March 3, 1970 G. F. KINGSLEY ET AL 3,499,141

SELF-SHIELDED FESTOON FOR ELECTRON IRRADIATION APPARATUS EMPLOYING OVERLAPPING ROLLERS HAVING RADIATION BLOCKING MEANS

Filed Nov. 13, 1967 4 Sheets-Sheet 1

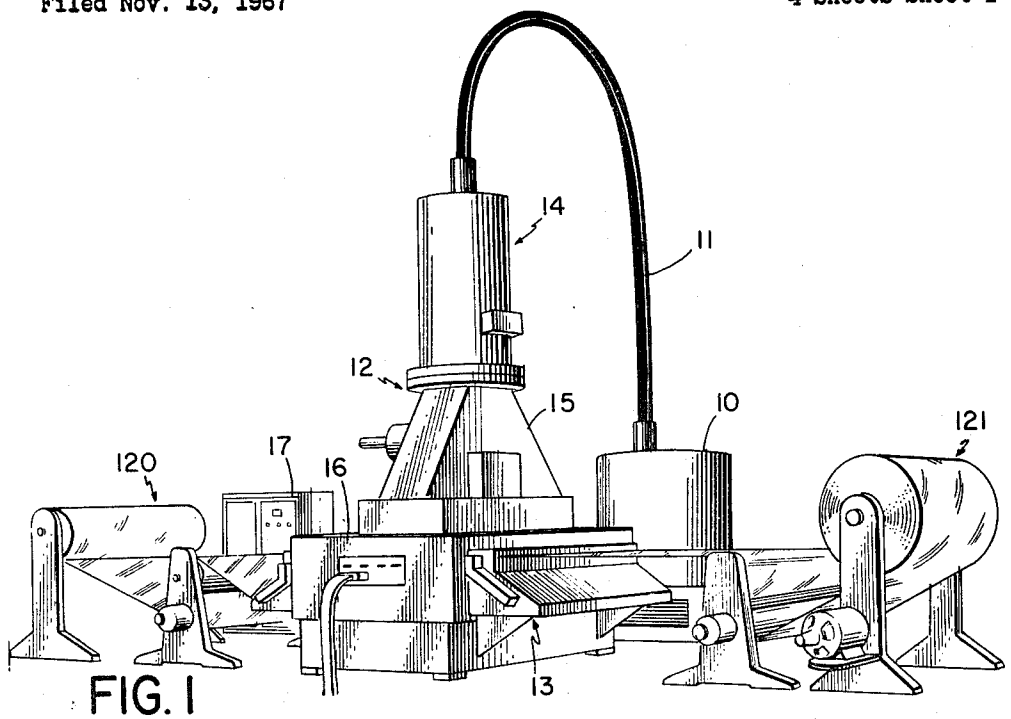


FIG. 1

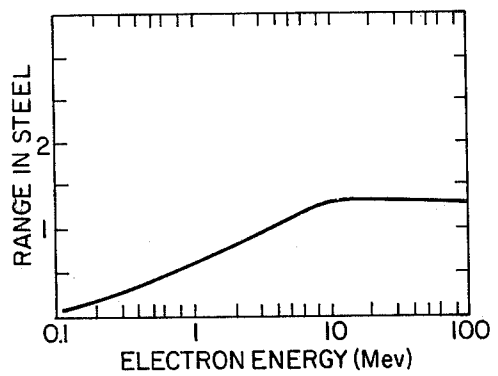


FIG. 4A

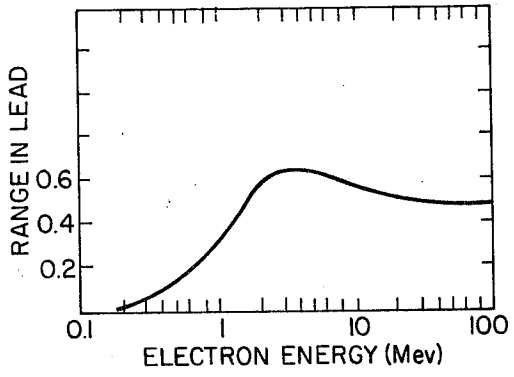


FIG. 4B

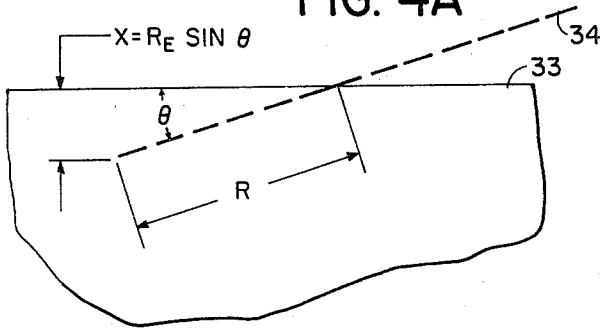


FIG. 5

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FIG. 2

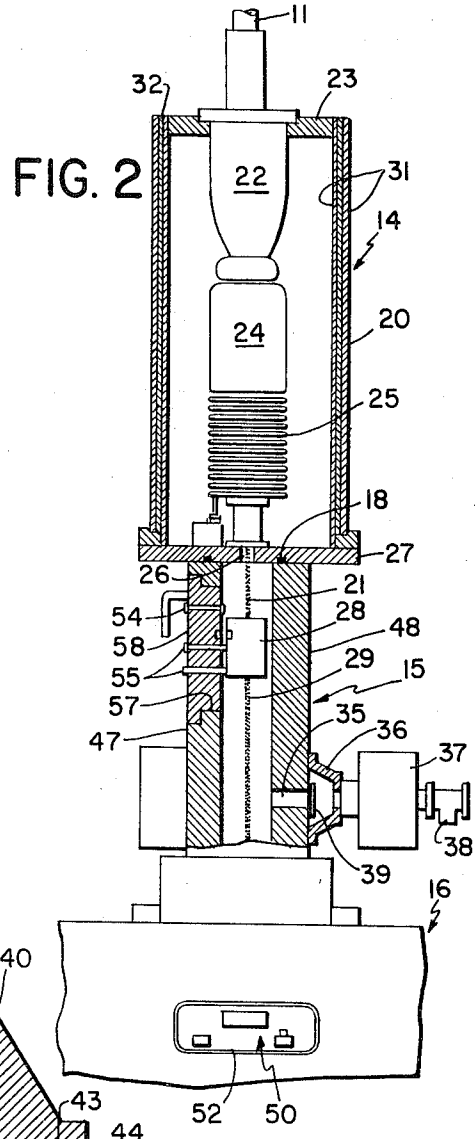
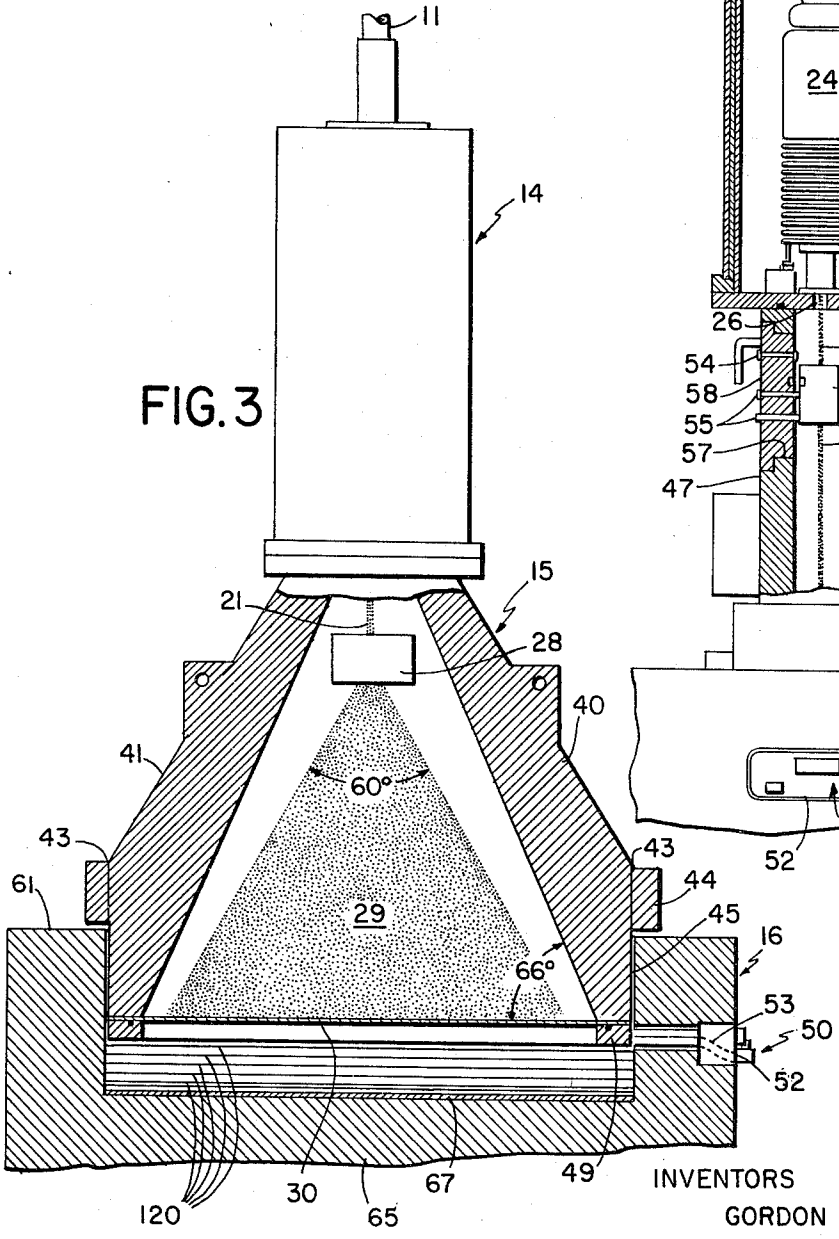


FIG. 3



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Filed Nov. 13, 1967 4 Sheets-Sheet 3

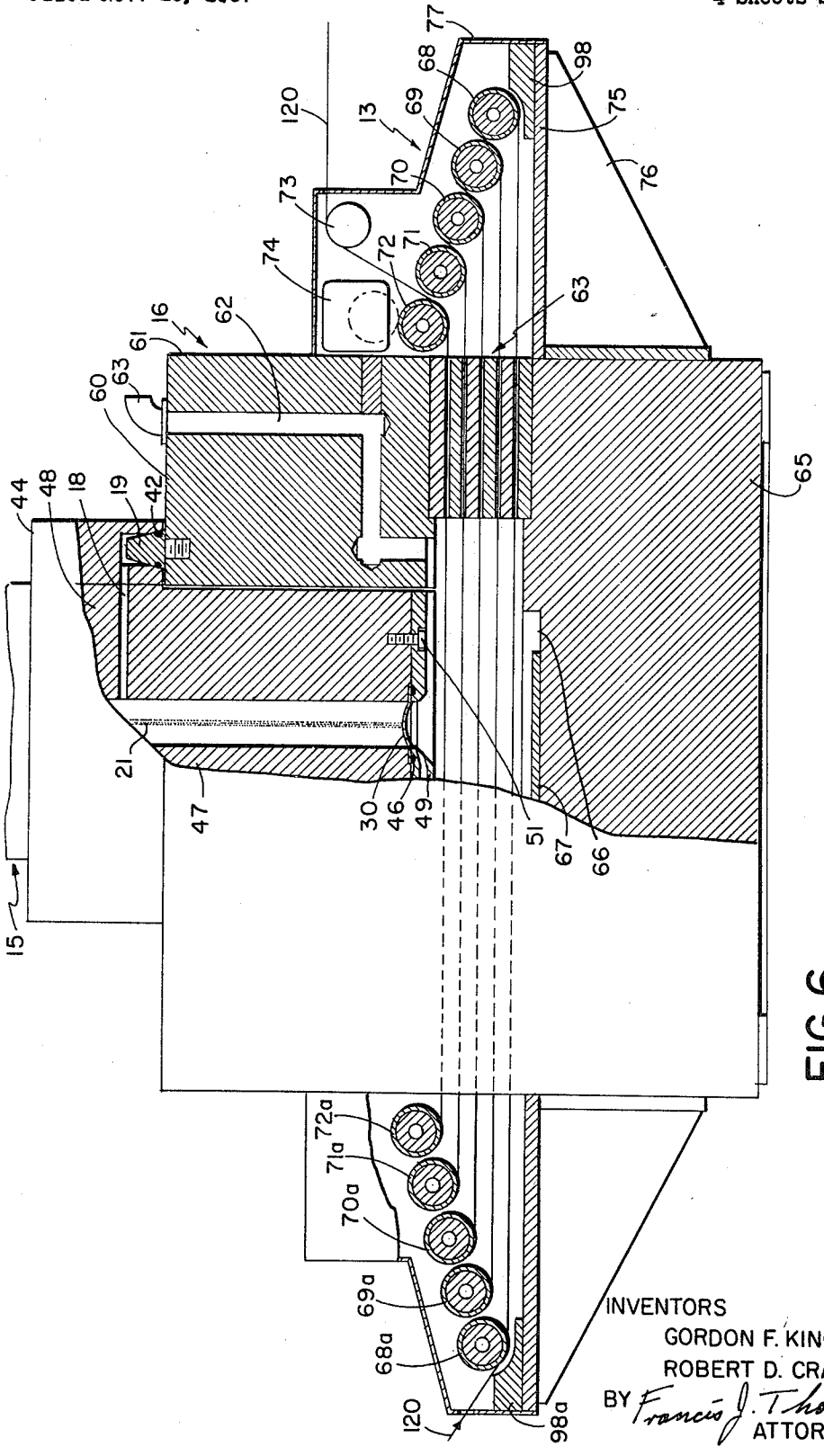


FIG. 6

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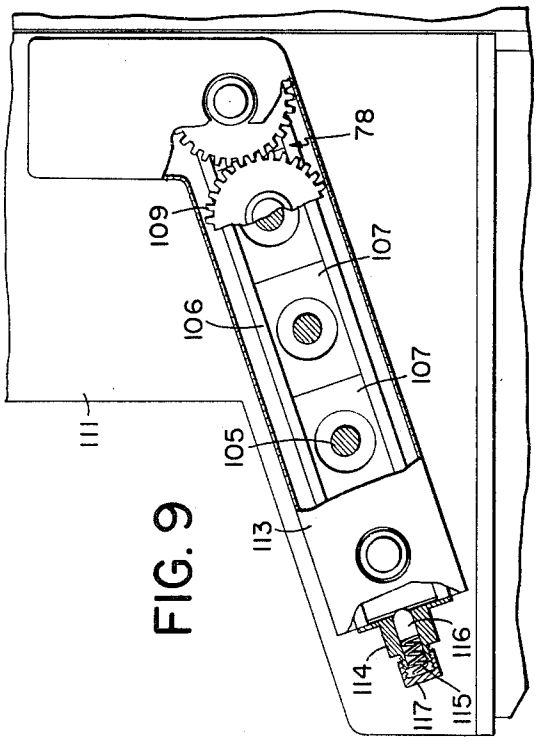


FIG. 9

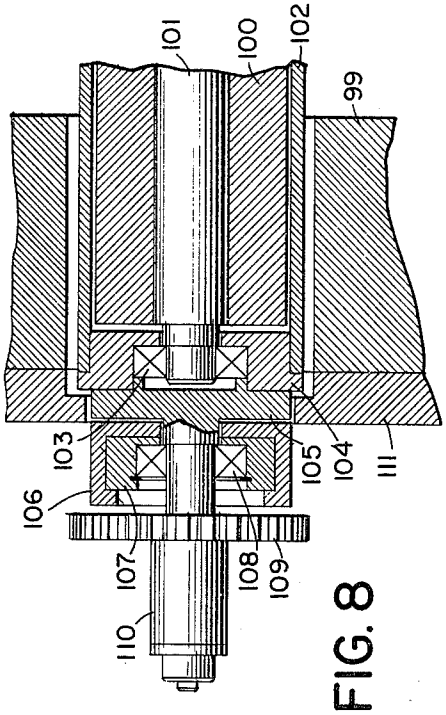


FIG. 8

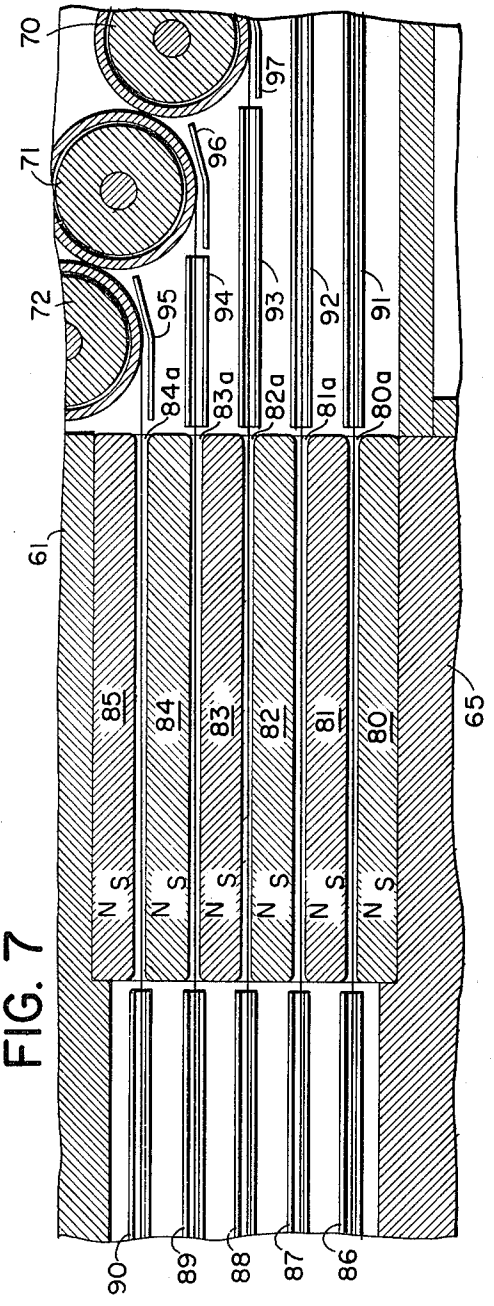


FIG. 7

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3,499,141

SELF-SHIELDED FESTOON FOR ELECTRON IRRADIATION APPARATUS EMPLOYING OVERLAPPING ROLLERS HAVING RADIATION BLOCKING MEANS

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Int. Cl. G21f 7/00
U.S. Cl. 250—49.5 2 Claims

ABSTRACT OF THE DISCLOSURE

A self shielded flexible material irradiation apparatus using a flexible material apparatus which is positioned outside of the irradiation chamber so that adjustments may be made thereto for varying parameters, such as the material speed or tension without exposing the operator to potentially hazardous radiation.

BACKGROUND OF THE INVENTION

Radiation processing has a wide variety of industrial and commercial applications including the curing of plastic material such as polyethylene. Many informative papers on radiation curing are available in the literature. Basically, however, such curing requires the exposure of the material to a beam of high energy electrons. One method for irradiating flexible plies of polyethylene and the like is to thread the material back and forth through the beam over a series of rolls at each end of the irradiation field.

In the prior art this festooning of the material takes place within the region of hazardous radiation. Thus to make adjustments in the speed, tension, etc. of the material being irradiated or to change the material it is necessary that the machine be shut down thus leading to inefficiency and other losses.

The present invention was conceived against this background and is directed towards a machine permitting adjusting, tensioning, positioning etc. of the material being processed while the machine is in operation.

SUMMARY OF THE INVENTION

Broadly speaking these and further advantages and features are realized in a machine provided with radiation proof walls, exteriorly positioned festooning apparatus and radiation traps thus permitting the safe and reliable use of such equipment in hitherto impossible locations.

DESCRIPTION OF THE DRAWINGS

FIGURE 1 shows an overall view of one embodiment of the present invention;

FIGURE 2 shows a sectional view of the acceleration portion of the apparatus of FIGURE 1;

FIGURE 3 shows a sectional view of the apparatus of FIGURE 1 taken at right angles to the view of FIGURE 2;

FIGURE 4A is a graph of electron energy vs. range in steel;

FIGURE 4B is a graph of electron energy vs. range in lead;

FIGURE 5 shows the effect of angle of incident electrons in determining range;

FIGURE 6 shows a quarter section of the festooning apparatus and irradiation chamber of the apparatus of FIGURE 1;

FIGURE 7 shows details of the electron trapping arrangement and material feeder of FIGURE 6;

FIGURE 8 shows details of the festooning rollers used in the invention;

FIGURE 9 shows in section details of the festooning rollers used in the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the drawings and, more particularly, to FIGURE 1 there is shown an overall view of one model of the invention which is an integrally shielded electron beam processing machine for the irradiation of flexible sheets or films.

Basically the machine comprises a high voltage D.C. power supply **10** connected by a cable **11** to an integrally shielded electron beam assembly **12** coupled to an integrally shielded festoon assembly **13**. A roll of material **120** is shown being fed into the machine. After processing the material is fed on to a take-up roll **121**. With control panel **17** the equipment appears in this view as it is used on a factory production floor.

Preferably the power supply **10** is of the insulating-core transformer type as shown in Dr. Robert J. Van de Graaff's patent, No. 3,187,208 dated June 1, 1965. Basically this supply is a three-phase transformer-rectifier with multiple secondary cores for each phase.

The power produced by supply **10** is delivered to the accelerator assembly **12** by a flexible coaxial cable **11** whose length is adjustable so that the supply may be placed at any desired position with relation to the remainder of the equipment. The console **17** may also be situated in any convenient place and will be connected to the other necessary assemblies by cabling (not shown).

Turning now to FIGURES 2 and 3, the electron beam assembly **12** will be discussed in greater detail. The assembly **12** comprises an accelerator subassembly **14**, a shielded scanner chamber **15** and a chambered base **16**.

The accelerator subassembly **14** comprises a cylindrical tank **20** within which there is contained a bushing **22** which passes through the distal end **23** of tank **20** and electrically couples cable **11** to an accelerator terminal shell **24** containing a transformer and a cathode (not shown). The cathode provides a supply of electrons which are electrostatically focused into a stream by suitable means (not shown), and accelerated by the multiple electrode accelerator column **25** located directly below the shell **24**. The accelerated electrons pass in the form of a beam **21** out opening **26**, provided in the proximal end **27**, of tank **20**, into the shielded evacuated scanner chamber **15**. Directly after entering chamber **15** the beam **21** passes into an electromagnetic scanner **28** which continuously sweeps the beam **21** from side to side to form a wide, elongated, fan-line pattern **29**. The widened beam of accelerated electrons passes out of chamber **15** via a thin metal foil window **30** located below the chamber **15** and within the base **16**.

Such highly accelerated electrons are potentially hazardous to human life not only in themselves but especially because of the harmful X-rays produced when such electrons strike solid matter. The present invention contains these harmful radiations by providing the entire assembly with integral shielding which cannot be removed without causing shut-down of the electron source and hence of all radiation.

The present invention will first be described in reference to the embodiment shown in FIGURES 1 to 3. For purposes of illustration only, it will be assumed that a twenty milliampere electron beam will be accelerated to a maximum of 500 kilovolts and scanned 30° on either side of the beam centerline.

Since electrons become more hazardous after they are accelerated, the shielding disposed about the terminal shell need not have the large impedance required of the shield-

ing made integral with the scanning chamber. However, the shell must be sufficiently strong to accommodate a high pressure insulating gas. To meet both these requirements the tank **20** is made in the shape of a double-walled steel cylinder, formed of ¼ inch steel sheets **31**, separated by a 1 inch thick filling of lead **32**, and having upper and lower ends **23** and **27** respectively formed from 2 inch thick steel plate. End **23** is in the form of a flat annular ring welded to the inner wall of the cylinder **20** and has the terminal bushing **22** passing therethrough. The lower tank end **27** is a large circular disc which is welded to both walls of the tank **20**. This disc is provided with orifice **26** aligned with the beam **21** and sealed off by column **25**. Thus there is formed around the evacuated column a strong pressurizable tank which in operation is filled with 100 p.s.i. insulating gas. When electrons are generated at the cathode, they are accelerated by the field in column **25** and pass through orifice **26** as an electron beam **21** into scanner **28**.

After the accelerated electrons pass through scanner **28** into chamber **15**, they strike the window **30** and most pass therethrough into the material **120** being irradiated. Some electrons however upon striking the window, the material being processed, or the underlying bed **65** of base **16** become deflected or produce X-rays which emanate, from the struck material, at various angles. These potentially harmful radiations must not be permitted to pass out of the apparatus unless attenuated or reduced to a safe level. To this end the walls of chamber **15** and base **16** are made to attenuate the electrons and harmful X-radiations and reduce them to safe levels, that is below 2.5 millirads per hour.

In order to properly design the walls of chamber **15** it is necessary to call to mind that the penetrating ability, or range, of such electrons in most materials is short but the range of X-radiation generally increases with its energy and decreases with the density of the material being struck. This relationship is shown graphically in FIGURES 4A and 4B. By expressing the range in terms of half value layers, the energy in terms of the generating electron, and using the general absorption equation

$$1=1^{\circ}e^{-ue}$$

any worker, skilled in the art, can determine the wall thickness necessary to attenuate the generated X-rays below 2.5 millirads/hour. It should be understood, however, that since the X-ray energy and density generally increases with electron beam energy and current, the thicknesses given in the specific embodiments described herein are illustrative only for a 500 kev. 20 milliampere beam and that for most energetic beams thicker walls would be required. Conversely, with less energetic beams a thinner wall could be utilized.

As is well known, the penetration depth taken normal to the surface is dependent on the incident angle of the radiation with respect to the surface being struck. In other words the point at which the radiation is attenuated to a safe level is determined by the angle at which it strikes the surface. This may be better understood from FIGURE 5. In this figure the path of an incident ray of radiation striking a surface **33** is shown by the dotted line **34**. X is the distance from the surface at which the ray is attenuated to a safe level when R is the range of the radiation when it has an initial energy E and θ is the angle of the incident beam with respect to the surface **33**. Thus under these circumstances

$$X=R_E \sin \theta$$

With this information one may readily calculate the necessary impedance in terms of the thickness required for the chamber walls.

For ease of fabrication slabs of mild steel was selected for the walls of chamber **15**. These slabs were welded together such that a vacuum could be maintained in the chamber. The general shape of channel **15** resembles the center zone of a truncated pyramid as shown in FIGURES 2 and 3. The configuration shown in these views was chosen to provide sufficient width for a 60° beam and for the scanner **28** while matching the upper surface of the chamber to the tank **20** for vacuum purposes. Thus the inner surface of the sidewalls **40** and **41** of chamber **15** were inclined at an angle of 66° to the horizontal. Since radiation intensity is inversely proportional to the square of the distance from the source and since with increasing θ the distance X becomes smaller, the chamber walls **40** and **41** can be made thinner as they recede from the window **30**. Thinning these walls at their upper points realizes a considerable savings in both weight and cost of material.

To obtain proper matching between the chamber and tank and yet retain a sufficient thickness for protection against radiation leakage, the outer surface of the walls **40** and **41** were tapered at an angle of 50° to the horizontal. In the actual machine, built in accordance with the invention, the walls **40** and **41** were each 7 inches thick at their top and 13 inches thick at their widest point **43**. In order to properly align the chamber in the base **16**, and yet retain sufficient shielding, the outer surface of the chamber walls **40** and **41** were cut on a vertical line from point **43** to the bottom and an eight inch high square ring **44** of 3 inch thick steel was welded around the chamber. As shown in FIGURE 6, this ring **44** is provided with a plurality of L shaped ports **18** which enter the interior of chamber **15** at right angles to the beam but emerges through the lower edge of ring **44** in the direction of the beam so that it can engage an aligned tapered pin **19** secured to the upper surface **60** of base **16**. To assure good vacuum sealing of port **18** when assembly **15** is situated on base **16** the pin **19** is provided with a deformable gasket **42**. The ring further shields the clearance space **45** provided between the chamber **15** and the base shield **16**.

Ports **18** and pins **19** also serve to make the unit safe. Removal of the shielded chamber **15** from base **16** immediately causes pin **19** to withdraw from port **18** which permits air to flow into chamber **15** and thence to subassembly **14**. Destruction of the vacuum and the presence of an atmosphere containing oxygen around the cathode cause it to be immediately consumed thus stopping the beam before the scanning chamber can be raised to a height sufficient to expose anyone to the radiation. Thus the device is fail safe in the event repairs are attempted while the beam is still on.

Since the angle of the incidence of any radiation directed towards the front and back walls **47** and **48** will be very slow in any region higher than ring **44**, these walls need not exceed 4 inches in thickness.

Ring **44** transmits the weight of the unit to the base shield **16**. The window assembly **49** is secured to walls **47** and **48** by bolts **51**. Cooling air is supplied to the window assembly **49** through a coupling **50**. Located between the bottom of chamber **15** and the window assembly **49** is gasket **46** of suitable deformable material such as Indium, which makes this joint vacuum tight.

The upper portion **61** of the base **16** also has a substantially square ring configuration. In detail, for the described apparatus, this portion **61** has a height of 16 inches and a wall thickness of 12 inches.

Adequate protection is afforded around the air supply coupling **50** which passes through an opening in the base shield by providing around the coupling and the air duct **53** a bearing plate **52** made of 4 inch thick lead. The air duct **53** (shown in phantom) passes in a single labyrinth fashion through this bearing plate **52** and to parallel the side of the window **30**.

As is well known in the art, it is necessary that a

vacuum be maintained in the device between the cathode and the window. To this end suitable vacuum tight seals have been provided at the various assembly joints and means provided in the back wall **48** of chamber **15** for evacuating this region. These means consist of a port **35** provided in the rear wall, a vacuum flange **36** around the port, an ion pump **37** and a vacuum valve **38** for coupling on a roughing pump (not shown). To prevent any possible stray radiation from passing out of the port **35**, a baffle plate **39** of 1" lead is provided in front of ion pump **37**.

The forward wall **47** is also provided with a port **57** through which the scanner **28** can pass. This port **57** is sealed with a plug **58** of the same thickness as the wall **47**. A plurality of electrical feed through connectors **54** and screw means **55** for adjusting the scanner pass through this plug.

FIGURES 6 through 9 illustrate additional details of the machine and in particular portray the details of the festooning apparatus.

The chambered base **16**, as previously noted, comprises an upper portion **61** and a lower portion **65**, both of which are made sufficiently thick enough to annenuate impinging radiation to an acceptable level. Provision is made, in the base **16**, for the passage of multiple plies of the material **120** through the base by having in each end of the base, in line with each festoon assembly **13**, large openings **63**. To prevent the escape of radiation through these openings **63**, a plurality of magnets **80** through **85** are fitted therein, the thickness of which is made sufficient to attenuate impinging X-rays. Slits **80***a* through **84***a* are left between these magnets which permit the introduction of the material **120** into the base. These slits should have the smallest possible width to reduce, to the lowest possible level, the probability that X-rays could pass therethrough without suffering attenuation due to reflection. Electrons are impeded in their passage through these slits by virtue of the magnetic field which exists between the magnets and extends across the slits.

Although it is improbable that X-rays or electrons will pass through these slits without suffering attenuation to a suitable level a further precaution is provided by the rollers **68** to **72** and **68***a* to **72***a* and blocks **98** to **98***a* which are positioned in the festooning assembly **13** so as to overlap the slits and thus block any escaping radiations.

To assure attenuation of the radiations and yet permit free and easy conveyance of the material **120** through the base the rollers are arranged as shown in FIGURE 8. These rollers consist of separately rotatable portions, an inner core, consisting of an axle **101** covered with a lead sheathing **100**, and an outer stainless steel shin **102**.

The axle (and sheathing) is rotatable supported in a journal block **104** by bearing **103**. Independently carried by the same journal block **104** is the stainless steel skin **102**. Because the journal block **104**, affixed to a drive shaft **105** through bearing **108** supported by bearing retainer **107** and channel **106**, is directly coupled to the gear train **78** and because the core (axle **101** and sheathing **100**) is rotatable in the journal block, each segment of the roller may rotate at different speeds without affecting the transmission of the material **120**.

Affixed to each gear **109** of gear train **78** is a small clutch **110** which will maintain each roller at a desired speed, independently of the speed of the other rollers.

If desired the rolls of festoon assembly can be laminated and consist of an outer steel shell **11** and an inner lead shield **99**. Also a gear train cap **113** can be provided.

The material **120** is fed into the machine as shown in FIGURE 6 beginning at roller **68***a* crossing to roller **68** and thence back to roller **69***a*. This passing back and forth of the material **120** continues until it finally passes roller **72** after which it passes over an idler roller **72** and out of the festooning assembly cover **77**.

Because of the complete protection afforded by the machine, of the invention, the material **120** may be fed into the machine while it is in operation, that is while the beam **21** is passing through the window **30**.

Feeding of the material into the machine is facilitated by affixing a relatively stiff leader of paper, cardboard, nylon, or the like to the end of the material **120**. This leader will be guided through the base and by the rollers by guide channels and lips such as **90** through **97**, shown in FIGURE 7.

The leader material shown should, of course, be thin enough to easily pass through the slits **80***a* to **84***a* but can be considerably thicker than the material **120** and long enough to extend past rollers **68** and **68***a*. Because the pillow blocks **107** are spring loaded in channel **106** by a spring loading mechanism which consists of a spring **115**, and a plug **116** retained in extension **114** by cap **117**.

Additional features of the present invention include a labyrinth passageway **62** in base **16** for the removal of spent cooling gas. By means of a coupling **63** this exhaust passageway may be connected to an exhause system (not shown) for discharging these gases at a remote location.

Having now shown and discussed each unique feature of the present invention it is desired that the invention not be limited by the specific details disclosed herein only by the appended claims.

What is claimed is:

1. An apparatus for electron irradiation of goods comprising an enclosed, evacuated chamber having affixed thereto means for producing a beam of electrons with energies in the KeV range or greater, along an axis of said chamber, scanner means, in said chamber, for expanding said beam to form an elongated fan-line configuration, a beam transparent window means comprising an elongated narrow pane element positioned in a wall of said chamber transverse to said beam to permit transmittal of said beam out of said chamber, into a chambered base and transport means, positioned adjacent said chambered base, to convey goods, to be irradiated, through said base and transversely through said beam after said beam passes through said window, each of said means and said base having integral shielding therewith of sufficient density and thickness to attenuate X-rays created in said means to a level below 2.5 millirads per hour, said transport means comprising a real for rotatably supporting a roll of flexible sheet material, a festooning apparatus, for passing flexible sheet material under said beam, positioned outside of said base, means for introducing said sheet material into the festooning apparatus, and means for taking up said material after its passage through the beam, said festooning apparatus comprising a plurality of rollers positioned on each side of said base for supporting a plurality of layers of said flexible material through the path of said beam, the axis of each roller being parallel to the long dimension of said expanded beam, roller means and gears coupled to each roller and to one another to synchronize each of said rollers with its adjacent rollers, guide means, for directing and maintaining said material along predetermined paths through said base, magnetic electron trapping means located in said base parallel to the long dimension of said expanded beam and between said beam and said rollers to create a magnetic field transverse to said material to trap electrons traveling parallel to said material, and means for attenuating X-rays generated in said base by said beam to a level below 2.5 millirads per hour, said attenuating means comprising said rollers, overlapping one another, and a pair of blocking members, arranged to overlap the rollers adjacent said blocking members to block the line of sight through said base.

2. The apparatus of claim **1** wherein said rollers each comprise an axle bearing a lead rotatably mounted at each end within a closed stainless steel cylinder, said cylinder being supported at each end by journals fitted within channels, spring loading means on said journals

within said channel to permit one degree of freedom of movement of said pournals, roller means and gears.

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U.S. Cl. X.R.

250—108