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Conf. 751125--33

PREPRINT UCRL- 77240

Lawrence Livermore Laboratory

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November 14, 1975

This paper was prepared for submittal to the Proceedings of the Sixth Symposium on Engineering Problems of Fusion Research, November 18-21, 1975, General Atomic Company, San Diego, California.

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VACUUM SYSTEM FOR THE LIVERMORE
INTENSE NEUTRON SOURCE*

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Summary

To fulfill the need for intense 14-MeV neutron sources for controlled thermonuclear reactor material damage studies, several accelerators will be built at the Lawrence Livermore Laboratory. A high-capacity vacuum system will be required to handle the large deuterium gas load needed to produce the beam current. Outgassing of tritium from the target necessitates special handling of the exhaust from the vacuum pumps. A vacuum system utilizing turbomolecular pumps was selected after comparing its performance with mercury vapor diffusion and titanium bulk sublimation/ion pumps.

Introduction

A vacuum system design has been selected for several new accelerators¹ to produce high-energy neutrons for material damage studies (see Fig. 1). A source strength of 4×10^{13} 14-MeV neutrons/s will be produced by a 400-keV beam of atomic deuterons colliding with a tritium-titanium rotating target. The accelerators will be operated in a direct current mode on a 24-hr basis. Except for periodic replacement of the tritium-titanium targets, equipment maintenance will be kept to a minimum.

To produce a 150-mA beam, 5 to 10 atmospheric cm³/min of deuterium gas will be ionized and accelerated

in the ion source unit. To remove the unwanted D_2^+ and D_3^+ ion species, the D^+ beam is magnetically bent 90°. Vacuum pumps in this section of the accelerator must remove 75% or more of the deuterium gas to maintain a vacuum of 10^{-4} Torr or lower in the bending chamber. This equipment will be mounted in the 400-kV equipment dome.

To minimize heating effects and reduce the expansion of the beam, the vacuum in the accelerating electrode section of the accelerator will be maintained at 5×10^{-5} Torr pressure or lower.

The beam will be focused through the shielding wall to the tritium-titanium rotating target by a series of quadrupole triplets. The deuteron-tritium collision produces 14-MeV neutrons and helium gas. The vacuum pressure in this section of the accelerator is not critical, but will be maintained in the 10^{-5} Torr pressure range. Because a considerable quantity of tritium gas will outgas from the target (200 kCi/yr), special provisions are required to contain and scrub all vacuum exhaust from the accelerator. Tritium will be removed from the vacuum exhaust by a catalytic combiner before releasing the exhaust gas to the atmosphere.

Fig. 1. Livermore intense neutron source facility.

* This work was performed under the auspices of the U.S. Energy Research & Development Administration, under contract No. W-7405-Eng-48.

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Evaluation of Various Vacuum Pump Components

Several types and combinations of vacuum pumps were investigated to determine the most efficient and maintenance-free vacuum pumping system for the accelerators. Mercury vapor diffusion, titanium bulk sublimation/ion, and turbomolecular vacuum pumps were judged to be suitable for use as major vacuum components in the system. Cryogenic pumping was attractive because it can handle large gas loads, but was not considered because of the cyclic nature of the pumps. Also, considerable liquid helium equipment and vacuum backing pumps are needed to support the cryogenic system. An oil diffusion pump system was not considered because of the possibility of oil contaminating high-voltage parts during a system failure.

A mercury vapor diffusion pump system is the lowest in capital cost and requires the least maintenance of the three systems considered. Although mercury vapor diffusion pumps have a high deuterium pumping rate, the addition of LM_2 traps, valves, and manifolds to the pumps seriously reduces the overall pumping rate. Thus, large-sized components and manifolds would have to be installed in spaces where compact equipment is required.

The titanium bulk sublimators/ion pump combination vacuum pump has been used successfully on a smaller 0-1 type neutron generator.² It was found that 95% of the tritium released from the target from deuteron bombardment was permanently buried in the sublimator walls as titanium tritide and that the operating pressure could be regulated by adjusting the rate of sublimation.

Because of the high gas load and 24-hr operation, a large capital investment would be necessary to outfit the accelerator with this type of pump. Regular maintenance is required to replace the titanium-bulk sublimation sources and clean the gettering arrays. Ventilated hoods for cleaning the gettering array and servicing the ion pumps would be required to protect personnel from tritium exposure.

Turbomolecular Vacuum Pump System

Of the three systems considered, the performance and configuration of the turbomolecular vacuum pumps were preferred for this accelerator (see Fig. 2). The initial capital investment is high, but less than the titanium bulk sublimation/ion pumps. The turbomolecular pumps (1600 L/S) can handle the large gas load on a continuous basis and yet achieve the desired vacuum pressures. Except for occasional oil changes that must be made in a controlled manner because of tritium contamination, maintenance on the pumps is anticipated to be minimal. The turbomolecular pumps are compact and can be close-coupled to the accelerator (see Fig. 3) to reduce the conductance losses that are inherent in vacuum manifolds. Vacuum valves between the turbomolecular pump and the accelerator are not required. Bypass roughing lines are also eliminated because the system may be roughed down through the turbomolecular pump.

To remove the high gas load (7 atmospheric cm^3/min) in the beam-bending chamber, the turbomolecular vacuum pump will be backed with a large capacity, two-stage mechanical pump (100-cfm displacement). In the 10^{-4} Torr pressure range, the pumping rate of some models of turbomolecular pumps is increased with the larger pumps. Freon traps have been provided to reduce the movement of oil into the accelerator and to the electrically insulated exhaust pipe. Both turbomolecular and mechanical vacuum pumps are mounted in the 400-kV equipment dome. The vacuum exhaust is maintained near atmospheric pressure so that when it passes from the high voltage dome to the ground potential, voltage breakdown will not occur.

To maintain a lower pressure in the accelerating electrode, two turbomolecular pumps (1600 L/S each) are backed by a Roots Blower^{*} (1383-cfm displacement) and two mechanical vacuum pumps (100-cfm displacement each). In the target section of the accelerator, only one turbomolecular vacuum pump (1600 L/S) is required.

All exhaust from the mechanical pumps will pass through freon-cooled traps to remove oil vapor that might contaminate the catalytic combiner in the tritium scrubber.

Because one or two accelerators may be in operation simultaneously, block valves have been provided to control the vacuum exhaust to the tritium scrubbers. To prevent blowout of shaft seals in the mechanical pumps from overpressurization caused by a closed block valve, a pressure alarm and relief valve have been included.

* 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. Energy Research and Development Administration to the exclusion of others that may be suitable.

References

1. J. C. Davis, et al. Livermore Intense Neutron Source: Design Concepts, Lawrence Livermore Laboratory, Rept. UCRL-76856 (1975).
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Legend

Two-stage mech. vac. pump	Refrigerated trap	Manually operated vacuum valve
Turbomolecular vac. pump	Safety relief valve	
Roots blower	Pneu. oper. vac. gate valve	

Fig. 2. Schematic of the vacuum system.

Fig. 3. Ion source and acceleration sections.