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Livermore Intense Neutron Source: Design Concepts

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LIVERMORE INTENSE NEUTRON SOURCE: DESIGN CONCEPTS

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ABSTRACT

The Lawrence Livermore Laboratory proposes to build an irradiation facility containing several 14 MeV T(d,n) neutron sources for materials damage experimentation. The sources will operate as a national facility for CTR materials damage studies under the auspices of the Materials and Radiation Effects Branch of the Division of Controlled Thermonuclear Research. A source strength of 4 x 10^{13} n/s can be produced with 400 keV D^+ beam on the tritium in titanium target system now used on the Livermore Rotating Target Neutron Source (RTNS).

To produce the desired source strength an accelerator which can deliver 150 mA of 400 keV D^+ ions must be built. For the target to remain within the time-temperature regime of the present system it must have a diameter of 46 cm and rotate at 5000 rpm. With a beam spot 1 cm fwhm the useful target lifetime is expected to be the 100 hours typical of the present system. A maximum flux of 1.5 x 10^{13} n/cm^2 s will be attainable over a sample 1 mm thick by 8 mm in diameter.

Each accelerator will use a Cockcroft-Walton HV supply with high speed diodes, a multiple aperture ion source with pre-acceleration species selection, and a short, uniform gradient acceleration tube. The beam transport system from accelerator to target will accomodate a considerable amount of residual space charge on the 400 keV beam. Development of the 5000 rpm differentially pumped air bearing seal for the target system is complete. Prototype targets with internal water cooling have operated at 5000 rpm using this seal. Advanced target development may allow the accelerators to be upgraded to 400 mA current, providing source strengths above 10^{14} n/s.

The neutron sources will be supported by a laboratory building providing mechanical, electronic, computer, dosimetry, and materials handling services for the users of this facility. Facility subsystems will allow rapid retrieval of experimental apparatus for

sample changes and have extensive data logging capability for in-situ measurements.

INTRODUCTION

If the CTR program is to meet its time schedule for the construction of large demonstration experiments and large scale materials damage facilities such as FERF, there is an urgent need to acquire 14 MeV neutron damage information on critical first wall and insulator materials in the next five years. To obtain this information, beam-target sources providing higher fluxes than now available are needed as soon as possible during this period. We have designed a 14 MeV source that will provide flux levels a factor of ten higher than those now available.

The near term goal of the project is to build two or three sources that produce 4×10^{13} 14 MeV n/s with a maximum attainable flux of 1.5×10^{13} n/cm^2 s. This goal can be accomplished while staying within the operating range of the tritium in titanium system used on the RTNS now in operation [1-3]. The new sources will be in operation on a production basis for experiments in early FY 78.

A longer term goal of the project is to determine the limits of this approach to beam-target sources. In particular, we wish to determine whether it is possible to upgrade these sources to source strengths of 1×10^{14} n/s or higher to provide large volume irradiation capability with fluxes of 1×10^{13} n/cm^2 s or fluxes as high as 4×10^{13} n/cm^2 s for samples 1 cm in diameter. Development work is planned to determine the feasibility of such upgrading.

Finally, it is recognized that 14 MeV neutron damage experiments will become more elaborate than the present simple irradiation plus post irradiation analysis experiments done now. The facility which will house the new sources will provide support for sophisticated in-situ measurements and will be expanded to include the equipment required for simultaneous photon, charged particle, and neutron irradiation experiments. Data logging facilities will be provided for experimenters' use and to allow correlation of the results of in-situ measurements with neutron source parameters. Guidance in development of experiments and associated hardware will be provided by the facility staff. Allocation of irradiation time on the sources will be done by a users committee.

The construction of the proposed sources requires solution of severe accelerator and target problems and adequate treatment of several different radiation hazards. Proposed solutions are detailed in the following sections.

IRRADIATION AREA

All irradiation of materials and handling of activated samples will be carried out in a heavily shielded building separate from the control and light laboratory areas. This building must contain both the prompt and residual radiation resulting from operation of the sources. Facilities for handling target chargeout and routine work with activated apparatus must be provided. A floor plan for the irradiation area is shown in Fig. 1. The hot work area and activated storage vault are designed to convert to accelerator and target vaults for a third source in a future upgrade.

Each accelerator is equipped with a power supply room so semi-conductor supplies for magnets, lenses, and rf equipment can operate shielded from radiation. Each machine room will contain the rf oscillator, voltage multiplier, high voltage platform containing ion source, pumps, etc., and a portion of the beam transport system. A possible layout of machine room components is shown in Fig. 2. The target vaults (approximately 20' x 20') will hold the target, its operating systems, and the remainder of the beam transport. The target will be at approximately the center of the vault, leaving over half the room area free for the experimenter's equipment. Figure 3 shows a hypothetical experimental setup in which the target and irradiation samples are mounted on the same materials handling cart.

The balance of the irradiation area contains extra experimental equipment. A 4 MV Van de Graaff will be installed so H^+, D^+, $^3He^+$ and $^4He^+$ beams up to 4 MeV in energy will be available for simultaneous use with the neutron source in one pit. This accelerator can also be used separately to load samples with hydrogen or helium before irradiation with neutrons. A hot work area will be provided for work on apparatus just removed from the source. Depending upon the level of residual radiation, handling equipment ranging from a hot cell with remote manipulators to a glove box can be used in this area. Maintenance of the sources (target changes, repair of T-contaminated components, etc.) will be done in this work area. Finally, a shielded storage room is included for equipment that is too hot to transport off site or to the support building.

General access to the irradiation area will be limited. An eight foot high cyclone fence will surround the perimeter of the compound. Access to the compound will be gained through specific gates which are monitored and interlocked with the accelerators. On leaving the compound materials will be monitored for activation, and personnel radiation monitors will be read. The accelerator rooms and target vaults are designed so that with all sources operating at the 10^{14} n/s level the radiation exposure to personnel in the unenclosed area inside the compound is less than 0.2 mr/hr. Remote area monitors and interlocks on all entrance routes will prevent mistaken entrance to any vault or cell during hazardous operation.

Prompt Shielding

During operation [illegible] D-T neutron source the source must be shielded to contain the radiation in the target and accelerator cells. The shielding is designed to reduce prompt radiation resulting from one accelerator to less than 0.2 mr/hr in adjacent vaults. Access to adjacent vaults will not be limited by the prompt radiation. All access to areas which are exposed to hazardous levels of prompt radiation will be limited and interlocked with the accelerator operation.

A D-T neutron source at 10^{14} n/s produces a neutron radiation field of 2×10^7 mrem/hr at 3 meters from the source. This indicates that the shielding of the walls of the target vault must be 10^{-8} attenuating in dose for neutrons of about 14 MeV energy in order to achieve 0.2 mrem/hr outside the vault. This attenuation factor can be obtained with a number of materials. Concrete, a material often used for neutron shielding, attenuates the dose from 14 MeV neutrons to 1/10 the original value in 0.3 m (1 ft.).

Eight feet of concrete in the walls of the target vault are sufficient to attenuate prompt radiation. Unfortunately, activation data from the concrete walls in an existing high intensity D-T neutron facility at Livermore indicates that concrete is unsuitable as the inner liner of the target vault. Scaling data from this source indicates the activation of a concrete target pit wall to be 750 mrem/hr after 10 hours of cooling. Consequently some other material which has fewer activated species must be used. The walls, ceiling, and floor of the target pit are a combination of 2 m of concrete lined with 0.6 m (2 ft.) of gypsum supported by aluminum beams. The concrete and gypsum are poured without cracks rather than formed in blocks to limit neutron leakage through cracks. With the exception of the beam transport opening, vents, utilities, and control penetrations will be designed to preserve the integrity of the shield.

Residual Activation

After exposure to the intense high energy neutron flux in the target cell much of the associated material and equipment will become highly activated. The activation of the target, beam transport system, experimental equipment, and room walls all present special problems. At 10^{14} n/s the target can be expected to be 500 R/hr on contact immediately after shutting off the beam. This would drop to 220 R/hr in one hour and 80 R/hr after 10 hours. Material in the experimental apparatus will be comparably exposed and must be expected to have activation levels as high as the target. Target changes and sample manipulation will necessarily be done with remotely controlled equipment.

Once the target assembly is removed, further target vault entry will not be necessary for scheduled maintenance. Unscheduled maintenance will require a cooling period of several days before casual vault entry. In the cooling period the short half life activity induced in materials used in the beam pipe will decay away. Portable shields will be placed around the remaining activated parts of the beam pipe at that time. With the shields in place the remaining source of exposure is the walls, floor and ceiling of the vault.

Containment of Gaseous Radioactivity

In the intense neutron source accelerator system there are two principle sources of radioactivity which may be airborne. One source is tritium, which evolves from the target both during storage and during operation. The second source results from activation of the air and materials in the room.

The radioactive product of greatest interest is ^{13}N. In order that ^{13}N, radioactive dust, and also tritium are not released at ground level a negative pressure will be kept in the target vault during operation. The target vault exhaust will be filtered through high efficiency particle (HEPA) filters, monitored and passed into the accelerator vault which is maintained at positive pressure to keep it clean and dust free. As the mixing time of air in the room is long compared to the radioactive half life, the ^{13}N has decayed for several half lives before being exhausted from the accelerator vault through a monitored stack 10 meters from the ground.

Tritium will evolve from the targets at a slow rate during storage and at a substantial rate during beam operation. Each target will contain as much as 6 kCi of tritium bound in the titanium substrate. Measurements of the tritium depth profile in targets used on the present source indicate that 85% of the tritium remains in the target after its useful life. Similar behavior is expected for targets on the new source. The amount of tritium released into the accelerator vacuum systems of this facility during a year's operation could be a maximum of 200 kCi. To prevent release of any of this gas to the environment it will be buried in titanium sputtering pumps and scrubbed from the exhaust of all mechanical pumps and vent systems in the irradiation area. The economics and ecological impact of recovery versus burial are being considered.

Materials Handling

Handling of activated or contaminated materials within the irradiation area falls into two distinct categories: operations which must be carried out within the target vaults where the possibility of large whole body doses exists because of activation of the entire room, and handling of hot material outside the target vaults where the radioactive source will be small and proximity shielding will be adequate.

In vault operations, to avoid the risk of large whole body doses to operating personnel and users, special remote handling equipment will be developed so all routine operations within the target vaults can be performed from the control room or the vault door. These operations include removal and replacement of the target subsystem, removal and replacement of experimental assemblies, and making the utility, signal, and control connections necessary for operation of these systems. Coupling and final alignment of the sample holding assembly with respect to the target must be carried out in this fashion.

To meet these requirements, a tracked or air pad system will be built on which the target and experimental assemblies will ride on separate carts. The target assembly will be complete enough (air bearing, drive system, vacuum pump, controls, etc.) that it can be tested at full speed rotation on this cart. The cart for the target assembly will lock to the target cart and initial (or subsequent) alignment of sample holder with respect to target performed manually in a hot cell. The two carts will then be placed in the target vault and the alignment rechecked remotely. Some constraints of weight, power, and control, etc. are placed upon the experimenter by such a system but they do not appear serious. It seems quite feasible to accommodate 500-700 kg assemblies of apparatus in this manner.

Extrapolation from measurements on the present source suggests that an upper limit of 500-1000 R/hr for post-irradiation contact activity may be expected for target and sample assembly components. This activity is within the limits of even modest hot cell technology. A cell with access from two sides will be built and equipped with manipulators, gloves and long handled tools, pass-through drawers, etc. so these assemblies may be maintained and samples withdrawn. As the high flux region of the source is relatively small, the highly activated region of the apparatus is small also so specialized tools may be developed to work on it. Also, proximity shielding of this region (or removal of the hottest components) will make possible manual work on other parts of the assembly. Because of the T-contamination of the target system, it will probably be preferable to build a separate specialized hot cell for target changing operations.

SUPPORT BUILDING

The floor plan for the support building is shown in Fig. 4. This building has a gross area of about 8000 square feet. The purpose of this building is to provide control and data taking areas for the neutron sources and experiments, work space for source development and maintenance, and laboratory space and support facilities for preparation of equipment by outside users. Only those activated materials which pose no contamination threat or can be handled in simple shielded containers will be brought into this building.

The main activities to be carried out in this building are discussed below. Emphasis is placed upon those use requirements which most strongly affect building design.

Accelerator Control

The control and data taking room is placed at the end of the building nearest the irradiation area. All access to the irradiation area will be through this room or through gates in the perimeter fence controlled from here.

Accelerator Support

A laboratory of about 1000 square feet in size is provided for accelerator maintenance and development. A test stand which duplicates the beam optics of the accelerators' high voltage terminals will be installed in this laboratory. Ion sources can thus be repaired and their performance checked before being reinstalled.

User Support

A large (∿1500 square feet) light laboratory is provided for users of the facility. Equipment shipped to Livermore may be uncrated, assembled, and put into operation here. The laboratory will be equipped with light hand and power tools and electronic instrumentation (oscilloscopes, multichannel analyzer, etc.) for this purpose. Also included in the laboratory will be a complete mockup of the rotating target assembly for purposes of preliminary alignment.

Office and conference room space is provided for the users and clerical services will be available. A counting laboratory is included and will be equipped with nuclear instrumentation so fluence obtained in a run may be determined by counting diagnostic foils. Ducting is provided for a fast rabbit system to bring irradiated samples to this room for counting after an intermediate stop for radiation monitoring in the hot work area. The services of both the mechanical and electrical shops are available for repair or modification of experimenters' apparatus.

ACCELERATOR

To meet the source strength goal of 4×10^{13} 14 MeV n/s an accelerator capable of producing a 150 mA beam of 400 keV atomic deuterons must be built. Most accelerators which operate in this range of current and energy serve as injectors for linacs or synchrotrons which are inherently low duty factor machines (<2%). Those injectors are operated in a pulsed mode and avoid the problems of DC operation.

To operate in DC mode requires that serious problems of power dissipation and cooling be solved in the ion source, the acceleration tube, and in the transport system. Our design approach has been to decouple accelerator components to the maximum extent possible and retain design flexibility through prototype accelerator construction. The design of accelerator subsystems as they now exist is detailed in the following sections.

Ion Source

An ion source which provides more than adequate current for this application is the MATS III source [4] developed at LLL as a neutral beam injector for the Baseball II magnetic confinement experiment. This multiple aperture source has produced 1.5 A of H^+ at 20 keV in DC operation with a lifetime of several thousand hours. Gas efficiency is good, typically 50%, and the D^+ fraction of the output beam is nominally 70%. The normalized emittance of the central section of the beam is 0.22 mrad-cm. The source is shown in Fig. 5. It has the advantage that the plasma chamber and extraction surfaces are decoupled so the source can be scaled down simply by varying the number of apertures in the extraction electrode set.

Accelerator design to date assumes that a scaled down version of the MATS III source will be used with a 90° magnetic bend before acceleration to remove diatomic and triatomic beam components. A solenoid lens following the 90° bend will be used to adjust the divergence of the beam as it enters the acceleration tube. No beam expansion due to space charge occurs in this low energy drift space if the residual pressure is of the order of 5×10^{-5} torr.

Acceleration Tube

After the ion source and associated optical have produced a low energy D^+ beam of the proper current and emittance, the beam must then be accelerated to its final energy. Several design problems must be solved if the acceleration tube is to operate properly. The high electric fields (10-40 kV/cm) within the acceleration tube will remove all electrons from the region near the beam. In the tube the beam experiences the full effect of its own space charge and will expand rapidly. One thus wants to reach final energy in a short distance to minimize this expansion. The beam tube must operate at as high a gradient as possible. Commercially available acceleration tubes for electrostatic generators operate at gradients up to 20 kV/cm quite reliably. Although this gradient can be supported in vacuum, it cannot be easily sustained in air at one atmosphere. The beam tube must thus either be of a re-entrant design to reduce the gradient on the outside or be surrounded with gas such as SF_6 at a pressure of one or two atmospheres to increase the breakdown strength on the outside of the tube.

Acceleration tubes can be built which balance the space charge force on the beam by careful electrode shaping, the so-called "Pierce geometry." However, these Pierce tubes have several disadvantages for the present application. First, the ion source must look directly into the acceleration tube. In this geometry, it is not possible to separate the D_2^+ and D_3^+ components from the ion source from the D^+ component. One must accelerate both unwanted components to full energy before separation. This results in power dissipation and background radiation problems. We wish to remove these components to prolong target life. When the target is bombarded with a mixed beam, the molecular components displace tritium at the depth at which the yield from the atomic component is highest, causing a rapid decay of total yield.

The optics of the acceleration tube are not optimized for the D^+ beam but rather for the mixture of beams. The tube is designed for only one current and to maintain the proper gradient the electrodes must approach very closely the edge of the beam. Operation at currents other than the design current may be difficult or impossible because of radiation and electron multiplication occurring when small amounts of the beam strike these electrodes.

Given the disadvantages of the Pierce geometry, we have picked an accelerator design which decouples the ion source from the tube. The tube can then be of a simple uniform gradient, large aperture design. As only D^+ will be accelerated through the tube, the optical properties of the tube and the following transport system can be optimized for that ion species alone. While the electrodes are re-entrant, they are simple in shape and symmetric about the center of the tube. A graded length of 25 cm will be used with electrode apertures 17.5 cm in diameter, providing excellent pumping speed through the tube. To compensate for the variation in space charge force at different beam currents, a solenoid lens is inserted before the tube so the focusing effect of the lens plus tube can be held constant. The angular divergence of the D^+ beam delivered to the transport system is thus the same over a wide range of beam current. The tube will be built with ceramic insulators bonded to titanium alloy rings. The electrodes will be coupled to the rings for mechanical support and cooling. Removal of the electrodes for replacement or modification will be possible.

Beam Transport

Once accelerated to 400 keV, the D^+ beam must be transported through the shield wall between the accelerator room and the target vault and then focussed to the 1 cm fwhm spot size necessary to produce the desired neutron flux. The only optical elements in the system are quadrupole triplets with 10 cm apertures. The triplets have outer pole tips 10 cm long and inner pole tips 17.5 cm long. Such lenses are standard items and can produce 3 kg fields at the pole tips with 500 watt power supplies. A beam envelope calculation for the accelerator plus transport system is shown in Fig. 6. This calculation was run for a 150 mA D^+ beam with initial emittance expected for a scaled down version of the MATS III ion source. The beam spot size produced at the target (2σ = 1.3 cm, fwhm = .89 cm) is below that required. Only two of the quad triplets are running at appreciable fractions of their maximum field strength.

The sensitivity of the spot size on target to changes in beam energy was investigated for this system. All lens parameters were held fixed while the voltage on the accelerator was varied. For this system, which is not optimized, an 0.5% variation in energy produced only a 10% change in area of the target spot. This sets an upper limit of 0.5% regulation of the high voltage power supply which is acceptable. No trim magnets are included in this calculation although they would be installed on a working system to provide correction for slight misalignment.

A major uncertainty in the design of the transport system is the degree of neutralization of the beam's space charge. Experience with high current beams at 10-20 keV indicates that the beam is neutralized to better than 1% in drift spaces when the background pressure is 10^{-5} torr or greater. Measurements with pulsed beams from linac injectors suggest neutralization of the beam due to electron buildup after the beam has been on for 300 μs. We plan to measure the degree of neutralization of the 20 mA 400 keV D^+ beam from the ICT accelerator to provide information for the final transport system design. With the system discussed here, the effects of up to 10% residual space charge in post acceleration drift can be compensated for with the last triplet lens alone.

The exceptionally high power level of the beam from these accelerators will make it impossible to use conventional diagnostic tools such as rotating wire scanners or quartz viewers. Well cooled tapered apertures which are split to provide directional information will be used to locate the beam. Currents from these apertures will be processed by the monitor computer system to provide the most effective tuning aid for the accelerator operators. Spot size on target will be monitored with a neutron pinhole camera.

Gas loads in the beam transport system will be relatively modest. The contribution to the load from ion source gas will be on the order of 5-10 atm cc/min. Tritium and deuterium outgassing from the target should total no more than 0.5 atm cc/min. Outgassing load from the beam line should be no more than 1-2 atm cc/min. To maintain the entire system at pressures in the 10^{-5} torr range, a delivered pumping speed of only 2000-4000 ℓ/s is needed. Readily available turbomolecular and ion pumps can meet these requirements.

TARGET

The Livermore Intense Neutron Source will use titanium tritide targets similar to those presently employed. The neutron yield from these targets decreases with use because the tritide is subjected to intense heating from the incident deuteron beam and deuterium implantation. The peak temperature to which the tritide is heated depends upon beam power density and the linear velocity of the target. Calculations of diffusive mass transport [5] and observations on the present target have shown that the higher current density at the LINS will require about ten times the linear velocity of the present targets. This will be achieved by increasing the target diameter to 46 cm and the rotation rate to 5000 rpm. Under these conditions we expect the target yield to decrease to one-half the initial value in 100 hours of operation.

Rotating Seal

In the present target system there is a sliding seal between the rotating target and the stationary vacuum system of the accelerator. This design is satisfactory at 1100 rpm but because the sliding contact causes heat and wear it would not be suitable for higher rotation speeds. The LINS will utilize a rotating air bearing. Air is supplied at normal shop pressures and fed through tiny passages to the gap between rotating and stationary parts. This air cushion prevents contact of the metal parts thus serving both as a lubricant and as a coolant. The air is exhausted to the atmosphere as shown in Fig. 7. On the surface which serves to seal the air cushion from the accelerator vacuum, two regions are separately vacuum pumped to remove any gas which flows past the exhaust port. The final sealing region runs with the same clearance as the air cushion but with an air pressure in the micron range. Sliding contact is avoided and gas leakage into the accelerator vacuum is very slight. This leakage is further reduced at high rotation rates by pumping grooves in the final sealing region. Since the only metal wear or erosion is from moving air, lifetime is expected to be very long and maintenance low. Air consumption is modest and driving power required for the bearing is small compared to windage losses. The bearing is suitable for operation at any speed up to 10,000 rpm because of a unique design feature which compensates for the dilatation of the rotating part at high rotation rates.

Three complete air bearing assemblies are being built. A test stand with monitoring and control instrumentation will be built and each assembly run under simulated machine conditions, then disassembled and inspected. After completion of bench tests, the air bearing will be installed on the present RTNS and become the standard system for machine operations in January 1976. We will then have operating experience with the bearing and seal system prior to installation on the LINS.

Cooling

The present target is cooled by water contained between the outside of the rotating target and a stationary water spreader. The target rotation provides sufficient relative velocity between the target and coolant to assure turbulent flow and adequate heat transfer. With this arrangement the viscous loss in the coolant scales as the cube of the angular velocity and the fifth power of target radius. This results in a prohibitive power consumption at the speed and size projected for the LINS.

In order to avoid the drag exerted on the target by rotation against the water and to decouple the target cooling from target rotation, a new design has been developed which circulates the coolant within the target itself. The water enters the target and returns through a center hub assembly. Water flow channels are etched into a copper alloy sheet which is then bonded to a second sheet to form a blank from which the target is formed. The cooling channels are designed to attain the largest possible surface heat transfer coefficient. The cooling channels have a wiggly pattern which gives surface coefficients about twice what is attainable with straight turbulent flow.

Detailed design of the hub assembly and fabrication of prototype 23 cm diameter targets will be complete in 1975. Performance evaluation on the existing RTNS will be complete in early 1976 at which time it will become the standard target for the RTNS. The present facility for tritium loading is limited to a target of 23 cm diameter or less. Development of the internally cooled target will proceed using this diameter to maintain compatibility with these loading facilities.

PROJECT MILESTONES

The Livermore Intense Neutron Source project is included in the FY 76 ERDA budget request. Assuming approval by Congress in early FY 76, detailed design of sources and buildings can be completed rapidly. The requested funding for construction of the facility is $5M. The major milestones in execution of the project are listed below.

December 75 - Ion source testing will begin on a 50 kV, 1A test stand which will duplicate the optical and vacuum system layout of the high voltage terminal.

Initial testing of the 5000 rpm air bearing with internally cooled water targets will start on the RTNS.

July 76 - A prototype accelerator and beam transport system will be completed in an existing laboratory building for emittance, beam transport and component lifetime tests with hydrogen beams.

Construction starts on the buildings.

October 76 - Tests of 46 cm deuterium filled targets with hydrogen beams from the prototype accelerator. These tests will establish target lifetime.

May 77 - Construction of buildings complete.

October 77 - First neutron source operational.

April 78 - Second neutron source operational.

October 78 - Electrostatic generators, x-ray generator operational.

ADVANCED SOURCE DEVELOPMENT

There are several avenues of development of these neutron sources which should be investigated during the construction phase of the LINS facility. It is important to determine the limits of the rotating target system so the long term value to the materials damage program of such sources can be compared to that proposed for other source concepts. Specific goals of this work are to demonstrate whether the rotating target approach can provide source strengths of 1×10^{14} n/s or greater and/or fluxes of 4×10^{13} n/cm^2 s. If these goals can be met then the study of neutron irradiation effects for bulk samples might be accomplished by building many such sources.

Accelerator development will concentrate upon the problems of raising the available D^+ current from the 150 mA design value to the 400 mA level required for 1×10^{14} n/s operation. When the ion source test stand and prototype accelerator are operational the difficulties in taking this step can be readily determined.

Target work will progress along two lines. First, we wish to model the process of hydrogen isotope transport in the present target system and to determine the macroscopic factors (film adhesion, microfissures, barrier layers, etc.) that influence the performance of the targets. This work will be pursued with diagnostic tools such as neutron time-of-flight depth profiling [6], RGA analysis of target outgassing in operation, total isotope inventories, and SEM analysis of targets. When the present target system is sufficiently well characterized to provide normalization points for code modeling, a systematic analysis of target materials for a 1×10^{14} n/s target capable of withstanding higher power levels will be undertaken. Materials having better thermal properties and higher stoichiometric densities of tritium will be investigated. Candidate materials are erbium, scandium, and yttrium tritide. Layered targets having diffusion barriers for tritium and/or underlying absorption regions for deuterium will be fabricated.

The performance of these targets will be determined relative to that of titanium tritide by performing small target simulation experiments with the ICT accelerator of the RTNS. As this machine can be operated in an arc pulsed mode to produce pulses of millisecond duration, the thermal cycle of an element of a rotating target can be duplicated on a small stationary target. In particular, temperature excursions resulting from power densities higher than those produced by either the ICT or LINS accelerator beams can be produced. Assuming the performance of small targets is promising, full size prototypes will be produced for testing on the ICT or the LINS prototype accelerator.

By the second quarter of FY 77 the prototype accelerator should have operated at a reasonable duty factor for six months. The results of target development work done by this time should indicate the feasibility of higher flux and source strength options.

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Figure Captions

Fig. 1.	Floor plan of irradiation area
Fig. 2.	Layout of components in accelerator room
Fig. 3.	Mockup of target and irradiation apparatus on remote handling cart
Fig. 4.	Floor plan of support building
Fig. 5.	MATS III Ion Source
Fig. 6.	Beam envelope through transport system
Fig. 7.	Air bearing target

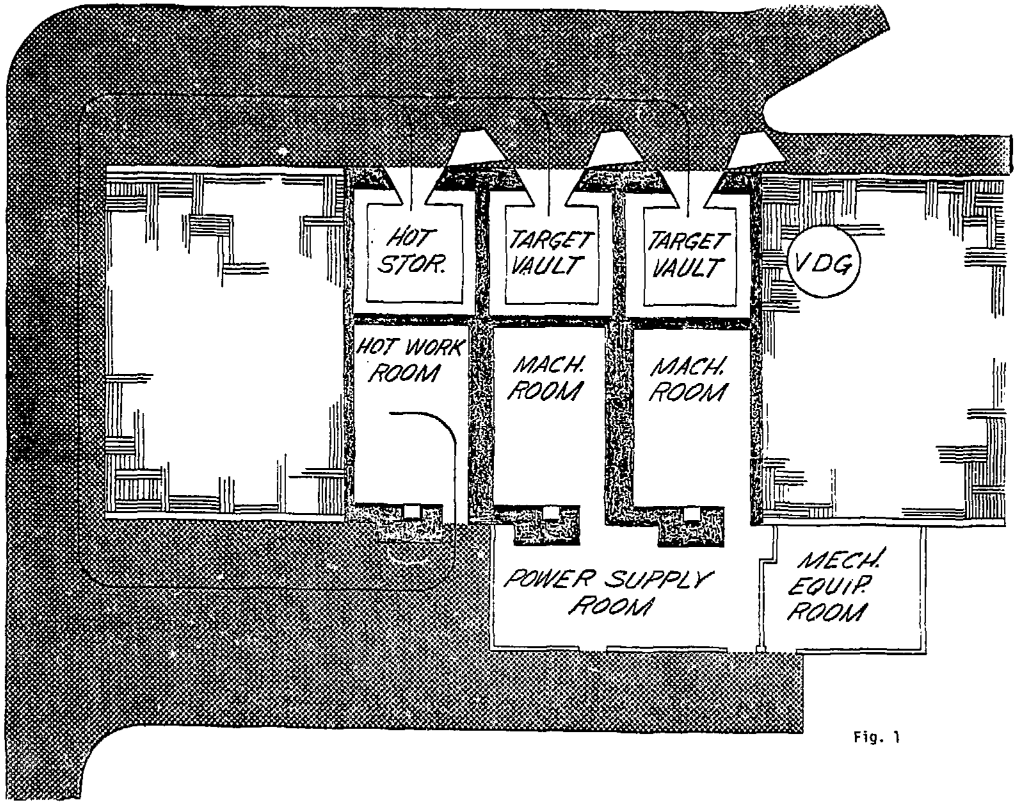
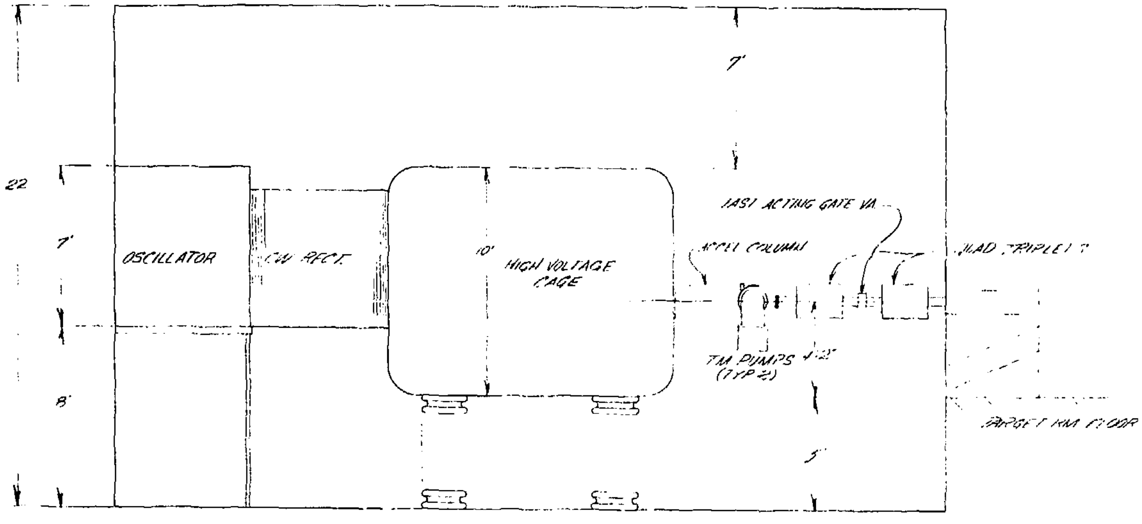

HOT STOR.
TARGET VAULT
TARGET VAULT
VDG
HOT WORK ROOM
MACH. ROOM
MACH. ROOM
POWER SUPPLY ROOM
MECH. EQUIP. ROOM

Fig. 1


22
7'
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OSCILLATOR
CW RECT.
HIGH VOLTAGE CAGE
ACCEL COLUMN
FAST ACTING GATE VA.
QUAD TRIPLET
TM PUMPS (TYP 2)
4.25"
TARGET RM FLOOR
ELEVATION

Fig. 2

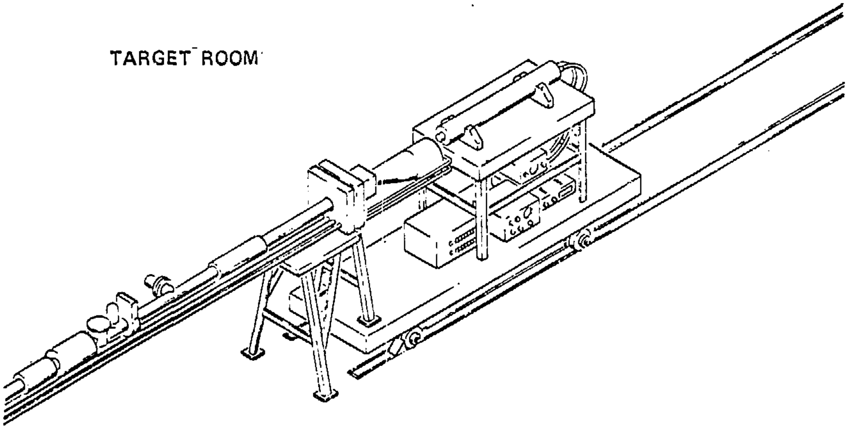

Fig. 3

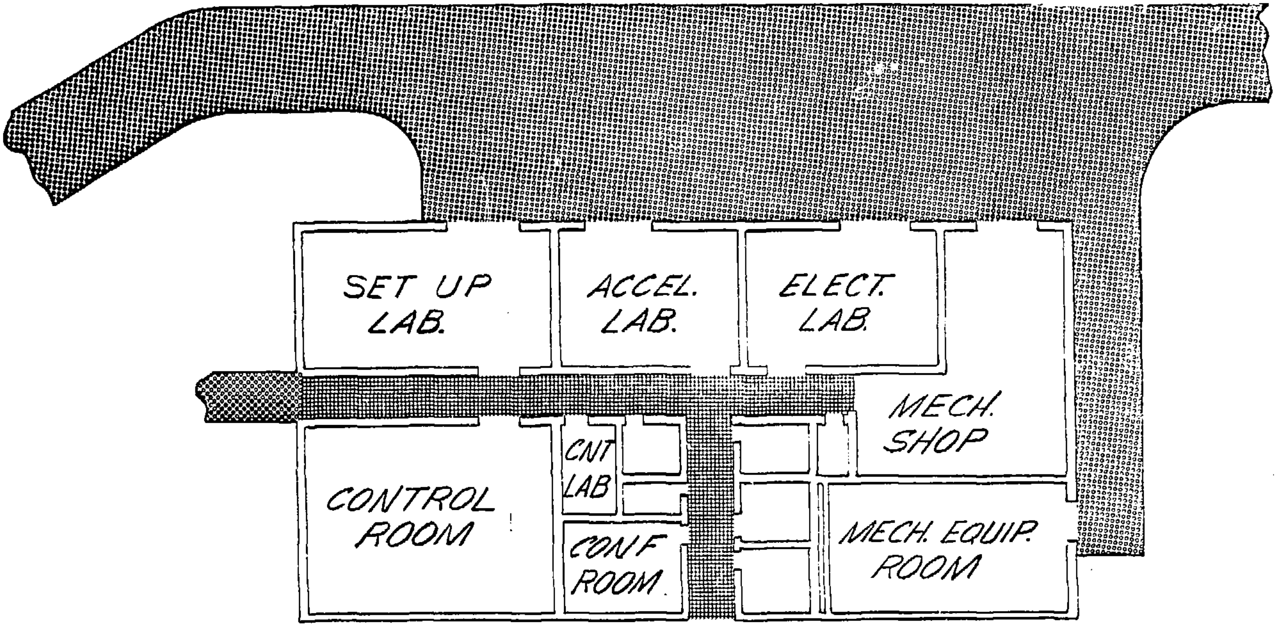
SET UP LAB.
ACCEL. LAB.
ELECT. LAB.
MECH. SHOP
CNT LAB
CONTROL ROOM
CONF ROOM
MECH. EQUIP. ROOM

Fig. 4

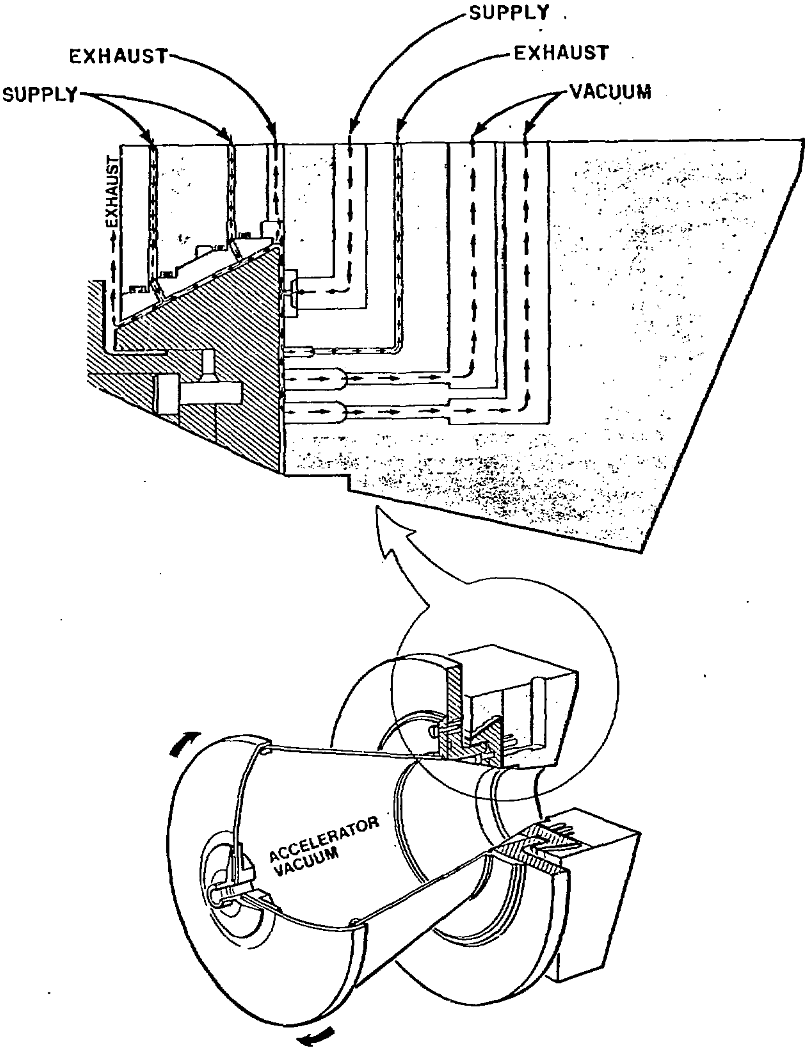
SUPPLY
EXHAUST
EXHAUST
SUPPLY
VACUUM
EXHAUST
ACCELERATOR VACUUM

Fig. 5

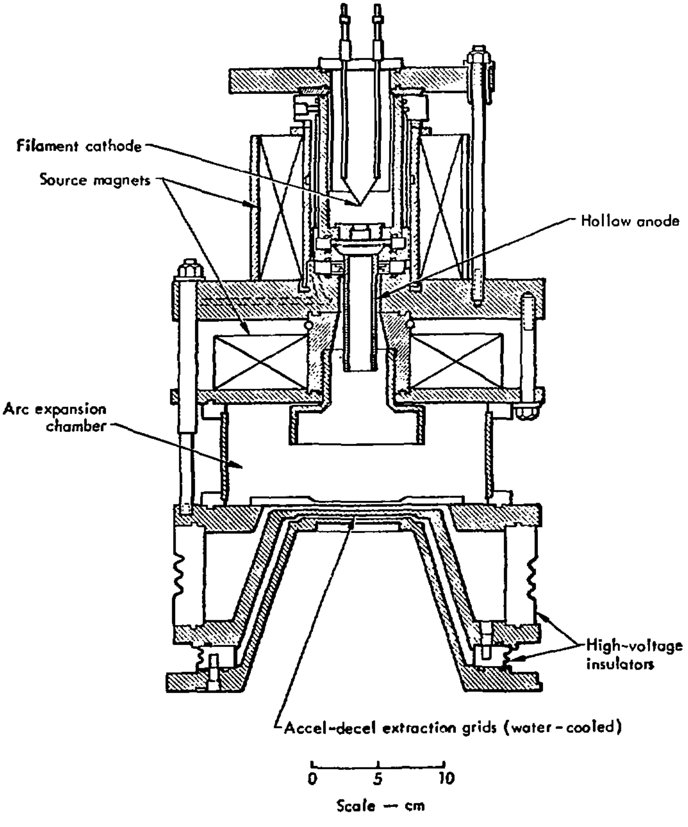
Filament cathode
Source magnets
Hollow anode
Arc expansion chamber
High-voltage insulators
Accel-decel extraction grids (water-cooled)
0
5
10
Scale — cm

Fig. 6

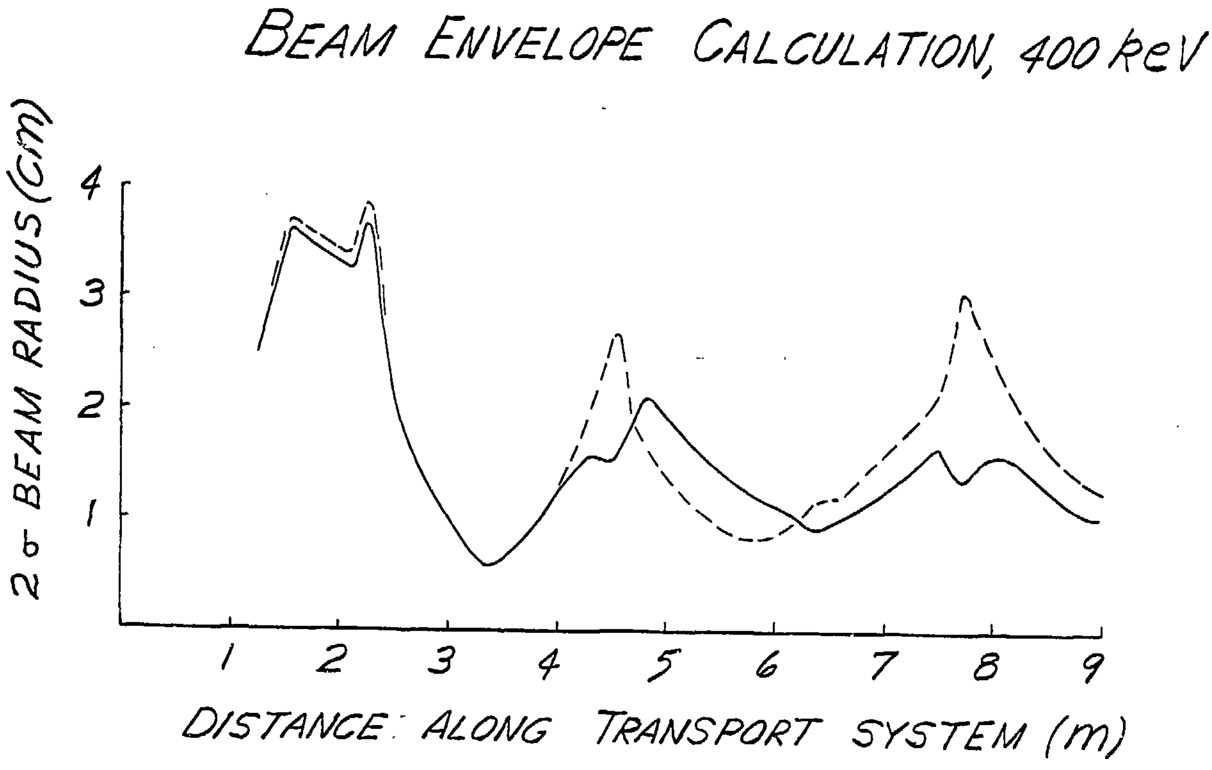
BEAM ENVELOPE CALCULATION, 400 keV
2σ BEAM RADIUS (cm)
4
3
2
1
1
2
3
4
5
6
7
8
9
DISTANCE ALONG TRANSPORT SYSTEM (m)

Fig. 7