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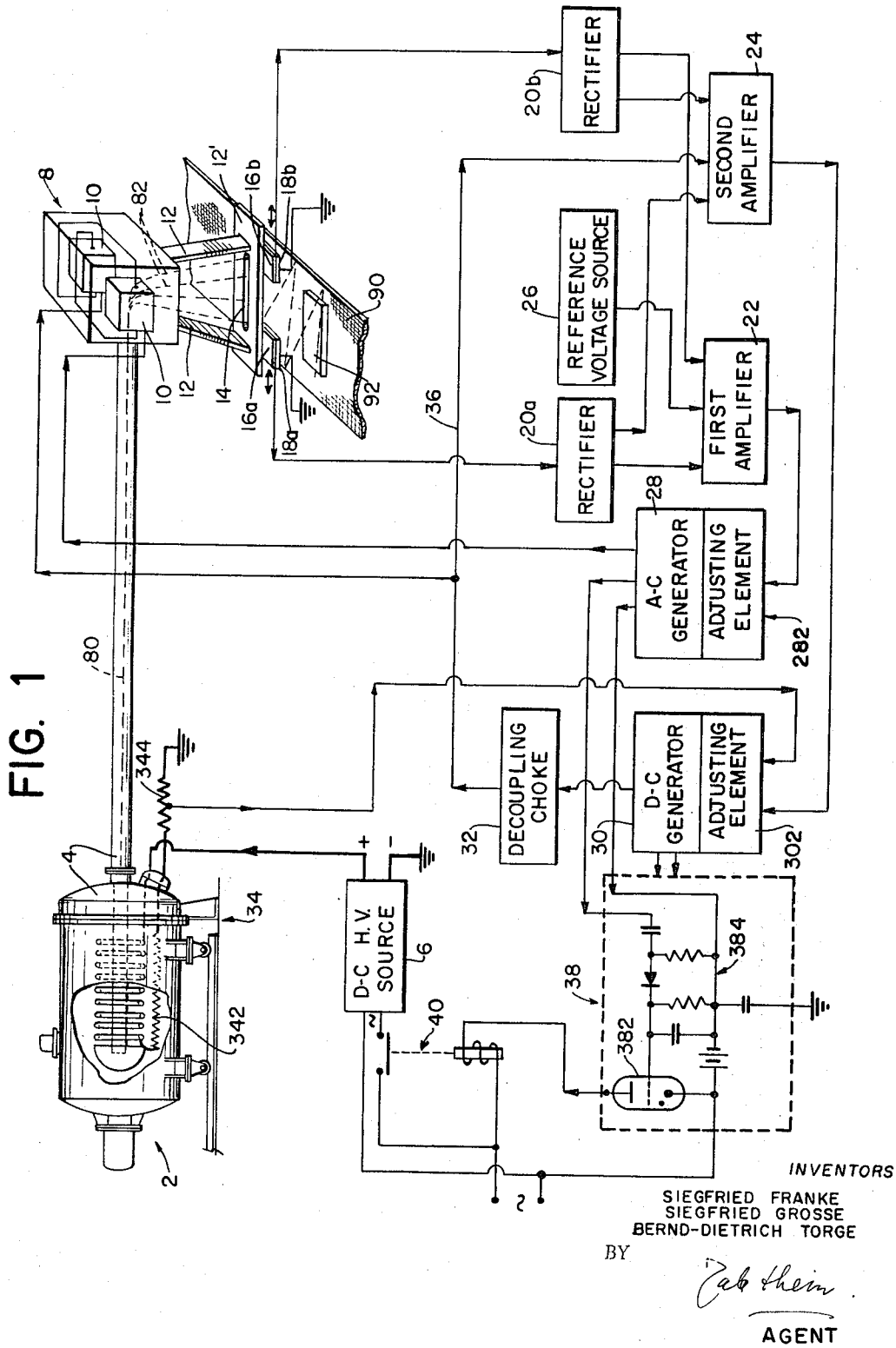
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EQUIPMENT FOR CONTROLLING AND MONITORING THE ELECTRON BEAM OF
A HORIZONTAL-TYPE PARTICLE ACCELERATOR

Filed July 27, 1965

2 Sheets-Sheet 1



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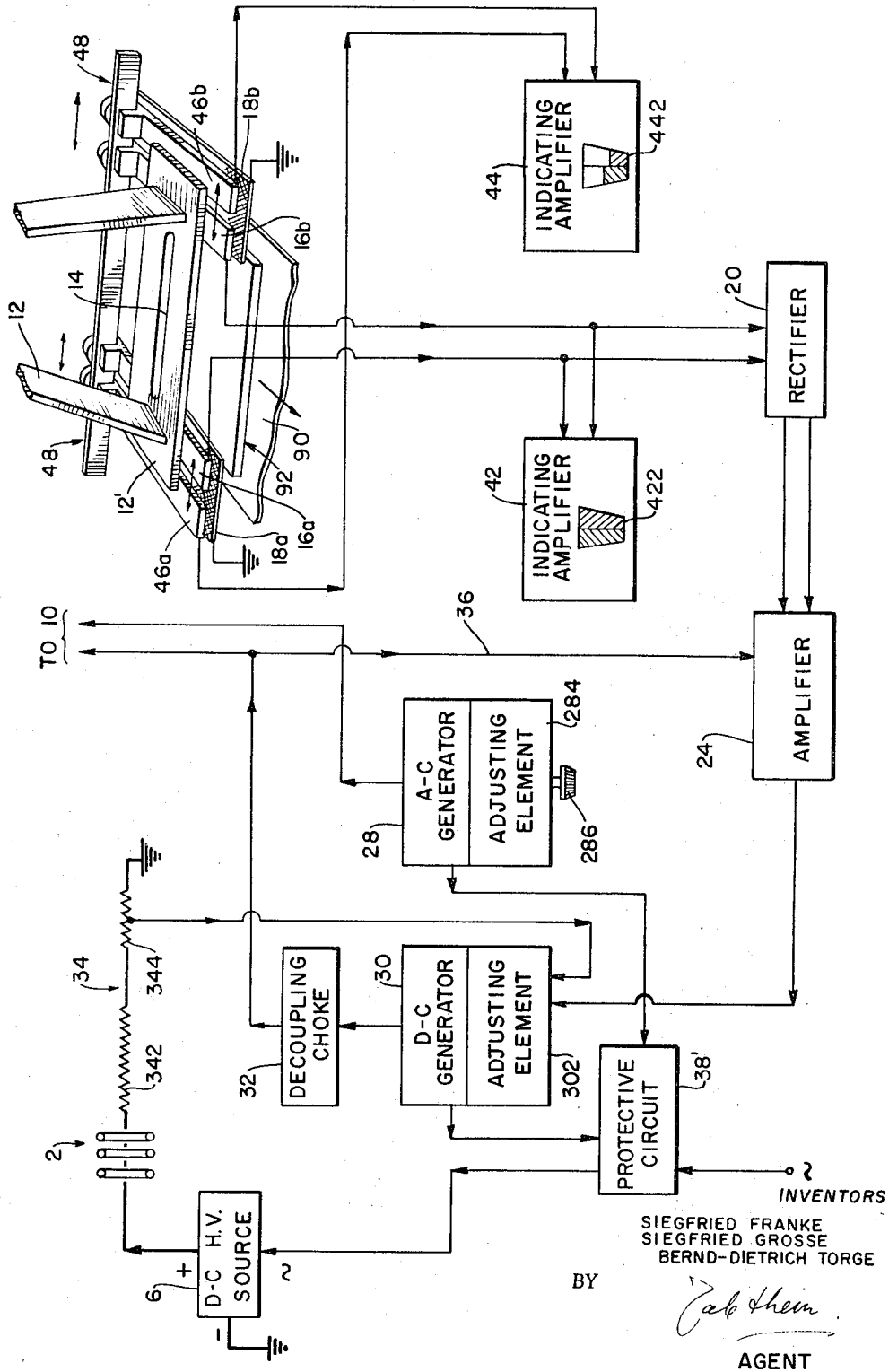
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2 Sheets-Sheet 2

FIG. 2



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EQUIPMENT FOR CONTROLLING AND MONITORING THE ELECTRON BEAM OF A HORIZONTAL-TYPE PARTICLE ACCELERATOR

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ABSTRACT OF THE DISCLOSURE

Equipment for controlling and monitoring the electron beam of a horizontal particle accelerator, with electromagnet means at the outlet end of the accelerator tube, having two windings, of which one is excited by direct current and serves to deflect the beam from horizontal into vertical, while the other is excited by a low-frequency alternating current for fanning out the deflected electron beam.

The present invention relates to an equipment for controlling and monitoring the electron beam of a horizontal-type particle accelerator, where an electromagnet is provided at the outlet or exit end of the accelerator tube, whose one winding is excited by a direct current and which thus serves to deflect the electron beam from the horizontal into the vertical, while the other winding of the magnet is excited by a low-frequency, sinusoidal, triangular or saw-tooth-shaped current and which thus serves to fan out the deflected electron beam. In a preferred embodiment, two coil structures may be provided, with serially connected winding portions.

The application of high-speed electrons in radiation chemistry and for sterilizing foods, medicines, surgical dressings and medical instruments requires, in addition to a powerful generator for the production and acceleration of the electrons, the so-called particle accelerator, an additional equipment which feeds the electron beam, which is focused after passing through the accelerator tube of the particle accelerator, to the material to be irradiated with uniform intensity and possibly without any loss of energy.

The material or object to be treated is usually passed under the vertically arranged arrangement which also includes the aforementioned additional equipment. The latter consists of an electromagnet at the exit end of the accelerator tube, excited by a low-frequency sinusoidal, triangular or saw-tooth-shaped current and performing the fanning out of the focused beam to a variable degree, depending upon the amplitude of the exciting current.

The material passes, as a rule, on a conveyor belt under the exit window of the particle accelerator. Due to the fanning of the electron beam, arriving perpendicularly from above in vertical-type particle accelerators, the beam can be adapted to the width of the material to be irradiated so that a uniform distribution of the beam dose on the surface of the irradiated material is achieved, and on the other hand, the beam exit window of the particle accelerator, which usually consists of a very thin aluminum foil, is under a uniform thermal stress.

In vertical-type particle accelerators it is known manually to adjust the amplitude of the sinusoidal, triangular or saw-tooth-shaped current effecting the fanning out of the electron beam, thus adapting it to the width of the particular material to be irradiated. The extent of the fanning is measured and controlled by either differentiating the sinusoidal, triangular or saw-tooth-shaped impulses at the exciting coil of the electromagnet, after which they

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are rectified and indicated on an ammeter, or by making the differentiated impulses at the exciting coil of the electromagnet visible on the screen of an oscilloscope.

Such a measurement and control of the fanning width of the electron beam is very inaccurate, since even minor variations of the acceleration voltage, which cannot always be sensed, can vary the fanning width without this being recognized from the indicated electric values derived from the exciting current of the electromagnet. Furthermore, the use of a vertical-type particle accelerator is in many cases not feasible insofar as it has a relatively great overall height, due to the high acceleration voltages, and therefore cannot be always installed without additional constructional expenditure. Besides, the disassembly of the high-voltage generator and/or particle accelerator in case of an inspection is difficult in the vertical arrangement.

These last-mentioned disadvantages of the vertical-type arrangement are not found in a horizontal-type particle accelerator since the high acceleration voltages have only a minor effect on the overall height and rather affect the overall length of the entire set-up. Such particle accelerators can, therefore, be used practically everywhere without additional constructional expenditure, apart from the necessary radiation protection. The disassembly in case of an inspection is simple since the pressure tank, for example, surrounding such a particle accelerator equipment can be removed from the active portions of the equipment after loosening a few connections.

But in addition to fanning out the electron beam, it is necessary in a horizontal-type particle accelerator to deflect the electron beam from the horizontal into the vertical, that is, by an angle of 90 degrees, if the material to be irradiated is to pass on a conveyor belt under the beam exit window.

This is achieved by providing the electromagnet arranged at the outlet end of the acceleration tube with a winding for fanning out the electron beam, excited by a sinusoidal, triangular or saw-tooth-shaped current, and with an additional winding which is excited by a direct current and whose magnetic field effects the 90 deg. deflection of the electron beam. The windings may be combined into one or two adjacent coil structures.

In addition to the above-mentioned difficulty of measuring exactly, and respectively controlling the size of the electron-beam fanning effect, and taking into account any variation of the acceleration voltage that cannot be ascertained and therefore not corrected, there is here an additional difficulty, namely of keeping the deflection of the electron beam constant at an angle of 90 degrees, independent of the above-mentioned, not always determinable variations of the acceleration voltage, and of precisely adapting it to a deliberate variation of the latter.

If the deflection of the electron beam differs from 90 deg. due to a wrong adjustment of the direct current exciting the electromagnet or due to an undeterminable variation of the acceleration voltage, the electron beam could run under certain circumstances against or impinge upon the walls of the deflection chamber or the tube, and the X-rays thus produced, which are very hard owing to the very high acceleration voltages, can cause considerable secondary damages.

One of the main objects of the invention is to eliminate the disadvantages and difficulties encountered in the control of the deflected and fanned-out electron beam of known particle accelerators.

It is one object of the invention to provide an equipment for controlling and monitoring the electron beam of a horizontal-type particle accelerator, which permits, on the one hand, an accurate adjustment of the direct current deflecting the electron beam from the horizontal

into the vertical in dependence on the prevailing, adjusted acceleration voltage, and on the other hand, an automatic correction of deviations in the deflection angle due to unavoidable differences of the acceleration voltage.

Another object is to permit the adaptation of the electron-fan width to the actual width of the irradiated material, possibly automatically, and the indication or automatic correction of the variations in the width of the electron-beam fan caused by operational factors, for example, undeterminable variations of the acceleration voltage, so that an optimum distribution of the radiation dose on the irradiated material is achieved.

This problem is solved, according to one of the important features of the present invention, by providing a generator supplying the direct current for the deflection of the electron beam with a preferably electronic adjusting element which is, on the one hand, controllable by an electric parameter proportional to the acceleration voltage of the particle accelerator, preferably by the column current of the high-voltage generator, and is, on the other hand, regulable in dependence on the size of the output voltages of a probe assembly arranged in front of the beam exit window of the particle accelerator and adjustable according to the prevailing irradiating conditions.

Another feature relates to making the generator which supplies the low-frequency, sinusoidal, triangular or saw-tooth-shaped current for fanning the electron beam, regulable over an additional, preferably electronic adjusting element in dependence on the size of the output voltages of the probe assembly.

An advantageous and preferred embodiment of the equipment according to the invention comprises two probes which can be set oppositely and symmetrically to the central beam, corresponding to the width of the material to be irradiated, and which are so arranged in front of the beam exit window of the particle accelerator that they are only irradiated partly, preferably half, with the correct size and position of the fanned-out electron beam, corresponding to the setting of the probes and thus to the width of the material to be irradiated; the probes attain in this case the nominal value of their output voltages.

The two probes are so connected electrically, over a rectifier and/or a smoothing element, with two variable-gain amplifiers acting as differential amplifiers that the sum of the rectified and/or smoothed output voltages of both probes is in one amplifier oppositely connected to the constant voltage of a reference voltage source, and that the amplified difference of these voltages, in case it differs from a pre-determined nominal value, influences the adjusting element of the generator supplying the sinusoidal, triangular or saw-tooth-shaped current for fanning out the electron beam, so as to increase or decrease the amplitude of this current.

In the second variable amplifier acting as a differential amplifier the rectified and/or smoothed output voltage of one probe is oppositely connected to that of the other probe, and the amplified difference of the voltages, in case it likewise differs from a pre-determined nominal value, influences, together with the electric parameter proportional to that of the acceleration voltage of the particle accelerator, the adjusting element of the generator supplying the direct current for deflecting the electron beam, so as to increase or decrease the latter current.

It seems particularly advantageous, according to an inventive concept, if the nominal values of the rectified and/or smoothed output voltages are equal and if their sum corresponds to the size or level of the constant voltage of the reference voltage source. With such an arrangement of the probes, the voltage at the output of the two variable-gain amplifiers is zero when the probes attain their nominal voltage values, that is, when they both are, for example, half irradiated, so that the size and

position of the fanned-out electron beam corresponds to the setting of the probes and also to the width of the irradiated material.

The adjusting elements for the two generators must have in this case either a high zero-point sensitivity or the outputs of the variable amplifiers must be superposed on a constant voltage at the inputs of the adjusting elements.

Another feature suggested by the invention provides a series arrangement of two pairs of probes which can be set oppositely and symmetrically to the central beam, corresponding to the width of the material to be irradiated, in front of the exit window of the particle accelerator in the fanning direction of the electron beam, in such a way that the individual probes of each pair which are closest to the central beam are completely irradiated with the correct size and position of the fanned-out electron beam, corresponding to the setting of the probes, while the probes of each pair arranged on the outside in fanning direction are only partly irradiated, and all probes attain in this case the nominal values of their output voltages. The pair of probes closest to the central beam and that arranged on the outside in fanning direction are each electrically connected with an amplifier which makes the irradiation of the respective probes visible, for example, over "magic fans" or electron-beam indicators.

The probes closest to the central beam are preferably also electrically connected with a variable-gain amplifier acting as a differential amplifier by way of a rectifier and/or a smoothing element. The rectified and/or smoothed output voltage of one probe is oppositely connected in this amplifier to the output voltage of the other probe, as already described in the first embodiment of the equipment, and the amplified difference of these voltages influences, here again, together with the electric quantity proportional to that of the acceleration voltage of the particle accelerator, the adjusting element of the generator supplying the direct current for deflecting the electron beam, so as to increase or decrease this current, in case said voltage difference deviates from a pre-determined nominal value.

The amplitude adjustment and correction of the sinusoidal, triangular or saw-tooth-shaped current for fanning out the electron beam is not effected here over a closed electric control circuit and an electronic adjusting element, but by hand, on the basis of the optical indication by the electric eyes over a manual adjusting element, the circuit being thus closed or completed by the operator.

This embodiment of the invention seems of advantage wherever, due to substantially constant irradiation conditions, an automatic setting and correction of the electron-beam width is not imperative or where, due to the size and the utilization of the irradiation equipment, such an automatic setting and/or correction would not be economically justifiable.

In order to prevent the secondary electrons issuing from the irradiated material and the electric charges applied to the irradiated material by the electron beam, in case of an electric insulating material, from influencing the probes arranged in front of the beam exit window of the particle accelerator and from falsifying their output voltages, it is advisable, according to yet another inventive feature, to arrange grounded metal diaphragms between the probes and the irradiated material, adjustable together with the probes, in such a way that they only cover the surface of the respective probes toward the material to be irradiated.

According to a further feature, relating to an improvement of the equipment according to the invention, the generator supplying the current for the deflection of the electron beam produces a sinusoidal current, for example, distorted by non-linear circuit elements. It was found that if the electromagnet is excited, for example, with such

sinusoidal current distorted by magnetization, the electron beam is so conducted over the irradiated material that an optimum distribution of the radiation dose over the material is obtained.

The preferred embodiment to be described hereinafter has the advantage that the direct current for the deflection of the electron beam adjusts itself automatically depending on the selected acceleration voltage so that misadjustments and the resulting secondary damages are avoided.

The adjustment of the probe assembly in front of the beam exit window of the particle accelerator permits furthermore a simple adjustment of the electron-beam fan width to the width of the irradiated material and a simple indication, control and correction of its location and width.

Due to the action of the regulating circuit for the deflection and the fanning out of the electron beam, the particle accelerator is completely reliable even over prolonged periods, and additional measures for keeping constant the currents for the deflection and the fanning out of the electron beam, and for the acceleration voltage, are unnecessary and can be dispensed with.

The various objects, features and attendant advantages of the present invention will become more apparent from the following description of two preferred embodiments of the electron-beam controlling and monitoring equipment according to the invention, when considered in conjunction with the accompanying drawings, wherein

FIG. 1 shows the electric block circuit diagram of a first embodiment of the inventive equipment, with some of the structural elements of the generator, accelerator tube, irradiation system, probes, conveyer with material to be irradiated, also shown structurally, and having a closed electric adjusting circuit each for the deflecting and the fanning-out of the electron beam; and

FIG. 2 is a similar circuit diagram, with some structural elements broken away, of a second embodiment of the equipment, having a closed electric adjusting circuit for the electron-beam deflecting circuit, and another adjusting circuit to be operated by the attendant of the irradiating equipment, for the electron-beam fanning-out circuit, with visual indicating means.

FIG. 1 illustrates a high-voltage generator generally designated 2 (some of the inner parts being shown in phantom); preferably, a Van-De-Graaff-type generator is employed. The generator is connected to an accelerator tube 4 of the particle accelerator. A mains supply unit 6 feeds the generator 2 with the necessary D-C high voltage, e.g. from an A-C mains, as indicated. The intercalated, relay-operated contacts will be described somewhat later.

At the outlet end of the accelerator tube 4 is arranged an irradiating unit generally denoted 8 which incorporates an electromagnet 10 of which, schematically, two windings are shown. One winding serves to deflect the electron beam by 90 degrees (horizontal path within accelerator tube 4 and vertical path in unit 8), while the other performs the fanning out of the deflected beam, in a direction at right angles to the advance movement of the materials, as shown inside the unit 8. The horizontal electron beam inside the tube 4 is identified by numeral 80, while the fanned-out, plural, downwardly directed beam portions are identified by 82. In connection with the two windings of the electromagnet 10, it should be noted that for practical purposes, it has been found advantageous to provide two coil structures incorporating two winding portions each, serially connected in the deflecting and fanning feed paths. This has been shown schematically in FIG. 1 wherein, however, single leads have been shown and thus the return leads are omitted in both paths.

The windings or winding portions of electromagnet 10 are respectively connected to an A-C generator and to a D-C generator which perform the fanning out and the deflection of the electron beam 80; the interconnecting electric feed lines have only schematically been indicated.

The generators will be fully described as the specification proceeds with the description of the electric circuit.

The beam 82 is guided within a structure schematically shown at 12 and having a bottom exit window 14 in a bottom plate 12', preferably made from copper and having water cooling (not illustrated for the sake of clarity).

A conveyer belt system schematically shown at 90 carries materials or objects shown by a block 92, which are to be irradiated. For example, foods, medicines, surgical dressings and medical instruments may be subjected to the irradiation by the equipment according to the present invention. The electron beam 82 strikes the materials or objects 92 which are moved in a direction substantially perpendicular to the fanning of the beam, along the elongated exit window 14.

Between the window 14 and the material 92 to be irradiated are arranged two probes 16a, 16b, preferably made from tungsten, which are slidably mounted so that they can be adjusted by hand according to the width of the material 92 and at the same time symmetrically to the central electron beam, as shown by the double arrows thereunder. The probes 16a, 16b are highly insulated and electrically shielded from the rest of the structure 12. The adjusting means are not illustrated.

The arrangement of the probes 16a, 16b is such that they are only irradiated half, with correct positioning and width of the electron beam 82 with respect to the width of the irradiated material 92, and that they attain in this arrangement the nominal value of their output voltage impulse. Between the probes 16a, 16b and the material 92 are arranged grounded metal diaphragms 18a, 18b which can be adjusted together with the probes. These diaphragms cover only the surfaces of the probes 16a, 16b, respectively, facing the irradiated material 92 and keep off secondary electrons issuing from the material, while they ground the electric charge applied to the material 92 if this is electrically insulating. In the latter case, the material would accumulate an electric charge which unfavorably influences the probes.

The pulses derived from the probes 16a, 16b are fed to respective amplifiers and smoothing elements 20a, 20b, as shown in the block diagram of FIG 1, where these output pulses are rectified and/or smoothed. The D-C voltages thus obtained are conducted both to the inputs of first and second variable-gain amplifiers 22 and 24.

In the amplifier 22, the sum of the voltages arriving from the units 20a and 20b is oppositely connected to a constant voltage supplied by a reference voltage source 26. It should be noted that, for the sake of clarity, conventional mains and other supply leads have been omitted, from unit 26 as well as from the others shown in the circuit diagram.

The sum of the nominal values of the rectified and/or smoothed output voltages of probes 16a, 16b corresponds to the magnitude of the voltage of the source 26 so that, in case both probes are irradiated half by the fanned-out electron beam 82, the difference between the sum of the voltages arriving from the units 20a and 20b and the voltage derived from unit 26 is zero. There is consequently no control or adjusting order at the output of the variable amplifier 22, acting as a differential amplifier, in the direction of the A-C generator to be described shortly.

If the probes 16a, 16b are not irradiated at all, or less than half, due to an insufficiently fanned-out beam 82, the sum of the output voltages of the probes is zero or, respectively, below the nominal value. Thus at the output of the amplifier 22 there appears the full amplified voltage of the reference voltage source 26 and the amplified difference, respectively, with a positive sign, for example, as a control or adjusting order.

At 28 an A-C generator is schematically shown which produces a distorted sinusoidal current for fanning out the electron beam 80, by way of one of the windings of magnet 10, as has been described before. The generator

28 has an electronic adjusting circuit or element 282, e.g. in the form of an electron-tube circuit in, or acting on, the final stage of the generator 28. The control or adjusting order derived from amplifier 22 is fed to the adjusting element 282 which in turn increases the amplitude of the sinusoidal current until, on effect of the changes in the electromagnet 10 of the irradiating unit 8, the beam 82 is changed in its width and the probes 16a, 16b are half irradiated; now, again, the difference of the voltages at the input of the amplifier 22 becomes zero.

The same process takes place, but with an opposite sign, when the probes 16a, 16b are completely irradiated or more than half. The sum of the rectified and/or smoothed voltages of the probes is then greater than the voltage from the source 26. At the output of the amplifier 22 the amplified difference appears with a negative sign, so that the adjusting element 282 reduces the amplitude of the sinusoidal current supplied by the generator 28 to the unit 8, until the probes 16a, 16b are again half irradiated.

The foregoing considerations apply to all cases where the fanned-out electron beam 82 is symmetrical to the central beam and the deflection is therefore correctly 90 degrees, but is fanned out too little or too much for the actual spatial setting of the probes 16a, 16b, and for the width of the irradiated material 92, respectively.

Before describing the role of the second variable-gain amplifier 24, the source of direct current will be explained, which performs the deflection of the beam 80, by way of the other winding of the magnet 10, as has been described before. At 30 a D-C generator is schematically shown for this purpose; a decoupling choke 32 is series-connected between the generator and the appropriate winding of the electromagnet 10, and a branch line is shown between the output side of the choke 32 and the second amplifier 24.

The value of the D-C current output of generator 30 depends on the energy which the electrons receive on their path through the accelerator tube 4; in other words, on the acceleration voltage of the particle accelerator. A voltage divider is constituted by resistors 342 and 344, the former being within the high-voltage generator 2 while the latter, grounded at its free end, is preferably arranged outside. The column current flowing through the voltage divider, generally identified as 34, is directly proportional to the acceleration voltage.

The column current flowing through the voltage divider 34 should be further explained by stating that the high-voltage source 6 supplies D-C of approx. 60 kv. to concentric, vertical ring members disposed within the generator 2 (preferably of the known Van de Graaff type), as shown; in FIG. 1, the extreme left-hand ring member is connected to the free end of the resistor 342; this, in turn, is connected to the end resistor 344. The negative terminal or the D-C high-voltage supply unit 6 as well as the other end of resistor 344 are both grounded, closing thereby the circuit. The accelerating voltages produced by the high-voltage generator 2 are in the range of 1 to 5 MV. The afore-mentioned ring members are the high-voltage electrodes of the generator 2.

The resistor 344 has a tapping for deriving thereat a voltage produced owing to the voltage drop over this part of the voltage divider 34, due to the column current; this voltage is fed to an electronic adjusting element 302 associated with the generator 30. Unit 302 may, again, be a conventional electronic control circuit. It automatically adjusts the value or magnitude of the deflecting direct current depending upon the acceleration voltage.

As has been explained somewhat earlier, the D-C outputs of the units 20a, 20b are also fed to the second amplifier 24. Here the inputs are oppositely connected. If the deflection of the electron beam 82 deviates from 90 degrees, e.g. due to fluctuations of the acceleration voltage which cannot always be avoided, either the probe 16a or the probe 16b is irradiated more while the other is irradi-

ated less, or vice versa, regardless of possibly proper fanning width.

In either case we obtain at the input of the amplifier 24 a voltage difference with either a positive or a negative sign, which appears amplified at the output of this amplifier 24, and which serves as a control or adjusting order for the afore-mentioned adjusting element 302 of the D-C generator 30. The unit 302 either increases or decreases the direct current of the generator 30, fed to one of the windings of electromagnet 10, until both probes 16a, 16b are again uniformly and equally irradiated, that is, until the voltage difference at the input of the variable-gain amplifier 24 is zero again.

In order to prevent the two above-described control circuits from influencing each other if an unsymmetry and at variation of the width of the fanned-out electron beam should appear simultaneously, thus causing instabilities and adjusting variations, e.g. in the units 282 and/or 302, the time constants of the two control circuits are made to have different values. Appropriate means (not further described) may be incorporated either in one or both of the amplifiers 22, 24, or in one or both of the units 282, 302.

In addition, in order to insure the stability of the control circuit for the electron-beam deflection, acting by way of the D-C generator 30, an electric feed-back circuit 36 is provided from the output of the generator 30 (after the choke 32) to the input of the amplifier 24; this is the branch line which has already been mentioned when describing the generator 30 and the choke 32.

Both the A-C generator 28 and the D-C generator 30 act on a protective circuit designated 38 which shuts off the particle accelerator, that is, the acceleration voltage, should one of the generators 28, 30 fail. Although input leads are shown to circuit 38 from both generators 28 and 30, only the former is shown in some detail. A thyatron 382 is shown with an appropriate network 384 including separating, voltage dropping and other electronic elements known per se. The circuit in unit 38 associated with the generator 30 is similar to that shown and operates in parallel so that failure of either generator has the same effect.

The plate current of thyatron 382 may feed, for example, a relay 40 which is connected to the common mains input. The single- or double-pole contact of this relay will interrupt the mains-input circuit of the D-C supply 6. It will be understood that the protective circuit 38, as well as the relay 40, may be of the normally energized or normally deenergized type, depending upon local operational requirements.

In the protective circuit described for FIG. 1, the thyatron may, preferably, be made open or conductive when the deflection voltage for the electron beam is present; the thyatron closes if the deflection system fails, opening thereby the relay circuit, and interrupting the mains or D-C high-voltage supply.

It should be noted that the circuit 38 may be separate from or combined with the mains-supply unit and/or the necessary high-voltage source, like shown at 6. Such a modification will be explained in connection with the second embodiment shown in FIG. 2, to be described hereafter.

FIG. 2 illustrates a second preferred embodiment of the inventive equipment, wherein identical or basically similar elements have been designated with the same reference numerals. Part of the irradiating-unit structure has been omitted. In addition to the already described probes 16a, 16b, this modification also comprises a second pair of probes 46a, 46b, arranged side-by-side with the afore-mentioned probes. The probes 46a, 46b are arranged symmetrically with respect to the central beam and more outwardly than the probes 16a, 16b. They are manually adjustable, again as shown by double arrows.

At least the outer probes 46a, 46b can be adjusted with respect to the electron beam and/or to the other elec-

trodes 16a, 16b. The adjusting structure is generally designated 48 and may include, for example, a transversal rail member with appropriate tightening means (e.g. clamps and screws), preferably on both sides of the guide structure 12 (only the adjusting means behind it being shown).

The arrangement is such that while the probes 16a, 16b (closer to the central beam) are completely irradiated with the fanned-out beam (like 82 in FIG. 1), in case of its being properly positioned as to symmetry and width, in accordance with the irradiated material 92, the probes 46a, 46b are only partly irradiated. All four probes, however, attain the nominal value of the output impulses.

The output pulses of the probes 16a, 16a are fed into a first indicating amplifier 42, and the pulses of the probes 46a, 46b into a second indicating amplifier 44; both amplifiers have combined so-called magic eyes or electron-beam indicators 422, 442, respectively, each for simultaneous indication of two parameters, for comparison purposes. On the basis of the optical indications given at 422, 442, the operator can readily check the agreement of the width of the fanned-out electron beam by monitoring the indicator 422 (via probes 16a, 16b) and the indicator 442 (via probes 46a, 46b), respectively, comparing it with the width of the irradiated material 92. If necessary, manual corrections can be made by way of a control knob 286 operating an electronic adjusting element 284 of the A-C generator 28. This will regulate the fanning-out of the electron beam 82 to the width of the material 92.

It will be understood that the adjusting element 282 of generator 28 (FIG. 1) provides automatic regulation of the variable output, while the adjusting element 284 shown for the same generator in FIG. 2 represents a potentiometer or other manually adjustable control element, having a control knob 286 or like manual means of adjustment.

In addition to the amplifiers 42, 44, the output voltage pulses of the probes 16a, 16b are, here again, fed together to a rectifier and/or smoothing element 20 (instead of the two units 20a, 20b of FIG. 1), after which the rectified and/or smoothed output voltages of these probes are oppositely connected to the input of the variable-gain amplifier 24 (called second amplifier in connection with the first embodiment). It has been described before how the amplifier 24 influences the automatic adjusting element 302 of the D-C generator 30, for adjusting the electron-beam deflection. The only difference is that with the set-up of FIG. 2, the probes 16a, 16b attain here the nominal values of their output voltages with full irradiation (in FIG. 1, the same probes were irradiated only half by the fanned-out beam).

The diaphragms 18a, 18b are somewhat wider in FIG. 2 than in the first embodiment, so as to shield both pairs of probes. Otherwise the mechanical structure is identical. As to the electric circuit, the previously described units 28, 30 (with 302), 32 and 34 are also identical.

The second embodiment shows a protective circuit 38' which is acted upon by both generators 28, 30 so as to cut off the main supply and/or the high voltage applied to the equipment, and particularly to the voltage divider 34.

If both generator outputs should be monitored with the protective circuit, a multi-grid thyatron may be used in the circuits shown in FIGS. 1 and 2, each grid receiving the appropriate control voltage from a separate network similar to that shown at 384 (FIG. 1).

In the arrangement of FIG. 2, it is readily possible to use, instead of the output voltages of the fully irradiated probes 16a, 16b, the rectified and/or smoothed output voltages of the partly irradiated probes 46a, 46b, for the formation of the difference in a variable-gain amplifier (like the one described at 22), and thence for the formation of a control or adjusting order for the element 302 of generator 30 (circuit not further illustrated). The regulation would then be even more sensitive to deviations of

the fanned-out electron beam from its optimum symmetrical position.

The foregoing disclosure relates only to preferred, exemplary embodiments of the invention, which is intended to include all changes and modifications of the examples described within the scope of the invention as set forth in the objects and the appended claims.

We claim:

1. An equipment for controlling and monitoring the electron beam of a horizontal-type particle accelerator serving for the irradiation of materials, and having
 - a D-C high-voltage source,
 - a beam generator fed by said D-C source and operatively connected with
 - a horizontal-type accelerator tube emitting a substantially horizontal electron beam,
 - beam guide means,
 - electromagnet means at the exit end of said beam guide means and having at least two windings,
 - one of said windings being excited by a direct current for deflecting said electron beam from the substantially horizontal into a substantially vertical direction,
 - the other one of said windings being excited by an alternating current for fanning out the deflected electron beam, comprising, in combination,
 - a probe assembly arranged in front of said exit end of the beam guide means, between said exit end and said materials,
 - means for laterally adjusting said probe assembly according to prevailing operating conditions,
 - first generator means for supplying said direct current for said one winding,
 - second generator means for supplying said alternating current for said other winding,
 - first adjusting means for said first generator means,
 - second adjusting means for said second generator means,
 - means for controlling said first adjusting means by an electric parameter proportional to the acceleration voltage of said particle accelerator,
 - means for regulating said first adjusting means in dependence on the value of an output voltage derived from said probe assembly, and
 - means for regulating said second adjusting means in dependence on said value of the output voltage.
2. A controlling and monitoring equipment as defined in claim 1, wherein
 - said probe assembly includes two probes which can be set with said probe adjusting means oppositely and symmetrically to a central portion of the deflected and fanned-out electron beam, corresponding to the width of said materials, and which probes are irradiated only partly with said fanned-out electron beam so as to attain nominal values of their output voltages, further comprising
 - first and second variable-gain differential amplifiers for said probes,
 - rectifier means interposed between said probes and the respective amplifiers, and
 - a reference voltage source providing a constant voltage output, and wherein
 - the outputs of said rectifier means are connected in said first amplifier so as to form a sum which is oppositely connected to said constant voltage output,
 - the deviation of the difference between said sum and said constant voltage output from a predetermined nominal value is amplified and influences said second adjusting means with a view to regulating the amplitude of said alternating current, while
 - said outputs of the rectifier means are oppositely connected to one another in said second amplifier, and the deviation of the difference between said outputs from a predetermined nominal value is amplified and influences said first adjusting means with a view to regulating said direct current.
3. A controlling and monitoring equipment as defined

in claim 2, further comprising a feed-back circuit between the output of said first generator means and the input of said second amplifier, for insuring the stability of operation of said first generator means.

4. A controlling and monitoring equipment as defined in claim 2, wherein said outputs of the rectifier means have substantially equal nominal values so that said sum corresponds to the level of said constant voltage output.

5. A controlling and monitoring equipment as defined in claim 1, wherein

said probe assembly includes an inner and an outer pair of probes which can be set with said probe adjusting means oppositely and symmetrically to a central portion of the deflected and fanned-out electron beam, corresponding to the width of said materials,

the probes in each pair which are closer to said central beam portion are completely irradiated with said fanned-out electron beam, while

the probes in each pair which are farther from said central beam portion are irradiated only partly, so that all probes attain nominal values of their output voltages, further comprising

first and second indicating amplifiers for said inner and said outer pairs of probes,
a variable-gain differential amplifier for said inner pair of probes, and
rectifier means interposed between both probes of said inner pair and said differential amplifier, and wherein

the outputs of said rectifier means are oppositely connected to one another in said differential amplifier, and

the deviation of the difference between said outputs from a predetermined nominal value is amplified and influences said first adjusting means with a view to regulating said direct current.

6. A controlling and monitoring equipment as defined in claim 5, further comprising

visual indicator means actuated by said first and said second indicating amplifiers, and
manual adjusting means for regulating said second adjusting means in accordance with readings taken from said visual indicator means.

7. A controlling and monitoring equipment as defined in claim 5, further comprising a feed-back circuit between the output of said first generator means and the input of said differential amplifier, for insuring the stability of operation of said first generator means.

8. A controlling and monitoring equipment as defined in claim 5, further comprising laterally adjustable grounded metal diaphragms between said probe assembly and said material, substantially co-extensive with the overall surface of said inner and said outer pairs of probes, for shielding said probe assembly against secondary electrons issuing from said materials.

9. A controlling and monitoring equipment as defined in claim 1, wherein said second generator means includes non-linear circuit elements for distorting said alternating current so as to constitute a sinusoidal current for said fanning out of said deflected electron beam by way of said other winding of the electromagnet means.

10. A controlling and monitoring equipment as defined in claim 1, further comprising protective circuit means operatively connected with at least one of said generator means for disconnecting said high-voltage source in case of a disturbance in the respective generator means.

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