United States Patent [19]

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[54] **COLLIMATION DEVICE FOR IRRADIATION APPARATUS**

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[52] **U.S. Cl.**....................**250/106 S**, 250/105 R

[51] **Int. Cl.**....................**G21h 5/00**

[58] **Field of Search**.....250/106 S, 106 R, 105 R, 52; 313/117; 350/271, 276; 178/5.4; 219/354; 240/46.01, 46.31, 108

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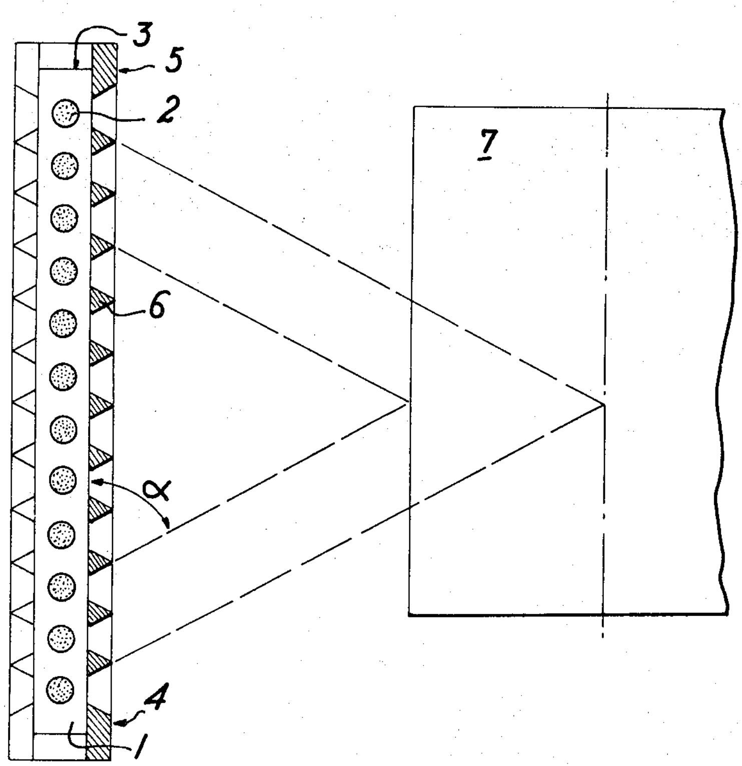
[57] **ABSTRACT**

A collimation device for an irradiation apparatus comprising in particular a radioactive source having a generally flat shape constituted by a source-holder frame in which radioactive elements are disposed in spaced relation, characterized in that it comprises a mask having open portions which is placed in parallel relation in front of at least one face of said source and in proximity thereto, said mask being made up of a series of screens formed of absorbent material and adapted to project in the direction of packages to be irradiated which pass in front of said source, each screen having a transverse cross-section which decreases from said source towards said packages.

8 Claims, 8 Drawing Figures



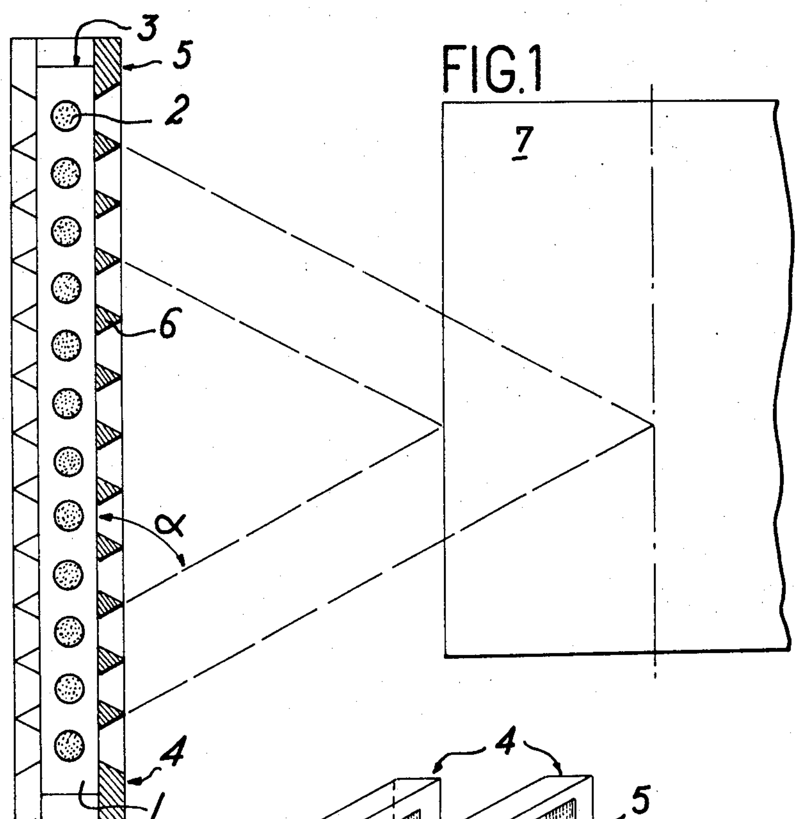


FIG.1

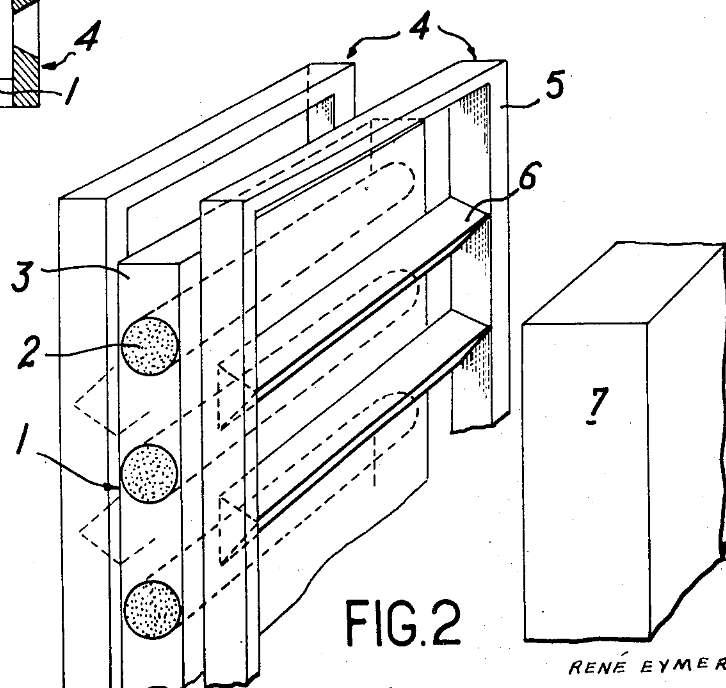


FIG.2

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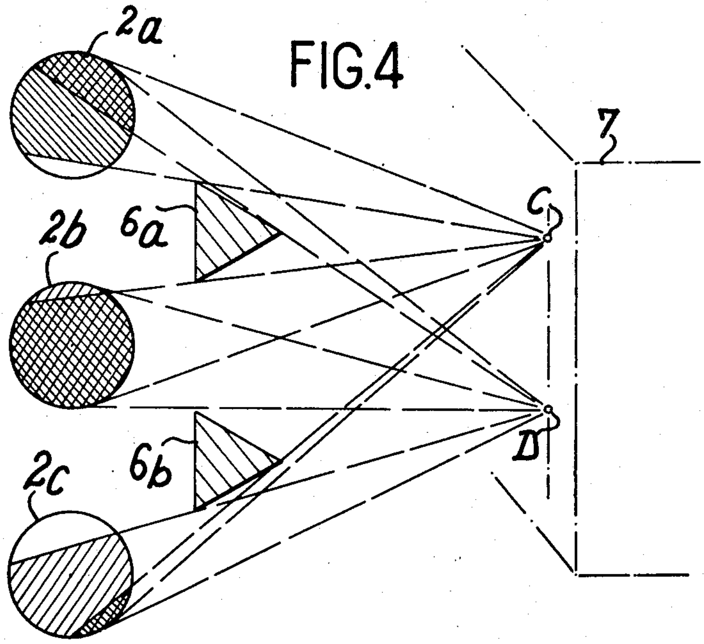

FIG.4

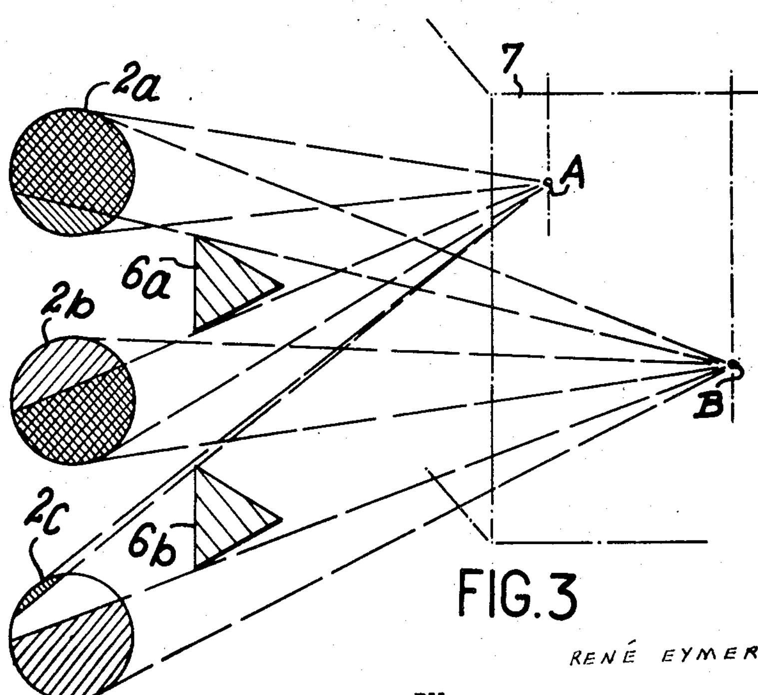

FIG.3

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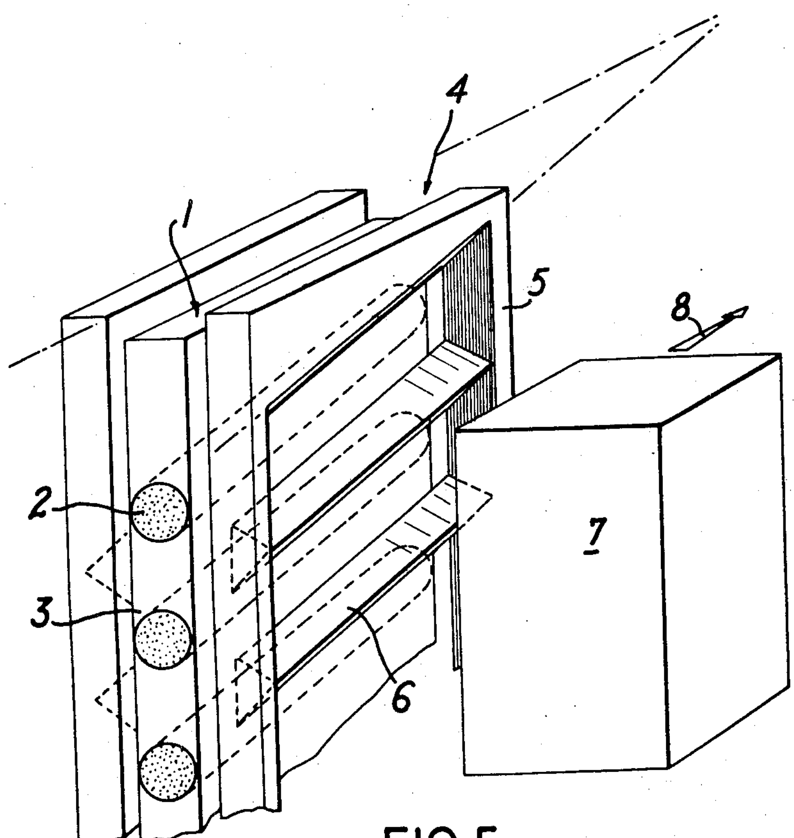

FIG.5

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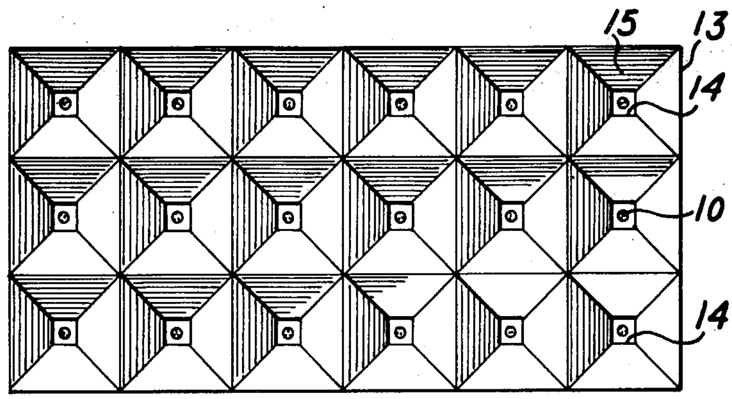

FIG.7

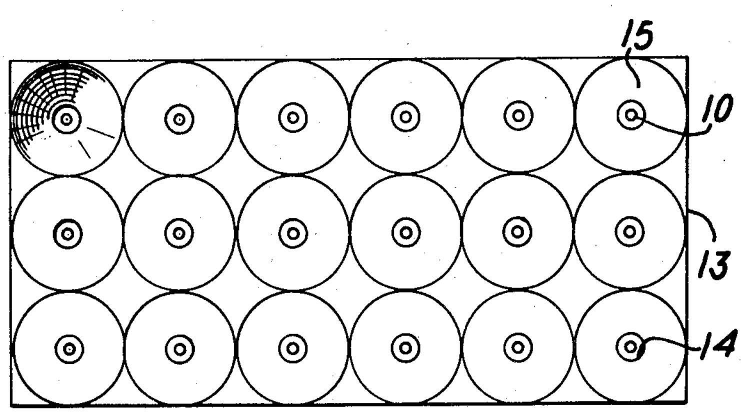

FIG.8

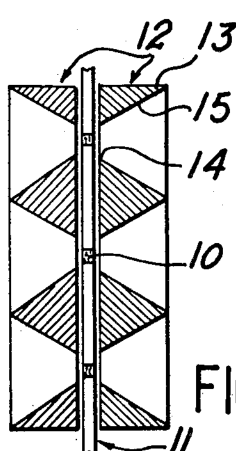

FIG.6

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COLLIMATION DEVICE FOR IRRADIATION APPARATUS

This invention relates to a collimation device for an apparatus in which objects or packages are exposed to radiation as they pass in front of a radioactive source and in which better uniformity of doses received by said packages at all points is achieved by means of said device.

Different methods or special devices for improving the distribution and homogeneity of radiation doses delivered to the interior of packages to be irradiated are already known. Thus, it is possible to increase the number of transfers of packages on each side of the radioactive source which is usually provided in the form of a vertically disposed "plaque" and which contains a series of suitably distributed radioactive elements. This is achieved by means of a conveyor which is designed to move the packages in front of the source a number of times in parallel relation to the faces of the source and at a distance from this latter which varies from one pass to the next.

A method of the type just mentioned makes it possible in particular to attenuate the heterogeneity of doses received in the transverse direction at right angles to the plane of the source ; however, this improvement is limited inasmuch as the most homogeneous doses delivered during passes which are carried out at a greater distance from the source are also the lowest in value and can correct only to a very partial extent the principal heterogeneity which results from passes carried out within close proximity to the source. If the initial passes are carried out at an even greater distance away in order to enhance the homogeneity of radiation doses, the efficiency of the installation falls off rapidly and limits the value of the improvement which it was intended to achieve. Whatever procedure may be adopted, it is nevertheless sought in the majority of cases to limit the thickness of packages while retaining the same density of constituent materials in order to improve the homogeneity in the transverse direction.

In order that the dose received by said packages should also be made uniform in the vertical direction, a transfer is also carried out in front of the source but at different levels ; the packages themselves should preferably have dimensions such that they extend to an appreciable distance beyond the apparent contour of the source. Finally, another method consists in determining in the plane of the source the best distribution of radioactive elements for the purpose of regularizing the doses which are delivered. In particular, provision can be made for a design in which the source projects beyond the top and bottom of the packages to be processed and comprises in this case a central zone which is relieved of radioactive elements. However, in all the designs which have been proposed, homogeneity of absorbed doses is not wholly satisfactory, especially in the case of packages of appreciable thickness.

The aim of this invention is to circumvent the disadvantages which have been discussed in the foregoing by means of a collimation device which is capable of being placed in proximity to the source so as to limit radiations which are delivered in certain directions while leaving a free passage for these radiations in other directions. Thus, the dose received at any point of a package under irradiation as defined by the solid angle through which said point "sees" the source and more particularly the radioactive elements considered together which constitute said source is substantially uniform both in the transverse direction and vertical direction. In addition, said device makes it possible to a certain extent to correct the effects of heterogeneity of the source itself.

A further aim of the invention is to provide a simple apparatus which can readily be placed in position and does not in any way affect the design of the source itself and in particular the distribution of radioactive elements in this latter.

To this end, the collimation device under consideration which is more particularly applicable to a radioactive source having a generally flat shape constituted by a source-holder frame in which radioactive elements in the form of cylindrical rods or point sources are disposed in spaced relation, is characterized in that it comprises a mask having open portions which is placed in parallel relation in front of at least one face of said source and in proximity thereto, said mask being made up of a series of screens formed of absorbent material and adapted to project in the direction of packages to be irradiated which pass in front of said source, each screen having a transverse cross-section which decreases from said source towards said packages.

Said mask preferably comprises screens which extend in front of each of the parallel faces of the source-holder frame.

By virtue of the foregoing arrangements, the screens of the mask are accordingly interposed between on the one hand the radioactive elements of the source and on the other hand predetermined points of the packages to be irradiated. In particular, as a result of the presence of the screens, said radioactive elements can only partially be "seen" or in other words are in direct line of access to the nearest face of the package considered only to a partial extent whereas the same elements can be "seen" directly by points which are located at the center of said packages or at an even greater distance from the plane of the source. The disparity between the doses received at these different points, especially between points of the package face which is located nearest the source in parallel relation to this latter and points which have a different location, is thus considerably reduced under these conditions. Thus, the dose applied to those parts of the package which would otherwise have received an excessive dose is accordingly reduced in suitable and especially greater proportions than those parts of the same package which would have received lower total doses without the collimation mask. Accordingly, a substantial improvement in homogeneity of the radiation doses which are delivered is thus achieved simply at the price of a slight reduction in output of the unit, this improvement being more marked as the packages are located closer to the plane of the source.

As an advantageous feature and in the case in which said source comprises a plurality of radioactive elements having the shape of cylindrical and parallel rods mounted in said source-holder frame which is placed in a vertical position, said screens are constituted by metallic triangular-base prisms which are parallel to the rods and one lateral face of which is disposed parallel to the plane of said source, said prisms being placed at intermediate levels with respect to the levels of said rods.

On the contrary, in the case in which said source comprises single-point radioactive elements which are disposed on a uniform lattice and especially a lattice having a square or rectangular pitch, said screens are constituted by a grid having perforations which are placed in front of each single-point element and are provided with extended portions in the form of outwardly flared recesses each having a volume in the shape of a pyramid or truncated cone.

In addition and in accordance with a further property of the invention, said screens in said mask and said radioactive elements in said source can be oriented in such a manner as to have a given inclination to the direction of motion of said packages in front of said source. It is thus possible to contemplate a horizontal array of elements and transfer of packages at a predetermined angle of slope or, conversely, to give an orientation to the elements and a direction of transfer which have two angles of inclination as desired but of different value.

Finally, a number of different alternative forms can be contemplated in the assembly of the mask and of the source ; thus, said mask can be directly secured to the source-holder frame or be separate from this latter so as to constitute a container in which said frame is slidably fitted.

Further properties of the collimation device under consideration will become apparent from the following description of a number of exemplified embodiments which are given by way of indication and not in any sense by way of limitation, reference being made to the accompanying drawings, in which :

FIGS. 1 and 2 are views taken in cross-section and in perspective showing a collimation device for an apparatus in which packages are subjected to irradiation as they move in front of a radioactive source ;

FIGS. 3 and 4 are schematic diagrams which serve to set forth the advantages provided by the collimation device under consideration for ensuring uniform radiation doses received at the different points of any package respectively in the transverse direction and in the vertical direction ;

FIG. 5 shows diagrammatically an alternative construction which is applied to the embodiment of FIGS. 1 and 2 and serves to limit the effects arising from inherent heterogeneity of the source ;

FIG. 6 and FIGS. 7 and 8 are respectively a sectional view and top views of other alternative embodiments of the collimation device as adapted more especially to the case in which the source comprises a series of single-point radioactive elements.

There is shown at 1 in FIGS. 1 and 2 a radioactive source which is constituted in this example of construction by cylindrical rods 2 of suitable radioactive elements, said rods being set in parallel relation at a suitable distance from each other and mounted horizontally within the interior of a source-holder frame 3, the source being designed under these conditions in the form of a flat plaque which is placed vertically.

In accordance with the invention, the source 1 is associated with a collimation device which is intended to conceal the source to a partial extent and is constituted by two masks 4 which are placed parallel to the two faces of the frame 3 and in proximity to these latter. These masks can be separate from each other or joined along their edges so as to form in this case a kind of narrow container in which the source 1 can readily be inserted by sliding. Each mask comprises a support 5 for a series of screens 6 each having the shape of a metallic prism with a triangular base and mounted in the support in parallel relation both to each other and to the cylindrical rods 2, said prisms being uniformly spaced over a distance such that they are located at intermediate levels with respect to the positions occupied by the rods 2 in the source-holder frame 3. There is also shown in FIGS. 1 and 2 a package 7 to be irradiated which is carried by a conveyor (not shown in the drawings) for the purpose of transferring said package in a given number of passes in front of both faces of the source 1 which is fitted with the masks 4.

FIGS. 3 and 4 serve to obtain a better understanding of the mode of distribution of doses within the package 7 in the case of a radioactive source and of collimation masks according to the arrangements which are contemplated in FIGS. 1 and 2, and especially of the manner in which doses are distributed at points of said package which are separated from each other either transversely (in the case of FIG. 3) or vertically (in the case of FIG. 4). In order to simplify the drawings, there are shown in cross-section in these figures only three cylindrical rods 2*a*, 2*b*, 2*c* and two prismatic screens 6*a* and 6*b* which are placed between the source and the package.

If one considers any two points A and B of the package 7 which are located at a given transverse distance from each other, it may be established that the doses received at these points which are defined by the solid angle through which said points "see" all the rods of the source are different at A and at B. In the case of the point A which is located nearest the source, it is thus observed that this point sees the whole rod 2*a*, approximately two-thirds of the rod 2*b* and only a very small portion of the rod 2*c* by reason of the presence of the two screens 6*a* and 6*b*. Similarly, the point B sees approximately three-quarters of the rod 2*a*, the whole of the rod 2*b* and a portion of the rod 2*c* which is approximately equal to two-thirds, namely an overall source volume which is greater than that seen by the point A but at a greater distance.

It is therefore apparent that the points A and B of the package are not subjected to uniform radiation doses inasmuch as these doses depend in particular on the shape of the screens which are placed in front of the source and more especially on the angle α at the base of these prisms. Moreover, it has been shown in FIG. 1 by means of a dashed-line representation that a point located on that face of the package which is located nearest the source sees a smaller number of rods than another point which is located at a greater distance within the interior of the package.

It can therefore be appreciated that, by virtue of a suitable choice on the one hand of the distance at which the package is placed with respect to the source and on the other hand of the shape of the screens of the corresponding collimation mask, the total dose received at each point of the package can thus be made more homogeneous, said dose being a function of the solid angle. The prismatic screens must accordingly mask the radioactive elements essentially in respect of those points of the package which are located nearest the source whereas the same prisms must be interposed only to a very slight extent between said elements and the center of the package and even less so between said elements and points located beyond the center.

Referring now to FIG. **4**, it is seen that the collimation device which is contemplated also makes it possible to improve the homogeneity of doses received in the vertical direction by a package which moves in front of the source. In fact, any two points C and D which are spaced apart but located on the same vertical generator-line of that face of the package which is located nearest the radioactive source, for example, do not see the radioactive elements **2***a*, **2***b* and **2***c* in the same manner inasmuch as each point is in direct line of access to radiation from only a limited number of elements which are either located opposite to said point or intercepted by a solid angle having its vertex at this point and being a function of the collimation angle. Broadly speaking and in the case of a radioactive source which is constituted by linear elements such as the parallel and horizontal cylindrical rods of the embodiment of FIGS. **1** and **2**, the intensity of radiation received at any one point of a vertical generator-line located close to the source will be determined solely by the radioactive elements which are located in a horizontal band. However, the width of the band must be sufficiently great to permit the intensities of radiations within said band to be substantially equalized, while also taking into account the inherent heterogeneity of the source which arises from the fact that the radioactive rods **2** are located at a given distance from each other in the frame **3**. Moreover, the distribution of radioelements within the interior of each rod cannot be perfectly uniform. Nevertheless, said bands must be sufficiently narrow to limit overlapping of the radioactive source in the particular case in which the package is moved in front of this latter in only a single pass.

In order to overcome the disadvantage which has just been referred-to and which arises from inherent heterogeneity of the source as constituted by an assembly of separate radioactive elements, an equal number of which is consequently not necessarily seen by two points of the package which are located at a distance from each other in the vertical direction, the structure of the mask **4** can advantageously be modified by providing the screens **6** within their supports **5** with an orientation which is slightly inclined to the horizontal plane (as shown in FIG. **5**) while the rods **2** remain parallel to the prisms which form said screens. On the other hand, the orientation of the package **7** is maintained and, in particular, there is no modification to the direction of motion of said package in front of the collimation masks as shown diagrammatically by the arrow **8**, said direction being horizontal in this case.

It is readily apparent that, by way of alternative, the screens and radioactive rods could be maintained horizontal while the packages are transferred at a given angle of inclination to the horizontal ; it would even be possible to choose two different angles of inclination on the one hand in the case of the screen and on the other hand in the case of the direction of transfer.

Whatever alternative embodiment is adopted, the following results may be put forward : in the case of a package which has a height of 20 cm, a thickness of 30 cm, a length of 50 cm, a density of 1 g/cm^3, which is subjected to two passes on each side of a vertically placed source and at a distance of 40 cm from said source, it is observed that the total heterogeneity of absorbed dose which is expressed as the ratio of maximum to minimum doses delivered at any point of the package and which is substantially equal to the product of partial heterogeneities in the transverse, vertical and longitudinal directions can be evaluated at $R = 1.40$. By means of a collimation device as hereinabove described, the total heterogeneity of the dose is reduced under the same conditions from 1.40 to 1.20 while the efficiency of the installation is reduced by only 10 percent.

FIGS. **6** to **8** illustrate another alternative embodiment of the collimation device in which the radioactive elements **10** are mounted in a source-holder frame **11**, are of the single point type and are provided especially in the form of spherical beads of small diameter which are disposed on a uniform lattice having a square pitch. In this alternative embodiment, masks **12** are associated with the source-holder frame in proximity to and on each side of the flat vertical faces of said frame, said masks being so arranged as to carry out a double collimation both in the vertical and horizontal directions. To this end, each mask is constituted by a grid **13** provided with a series of orifices **14** placed opposite to the single-point radioactive elements of the source and with progressively flared recesses **15** extending outwards from said orifices in order to permit the passage of radiations. In the example of FIG. **7**, said recesses **15** are designed in the form of truncated pyramids whereas in the case of the example of FIG. **8**, said recesses have the shape of cones which are also truncated. The operation of the masks otherwise remains similar to that which was described in connection with the first example given above.

In consequence, and irrespective of the form of construction adopted, the judicious determination of the different parameters of the masks (angle of collimation, nature of the constituent material of said masks, distance from the source and so forth) results in substantial homogenization of the doses received by the packages as these latter pass in front of the source without thereby imposing any undue limitation on overall efficiency. The advantage of this device in an industrial irradiation plant can thus take many different forms : in particular, by virtue of the use of collimation masks, the device makes it possible to achieve identical homogeneity of doses within packages which have the same dimensions but a different bulk density. This effect can result in particular in enhanced efficiency of the plant inasmuch as the increase in density substantially compensates for the relative reduction in efficiency which results from the interposition of masks. The versatility of an existing plant can therefore be substantially enhanced by thus increasing the range of densities of the products which can be processed.

The device considered also makes it possible to construct plants for the irradiation of unitary packages having a greater thickness than in conventional plants without thereby entailing any danger of substantial heterogeneities in absorbed doses and this also results in enhanced efficiency of the plant in respect of a given number of passes.

It must be understood that this invention is not limited in any sense to the forms of construction which have been described in the foregoing with reference to the accompanying drawings and which have been given solely by way of example ; on the contrary, the invention extends to all alternative forms and can be employed in particular for the irradiation of liquid substances.

What we claim is :

1. An irradiation apparatus comprising:
means for generating radiation to be directed at a material to be irradiated comprising a plurality of radiation elements substantially linear in one direction and arranged parallel to each other; and
means for masking portions of said generated radiation, including a plurality of screens made of absorbent material and being linear in said one direction, the entirety of each screen being located between and spaced apart from said radiation generating means and said material, the transverse cross section of each of said screens decreasing from said radiation generating means toward said material.

2. An apparatus according to claim **1**, wherein each of said radiation elements comprises a radiation generating rod and wherein each of said screens comprises a triangular-base prism.

3. An apparatus according to claim **2**, wherein the respective faces of said triangular-base prisms are substantially parallel to each other.

4. An apparatus according to claim **1**, further including means for moving said material to be irradiated past said radiation generating means in a direction substantially parallel to a plane extending throughout said radiation generating means.

5. An apparatus according to claim **4**, wherein the direction of movement of said material is non-parallel to said one direction.

6. An irradiation apparatus comprising:
means for generating radiation to be directed at a material to be irradiated including a plurality of substantially point sources arranged in a matrix array; and
means for masking portions of said generated radiation, including a plurality of screens made of absorbent material, the entirety of each screen being located between and spaced apart from said radiation generating means and said material, the transverse cross section of each of said screens decreasing from said radiation generating means toward said material.

7. An apparatus according to claim **6**, wherein each respective screen comprises an absorbent material formed in the shape of a truncated pyramid surrounding each point source.

8. An apparatus according to claim **6**, wherein each respective screen comprises an absorbent material formed in the shape of a truncated column surrounding each point source.

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