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Lawrence Ruby

May 14, 1956

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ABSTRACT

A laboratory pulsed neutron source has been constructed which may be suspended above or below floor level. The accelerator system consists principally of an ion source of the cold-cathode Phillips Ion Gauge type, extractor and focus electrodes, and an air-cooled target electrode. A cascade rectifier power supply allows the target voltage to be varied up to 100 kv. During the pulse the ion source is capable of delivering 4 ma of current, of which half is monatomic. The arc is pulsed for 200 μ sec at a repetition rate of 60 cps. The integrated yield produced on the target exceeds 6×10^5 neutrons per sec for the d-d reaction and 6×10^7 neutrons per sec for the d-t reaction. The pulsed neutron generator is characterized by the absence of critical adjustments in any of the parameters governing its operation.

A SUSPENDABLE PULSED NEUTRON SOURCE

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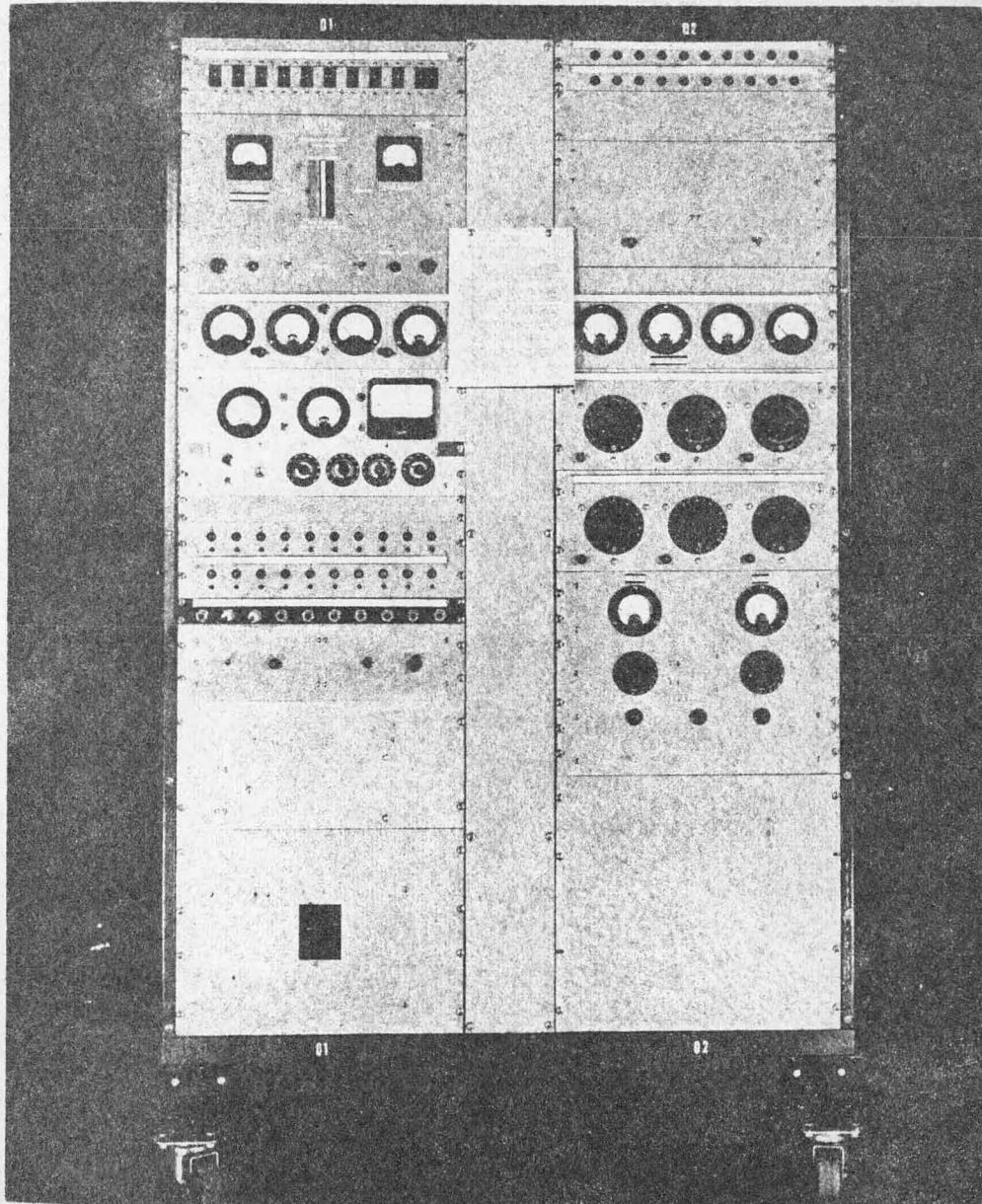
Introduction

Many new applications for pulsed neutron sources have recently been reported. These include, for example, the study of neutron behavior in various multiplying and non-multiplying media of use in reactor design, and the identification of materials through the use of neutron activation. Compact laboratory pulsed-neutron sources have been described before.^{1, 2} The one under consideration here, however, has the advantage that it may be conveniently suspended at any point between ten feet above and ten feet below floor level. Neutron bursts of 200 μ sec length at 60 cps are obtained by pulsing the arc, all other voltages being maintained dc. At maximum output the integrated yield exceeds 6×10^5 neutrons per sec for the d-d reaction and 6×10^7 neutrons/sec for the d-t reaction.

General Description

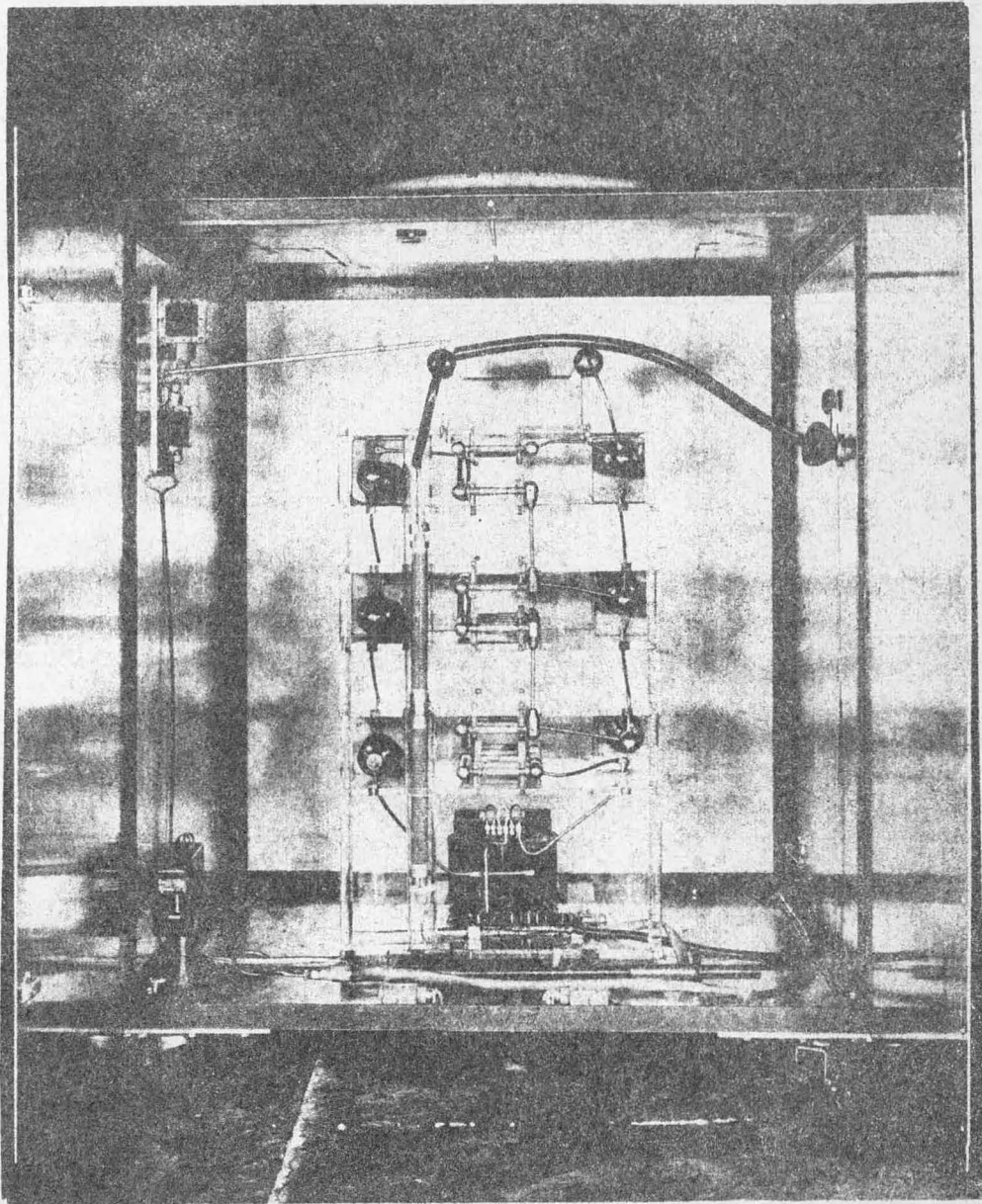
The pulsed neutron source comprises four separate components; constituted as follows:

1. All controls and monitored signals are available within a twin 7-foot rack mounted on casters. An operator's view is shown in Fig. 1. All power supplies are contained in the rack except the target high-voltage supply.
2. A 100 kv cascade rectifier power supply is contained in a caster-mounted cabinet, which is shown in Fig. 2.
3. Refrigeration and vacuum equipment is mounted on an iron-frame cart as shown in Fig. 3. Mounted on the cart can be seen a Kinney KC-5 fore-pump, a small refrigeration unit, and a 200-liter deuterium cylinder.
4. The accelerator assembly is shown in Figs. 4 and 5. It principally comprises the ion source and ion-source magnet, 4-inch pyrex accelerator tube, pump manifold, and a 4-inch oil diffusion pump. The particular arrangement of the components was dictated by some unusual space requirements in one intended application of the apparatus. Besides electrical cable, four flexible hoses made of shielded sylphon tubing connect the accelerator assembly to the cart. Two of these carry refrigerant, one holds deuterium gas, and the other constitutes the vacuum foreline. In addition, two rubber hoses connected similarly circulate cooling water to the diffusion pump. The accelerator assembly can be suspended as shown in Figs. 4 and 5, or it can be supported from an arm attached to the cart as shown in Fig. 6.



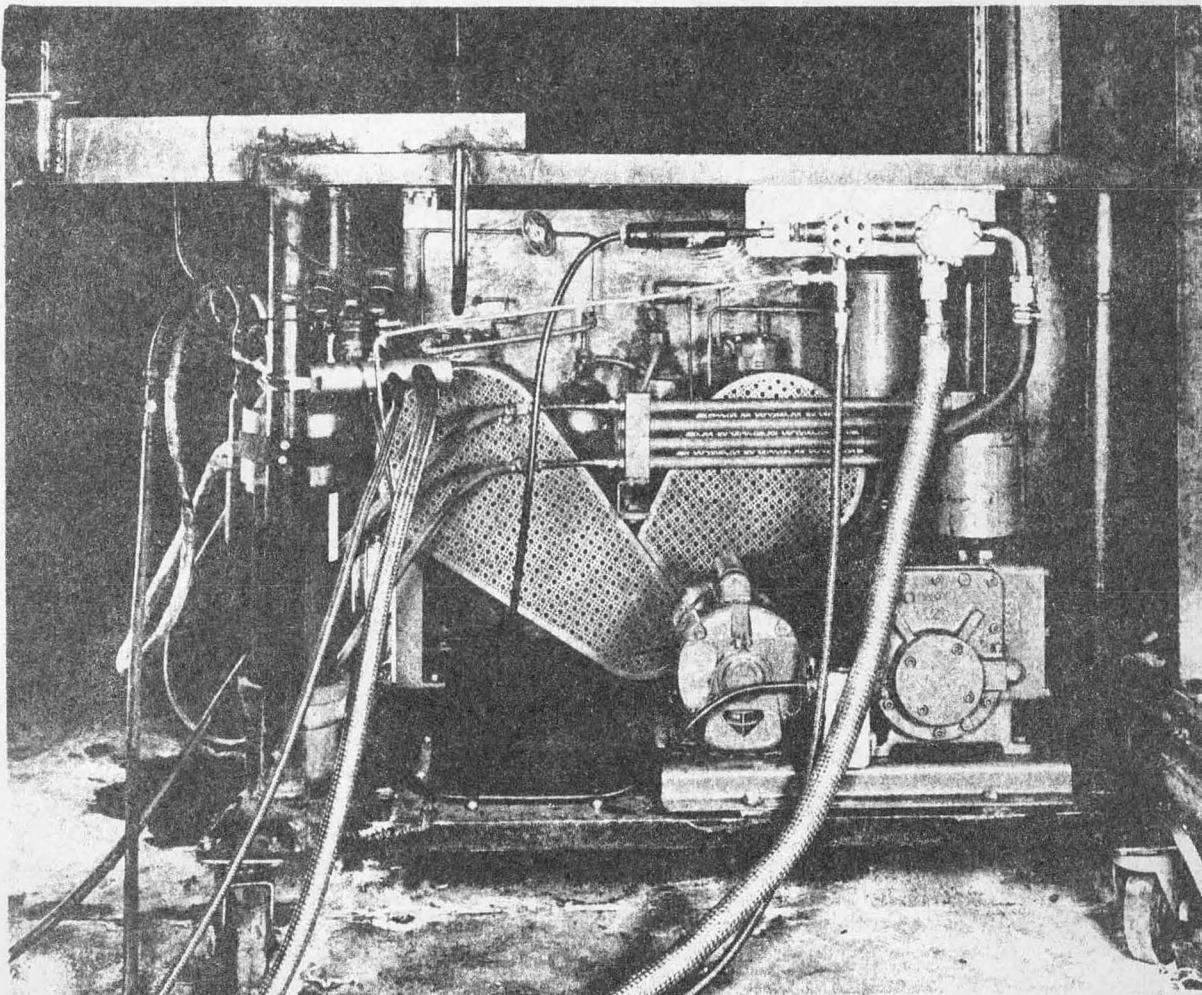
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Fig. 1. Twin seven-foot control rack



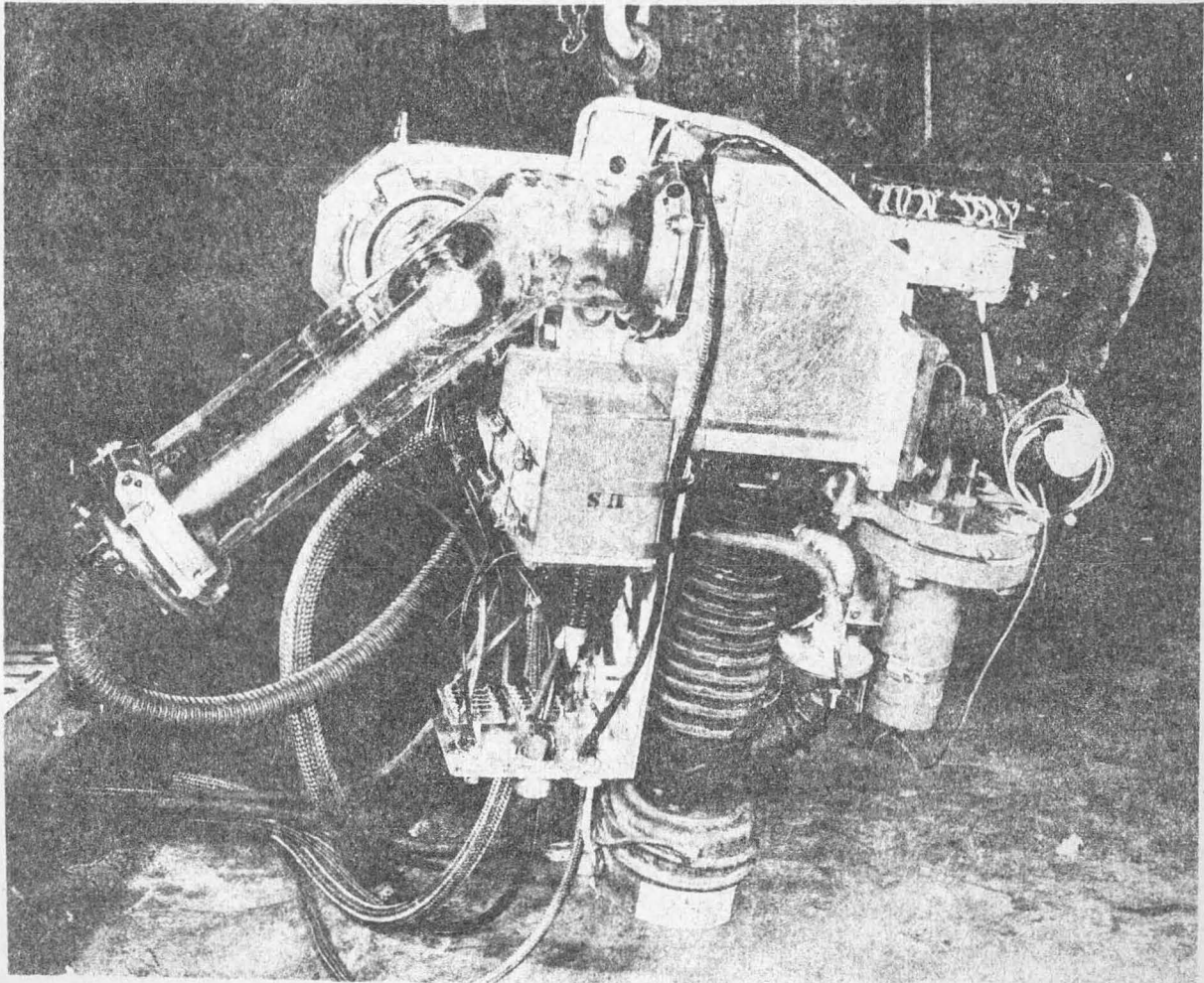
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Fig. 2. Iron-frame cart



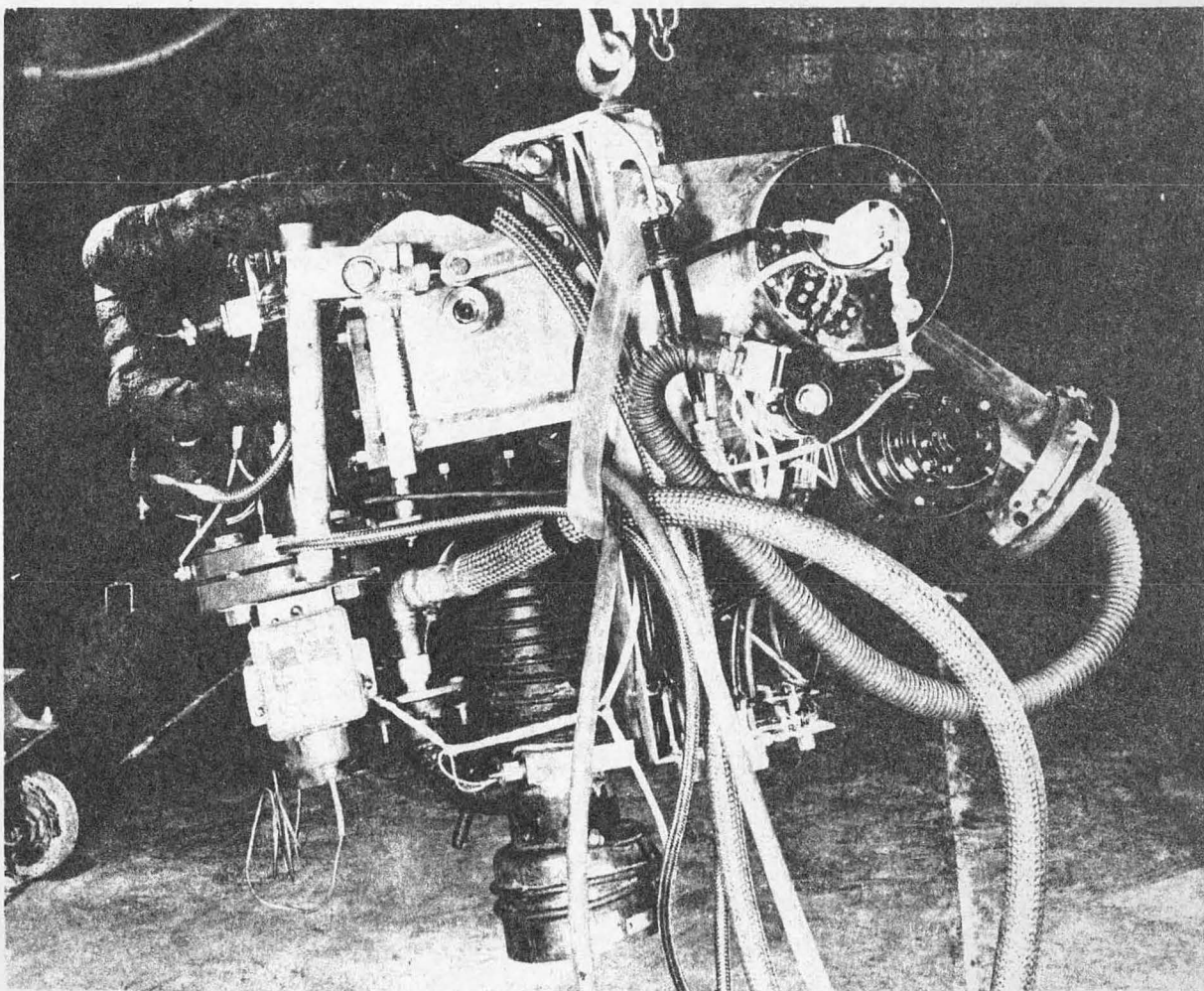
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Fig. 3. 100-kv cascade rectifier supply



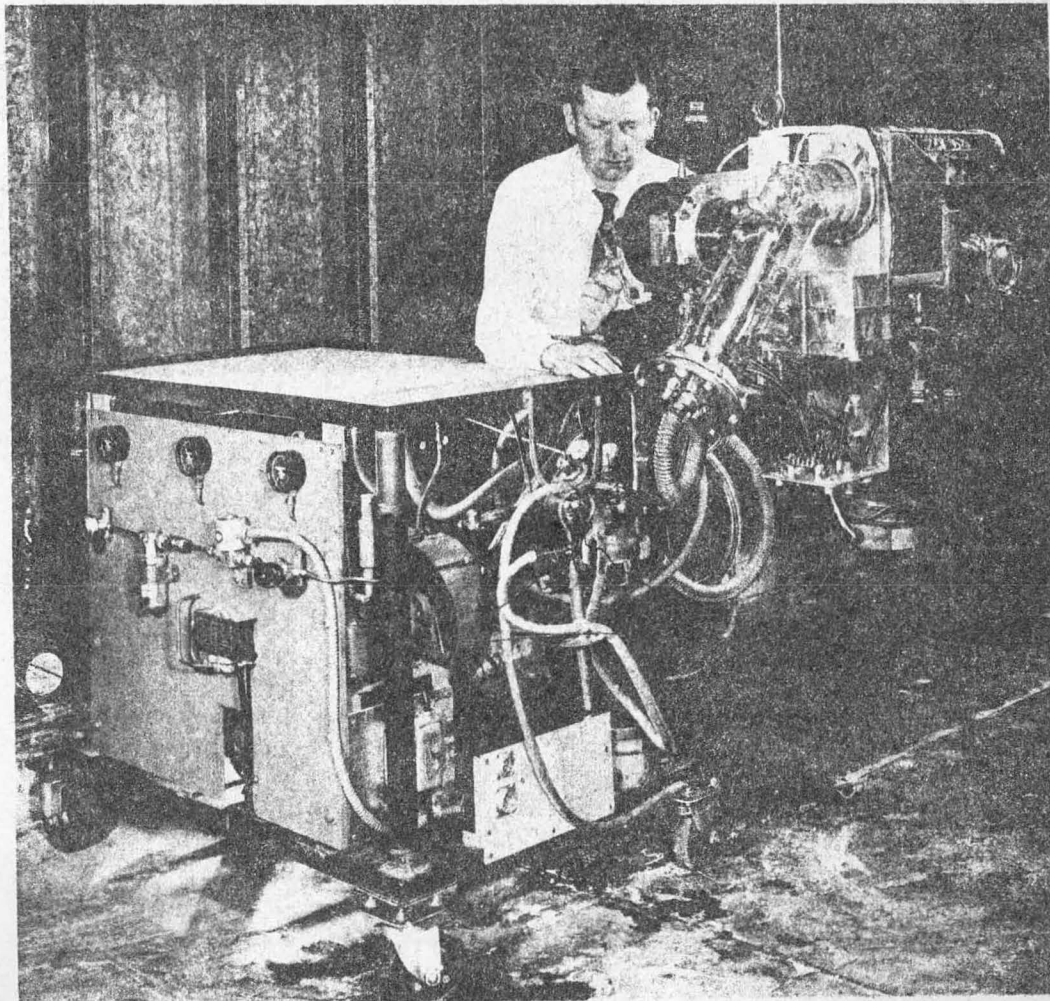
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Fig. 4. Accelerator assembly from target side



ZN-1509

Fig. 5. Accelerator assembly from ion-source side



ZN-1507

Fig. 6. Accelerator assembly mounted on cart

Vacuum System

In continuously pumped systems using liquid nitrogen traps, periodic refilling of the traps is necessary. There is also the danger that should the traps go dry, a film of condensing oil would coat the target. Since the range of 100-kev ions is extremely short, the neutron yield is especially sensitive to any surface contamination on the target. To avoid the problems of servicing and of possible accidents from dry traps, a single refrigerated baffle was designed into the pump manifold. A special low-temperature refrigerant, Kulene 131, was used, which cools the baffle to -120°F . A solenoid valve has been provided to reduce the starting load on the motor. By means of a manually operated gate valve in the manifold, the accelerator tube may be closed off and rapidly let up to air when it is necessary to change the target. The diffusion-pump current would be automatically interrupted by thermal sensing elements should the refrigeration fail or the cooling water cease flowing. The operating pressure as measured with an ion gauge in the manifold is in the range 5×10^{-5} to 7×10^{-5} mm of Hg.

Ion Source

The ion source is of the cold cathode Phillips Ion Gauge (PIG) type developed at this laboratory.^{3, 4} It can supply 4 ma of pulsed ion current, of which half is monatomic. A 1500-volt positive pulse, 200 μsec long, is applied to the ring anode. When the magnetic field and deuterium pressure are appropriate, the arc strikes and the voltage across it is reduced to 300 volts and is independent of current over a wide range. Before assembly the aluminum cathodes are heated in a highly oxidizing flame to enhance their secondary-emission property.

A palladium leak is used to regulate the flow of deuterium to the source. Pressure in the line between the leak and the deuterium cylinder is maintained at a few pounds per square inch above atmospheric, while operation pressure on the exit side of the leak is 150 to 250 microns of Hg.

Ion-Accelerating System

A tapered hole has been made in one of the arc cathodes. The minimum diameter at the intersection with the inside surface of the cathode is 0.040 in. A stainless steel cylinder, known as the probe, maintained at a negative potential in the range 10 to 20 kv, extracts ions from the surface of the arc plasma. One end of the probe is conical so that it fits into the tapered hole in the exit cathode. A larger stainless steel cylinder, known as the focus electrode, is placed about 0.5 in behind the probe and has the function of controlling the beam diameter. The target electrode is located about 2 in. behind the focus electrode. The target itself is a thin disk, 1.5 in. in diameter, which is clamped against the target electrode in a fashion to permit good heat exchange and easy replacement. The target electrode is hollow and air is blown through it to remove the heat generated by ion bombardment in the target.

Target Preparation

The art of preparing a deuterium or tritium target has become fairly common.^{5,6} A convenient way is to occlude the gas in a transition metal such as titanium which has been previously evaporated or fused onto a high-melting-point backing metal such as tantalum. Alternately, deuterated paraffin is particularly easy to use if it is available.

Target High-Voltage Power Supply

The target power supply is of the cascade rectifier type and produces 100 kv of negative dc voltage from 117-volt 60-cps input. The circuit employs selenium rectifiers and delivers an average current of 1.0 ma. The output is limited by 10 megohms and then taken on RG/19U to the target electrode. The cable supplies about 740 $\mu\mu\text{f}$ of capacity to stabilize the target voltage. A solenoid-operated grounding hook is arranged to drop on the high-voltage lead if the safety interlock chain is broken.

Arc Pulser

The arc pulser consists of a 200- μsec one-shot multivibrator, an amplifier, a cathode follower, and an 811 pulser tube. The 811 was chosen because of its constant current characteristics, high plate resistance, and small cutoff bias. Since it is connected in series between the arc power supply (2 kv, 50 ma) and the ion source, an isolation transformer is required for the grid. A large filter capacitor in the pulser serves to stabilize the arc voltage. A voltage divider in the pulser output allows the arc voltage to be monitored.

Probe and Focus Power Supplies

Two 20-kv 1-ma power supplies maintain the probe and focus potentials. At each electrode there is an 0.05- μf 30-kv voltage-stabilizing capacitor which is connected through a current-limiting resistor of 2400 ohms. In addition, the low-potential side of each capacitor is connected to ground through a 50-ohm resistor across which the current to that electrode can be monitored during the pulse.

Trigger Pulser

A 60-cps pulser supplies a trigger for the scope sweeps, and various timing circuits used with the neutron-counting equipment. It also fires the arc pulser multivibrator. A switch is provided for the alternate use of an external synchronizing signal.

Characteristics

The single noteworthy characteristic of this pulsed neutron generator is the absence of critical adjustments in any of the parameters governing its operation. Because the extraction process rapidly becomes emission-limited, the yield as a function of probe voltage does not exhibit the slope characteristic of space-charge-limited behavior; above 6 kv the yield rises slowly and at 10 kv is 90% of that at 16 kv. The focus voltage is a very insensitive parameter because the target is located so close to the focus electrode that beam divergence has little effect. Additional voltage on the arc power supply beyond that at which the arc strikes will produce more arc current, which is beneficial in overcoming emission-limited operation of the probe. In this range the yield shows a slowly rising characteristic similar to that in the case of the probe. The most sensitive parameter in the operating range is the target voltage. It is seen from Fig. 7 that the yield varies with the cube of the target voltage. A reproduction of the operating instructions is given on facing page.

Acknowledgments

The arrangement of the ion source and accelerating electrodes as well as the layout of the electronics have been patterned closely after a previous pulsed neutron source built at this laboratory by Robert G. Smits and Richard C. Sinnott. The author is indebted to Robert G. Smits for several helpful discussions, to Henry J. Dea for the design of many of the mechanical components, to Hugh R. Smith for the design of the refrigeration system, to Wesley A. Rutz for arranging the electronics installation, and to Wing G. Pon for assistance with assembly and testing.

This work was done under the auspices of the U. S. Atomic Energy Commission.

OPERATING PROCEDURE

Pumpdown

1. Check reducer gauge on deuterium bottle. Pressure should be 2 to 5 lb/in.² If it is necessary to recharge the feed line to restore pressure, be sure main valve on deuterium bottle is closed off afterwards.
2. Check that Hoke valve between Pd leak and ion source is open, and that Hoke valve on target flange is closed.
3. Open gate valve, but only if diffusion pump and refrigerator have been off for at least 1/2 hour.
4. When forepressure drops to 60 microns or less, turn on refrigerator motor. After about 30 sec, turn on refrigerator solenoid valve and diffusion pump (120v, 4.0 amp). An additional switch in the D. P. circuit will be closed after a few minutes when the refrigerated baffle cools sufficiently. Continuity in the D. P. circuit will also be interrupted in case of a failure in the water cooling system.
5. Wait until the vacuum has been reduced to 5×10^{-5} mm or better before attempting to start neutron generator.

Neutron Generator

1. Turn on Pd leak. About five minutes is required to attain equilibrium pressure. Operating range is 150 to 250 microns on the Pd leak thermocouple gauge. Never operate the Pd leak with vacuum on both sides of it.
2. Turn on PIG magnet to about 1 amp.
3. Turn on PIG voltage. Operating range is 800 to 1600 volts. Do not exceed 2000 volts. Finally, adjust magnet for minimum ripple on arc voltage pulse.
4. Turn on probe and focus voltages. Set focus about 10% higher--i. e. more negative--than probe. Operating range is 6 to 16 kv.
5. Slowly turn up target voltage. Neutron yield increases approximately as the cube of target voltage. If a spark causes overload to open, turn variac back to zero before resetting.

Changing Target

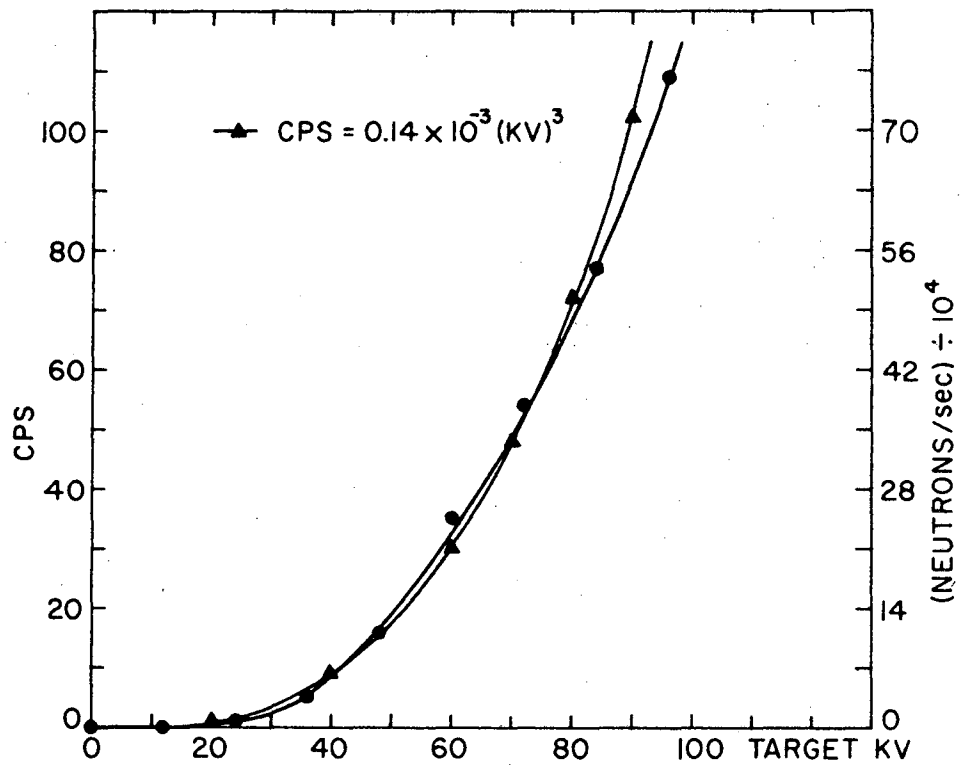
1. Open refrigerator-solenoid-valve breaker and after about 30 sec open all other breakers except forepump and vacuum gauges.
2. Break interlock chain by opening safety door and then discharge any voltages remaining on target, focus, probe, or PIG electrodes.
3. Close gate valve.
4. Open Hoke valve on target flange to let ion source down to air.
5. Remove target assembly and replace target. Take care not to touch active surface of target, as yield is extremely sensitive to any contaminant film.

Radiation Hazard

1. With the d-d reaction, at 100 cm from the target both the fast-neutron and x-ray fluxes are within tolerance.
2. With the d-t reaction, at 100 cm from the target the x-ray flux is within tolerance, but the fast-neutron flux considerably exceeds tolerance.

Overnight Shutdown

1. Proceed as under "Changing Target," but omitting Items 4 and 5.



MU-11422

Fig. 7. Neutron yield versus target voltage

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