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DEVICE FOR THE PRODUCTION OF SLOW NEUTRONS

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This invention relates to a device for the production of slow neutrons.

For the purpose of investigating substances of any kind including living bodies it has already been suggested to depict the objects to be investigated with the aid of slow neutrons in a similar manner as has already been done by means of X-rays. Such representations by means of neutrons are obtained by directing a beam of neutrons through the respective object or body and by causing the neutrons emerging from it to encounter a fluorescent or a photographic system made sensitive to neutrons. As the absorption relations for slow neutrons differ widely from those of X-rays, a representation obtained by neutrons and a representation made with X-rays from one and the same object are fundamentally different from one another. Obtaining representations of both kinds is, therefore, particularly important as regards the investigation of materials for medical purposes.

The neutrons required for these purposes are obtained in known manner by nuclei reactions. Thus, for instance, considerable amounts of neutrons are obtained by bombarding beryllium with α -particles of radium. But the production of neutrons with the aid of naturally existing radioactive substances is not suited for technical purposes, as, owing to the great rarity and costliness of radio-active substances, the slow neutrons cannot be produced with the desired intensity. By far larger amounts of neutrons can be produced if ions, preferably the ions of heavy hydrogen, are accelerated in a discharge tube and then made to impinge upon a suitable substance. If such an ion-current of 10^{-6} amperes accelerated to 10^6 volts impinges upon a Be-target, an amount of neutrons equal to that obtained from about 7 grams of radium closely mixed up with Be will be obtained. As it is today not difficult to produce currents of ions of 10^{-6} amperes and even much more and to accelerate them to a high potential, it is in this way possible to provide sources of neutrons having a thousand-fold stronger intensity than those sources which can be provided with a strongly radio-active sample. The yield of such artificial sources of neutrons increases with the speed of the bombarding particles, and one endeavors, therefore to accelerate the neutron-producing ions as much as possible.

As with these sources of neutrons the acceleration of ions to 10^6 volts is necessary, the problem to be solved in the provision of strong sources of neutrons is to perform an easily manageable discharge tube to which the above mentioned

high voltages can be applied. Usually an arrangement is chosen in which the source of ions which constitutes by itself a voluminous device is connected to the high positive potential and the ions proceeding from that source are accelerated between the high potential and the earth. With an arrangement of this type the ions impinge with the desired energy upon the earthed parts of the apparatus and produce there the neutrons in a suitable reaction layer. This source of neutrons is connected to the earth. This is particularly important in working with sources of neutrons because the objects to be irradiated can in the simplest manner be brought into the immediate proximity of the source of the neutrons without requiring any special protection against flashing-over of the high potential. This is particularly important in case exposures of living bodies are to be made.

But the abovementioned arrangement suffers from the drawback that, owing to the high potential employed, all distances from the walls must be rather large. Besides, the composition of the source of ions with the appertaining arrangement involves considerable difficulties in the case of a high potential. Finally, also, the centering of the beam of ions is considerably difficult because of the length of the discharge tube in which the ions are accelerated. As this tube, for instance in the case of an acceleration potential of 10^6 volt, has a length of from 2 to 3 meters, the beam of ions must be centered and held together along that length. If it would broaden anywhere this would involve a considerable loss of intensity.

As, thus, with such a high-potential tube with the source of neutrons connected to the earth, the high insulation and the centering of the beam of ions is troublesome, another arrangement has been designed in which not the entire acceleration voltage is placed between the source of ions and the earth, but the middle of the acceleration voltage is connected to the earth. In this case the source of ions is placed upon a positive potential corresponding to only one half of the entire acceleration potential, and the source of neutrons is placed upon a negative potential relative to the earth which likewise corresponds to one half of the entire acceleration potential. Thus, if the entire acceleration amounts to 600 kv. the source of ions would lie on a + potential of 300 kv. and the source of neutrons would lie on a potential of 300 kv. relative to earth. With such an arrangement the potentials to be generated and insulated against

earth amount only to half the potential relative to earth needed in the case in which the entire acceleration voltage is placed between the source of ions and the earth. Thus consumption of space and the costs for the requisite high-potential plant are considerably lower and also the centering and the adjustment of the beam ions can be carried out in a by far simpler manner, as the adjustment of the beam of ions need be effected only between the earth and the source of ions. If the beam of ions has once been centered and adjusted with one half of the potential, the subsequent further acceleration changes the adjustment only a little.

But now the arrangement suffers from the disadvantage that also the source of neutrons lies on a high potential and is, therefore, accessible only with difficulty in the case of making exposures with the neutrons. The simplest way to obviate this difficulty would be to place the objects to be irradiated so far remote from the source of neutrons that no flashing-over or sparking takes place. But this cannot actually be accomplished in a simple manner, since the distances requisite to obviate flashing over and sparking are so large that if they were to be maintained a very great loss of intensity would result, whereby the time of exposure would be extraordinarily prolonged. If a source of neutrons lying on a high potential relative to earth shall be used for the purpose of depicting objects, provisions must be made for rendering it possible to place the respective objects, etc., sufficiently near to the source of neutrons, in spite of its high potential, without running any risk of being damaged by flashing-over of the high potential or by sparking thereof.

It may be further considered in this connection that in general quick neutrons themselves as they are emitted by the source of neutrons are not used, but that, on the contrary, it is frequently necessary to reduce the speed of the neutrons before using them. This slowing down is effected, as is well known, by causing the quick neutrons to pass through substances containing hydrogen. Owing to the collisions of the quick neutrons with the hydrogen nuclei the neutrons lose a considerable amount of energy. For instance, with the aid of a layer having a thickness of from 10 to 20 cm. and consisting of paraffin or water large amounts of slow neutrons are obtained. Thus, in order to obtain slow neutrons, the source of quick neutrons has to be surrounded with a hydrogenaceous substance of sufficient thickness.

It is a purpose of the present invention to facilitate the working with a source of neutrons lying on a high potential relative to earth. This inventive purpose is attained by embedding the source of quick neutrons nearly on all sides into an insulating substance capable of slowing down the quick neutrons, and to surround that substance either wholly or at least partly with a grounded conductive protection body. If the substance reducing the speed of the quick neutrons consists of a liquid, it is enclosed in a receptacle connected on all sides to earth, apart from a leading-in-insulator perhaps provided. It is, however, necessary to choose such a thickness of the substance slowing down the quick neutrons that on the one hand the breakdown-strength thereof relative to the high potential employed is sufficient, and that, on the other hand, as many slow neutrons as possible are produced. With an arrangement of this kind

it is in many cases advantageous to embed into the insulating substance not only the source of neutrons, but also the insulating tube by which that source is insulated towards the earth, as is the case with the constructional form shown in Fig. 1. Such an arrangement presents the advantage that, on the one hand, one can step very near to the source of neutrons without running any risk of being damaged by the high potential, and that, on the other hand, an unnecessary loss of the intensity of the slow neutrons by excessively large distances is obviated.

The invention is illustrated diagrammatically and by way of example in the accompanying drawing, in which Fig. 1 is an axial section through a device designed according to this invention, and the Figs. 2, 3, 4, 5 and 6 show five modifications of the lower portion of Fig. 1, all as fully described hereinafter.

In Fig. 1, 1 denotes the source of ions which is designed in this case as a canal-ray tube and the upper covering disk 2 of which is connected to a positive potential $V/2$, if V constitutes the total acceleration potential. The source of ions is separated from the earth by the insulator 3. The beam of ions 5 leaving the tube 1 at the place 4 is accelerated by the field existing between the source of ions and the annular electrode 6 that is connected to the earth. The beam of ions traverses therefore the annular electrode 6 with an energy corresponding to the potential $V/2$. Having passed through the electrode 6, the ions are then again accelerated by $V/2$ between the electrode 6 and the electrode 7 which is likewise connected to a potential $V/2$. Then they enter into the ion collector 8 which is designed as a hollow body, and impinge at 9 upon a reaction layer emitting neutrons when being bombarded with these ions. The electrode 7 which is connected to a high potential, as well as the reaction layer 9, are separated from the earth by the insulator 10. This latter, as well as the source of neutrons 9, are housed in a large receptacle filled with an insulating substance 12 by which the speed of the quick neutrons is reduced. The wall of the receptacle 11 is grounded. The electrode 7 is supplied with the desired high potential by a metallic conductor 13 introduced by means of an insulator 14 likewise filled with an insulating substance. The high potential is insulated against earth by the insulator 14 and the insulator 10 which is completely embedded in oil and can therefore be relatively small. The cooling of the reaction layer 9 which is heated by the ion bombardment can be effected by the insulating and speed-reducing substances itself in that a circulation is brought about in it, but it may be cooled in any other suitable manner. Evacuating the entire discharge tube is effected through the earthed middle part 15, to the branch 16 of which the vacuum pump (not shown) is joined.

It is known that hydrogen-containing substances not only reduce the speed of the quick neutrons, but also absorb the slow neutrons. If it is, therefore, intended to obtain a possibly intense radiation of slow neutrons, the speed-reducing insulating substance should not be too thick, in that in such a case too few slow neutrons would pass to the exterior. There is for every speed-reducing substance an optimum as regards its thickness which permits as many slow neutrons as possible to pass to the exterior if the source of neutrons is surrounded nearly on all sides with the speed-reducing substance. The optimum of

the thickness lies, for instance, as regards paraffin oil, at about 12 cm. If the thickness is therebelow, the intensity of the neutrons will not be sufficiently reduced. If, however, the thickness is materially greater, the number of the slow neutrons will again be reduced, as then the absorption of the slow neutrons by the hydrogen becomes perceptible. This point of view must be paid attention to when electing the speed-reducing and insulating substance and devising its receptacle. If, for instance, an intensity of slow neutrons as high as possible is intended to be obtained at a certain definite place, the speed-reducing and insulating substance should be extended as much as possible to all sides, and only in that direction in which the slow neutrons are to pass to the exterior should the speed-reducing and insulating substance only be made only so thick as is just sufficient to insulate the source of neutrons with respect to the earth. If a small beam of electrons is desired, the earthed shell of the speed-reducing and insulating substance is covered with another substance 17, for instance boron, which absorbs the slow neutrons, and only at that place where the slow neutrons preferably escape the layer of boron is interrupted by an aperture for the passage of the neutrons.

Such an arrangement presents the advantage that it delivers an intense radiation of slow neutrons and that the objects to be investigated can be placed directly in the neighborhood of the source of the neutrons without any risk of being exposed to a flashing-over of the high potential. If the potential of the source of neutrons is very high, the minimum thickness of the speed-reducing and insulating substance between the exit point of the slow neutrons and the inner hollow space in which the quick neutrons are formed is often rather considerable. As the concentration of the slow neutrons is greatest in the hollow space within the substance 12, the intensity of the neutrons passing the exterior is still considerably weakened by the substance lying between said hollow space and the exit place for the neutrons, the weakening being due to absorption, as well as to scattering. If it is not possible to reduce the thickness of the layer sufficiently, it is nevertheless possible to increase the number of the slow neutrons passing to the exterior, in the following manner:

For this purpose the speed-reducing and insulating substance surrounding the source of neutrons may be not uniformly arranged, but an insulating body may be inserted within said substance between the hollow space and the exit point for the slow neutrons. Said inserted body under circumstances, likewise filled with a liquid prevents flashing over from the source of neutrons to the outer wall, but has the property of absorbing and scattering the slow neutrons less than the surrounding speed-reducing substance itself. Such a body inserted into the speed-reducing substance acts, by reason of its slight absorption and scattering, like a channel for slow neutrons and lets them pass from the interior (the place of largest concentration) to the exterior practically unimpededly.

The said body is inserted into the speed-reducing and insulating substance in order to increase the number of slow neutrons passing to the exterior. There may be used, for instance, a porcelain body, as porcelain absorbs and scatters slow neutrons by far less than a hydrogenaceous substance having the same volume. That body can be designed also in this way that it forms a thin-

walled insulating body filled with an insulating substance containing as little hydrogen as possible. Paraffin, in which the light hydrogen is replaced by heavy hydrogen, is, for instance, such a substance.

If the inserted body has not sufficient electric strength, or if discharges arise, on its surface, it is in such cases suitable to employ an insulating material for the construction of the exit place of the slow neutrons and the surroundings thereof and to cover only this material with the earthed layer. With such an arrangement the insulating material, for instance, porcelain, may, in general, be so thin that passage of the slow neutrons therethrough is practically not impeded in a perceptible degree.

With the inserting of an insulating body into the speed-reducing and insulating substance, there is always attended a certain danger that an electrical breakdown takes place along the surface of the inserted body. To avoid this, the surface should not be smooth but should be provided in a suitable manner with numerous ribs 18, as shown in Fig. 2. In the same manner the insulating material covering the receptacle at the exit place of the slow neutrons and the surroundings thereof should at its inner surface, adjacent to the speed-reducing and insulating substance, not be smooth but provided with ribs, as shown in Fig. 3.

In this modification (Fig. 3) in which the receptacle is closed by an insulating material 19 in the proximity of the exit place of the slow neutrons a body absorbing the neutrons only a little can be inserted which is hollow and which may be either filled with a gas or evacuated. This embodiment is illustrated in Fig. 6, in which the generally conically shaped hollow body 22 is arranged in container 11 relatively to the neutron source 9 in the same manner as is body 18 in the arrangement shown in Fig. 2. The chamber 23 of hollow body 22 is either evacuated or else filled with a gas which absorbs slow neutrons only very slightly. Preferably, the walls of hollow body 22 are formed from a solid substance which has a minimum absorptivity toward slow neutrons. It is further recommended that said walls be built as thin as possible.

In the constructional form illustrated in Fig. 2 the body inserted into the speed-reducing and insulating substance which absorbs and scatters the neutrons only a little has the shape of a truncated cone 18. To give said body this shape is important if the slow neutrons shall be emitted only through a relatively small aperture.

Finally, it is for certain researches important to be able to protect oneself from the quick neutrons emitted by the source of neutrons. At those places where the insulating and speed-reducing substance is particularly thick, said protection is afforded already by the great thickness of said substance, as this substance reduces the speed of the quick neutrons and prevents thereby these neutrons from passing to the outside and exerting a damaging effect. But at the places where slow neutrons escape by preference, also quick neutrons are emitted by preference, the reason being that on the one hand the speed-reducing substance has there the slightest thickness (as at 20 in Fig. 4) and that on the other hand, at these places bodies are inserted which absorb and scatter the slow neutrons only little. These substances have, however, also the property of reducing the speed of the quick neutrons only very little. In those cases in which

the quick neutrons emitted in the direction of the slow ones are troublesome the emission of quick neutrons can be reduced by arranging the body absorbing and scattering the slow neutrons only a little relative to the source of the quick neutrons in such a manner that the direction in which the slow neutrons pass to the exterior by preference does not correspond to a direction in which the quick neutrons are emitted by the source.

This can be attained in the simple manner disclosed in Fig. 5 in which the inner surface of the inserted body 21 is not directed strictly towards the source of the quick neutrons, but is arranged somewhat above this source. As the inner hollow space, especially if it extends sufficiently far into the speed-reducing substance, is nearly uniformly filled with the slow neutrons such an arrangement reduces the number of the neutrons passing to the exterior only imperceptibly. In spite thereof the observation place is now screened against the quick neutrons by a considerable thickness of the insulating and speed-reducing substance.

We claim:

1. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material; an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; means for maintaining the source of quick neutrons at a high potential with respect to ground; means for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material.

2. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material; an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; means for maintaining the source of quick neutrons at a high potential with respect to ground; means for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material, said device including means for reducing the effective thickness of the body of insulating material in a localized path extending outwardly from said artificial source of quick neutrons.

3. A device for generating slow neutrons as defined by claim 2, in which said casing is provided with a recess the innermost portion of which is materially closer to said source than is the casing as a whole.

4. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material, an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; a body which absorbs and scatters slow neutrons much less than does said insulating material in contact with said body of insulating material and between said source and said casing; means for maintaining the source of quick neutrons at a high potential with respect to ground; means

for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material.

5. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material; an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; a body which absorbs and scatters slow neutrons much less than does said insulating material in contact with said body of insulating material and between said source and said casing, said body being hollow and evacuated; means for maintaining the source of quick neutrons at a high potential with respect to ground; means for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material.

6. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material; an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; a body which absorbs and scatters slow neutrons much less than does said insulating material in contact with said body of insulating material and between said source and said casing, said body being hollow and filled with a gas; means for maintaining the source of quick neutrons at a high potential with respect to ground; means for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material.

7. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material; an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; a body which absorbs and scatters slow neutrons much less than does said insulating material in contact with said body of insulating material and between said source and said casing, said body being conical in form with its base substantially normal to a direct ray path from said source; means for maintaining the source of quick neutrons at a high potential with respect to ground; means for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material.

8. A device for generating slow neutrons, comprising a body of insulating material which is capable of slowing down quick neutrons; a grounded conductive casing surrounding the body of insulating material; an artificial source of quick neutrons within and substantially surrounded by the body of insulating material; a body which absorbs and scatters slow neutrons much less than does said insulating material in contact with said body of insulating material and between said source and said casing, said body

being generally conical in form with its base substantially normal to a direct ray path from said source and having its conical surface ribbed; means for maintaining the source of quick neutrons at a high potential with respect to ground; means for exciting the source of quick neutrons; and a rigid insulator within the conductive casing and interposed between the latter and the source of quick neutrons, said rigid insulator being surrounded by the body of insulating material.

9. A device for generating slow neutrons, as defined by claim 4, in which the body which absorbs and scatters slow neutrons much less than does the body of insulating material consists essentially of a substance deficient in light hydrogen.

10. A device for generating slow neutrons, as defined by claim 4, in which the body which

absorbs and scatters slow neutrons much less than does the body of insulating material consists essentially of an hydrogenaceous substance in which light hydrogen has been replaced by heavy hydrogen.

11. A device for generating slow neutrons, as defined by claim 4, in which the body which absorbs and scatters slow neutrons much less than does the body of insulating material is so positioned as to provide a localized path for slow neutrons which localized path does not correspond to a direction in which quick neutrons directly escape from said source.

12. A device for generating slow neutrons, as defined by claim 1, in which an apertured layer of substance absorptive of slow neutrons covers said casing.

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