given in May 1976. In the spring of 1977 the 400 kV, 300 mA high voltage supplies, high voltage terminals, and 75 kVA, 400 kV isolation transformers passed acceptance tests at Emile Haefely, Ltd. in Basel and were shipped to Livermore. By July 1977, one complete accelerator was under assembly in a temporary enclosure at LLL for prototype tests. In December 1977 the high voltage terminal was hipotted to 400 kV and H^+ and H_2^+ beams of over 150 mA at 15-20 keV were delivered to a diagnostic tank installed at the position of the acceleration column. The acceleration column was then installed and the accelerator completed as designed to the first quadrupole triplet in the beam transport system. The diagnostic tank was mounted in the drift space following the triplet.

Operation with hydrogen beams began in January 1978. Maximum H_2^+ current and energy obtained were 40 mA at 250 keV. Above 10 mA it was necessary to replace the stationary beam dump with a rotating target as the beam spot could be focussed to diameters less than 1 cm. The maximum current and energy were limited by bremsstrahlung radiation outside the unshielded electrostatic enclosure containing the accelerator. Fields up to 300 mrem/hr were measured at a location 3 m from the acceleration column at 90° to the beam line. Field mapping done by attaching thermoluminscent dosimeters to the acceleration column and various terminal components produced distributions consistent with electron flow up the acceleration colums. Several graphite liners were placed inside the transport system in the high voltage terminal without reducing these fields. Variation of the bremsstrahlung fields with current, voltage, and pressure in the transport system suggested that the most likely source of electrons was ionization of gas within the acceleration column itself; pressure at the ground end of the column rose from 6 x 10^{-7} Torr with beam on.

It was decided to attempt to reduce this problem in the final accelerator design by further decoupling the source and acceleration column. The ion source stand containing source, bending magnet, solenoid lens and 2000 l/s turbopump was moved 45 cm back from its original location. This change made possible installation of a 1500 l/s turbopump, a beam viewer, a beam stop for current measurement and a variable aperture collimator. Prototype accelerator operations were terminated in March 1978 and relocation to the new building begun.

FIRST NEUTRON SOURCE

In March 1978 the building housing the RTNS-II sources was completed and became available to the project for installation of the accelerators. The first accelerator to be installed was the second of the two systems; the prototype was relocated as the second accelerator in the new building. All modifications suggested by prototype operation were incorporated in both machines. A view of the high voltage terminal and Cockcroft-Walton power supply in shown in Figure 1. The beam transport system and target assembly in the separate target cell are shown in Figure 2.

Initial acceleration of a beam by the first accelerator was accomplished in August 1978. By November 1978 the facility tritium and closed loop water systems were complete allowing operation on a tritium loaded target. In the first run on a tritium target 1.2 x 10^{13}n/s were produced with a 50 mA D^+ beam at 330 keV. Neutron source strength was measured with a tissue equivalent ion chamber previously calibrated at the RTNS-I neutron source.[3] To measure the size of the beam spot on target, thin Cu foils were placed 2 mm from the rotating target and activated by 14-MeV neutrons. These foils were then used to expose photographic film, allowing the profile of the neutron-emitting region to be measured by photodensitometer tracing of the negative. For irradiation times of 30 minutes, the average beam spot size inferred from this technique

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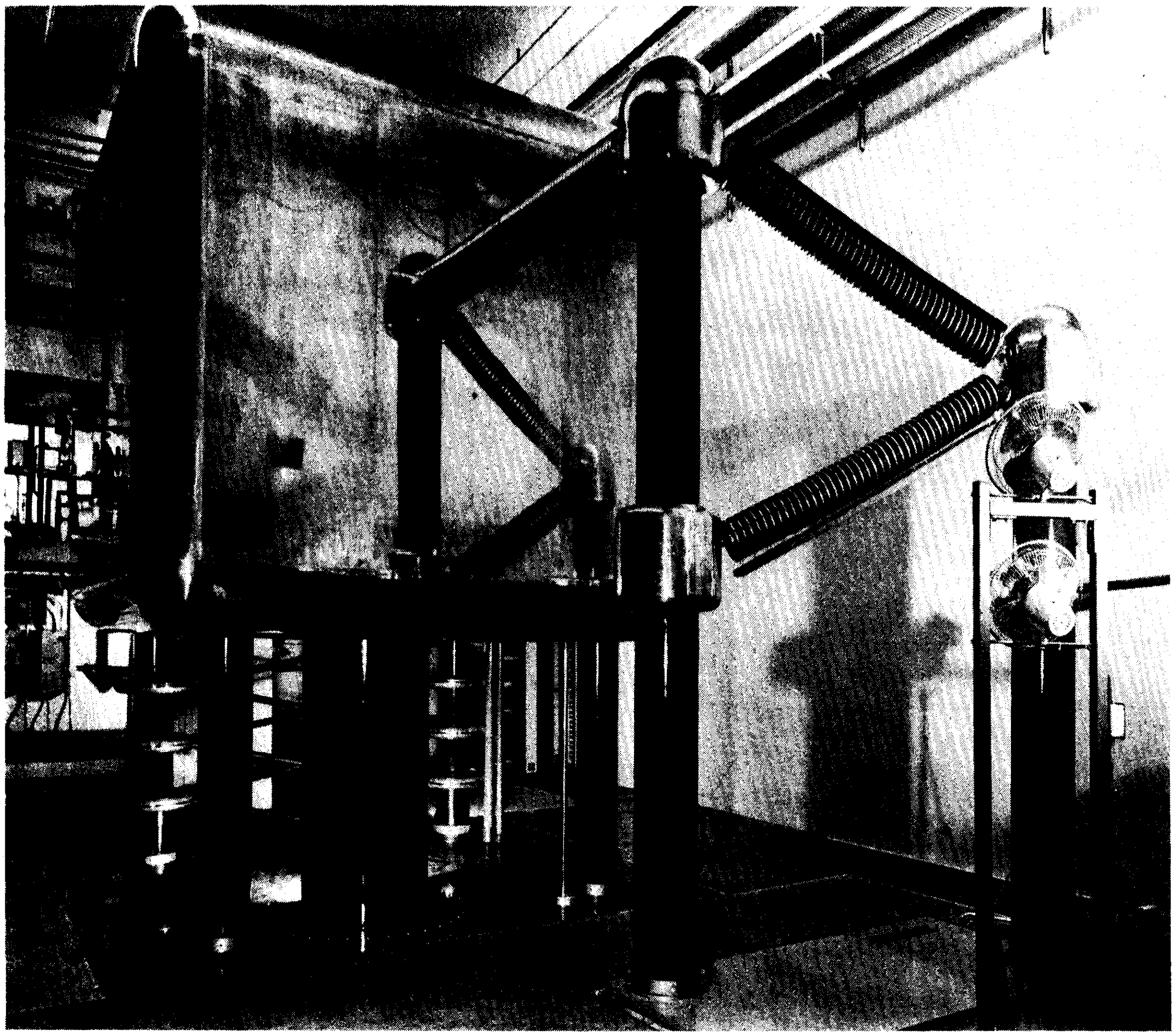

Figure 1. Cockcroft-Walton power supply and high voltage terminal on one of the RTNS-II accelerators. The top half of the isolation transformer shows beneath the terminal.

was 1-1.5 cm fwhm, consistent with that predicted for the beam transport system.

Accelerator parameters for runs at 300 keV and 400 keV are summarized in Table 1. Power supply currents are accurate to $\sim$1%; beam currents are measured by both electrical and calorimetric techniques and are probably accurate to only $\sim$10%. The atomic beam current is measured on a 7.5 cm diameter beam stop inserted before the entrance to the acceleration column in the high voltage terminal. The current measured on apertures is the sum of currents on three separate apertures protecting the beam transport system.

In operation to date, only small diameter (23 cm) targets have been used. Maximum permissable current on these targets is 60 mA. When full-sized 50 cm targets are installed, currents up to the design level of 150 mA can be tolerated. Accelerator performance to date has been satisfactory; the additional terminal pumping has reduced the radiation level from bremsstrahling by at least a factor of ten (matched by a factor of ten improvement in pressure at the exit of the acceleration column) and the added diagnostic equipment between bending magnet and acceleration column has been made operation simpler. However, there are two limitations to accelerator performance. First, ion source performance with deuterium has not been as good as that obtained with hydrogen operation; production of more than 100 mA of D^+ in the high voltage terminal has been difficult, even though 150 mA of H^+ and H_2^+ were obtained in test stand operation. It is expected that minor regapping of electrodes and work on the arc chamber will increase both gas efficiency and atomic beam fraction (currently 50-60%). Second, as the beam energy is raised from 200 to 400 keV, the beam diverges at the exit of the acceleration column as though it were overfocussed at the entrance of the column and were crossing over within it. Observation of the beam in the terminal shows electrostatic effects on the beam several diameters before the column rather than the one diameter assumed in transport calculations. Addition of another solenoid lens closer to the column may be required to achieve the adjustment in beam diameter required for optimum operation at 400 keV.

FUTURE EFFORT

At present operation of the first neutron source has been limited by performance of the target bearing and rotating vacuum seal. Design changes have been made to solve these problems and routine irradiations are now scheduled to begin mid-March. Large diameter targets are in the final stages of the fabrication cycle. Operation with these targets should begin during the summer. No major obstacle to eventual operation at the design source strength of 4 x 10^{13}n/s with a maximum flux of 1 x 10^{13}n/s has been found. The second accelerator/neutron source is now in debug.

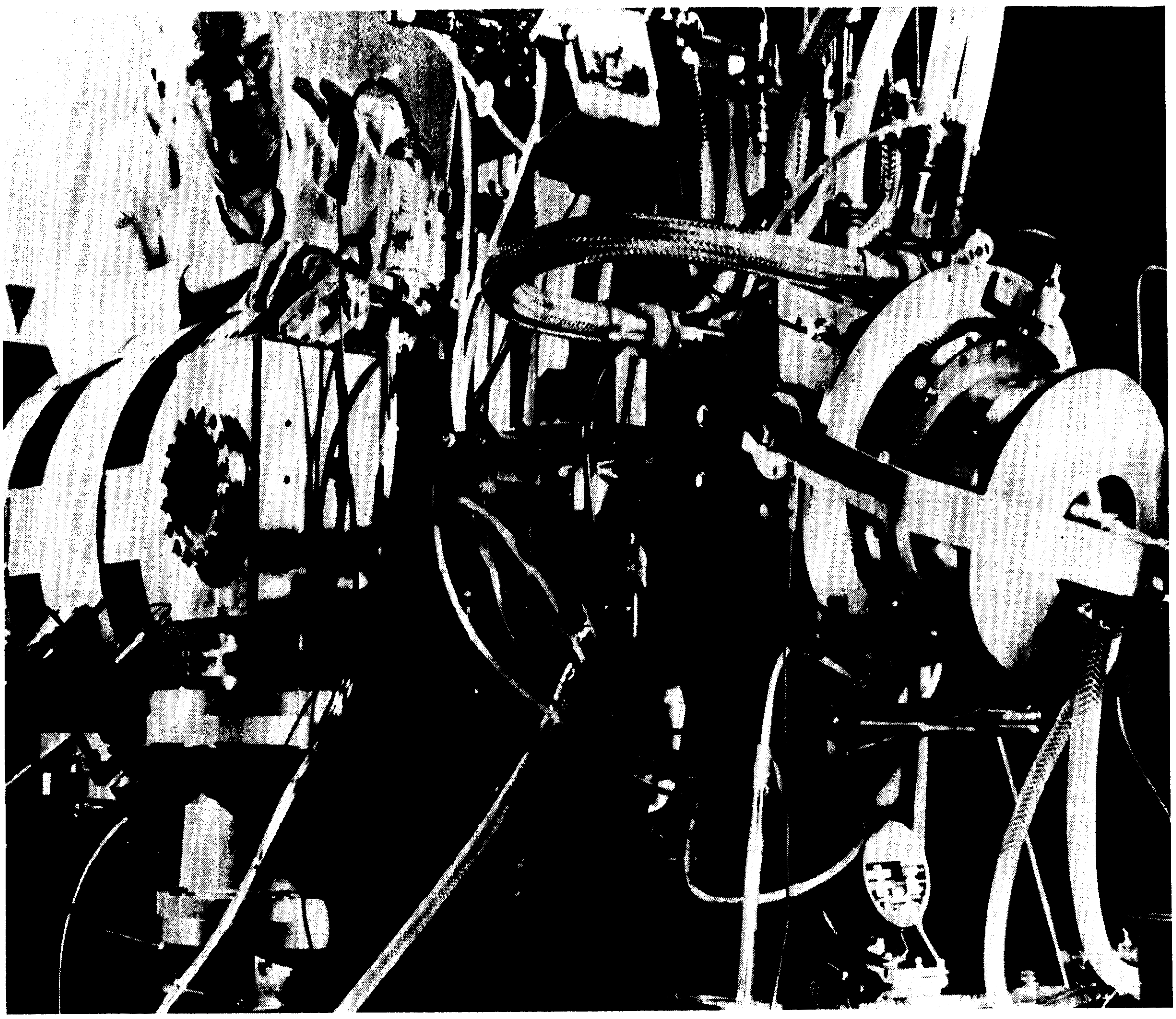

Figure 2. View of beam line and rotating target. Quadrupole triplet lens is at extreme left, 5000 rpm rotating target at extreme right.

Table I: RTNS-II Accelerator Currents (ma)

	300keV	400kev
Extraction Current (at 22.5 kV)	388	320
D^+ Current	104	75
HV Supply Current	100	75
Resistor String Current	1.3	1.7
Beam on Apertures	8	12
Beam on Target	87	60

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