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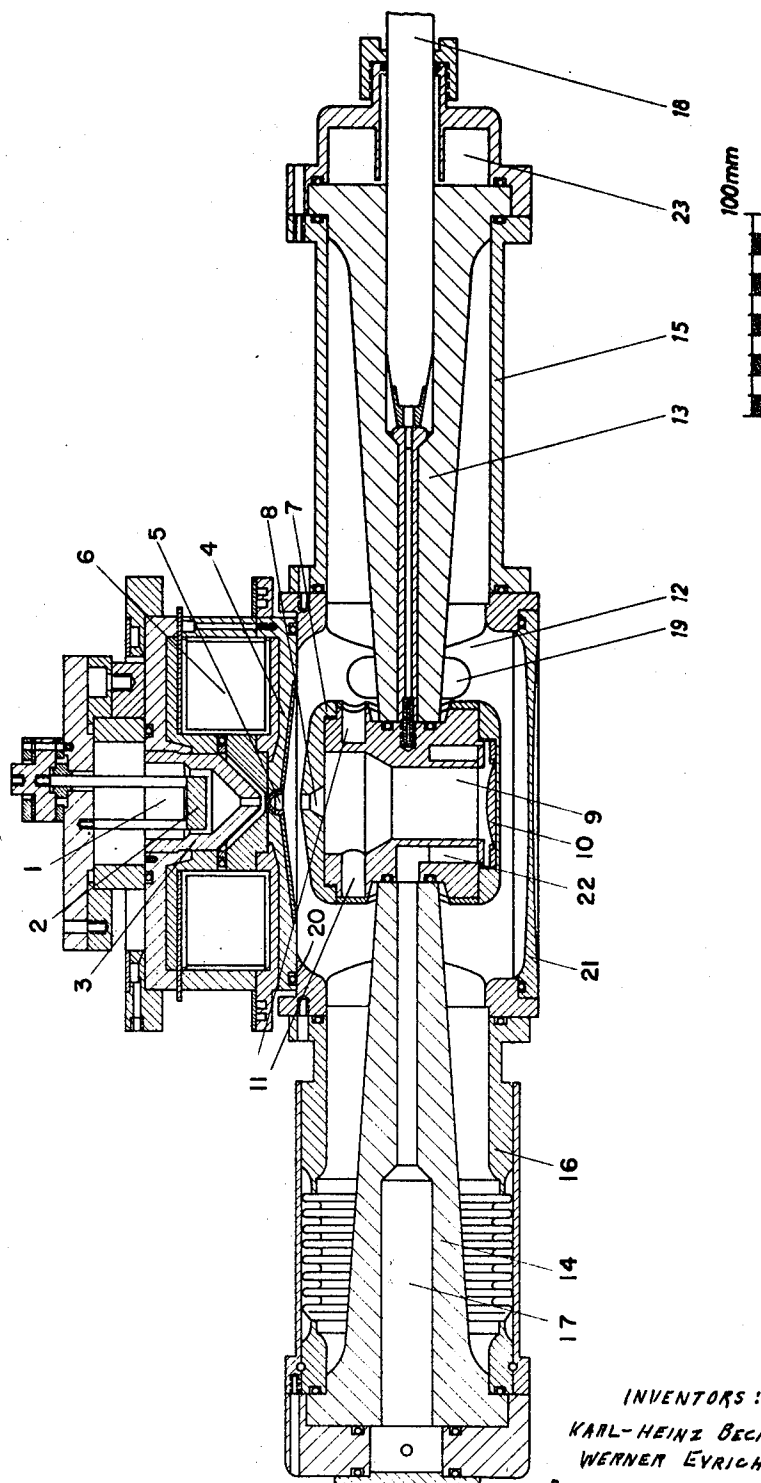
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NEUTRON GENERATOR

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2 Sheets-Sheet 1

Fig. 1



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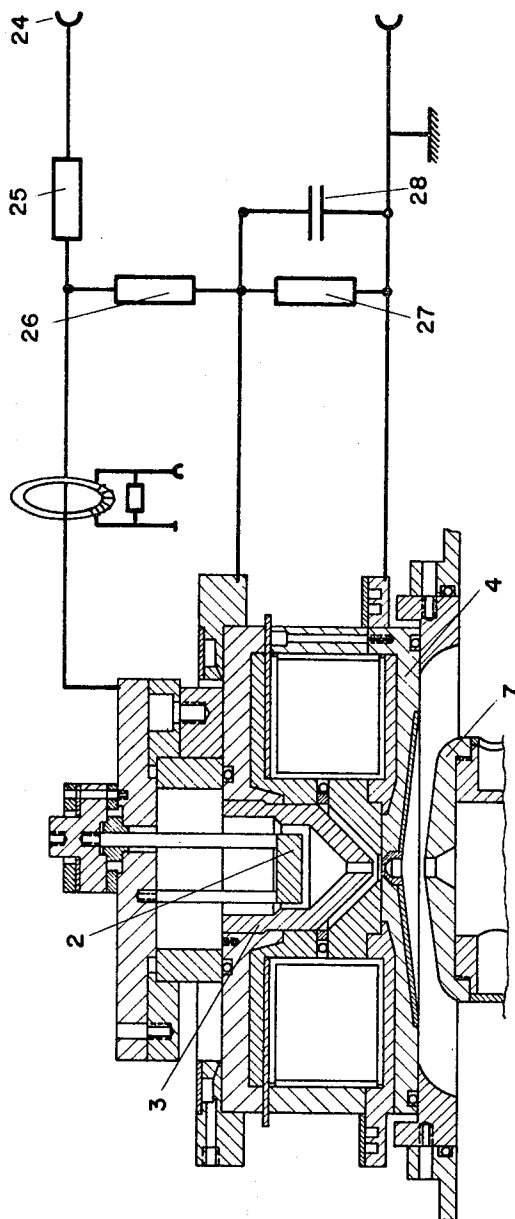
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Fig. 2



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NEUTRON GENERATOR

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9 Claims. (Cl. 313—61)

The invention relates to a neutron generator with an ion source, e.g. a duoplasmatron, and a suction electrode for the ions which generate neutrons when hitting the target.

There have been neutron generators accelerating the ion beam in a system of electrodes and concentrating it upon the neutron generating target. In a system of that type the ions have to cover long distances. Due to lens errors and to the space charge effects high losses occur at high ion currents. A duoplasmatron has also been used as an ion source for ion accelerators. Because of the long paths for the ions in the accelerators, however, it is impossible to fully utilize the ion emissivity of the duoplasmatron.

In one way of carrying out the invention, two variations of which are known, the ions are shot upon a target which is kept under high voltage. In one apparatus designed according to the invention the target has been placed at the end of an accelerating tube; the surrounding air is used as an insulator against high voltage. In order to avoid flashover the measuring setup has to be positioned relatively far away from the neutron source which causes part of the neutrons to get lost. In the other design according to the invention the ion source has been molten into a glass tube complete with accelerating path and target. However, this tube only has a maximum intensity of 10^8 neutrons/sec.

It is the task of this invention to create a failsafe neutron generator of small dimensions having a high neutron intensity. In the neutron generator according to the invention target and suction electrode have been placed in one housing suspended in a highly evacuated generator housing. This requires only small spaces between target housing and generator housing to prevent flashover. Correspondingly, the generator housing around the target housing to which the high voltage is applied, is small. By means of suitable openings in the target housing the neutral gas entering the target housing with the ion beam is sucked off so that a good vacuum is present also in the region of the inlet openings of the suction electrode, where there are high field intensities. As the target housing is kept at high voltage, the ion source in the generator according to the invention can be connected with the grounded generator housing. This makes the expensive current supply system of an ion source at high voltage unnecessary.

In one development of the device according to the invention a pulsed voltage synchronized with the pulsed ion source has been applied to the target housing instead of the D.C. voltage, thus making it possible to apply much higher voltages during the pulse than could be applied in operation at constant voltage. The neutron generator according to the invention reaches an instantaneous source intensity of up to 10^{14} neutrons/sec.

Details of the invention are explained on the basis of the drawings:

FIG. 1 shows a section through a neutron generator,

FIG. 2 shows the electric circuit diagram for the neutron generator.

As shown in FIG. 1 the ion source installed in the neutron generator is a duoplasmatron with a cathode 2 installed in the gas discharge space 1, with an intermediate

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electrode 3, an anode 4 and an emission opening 5. As the design of a duoplasmatron is generally known, no details are described here. In contrast to familiar designs only the magnet chamber 6 and the cathode 2 were changed in such a way as to enable cooling of the source by air at low average current load, by water at high loads.

From the emission opening of the duoplasmatron the ions are shot into the interior of a target housing 9 through the opening 8 in the suction electrode 7. At the side opposite the inlet opening 8 the neutron generating tritium-titanium target 10 has been installed at such a distance that it is just fully covered by the ion beam entering through the inlet opening 8 into the target housing 9 and then expanding. At a target diameter of 35 mm. the ion flight path in the target housing 9 is some 90 mm. In that case the target 10 is arranged so as to generate the neutrons as near to the front face of the generator as possible. Annular cooling channels 22 fed with coolant through the insulator 14 are arranged around the ion flight channel for cooling the target housing. The neutral gas is sucked off through openings 11 in the target housing. The openings 11 are so designed as not to be penetrated by electric fields extending into the target housing and deflecting the ion beam. The target housing 9 has a cylindrical or spherical shape of some 100 mm. diameter. It is freely suspended from two insulators 13 and 14 in the generator housing 12, the insulators themselves being fastened to the ends of two tubular supports 15 and 16. In order to prevent flashover, there is a pressure of some 5×10^{-5} torr in the generator housing 12 during operation. Moreover, there is an opening 19 for connecting the high-vacuum pumps, e.g. ion getter pumps and getter pumps to evacuate the accelerator housing and thus also the target housing and the gas discharge space. Coolant is fed to the target housing 9 through channels 17 via an insulator 14, whereas the second insulator 13, which is best placed opposite the first insulator, contains the high-voltage lead 18 to the target housing. The joints of the porcelain insulators with the target housing 9 have been shaped so as to make the insulators 12 and 14 emerge from the target housing field-free. The insulators are long enough to prevent current leakages and surface discharges from occurring at the voltages present. For measuring the ion current in the target housing there is an annulus 23 at the inlet of the high-voltage lead 18 into the insulator 13 which holds a current transformer coil. The channels 17 in the insulator 14 are sealed vacuum-tight towards the outer sphere. The target housing 9 is placed centrally in the generator housing. In order to prevent flashover the surfaces have been polished and well rounded off. The connecting pieces 15 and 16 are fixed to two openings in the generator housing; to their ends the insulators 13 and 14 are fixed by vacuum-tight seals. The duoplasmatron is flanged onto one side of the generator housing. It may be moved on the sealing surface 20 within moderate limits by three adjusting screws not described in more detail, which makes it possible to adjust the bores 5 in the anode in alignment with the inlet opening 8 in the suction electrode. On the opposite side the housing 12 is also sealed vacuum-tight with a lid 21. The lid is level on the outside so that this side of the neutron generator may be rested against objects to be irradiated.

FIG. 2 shows the electric circuit diagram of the duoplasmatron ion source. The accelerator was specially developed for pulsed neutron experiments. For this reason the ions, and thus also the neutrons, are generated in pulses. To do this a pulse generator 24 supplies negative pulses of a current up to 50 A which reach the cathode 2 through a resistor 25. Anode 4 is grounded. Between anode 4 and cathode 2 the resistors 26 and 27 have been connected as voltage dividers, the intermediate electrode 3 is connected between them. The capacitor 28 retains

the potential of the intermediate electrode up to ignition of the gas discharge at anode potential. Afterwards, due to the high discharge current, the intermediate electrode automatically adjusts to its operating potential. The penetration opening 5 for the plasma in anode 4 is 0.8 to 1.2 mm. wide. The magnetic field compresses the plasma beam coming from the intermediate electrode 3 to this diameter. Afterwards, the plasma is fed into an expansion of the penetration opening 5. This bell-shaped bore (diameter 8 mm.) is completely filled with plasma. The suction electrode 7, which is kept at voltages up to 120 kv. sucks the ions from the plasma layer on the outside of the bore.

The possibilities of executing the invention are not restricted to the example described here. It is possible also to provide, in a well-known way, slot-like openings offering a larger penetration surface instead of the bores in the duoplasmatron and in the suction electrode.

Additional accelerating stages can also be set up between the ion outlet opening of the ion source and the target housing.

Preferably, electrodes are used for this purpose whose design resembles that of the target housing, but which have an opening (outlet opening) instead of a target serving as a second outlet of the ion beam for further acceleration. The penetration openings may be adapted to an expansion of the ion beam.

Patent claims:

1. A neutron generator which comprises an evacuable outer housing having a wall portion the exterior surface of which is adapted to be positioned in close proximity to objects to be irradiated with neutrons, an ion source means operatively connected to said outer housing for introducing an ion beam therein directed generally toward said irradiation wall portion thereof, an inner housing means disposed within said outer housing in spaced apart relation thereto, said inner housing means including a suction electrode for accelerating ions within said ion beam and a target for generating neutrons upon impact by ions accelerated by said suction electrode, said inner housing means and its suction electrode and target being electrically connected together for maintenance at a common high electric potential difference with respect to said outer housing, and feed through insulator means operatively connected to said outer housing and to said inner housing means for supporting said inner housing means is spaced apart relation to said outer housing, electrically insulated therefrom, and with said target positioned in unobstructed opposite spaced relation to said irradiation wall portion.

2. The neutron generator according to claim 1 wherein said feed through insulator means includes at least one elongated feed through insulator disposed radially with respect to the path of said ion beam.

3. The neutron generator according to claim 1 wherein said ion source means has an ion outlet aperture disposed approximately 10 mm. apart from said suction electrode and in registry therewith.

4. The neutron generator according to claim 1 including means defining an annular coolant channel within said outer housing.

5. The neutron generator according to claim 4 wherein said feed through insulator means includes a first insulator containing a high voltage lead-in conductor, and a second insulator including means defining a coolant flow passage therein disposed for communication with said annular coolant channel within the outer housing, said first and second insulators being disposed radially with respect to the path of said ion beam.

6. The neutron generator according to claim 1 including means defining at least one passage extending through said inner housing means to accommodate removal therefrom of neutral gases collected therein.

7. The neutron generator according to claim 1 wherein said outer housing and inner housing means are generally cylindrical.

8. The neutron generator according to claim 1 wherein said irradiation wall portion of the outer housing is removable therefrom to accommodate installation of said inner housing means within said outer housing.

9. The neutron generator according to claim 3 wherein said target is generally circular and said suction electrode has an ion inlet aperture disposed to define an ion flight path between said target and inlet aperture which is approximately 2.5 to 2.8 times the target diameter.

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