April 13, 1954 D. T. SCAG 2,675,485

LEAD PELLET ABSORPTIVE SHIELD FOR BETATRONS

Filed Jan. 2, 1951

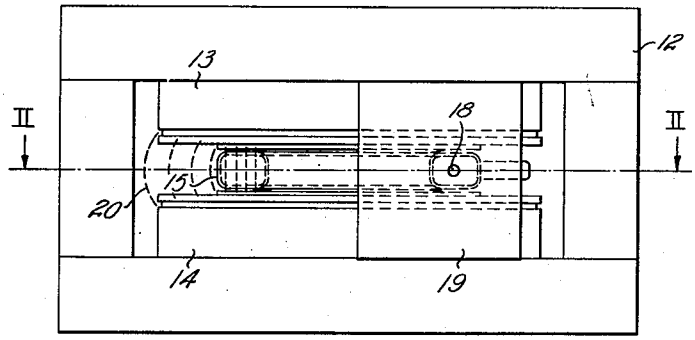


FIG. 1

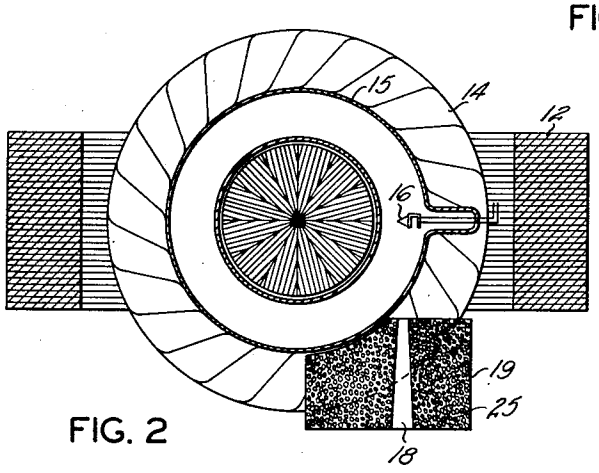


FIG. 2

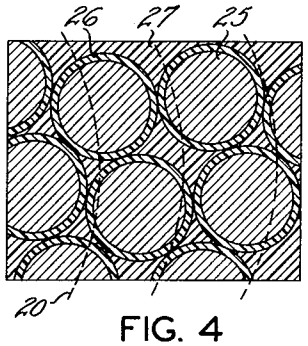


FIG. 4

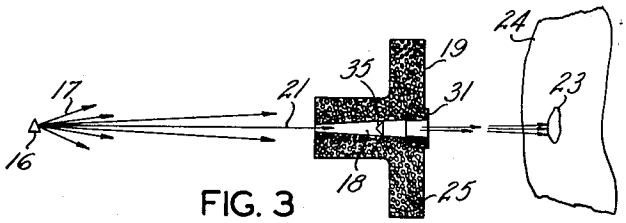


FIG. 3

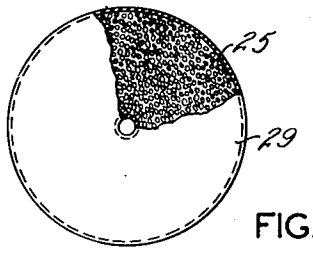


FIG. 5

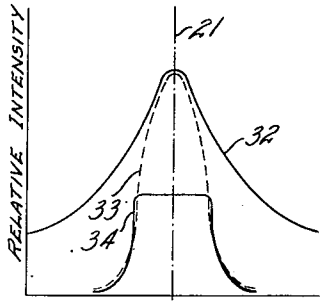


FIG. 6

INVENTOR
DANE T. SCAG

BY Joseph E. Kerwin
ATTORNEY

Patented Apr. 13, 1954

2,675,485

UNITED STATES PATENT OFFICE

2,675,485

LEAD PELLET ABSORPTIVE SHIELD FOR BETATRONS

Dane T. Scag, West Allis, Wis., assignor to Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Application January 2, 1951, Serial No. 203,857

5 Claims. (Cl. 250—84)

1

This invention relates to absorptive shields and diaphragms for X-ray apparatus, and, in particular, to absorptive shields for magnetic induction electron accelerating apparatus.

The development and improvements in apparatus capable of producing relatively high intensity X-rays, particularly the development of betatrons which accelerate electrons to twenty to twenty-five million electron volts, has made feasible the utilization of these electron accelerating apparatus in medical therapy as well as in industrial radiography. However, one of the problems involved in the various applications of such apparatus is the absorption or screening of X-rays produced thereby. The X-rays extending in directions such as not to be useful in the particular application of the apparatus must be absorbed or screened.

In particular, in medical therapy it is necessary to protect the portions of the patient's body, not requiring treatment, from a lethal or damaging dosage of X-rays and to provide a finely diaphragmed X-ray beam to the diseased tissues.

X-ray absorptive shields or diaphragms used with X-ray apparatus are provided with an aperture therethrough for the X-ray beam to pass. These shields are usually made of lead, an efficient X-ray absorptive material and are placed as near as possible to the source of X-rays. The shields or diaphragms may be a solid mass of lead but preferably are made by stacking layers of sheets of lead which are electrically insulated from each other.

With relatively high energy apparatus such as betatrons the diaphragming of the X-ray beam necessitates that the thickness of lead in the shield be greatly increased over that used at conventional therapy energies and that the shield be placed in the magnetic field of the device. A shield of prior art construction, if made for betatrons having an energy of 20 to 25 m. e. v., to screen unwanted X-rays and to diaphragm the beam will have considerable eddy currents induced in it by the time varying magnetic field. The eddy currents will cause overheating, will disturb the magnetic field of the betatron and will affect the geometry of the field. As a result the intensity of the X-ray beam will be reduced. In such relatively high intensity apparatus there are advantages to the positioning of the diaphragm or shield in the magnetic field. The first and most important advantage is that the absorption of X-ray by the lead causes secondary radiation of electrons which must not be allowed to reach the patient being treated. When the

2

shield is within the field the electrons produced by secondary radiation are influenced by the magnetic field in which the diaphragm is positioned and are thereby diverted away from the patient.

Another advantage for the shield being in the magnetic field is to minimize the bulk of the shield. With apparatus of relatively high intensity, if the distance between the conventional shield and the source of X-ray is increased so that the conventional shield does not materially interfere with the intensity output, the position of the shield will then be so far from the source of X-rays and the width of the pencil of high intensity X-rays will be so great that the size and weight of the shield will have to be unreasonably large.

It is, therefore, evident that the nearness of approach of the conventional shields to the acceleration orbit of such apparatus is limited by distortion of the precisely shaped magnetic field of the magnetic induction electron accelerating apparatus and by the heat produced from eddy currents.

It is an object of the present invention to provide an improved X-ray absorptive shield for magnetic induction electron accelerating apparatus.

Another object of the invention is to provide an X-ray absorptive shield which can be positioned a minimum distance from the source of X-ray with a minimum disturbance of the magnetic field of the magnetic induction electron accelerating apparatus.

Another object of the invention is to provide an X-ray absorptive shield relatively closely associated with a source of X-ray with the shield having a minimum effect on the high intensity X-ray produced and with the secondary radiation from the shield controlled by the magnetic field of the apparatus producing the X-ray.

Another object of the invention is to provide an absorptive shield for relatively high energy electron accelerating apparatus, that can be easily shaped to the configuration desired for embodiment in or attachment to the apparatus.

Still another object of the invention is to provide an X-ray absorptive shield which is easily adjustable to finely diaphragm an X-ray beam.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the accompanying drawings in which:

Fig. 1 is an elevation view of a magnetic induction accelerator with an X-ray absorptive

shield made in accordance with the teaching of this invention for medical therapy;

Fig. 2 is a view in cross section of the apparatus shown in Fig. 1, taken along line II—II;

Fig. 3 is a diagram illustrating the action of the absorptive shield illustrated in Fig. 1;

Fig. 4 is an enlarged partial sectional view of the X-ray absorptive shield illustrated in Fig. 1;

Fig. 5 is a view, partly in section, of a modified X-ray absorptive shield made in accordance with this invention; and

Fig. 6 is a graph showing the distribution of intensity of the X-ray beam.

In Fig. 1 a simplified illustration of a betatron type magnetic induction electron accelerator is shown. The basic apparatus comprises the core 12, coils 13, 14, and the electron accelerating tube 15. In such apparatus electrons are accelerated in the tube by an increasing magnetic field produced by the coils. The increasing magnetic field holds the electrons in an orbit and accelerates the electrons. United States Patent No. 2,297,305, granted September 29, 1942, to D. W. Kerst, for a Magnetic Induction Accelerator, discloses such an apparatus. A divergent X-ray beam 17 is produced by expanding the orbit of the accelerating electrons after they have reached a predetermined energy. The accelerated electrons are diverted from their accelerating orbit and caused to strike a target 16 positioned in the accelerating tube to produce the X-ray beam.

In the diagrammatic illustration of Fig. 3 the X-ray beam has a maximum intensity of X-rays along its central axis 21 which corresponds to the direction of the electrons when they strike the target. The X-rays are principally concentrated in a relatively small angle cone as a homocentric pencil. At twenty million volts energy approximately 4½ degrees from the axis of the cone the X-ray beam intensity drops quickly to about 50% of its maximum value. The width angle of that cone of relatively great intensity must be reduced or adjusted for application of the X-ray to medical therapy, and, of course, the X-rays outside the relatively high intensity cone must be reduced to the tolerance level for the patient being treated.

The beam of X-rays is diaphragmed by an absorptive shield 19 having a small aperture 18. A narrow cone of the high energy X-rays passes through the aperture in the absorptive shield to the diseased tissues 23 of the patient 24 being treated.

In order that the configuration of the absorptive shield 19 can be easily adapted to the various applications of magnetic induction apparatus and in order that the shield can be positioned close to the apparatus, even within the magnetic field of the apparatus, a new and improved shield is made by using a number of small pellets 25 of X-ray absorptive material, preferably lead. The pellets may be contained within a vessel or receptacle 29 or they may be contained in a thermosetting or thermoplastic material 27. The absorptive shield may include a replaceable plug 31 defining an aperture that can be varied by using different size plugs to adjust the width of the diaphragmed beam.

As shown in Figs. 1 and 2, the shield can be form fitted to the coils and tube of the magnetic induction accelerator. As a result, the shield can be more easily shaped and positioned within the magnetic field between and adjacent to the coils

than could the absorptive shield of the type previously available for X-ray apparatus.

Pellets approximately $\frac{1}{32}$ of an inch in diameter or smaller have been found to make a good shield. The pellets are coated with a varnish, plastic or other insulating material 26. The insulated pellets may be mixed with plastic material and formed into a solid unit by molding to produce a finished absorptive shield or the molded shield can be machined after being molded to fit the accelerator.

The insulated lead pellet shield can be placed within the magnetic field 20 of the accelerating apparatus without affecting the yield of the apparatus, as the finely divided insulated lead pellets prevent eddy currents therein even when positioned inside the magnetic field of the apparatus close to the tube containing the X-ray target, whereas, a laminated shield made of sheets of lead separated by electrical insulation will be affected by the bulging magnetic field and will have eddy currents produced therein.

In the embodiment illustrated in Fig. 5 the pellets instead of being bonded by a plastic material are held by a container 29. The container is preferably made of pliable insulating material such as rubber so that the shape of the container can be altered and the same container can be used for various modifications of the beam and various applications of the apparatus.

The new and improved absorptive shield made in accordance with this invention can be easily varied in thickness in the direction of or abaxial of the beam. The variations in thickness may be either gradual or abrupt. And the amount of absorptive material in any part of the shield can vary exactly as is necessary depending on the X-ray beam intensity shape.

The graph, Fig. 6 illustrates the natural and modified beam. The intensity shape of the natural beam is represented by curve 32 and is symmetrical about its central axis 21. The symmetry of the beam can be maintained even when it is modified by diaphragming.

Curve 33 represents the intensity of the beam after diaphragming through a shield such as that illustrated in Fig. 1. And curve 34 represents a beam compensated for certain therapy applications for which it is desirable to provide a beam of flattened intensity shape. This is done to avoid the considerable variation of intensity which is an inherent characteristic of the high intensity beam 32 or 33. The diaphragmed beam is flattened by a compensating filter 35 made of X-ray absorptive material, such as copper or carbon, which is placed in the opening, or X-ray penetrative aperture, of the shield.

Although but two embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In combination, an apparatus including a variable magnetic field and a shield disposed within said field, said shield comprising pellets of nonmagnetic X-ray absorptive metal and electrical insulation separating said pellets.

2. In combination, an apparatus including a variable magnetic field and a shield disposed within said field, said shield comprising pellets of nonmagnetic X-ray absorptive metal, elec-

trical insulation separating said pellets, and pliable insulating means retaining said pellets and insulation.

3. In combination with an electron accelerator having a variable magnetic field means for focusing and accelerating electrons, an X-ray producing target, and means to cause accelerated electrons to strike said target to produce X-rays; an X-ray absorptive shield, said shield comprising a plurality of pellets of X-ray absorptive nonmagnetic metal coated with electrical insulating material and means for holding said insulated pellets in contact with one another, said shield having an X-ray penetrative aperture therethrough coaxial with the pencil of X-ray produced by said target to produce an X-ray beam, said shield being at least partially immersed in said variable magnetic field and said insulating material substantially preventing the flow of eddy currents induced in said shield by said variable magnetic field, said X-rays excluded from said X-ray beam being absorbed by said shield causing the production in said shield of secondary electrons which reach the space surrounding said shield and the space within said aperture, said shield being so positioned in said variable magnetic field that said variable magnetic field removes said secondary electrons from the path of said X-ray beam and from the space adjacent the path of said X-ray beam through said aperture and through the space adjacent said shield.

4. In combination with an electron accelerator having a variable magnetic field means for focusing and accelerating electrons, an X-ray producing target, and means to cause accelerated electrons to strike said target to produce X-rays; an X-ray absorptive shield, said shield comprising a plurality of pellets of X-ray absorptive nonmagnetic metal coated with electrical insulating material and means for holding said insulated pellets in contact with one another, said shield having an X-ray penetrative aperture therethrough coaxial with the pencil of X-rays produced by said target, and compensating means of X-ray absorptive material cooperative with the variable intensity diaphragmed X-rays passing through said aperture to produce a beam of X-rays having substantially uniform intensity, said shield being at least partially immersed in said variable magnetic field and said insulating material substantially preventing the flow of eddy

currents induced in said shield by said variable magnetic field, said X-rays excluded from said X-ray beam being absorbed by said shield causing the production in said shield of secondary electrons which reach the space surrounding said shield and the space within said aperture, said shield being so positioned in said variable magnetic field that said variable magnetic field removes said secondary electrons from the path of said X-ray beam and from the space adjacent the path of said X-ray beam through said aperture and through the space adjacent said shield.

5. The combination of an electron accelerator having means including a variable magnetic field for producing X-rays and an X-ray absorptive shield, said shield including a plurality of pellets of X-ray absorptive lead, electrical insulating means separating said pellets, and retaining means for holding said pellets in a confined space, said retaining means having an X-ray penetrative aperture therethrough to diaphragm said X-rays and produce a beam of X-rays, said shield being at least partially immersed in said variable magnetic field and said insulating material substantially preventing the flow of eddy currents induced in said shield by said variable magnetic field, said X-rays excluded from said X-ray beam being absorbed by said shield causing the production in said shield of secondary electrons which reach the space surrounding said shield and the space within said aperture, said shield being so positioned in said variable magnetic field that said variable magnetic field removes said secondary electrons from the path of said X-ray beam and from the space adjacent the path of said X-ray beam through said aperture and through the space adjacent said shield.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,227,884	Caldwell	May 29, 1917
1,939,829	Page	Dec. 19, 1933
1,982,689	Polydoroff	Dec. 4, 1934
2,105,070	Bandur	Jan. 11, 1938
2,533,701	Watt et al.	Dec. 12, 1950

OTHER REFERENCES

"The Use of Metallic Shot in X-Raying Steel," Moriarty, General Electric Review, March, 1939, pages 109–113.