RTNS-II: PRESENT STATUS^{*}

D. W. Heikkinen and C. M. Logan
Lawrence Livermore National Laboratory
Livermore, California 94550

Summary

The present status of the RTNS-II facility is described and typical operating parameters are given. A brief discussion is given of the methods used in production of the $TiTi_2$ targets as well as their performance and tritium handling at RTNS-II. The various types of non-interactive beam diagnostics presently in use at the neutron sources are outlined. The on-line computer system which provides a time history of an irradiation and records target performance is described. Examples are listed of several representative experimental programs which have been carried out thus far at RTNS-II. These include both active and passive experiments. Finally, several of the major improvements to the facility made since the beginning of the experimental program are given.

Introduction

The Rotating Target Neutron Source-II facility (RTNS-II) was constructed by Lawrence Livermore National Laboratory (LLNL) for the Department of Energy. The facility contains two identical deuteron

beam rotating titanium-tritide target neutron sources. These are used to provide an intense source of 14-MeV neutrons for studies of neutron-induced radiation damage.

Tests of the first deuteron accelerator were begun in September 1978. In November 1978 the first production of 14-MeV neutrons was achieved with a source strength of 1×10^{13} n/s.

Beginning in early 1979 the first neutron source began irradiations on a regularly scheduled basis. This neutron source is presently operated by LLNL on a 80-hr/wk basis as a national facility for the Materials and Radiations Effects branch of the Office of Fusion Energy.

Up to the present time irradiations have been performed for experimenters from twelve different laboratories.

Operating Characteristics

A schematic drawing of one of the RTNS-II neutron sources is shown in Fig. 1. Each source consists of a

Figure 1. A schematic diagram of one of the RTNS-II neutron sources.

400 kV air-insulated deuteron accelerator, beam transport system and a rotating target assembly. Design features and initial operating characteristics have been discussed previously.^{1,2} The basic design parameters and their corresponding present values are given in Table 1. The source strength value is that which is attained using a new 23-cm diameter target. The flux value is given for a sample position 2.5 mm axially from the neutron source. This is the normal distance of closest approach a sample can be placed for irradiation.

Table 1: Neutron Source Parameters

	Design	Present
Beam energy	400 kV	360-380 kV
Target current	150 mA	80 mA
Spot size	1 cm	~ 1 cm
Source strength	4×10^{13} n/s	2.2×10^{13} n/s(max)
Maximum flux	$\sim 1.0 \times 10^{13}$ n/cm ² ·s	$\sim 5 \times 10^{12}$ n/cm ² ·s
Target diameter	50 cm	23 cm
Target speed	5000 rpm	4000-5000 rpm
Target lifetime	100 hrs	80-100 hrs

Targets and Tritium Handling

The 23-cm internally-cooled backing for the rotating target are presently being made in two ways. Passages for the chilled water cooling are photochemically etched in a flat sheet of Cu alloy. This is then gold-plated and diffusion bonded to a similar flat sheet of Cu alloy at high temperature and pressure. In the second method of target backing production, the diffusion bonding process is replaced by an electroplating process in which a cover layer of pure Cu is plated on the sheet with the water passages. The total thickness of the backing is 1.5 mm in both cases. The backing is then hydroformed to a spherical segment shape.

After cleaning and final machining, the backings are sent to Oak Ridge National Laboratory for titanium and tritium loading. The titanium layer is ~ 10 µm thick corresponding to 4.5 mg/cm². After tritium loading, each target contains 1000-1500 Ci of tritium. The initial yield of neutrons from an "average" target is typically 2.5×10^{11} n/s·mA. However some targets have initial yields much lower than this and a correspondingly lower total neutron production. Figure 2 shows an example of total neutron production vs mA·hr for two recently used targets. Also plotted is a least squares fit to the functional form; $y = A_1(1 - e^{-A_2 X})$ where y = neutron yield and X = mA·hr. The figure clearly shows the variation in neutron yield from different targets used under essentially identical conditions. For target T2022B, $A_1 = 4.9 \times 10^{18}$ neutrons and $A_2 = -.185 \times 10^{-3}$ /mA·hr, while for target T2025B, $A_1 = 3.3 \times 10^{18}$ neutrons and $A_2 = -.228 \times 10^{-3}$ /mA·hr.

During bombardment of the titanium-tritide target, large quantities of tritium are evolved into the vacuum system. The vacuum pumping system consists of six turbo-molecular pumps backed by two large blower-forepump combinations. The exhaust from the vacuum system is sent to a tritium scrubber. The scrubber catalytically oxidizes the tritium to water and the tritiated water is trapped in a series of two molecular sieves. The reduction factor in tritium content after passing through the scrubber is 10^6 .

Tritium handling experience at RTNS-II and details of the tritium scrubber have been recently described elsewhere.^{3,4}

Figure 2. Total neutron production from two recent RTNS-II targets. Also shown is a least-squares fit to the target data using the functional form $y = A_1(1 - e^{-A_2 X})$.

Beam Diagnostics

Because of the power density in the beam, non-interactive beam diagnostics are extensively used at RTNS-II. The beam is viewed by TV cameras at two points along the beam line. The first point is in the high voltage terminal before the beam enters the acceleration column. The second point is just before the beam enters the target room. These allow position and size measurements of the beam (in the terminal only vertical position and size). An additional TV camera system located in the high-voltage terminal allows the image of the beam on target to be viewed. The video signal is sent to a commercially available video micrometer which allows a quantitative determination of position and beam size on target. The same video signal can also be sent to a color quantizer to convert the image into different colors depending on light intensity. This allows a qualitative determination of intensity variations in the beam on target.

In addition to the TV diagnostic system, beam transport can be measured using magnetic coil pickups located at two points along the beam line. These suffer however from their sensitivity to stray magnetic fields and some apparent thermal instability and appear to be useful only under steady state conditions for beam measurement. A schematic diagram of the accelerator and beam transport system is given in Fig. 3 and indicates the position of the various diagnostic systems.

Electrical and calorimetric measurements of beam current are made at the insertable beam stop in the high voltage terminal and on the rotating target. Additional

Figure 3. A schematic diagram showing the entire beam transport system.

calorimetric measurements are made along the beam transport system.

Neutron Monitoring

The neutron fluence delivered to samples is measured using foil dosimetry. In general these foils are ^{93}Nb and activity from the $^{93}\text{Nb}(n,2n)^{92}\text{Nb}$ ($t_{1/2} = 10.16\text{d}$) is measured. For purposes of monitoring the progress of an irradiation, total neutron production is measured using two ionization chambers and a proton-recoil counter. To provide a time history of an irradiation, parameters (such as beam current, H_2O flow, instantaneous and total neutron production) are recorded by an on-line desk-top computer. These are displayed every five minutes on a TV terminal and output to a printer every 0.5 hrs. In addition a live display of cumulative neutron production, and $\text{mA}\cdot\text{hr}$ vs radial position of the beam in the 6-cm TiI_2 target band is provided and retained for permanent storage. This is done for each target used at RTNS-II.

Experiments

Since the experimental program began, well over 1000 samples have been irradiated. Most of the irradiations have not involved active on-line diagnostics of samples during the course of the experiment. However, in several cases active diagnostics and/or control were employed. The first involved a measurement of in-situ creep of Nb during neutron bombardment.⁵ Another experiment involved a two-temperature zone furnace and associated vacuum system in which samples were maintained under vacuum at 80°C and 290°C .

Examples of other types of experiments in which the effects of 14-MeV neutrons were studied are:

- 1) Examination of the transition temperature, critical field and critical current in Al₅ superconductors.
- 2) Hydrogen trapping at damage sites in stainless steel for the Tokamak Fusion Test Reactor (TFTR).
- 3) Damage rate in pure Cu and Al by resistivity measurements at 4°K .

- 4) Helium production in twenty-four elements, forty-three separated isotopes and eleven compounds and alloys.
- 5) Post-irradiation tensile properties of Ni, V, Ti, Nb and stainless steel.

Improvements

Since the start of the experimental program, several improvements have been made at the RTNS-II facility:

- 1) All internally-cooled thin-walled stainless steel beam line has been replaced with externally cooled Cu beam pipe.
- 2) A new fiber optic control system has been installed in the high voltage terminal using radiation resistant fiber optic cables.
- 3) The beam spot video micrometer and color quantizer has been implemented. See the discussion above.
- 4) Improvements have been made to the rotating target system which have greatly improved reliability.
- 5) On-line computers are used to record the time history of an irradiation as well as target performance.
- 6) Initial production of 50-cm target backings has been achieved. Problems had been encountered earlier in the production process.

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

References

- 1) R. Booth, J. C. Davis, C. L. Hanson, J. L. Held, C. M. Logan, J. E. Osher, R. A. Nickerson, B. A. Pohl and B. J. Schumacher, Rotating Target Neutron Sources, Nucl. Instr. & Meth. **145**, 25 (1977).

- 2) J. C. Davis, D. W. Heikkinen, J. L. Held, C. M. Logan and J. E. Osher, RTNS-II Neutron Sources: Status Report, IEEE Trans. Nucl. Sci. 26, 3058 (1979).
- 3) C. M. Logan, J. C. Davis, T. A. Gibson, D. W. Heikkinen, B. J. Schumacher and M. S. Singh, Tritium Experience at RTNS-II, Proc. Conf. on Tritium Technology in Fission, Fusion and Isotope Applications, Dayton, Ohio, ANS, 1980, (U.S. Department of Energy, Document No. CONF-800427) pp. 372-376.
- 4) B. J. Schumacher, RTNS-II Tritium Scrubber Design and Performance, Proc. Conf. on Tritium Technology in Fission, Fusion and Isotope Applications, Dayton, Ohio, ANS, (U.S. Department of Energy, Document No. CONF-800427) pp. 267-273.
- 5) W. Barmore, A. Ruotola, E. Raymond, RTNS-II Irradiation Program Provides New Materials Data, Magnetic Fusion Energy Quarterly Report, July-Sept. 1979 (National Technical Information Service UCRL-50051-79-3) pp. 41-42.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.