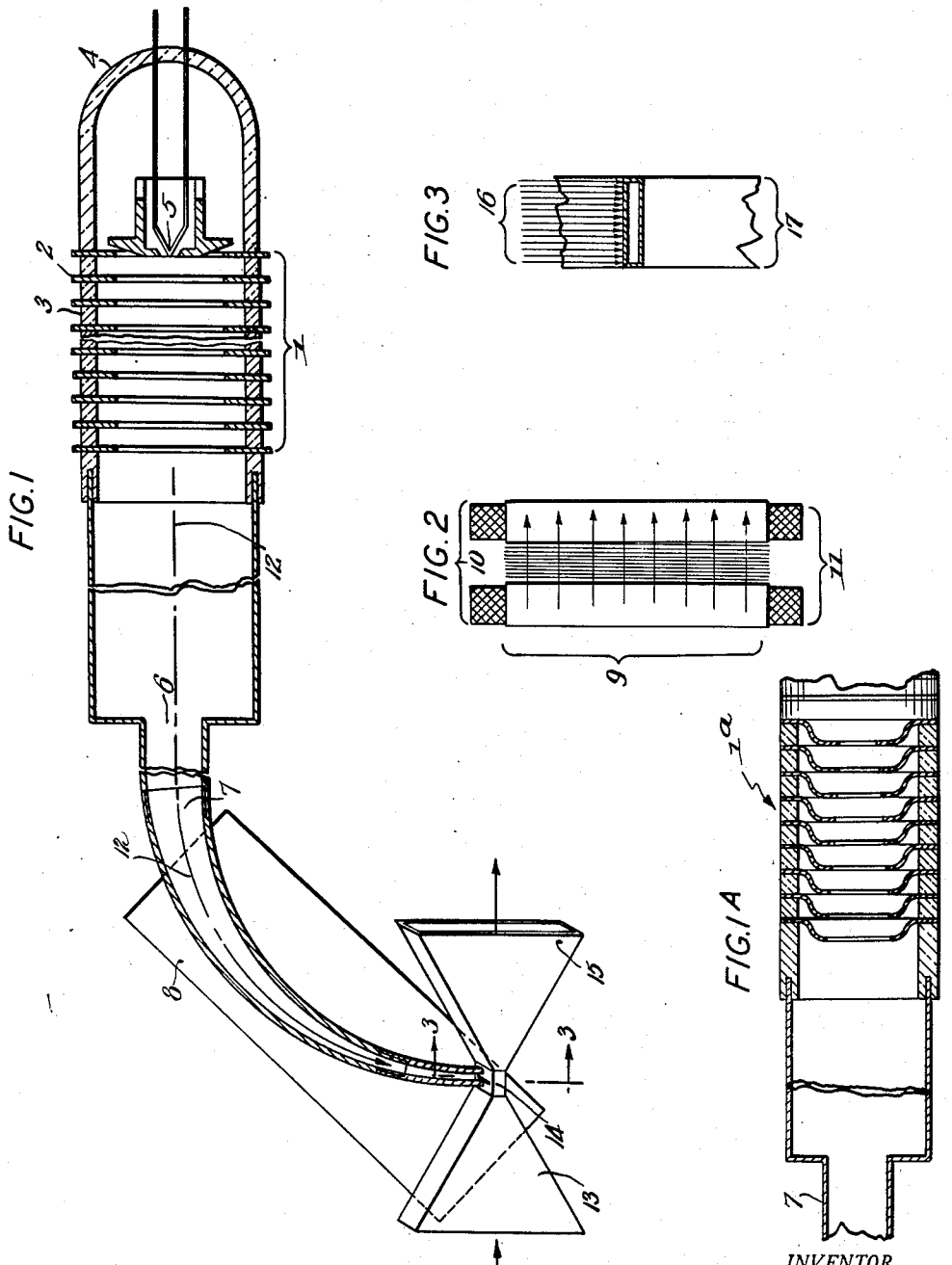
June 8, 1954 D. M. ROBINSON 2,680,814

METHOD OF AND APPARATUS FOR STERILIZING STREAMS OF FLUENT MATERIAL

Filed Sept. 14, 1950 2 Sheets-Sheet 1



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METHOD OF AND APPARATUS FOR STERILIZING STREAMS OF FLUENT MATERIAL

Filed Sept. 14, 1950

2 Sheets-Sheet 2

FIG. 4

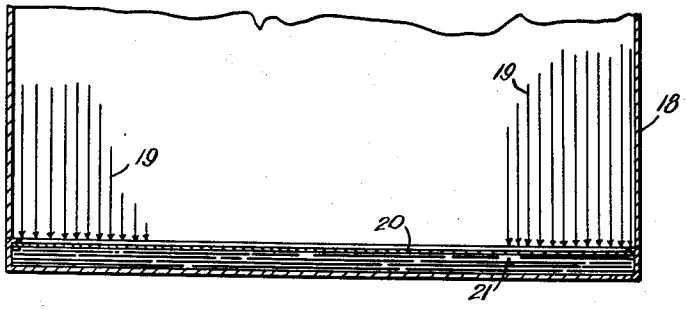


FIG. 5

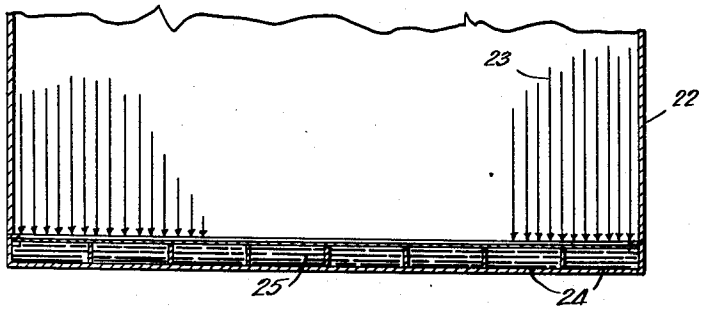
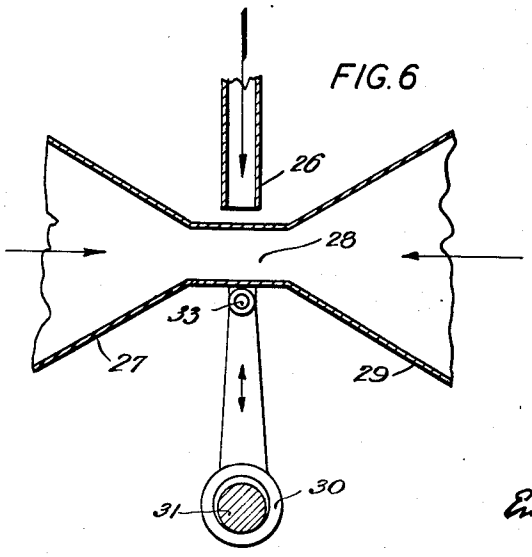


FIG. 6



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UNITED STATES PATENT OFFICE

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METHOD OF AND APPARATUS FOR STERILIZING STREAMS OF FLUENT MATERIAL

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Application September 14, 1950, Serial No. 184,882

33 Claims. (Cl. 250—49)

1

This invention relates to the method of and to apparatus for sterilizing streams of liquids, or involving suspension of solids in liquid mediums, or streams of gases and vapors, or streams of finely divided solids by electron beams, preferably of continuous, high, instantaneous ionization density.

In order that the principle of the invention may be readily understood, I have, in the accompanying drawings, disclosed several embodiments of means whereby the invention may be practised.

In said drawings:

Fig. 1 is a view, partly in longitudinal section and partly in side elevation, of an acceleration tube of a high-voltage electrostatic generator, as for example of the Van de Graaff type, wherein is created, and axially along which is directed, a beam of high-energy electrons, said beam being of substantially circular cross-section and of small diameter which, by suitable focusing means, is shaped into a very thin sheet that is in this figure shown as narrow and impinging directly downward onto a very thin stream of any desired nature, but at the full width of the electron beam sheet, and forced under high pressure through a substantially horizontally positioned conduit.

Fig. 1A is a longitudinal sectional view on a small scale of an acceleration tube of late Van de Graaff type that may be employed in the practice of my invention;

Fig. 2 is a side view of the magnetic field and representing diagrammatically focus means for changing the form of the electron beam of very small circular diameter into a thin sheet;

Fig. 3 is a vertical section upon the line 3—3 of Fig. 1, indicating the electron beam, now in sheet form, impinging upon the stream through the very thin top wall of the conduit in a vertical direction and along a line whose thickness is that of the electron beam sheet;

Fig. 4 is a vertical section representing another embodiment of apparatus for practicing the method of my invention, and wherein the electron beam is created as a wide, thin, electron sheet by the employment of a cathode that is of corresponding width and thickness, and which sheet is projected downward through a correspondingly shaped acceleration tube of a high-voltage electrostatic generator onto a thin stream in a single conduit of the full width of the electron sheet and having a very thin top wall constituting a window at the elongated, narrow area where the electron sheet impinges vertically upon the top wall of the conduit and penetrates therethrough to sterilize the stream of whatever nature;

2

Fig. 5 is a view similar to Fig. 4, but representing the thin stream as forced under high pressure through a conduit that is composed of a series of thin, narrow tubes that together may equal the width of the single conduit represented in Fig. 4; and

Fig. 6 is a diagrammatic representation of means to impart constant vibration to the conduit to prevent the possible adherence, to the inner surface of the conduit, of any portions of the stream that may be coagulated under the action of the high-energy electron sheet beam.

Referring broadly to the nature and purpose of my herein disclosed invention, the method thereof is applicable to any source of high-voltage electrons and particularly to any source capable of producing an intense beam, preferably continuous, and, broadly stated, is a method of sterilizing material by irradiation which consists in converting potential energy of the material into kinetic energy, and then passing the resultant stream of the material through a beam of high-voltage electrons so that the material receives an irradiating dose in an extremely short time.

The method herein disclosed is one for irradiating materials in which a thin stream of material is passed at high velocity through an intense, high-energy electron beam, thus effecting the sterilization in an exceedingly short time. I preferably use an intense, continuous beam, thus making it still possible to have a sterilizing dose even though the dependent particles of the material to be sterilized are shot, passed or forced through the intense beam very quickly.

The invention is applicable broadly to streams of material, and therefore not only to liquids, to liquids holding finely divided solids in suspension, and to chemicals in powder or grain form, but also to gases and vapors which may be at high velocities, either alone or as carriers for small solid or liquid particles, and including dusts and sprays and to such particles alone (that is, not in a carrier). The term "stream" and like terms include liquids, gases and vapors, alone or containing finely divided material, and also finely divided material alone. The term "fluid" covers or includes liquids, gases, and combinations thereof.

The method herein disclosed and claimed may, so far as the step of creating an electron beam of high intensity is concerned, be carried out by the acceleration tube shown in Fig. 1 and Fig. 1A

hereof, or by any of the numerous structures of apparatus shown in the co-pending application of Van de Graaff and Buechner, Ser. No. 297,036, filed July 3, 1952, among which are the structures of apparatus identified as Exhibits A, B, D and E and referred to as such by the Board of Appeals of the Patent Office in its decision dated March 31, 1952, in the co-pending application of Van de Graaff and Buechner, Ser. No. 128,084, filed November 18, 1949, now Patent No. 2,608,664, August 26, 1952. The step of establishing the sheet-like form of the beam can be, and is herein described, as carried out by focusing the beam into a sheet-like form, or by originally creating said beam in sheet-like form, and the step of presenting the thin stream of material under high pressure may be carried out by the means shown in Figs. 1 and 6, or by the means shown in Fig. 5 of this application.

In accordance with my invention, which I thus broadly define, I irradiate a very thin stream of material at high velocity, such as liquids, gases, vapors, liquids having material in suspension, and finely divided solids, etc., by passing such stream at high velocity through a beam of high voltage electrons, which beam preferably penetrates such very thin stream in sheet form, which sheet form may be obtained by focusing the beam into sheet form or by constructing and employing a cathode of corresponding width and thickness and therefore capable of emitting such a sheet. However, as stated in a preceding paragraph, my invention is applicable broadly to streams of material. I deliver or discharge, in accordance with my invention, such streams under high pressure or velocity into the path of a continuous beam of high energy electrons. While I herein disclose several embodiments of means for delivering or discharging the material to be irradiated into a confining conduit, my invention may be otherwise practiced, within the scope thereof, to effect the irradiation of material, such as liquids, gases, vapors, liquids having material in suspension, and finely divided solids, etc. projected at high velocity through a beam of high voltage electrons.

While preferably I employ a thin, or even a very thin, sheet of electrons, I may employ a pencil of electrons provided the velocity of the liquid or gas is high enough.

Referring more specifically to the nature and purpose of my invention in the disclosed embodiments thereof, I create a high-energy electron beam which, either by a cathode shaped to provide a sheet-like beam or by suitable means, is either created as, or is shaped into, a sheet of substantial width from edge to edge, but preferably very thin from front face to back face, such sheet-like beam impinging preferably at right angles downwardly onto a horizontally flowing stream, of the broad or generic character hereinbefore stated, under high pressure, the width of which stream is preferably equal to the width of such electron beam in sheet form, so as to act only along a thin transverse line on the constantly traveling liquid or other stream to irradiate it as the stream passes under such transverse line, which is the thin sheet of high-energy electrons. Such stream may, as stated, be a liquid or gas or vapor alone, or holding in suspension such finely divided solids as flour, small grains such as wheat, or chemicals in powder or grain form or even gases and vapors, or the stream may be composed wholly of finely divided solids.

When the product to be irradiated is a liquid of viscosity not too much greater than that of water, such liquid may be forced under pressure through a thin-walled tube or conduit at high velocity, and if such tube or conduit is in the path of the electron beam, the required dosage is delivered at a very high instantaneous ionization density. If the velocity of the liquid or other stream is high and if the depth of the liquid and the dimension of its confining tube or conduit in the direction of motion of the high-energy electrons is small, and if the dimension of the focused electron beam that impinges upon the said tube or conduit is small in the direction of the flow of the liquid or other stream (that is, if the electron beam be delivered as a thin sheet of width substantially the same as the width of the liquid or other stream), the result is that there is achieved an instantaneous ionization density as great or greater than I have obtained by favorable scanning or by scanning in a pulsing manner as disclosed in other co-pending applications filed by me.

Moreover, if the stream be a liquid, the liquid, in being subjected to the irradiating action while rushing through the narrow-walled conduit or tube, is by its scouring action on the inner surface of the walls of the conduit or tube, an extremely efficient coolant, and carries away in a satisfactory manner all the energy that is dissipated in the thickness of the conduit or tube and in the liquid itself.

Referring more particularly to the drawings and first to the construction shown in Figs. 1, 1A, 2 and 3, I have at 1 in Figs. 1 and 1A represented in central, longitudinal section an acceleration tube of a high-voltage electrostatic generator of a Van de Graaff type, but I may use any source of high-voltage electrons, and particularly any source capable of producing a continuous intense beam. The wall of said acceleration tube is herein shown as composed of a multiplicity of alternating metallic electrode rings 2 and insulation rings 3 bonded together as disclosed in the U. S. patent to Trump and Cloud, No. 2,460,201, or as in the U. S. patent to Van de Graaff and Buechner, No. 2,517,260. At one end the said acceleration tube is provided with the cathode assembly 4 having therein the cathode 5, and at its opposite end, instead of being provided with an anode, it is open so that the high-vacuum interior of the acceleration tube is in open communication at 6 with the continuation 7 of the acceleration tube. While in Fig. 1 the acceleration tube is shown as horizontally positioned for use, it may be and in some cases is desirably vertically positioned for use, and is so indicated in Fig. 1A.

Certain of the metallic electrode rings 2, as for example every third ring, are (as usual in the Van de Graaff type of acceleration tube) connected to corresponding electrodes of the electrostatic generator, with the result that a substantially uniform electrostatic field is formed of substantially the entire cross-sectional area of the acceleration tube, extending along the wall of the tube in a manner not herein necessary to describe more fully.

While I have described in some detail an accelerator of the Van de Graaff type, it is to be understood that my invention may be practiced, as stated, by the use of any source capable of producing intense beam or any source of high-voltage electrons.

Referring further to the type of acceleration tube here shown, and particularly to Fig. 1, the high-energy electron beam emanating from the

cathode 5 and directed lengthwise the said acceleration tube 1 is of small diameter and is substantially circular in cross section. It may, for example, have a diameter on the order of one centimeter. That beam, entering the narrower portion of the tube at 6 and passing along the small diameter tube 7 constituting a part or continuation of the acceleration tube 1, within which is preserved the high-vacuum condition that exists in the portion of the acceleration tube of greater diameter, enters the region of action of the focusing means (merely diagrammatically indicated at 8) which extends to and includes the conduit or tube through which the liquid, gas, vapor or other stream to be irradiated is forced under high pressure. I have diagrammatically indicated in Fig. 2 at 9 the magnetic field, and at 10, 11 the coils producing the electric field, which are in a suitable direct current circuit that need not be more fully referred to.

The means diagrammatically indicated at 8 in Fig. 1 and at 10, 11 in Fig. 2, focuses into a well defined rectangle or preferably a sheet of any desired thickness, the electron beam indicated by a line 12 in Fig. 1 extending axially of the acceleration tube 1 and its continuation 7 from the cathode 5. The longer dimension of the electron beam thus focused into a preferably thin sheet, has one dimension preferably equal to the width of the liquid, gaseous or other stream; that is, the width of the electron-sheet beam has been retained equal to the width of the liquid, gaseous or other stream, and the other dimension of the electron-sheet beam, measured in the direction of motion of the liquid, gaseous or other stream that is being sterilized thereby has, by the focusing means, been made as small as it is practicable to make it.

Such a system, producing focusing in one plane considerably greater than in a plane at right angles to it, is known as a system of cylindrical optics, and is diagrammatically indicated at 8, 9, 10 and 11 in Figs. 1 and 2. Such a result (namely, that of changing the shape of the high-voltage electron beam, originally circular in cross section, into a sheet) is obtained by the means diagrammatically represented in Figs. 1 and 2. Therein, the high-voltage electron beam 12, directed at great speed from the cathode 5 along the axis of the acceleration tube 1, has a circular cross section and a diameter, for example, of one centimeter. On passing in a uniform magnetic field, it is bent at right angles and focused in one plane, but not in the other. That is, on arriving at the focus point, the high-voltage electron beam comes to an extremely sharp focus in one direction, but remains in its original size in a direction at right angles to the plane first referred to just above. That is, the high-voltage electron beam, now in sheet form, remains of its original dimension in the direction that is the width of the electron sheet, but its dimension has greatly decreased in the direction which is the thickness of the now shaped or focused electron sheet.

Referring further to Fig. 1, I have diagrammatically indicated the liquid, gaseous or other stream and its containing conduit or tube as not very wide, but the illustration thereof in this figure is more for the purpose of indicating that the high-voltage electron sheet is delivered vertically downward onto the top wall of the conduit or tube that conducts a very thin stream of a liquid, gaseous or other nature, to be irradiated. Actually, but not necessarily, that stream

has a width which is the same as the high-voltage electron sheet into which form the electron beam 12 has been shaped. My invention is not limited with respect to the width of the high-voltage electron sheet.

Referring again to Fig. 1, I have at 13 indicated a funnel-shaped inlet for delivering the stream of the broad or generic character defined to be irradiated under high pressure to a conduit, tube or pipe 14 which has a very small interior dimension from top to bottom, that is, in the direction in which the high-voltage electron sheet impinges upon it, and also its wall is very thin. Extending from the conduit, tube or pipe 14 is an outwardly flaring member 15 for delivering the now irradiated liquid, gaseous or other stream for further processing. Actually and in practice the wall of the conduit, tube or pipe 14 is equal to the width of the high-voltage electron sheet, and it is to be understood that the high-voltage electron sheet impinges in a substantially vertical direction in a transverse line onto the top of the conduit, tube or pipe 14, and that all along such transverse line the top wall of the said conduit, tube or pipe 14 is very thin, that is, as thin as possible while retaining strength enough to resist the high pressure of the liquid, gas, vapor, finely divided solid material or the like that is being irradiated. As already stated, the electron beam and the sheet into which it is shaped are within the vacuum system at all times.

As already indicated, the stream, when a liquid, has a scouring action upon the inner surface of the walls of the tube 14 and acts as a very efficient coolant.

In Fig. 3 I have indicated, but merely diagrammatically at 16, the width of the high-voltage electron sheet and at 17 the width of the conduit or tube for the stream of liquid, gas or of other character, as hereinbefore set forth, and it will be seen that the two are of equal width. The width is merely diagrammatically there indicated.

In Fig. 4, I have represented in vertical section and merely diagrammatically, the lower end only of an acceleration tube which at its upper end has an emitting cathode much longer than it is broad or otherwise stated, it is wider than it is thick, at its emissive area, to create a high-voltage electron beam that initially has the form of a sheet that may be of great width or of any suitable width, and may be very thin from back to front, but which may be of any suitable or desired thickness.

In said Fig. 4 the lower end of the acceleration tube is indicated at 18, and the high-voltage electron beam in sheet form is indicated by the downwardly directed arrows 19 which, it is to be understood, are not shown entirely across the acceleration tube, though the high-voltage electron sheet does so extend. I here employ the normal focusing means in the acceleration tube to produce an image of the same type on the top wall of the conduit or tube 20 through which is forced, under high pressure, the stream 21 of liquid, gas, or other character as hereinbefore stated, and which desirably is very thin and which is of the full width of the high-voltage electron sheet. In Fig. 4 the conduit or tube 20 is of the full width of the high-voltage electron sheet 19, and in its upper wall there is provided a very thin window-like area that may be of aluminum or other material that will withstand the pressure of the stream 21 of liquid, gas or other character.

In Fig. 5 the construction is or may be the same as in Fig. 4, the lower end of the accelerator tube

being indicated at 22, and the high-voltage electron stream by the arrows 23, but instead of employing a single conduit or tube for the stream of liquid, gas, or other substance, as in Fig. 4, I provide a series of conduits or tubes 24 placed side-by-side and together equaling the total width of the high-voltage electron sheet 23. The top wall of each conduit or tube 24 has formed thereon a thin window-like area, as in Fig. 4. The series of streams, each under high pressure, are indicated at 25.

It is to be understood that when I employ a series of conduits or tubes for a series of streams of liquid, gas or other substance to be irradiated, I may provide a single wide electron sheet of the full width of all the conduits or tubes, or I may provide a series of high-voltage electron beams or relatively narrow sheets, each of the width of a single conduit or tube, and together equalling the width of all of said conduits or tubes.

In all of the embodiments of the invention, I prefer to have the described stream-carrying tube or tubes, conduit or conduits, pass through the vacuum system connected to the lower end of the acceleration tube, and I have so indicated in Fig. 1, so that the high-voltage electron beam in sheet form impinges upon the tube or tubes, conduit or conduits, without suffering any scattering by passing through interventing air or gas. The wall thickness of each tube or tubes, and particularly the upper horizontal face thereof, is preferably the very minimum necessary to support the pressure of the gas or vapor stream. Because of the narrowness of the high-voltage electron beam in the direction of motion of the liquid, gas, vapor or stream of other character (that is, the thinness of the high-voltage electron sheet from the front face to the back face thereof), the region of the tube wall (or tube walls) that is required to be extremely thin, is also very narrow (that is, in the direction of flow of the stream that is being irradiated), and preferably the "window" through which the high-voltage electron beam in sheet form passes to and impinges upon the stream of liquid, gas, vapor or of other character, is only slightly bigger than the cross-sectional size of the high-voltage electron sheet itself. This small window is supported on both sides (that is, transversely of the direction of flow of the said stream) by suitable members to give the necessary reinforcement, thereby effectually supporting the pressure of the liquid.

In order to counteract the effect of or to prevent the occurrence of any degree of coagulation in a liquid or like stream under the influence of the high-voltage electron beam or beams, I provide means acting mechanically or supersonically to scrape the insides of the tube or tubes or to vibrate the tube or tubes or the contents with supersonics, or I may otherwise periodically or continuously vibrate the tube or tubes. I thus prevent any coagulants from stopping the free flow of the liquid stream.

As one form of means for accomplishing this purpose, I have, in Fig. 6, diagrammatically indicated at 26 the lower end of the focusing means, such as diagrammatically indicated in Fig. 1, and I have at 27, 28, 29 indicated the conduit or tube through which the stream of liquid, gas, vapor or other substance flows under high pressure. The parts are herein merely diagrammatically indicated and the depth of the stream and the thickness of the high-voltage electron sheet are exaggerated. In order to vibrate the conduit, I have herein shown an eccentric 30 upon a shaft 31, to impart at any desired speed a slight up-and-down movement to the said conduit by the eccentric arm 30 which at its upper end has a small roll or other formation upon which the conduit rests. In this construction I have represented a space between the upper face of the conduit and the lower end of the focusing means so that the jarring movement will not be imparted to the focus means. Any suitable means may, however, be provided to retain the vacuum in the high-voltage electron conduit or tube.

The high-voltage electron sheet is not actually increased from its dimension in the acceleration tube. It is possible to have a high ratio between the width and the thickness of the high-voltage electron sheet, but this is done by making the high-voltage electron sheet exremely thin, not by widening the said sheet itself.

Although the initial pressure is very high at the entrance of the orifice of the tube or tubes, conduit or conduits into which the stream of liquid, gas, vapor or other material, such as herein set forth, is introduced to be therein irradiated as described, the pressure at the constriction (shown, for example, in Figs. 1 and 6) may be very low, in accordance with Bernoulli's principle, and therefore the herein described high-voltage electron window itself does not have to withstand a high fluid pressure. The window may, therefore, be made very thin in order to have minimum electron scattering.

In order to obtain quantity flow of the liquid to be sterilized, I provide a wide but thin stream thereof. Under certain circumstances, a stream thickness of one-half or one millimeter may be sufficient.

This invention, as already stated, is applicable not only to liquids, but also to the suspension of solids in liquid mediums, such solids, for example, as finely divided flours, small grains such as wheat, chemicals in powder or grain form, also to streams composed wholly of finely divided solids, and to gases or vapors at high velocities, either alone or as carriers for small solid or liquid particles (that is, to dusts and sprays). When gas rather than liquid is the carrier, the velocity may be exceedingly high, much higher than those obtainable with liquids. The invention is also applicable to chemical processes involving liquids where high, instantaneous density is required, or is desirable, to produce effects of direct ionization without side effects.

In the case of the ionization of gas or vapors, the dimension of thickness thereof in the direction of electron flow may be greater than the indicated thickness of a liquid stream or streams. Therefore, the proportions of the tubes or conduits through which the gas and/or vapor is forced under any suitable pressure, will be varied accordingly.

The following is an approximate calculation illustrating that a high dosage, sufficient to sterilize, can be given by the method herein disclosed and claimed, in a flowing liquid in an exceedingly short time, for example, in 10^{-5} second.

If, for example, a liquid is forced to flow through an opening 1 mm. x 1 mm. square, under a pressure of 150 pounds per square inch, then, assuming that the density of the liquid is equal to that of water, that the liquid is non viscous (no internal friction), and that there is uniform velocity across the cross-section of the stream:

Let

v=velocity of stream in ft./sec.
p=initial pressure in lbs./ft.^{2}
ρ=density in slugs/ft.^{3}

Then:

$$v=\frac{\sqrt{2p}}{\rho}=\sqrt{\frac{2\times150\times144}{62.5/32.2}}=149 \text{ ft./sec.}$$

$$v_{mm.}=30\times10\times149=44{,}700 \text{ mm./sec.}$$

Assuming that the cathode-ray beam is .5 mm. thick in the direction of flow of the liquid stream, and letting t = the dosage time,

$$t=\frac{5.}{44{,}700}=1.12\times10^{-5} \text{ sec.}$$

Now, assume that 1/15 of the total energy of a 2-mv., 250 microampere cathode-ray beam is absorbed by the liquid stream.

Energy absorbed=

$$2\times10^6\times250\times10^{-6}\times\frac{1}{15}=W=33.3 \text{ watts}$$

Letting volume of liquid flow/sec.=V

$$V=\frac{44{,}700\times1\times1}{1000}=44.7 \text{ cc.}$$

If a dose of 1 roentgen requires a dose of

$$8.5\times10^{-6}$$

joule/cc., then the dosage given to the flowing liquid is

$$D=\frac{W}{8.5\times10^{-6}V}=\frac{33.3}{8.5\times10^{-6}V}=87{,}500 \text{ roentgens}$$

The dose thus delivered in about 10^{-5} seconds may be increased to any desired or required level; for example, it may be made two million roentgens, by suitably increasing the current in the electron beam apparatus, giving a beam sufficient to produce two million roentgens in 10^{-5} seconds under the conditions above described, such apparatus being under construction by High Voltage Engineering Corporation, to which this application is assigned.

The present invention also comprehends and includes a process or method of irradiating a liquid or liquids with solids in suspension or a stream composed wholly of very finely divided solids, in which stream, whether it be liquid or partly liquid, or wholly or finely divided solids, it is required to produce a chemical change by a direct ionization process, and wherein it is at the same time desired to keep to a minimum undesirable secondary or side chemical processes or actions produced by indirect action of ionization. Such a process consists, therefore, in irradiating the said stream of liquids, or liquids with solids in suspension or finely divided solids, including chemicals in powder or grain form or a stream composed wholly of finely divided solids, with an electron beam of small cross-sectional area and high-charge density, and causing the material to be irradiated to flow rapidly through such thin electron beam, thereby delivering the required total dosage with maximum instantaneous ionization density.

Having thus described several embodiments of apparatus for practicing my invention and by which the method or process thereof may be carried out, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims.

I claim:

1. Apparatus for sterilizing by irradiation a thin stream of material such as liquids, gases, vapors, liquids having material in suspension, and finely divided solids, comprising in combination, a source of high-voltage electrons having means for discharging the same as an intense, high-energy, electron beam, means for focusing said beam into a sheet, and means for passing such thin stream at high velocity through said beam focused into sheet form.

2. An apparatus in accordance with claim 1, wherein the said intense high-energy electron beam is focused into a sheet of substantially the same width as such thin stream of material to be sterilized.

3. That method of sterilizing liquids of relatively low viscosity comprising the following steps: creating and directing in sheet form a beam of high energy electrons in an enclosed space; directing the liquid stream to be sterilized in a thin liquid stream of substantially the width of the electron sheet; and directing the electron sheet onto, so as to extend transversely across the surface of said liquid, thereby to deliver the required total dosage at a very high, instantaneous ionization density.

4. Apparatus for sterilizing streams of liquids or suspensions of solids in liquid mediums, of gases or vapors of relatively low viscosity or of finely divided solids, comprising in combination, an acceleration tube of a high-voltage electrostatic generator having means to create and direct a beam of high-energy electrons, focusing means to shape said electron beam into a form substantially rectangular in cross section, the longer dimension thereof being substantially equal to the width of the conduit-conducted stream that is to be sterilized and the shorter dimension of said beam from face-to-face thereof being very small in comparison with said longer dimension, a conduit for the flow of the stream to be sterilized having a very thin wall portion through which the focused electron beam may penetrate, and means to force the stream to be sterilized through said conduit at high velocity, the width of said conduit being substantially the same as the said longer cross sectional dimension of the focused electron beam, so that the conduit-conducted stream is subjected to the action of the focused electron beam from edge-to-edge of said conduit-conducted stream, and the dimension of said conduit in the direction of movement of the high-energy focused electron beam being very small, so that the electron beam, being shaped by said focusing means into a rectangle very thin from face-to-face thereof, is projected through said very thin wall portion against said stream in said conduit in the direction of the said very small dimension of said conduit, whereby the required total dosage is delivered at a very high instantaneous ionization density.

5. Apparatus for sterilizing streams in accordance with claim 4, wherein the conduit is horizontally arranged and the focusing means is arranged at a downwardly directed angle thereonto, so that the conduit and the focusing means are at a substantial angle to each other.

6. Apparatus for sterilizing streams in accordance with claim 4, wherein the focusing means is such that it shapes the electron beam into a thin sheet having a width equaling that of the stream in said conduit.

7. Apparatus for sterilizing streams in accord-

ance with claim 4, wherein the focusing means is such that it shapes the electron beam into a thin sheet having a width equaling that of the stream in said conduit, and wherein the thin wall portion extends across the top wall of said conduit in the direct path of the electron sheet and having its dimension in the direction of flow of the stream slightly greater than the thickness of said electron sheet.

8. Apparatus for sterilizing streams in accordance with claim 4, wherein the conduit for the flowing stream to be sterilized is composed of a series of tubes placed side-by-side.

9. Apparatus for sterilizing streams in accordance with claim 4, wherein the focusing means constitutes a system of cylindrical optics.

10. Apparatus for sterilizing streams in accordance with claim 4, wherein the focusing means provides a uniform magnetic field.

11. Apparatus for sterilizing streams in accordance with claim 4, wherein the focusing means bends the electron beam at substantially a right angle in changing its shape into that of a rectangle in cross section.

12. Apparatus for sterilizing streams in accordance with claim 4, wherein the focusing means focuses the electron beam in one plane but not in the other.

13. Apparatus for sterilizing streams in accordance with claim 4, wherein means is provided to act upon the conduit to prevent any coagulants from interfering with the free flow of the stream.

14. Apparatus for sterilizing streams in accordance with claim 4, wherein means is provided to jar periodically the conduit, to prevent coagulants from adhering to the inner surface thereof or otherwise interfering with the free flow of the streams.

15. Apparatus for sterilizing streams in accordance with claim 4, wherein the conduit is rectangular in cross section, being very shallow from top to bottom and having its longer cross dimension equal to that of the shaped electron beam.

16. Apparatus for sterilizing streams comprising in combination, an acceleration tube of a high voltage electrostatic generator having means to create an electron beam of high intensity and to impart thereto a sheet form and to direct such electron beam in sheet form, a conduit for the flow of the stream to be sterilized having a very thin wall portion through which the electron sheet may penetrate, said conduit having a width substantially the same as the width of the electron sheet, and means to direct said electron sheet through said thin wall portion onto the stream, thereby subjecting it to a sterilizing action.

17. Apparatus for sterilizing streams comprising in combination an acceleration tube of a high-voltage electrostatic generator, a cathode having an emission area much longer than it is broad to create a high-voltage electron beam that initially has the form of a sheet, cooperating focusing means for maintaining said electron beam in sheet form, a conduit for conducting under pressure the stream to be sterilized and having a thin wall portion through which the electron sheet may be directed against said stream, and means to direct said electron sheet directly against said thin wall portion.

18. Apparatus for sterilizing by irradiation a very thin stream of material, such as liquids, gases, vapors, liquids having material in suspension, and finely divided solids, comprising a source of high voltage electrons, means for discharging such electrons into such very thin stream, as a continuous beam, pencil or the like, as a dosage to each succeeding portion of the said stream at a very high instantaneous ionization density, a stream enclosing conduit for such very thin stream, having two opposite walls very close together, through which conduit such very thin stream of material passes and through one of which said walls the said beam or pencil constantly penetrates through said very thin stream for effecting such sterilization by irradiation, the said conduit having its walls sufficiently strong to resist the pressure of the said very thin stream at very high velocity, the conduit having a very small area that is of material penetrable by said electron beam or pencil and which is positioned in the path of the said high voltage electron beam or pencil, the said apparatus having means for forcing said very thin stream through said conduit at very high velocity, whereby there is achieved in each succeeding portion of the said very thin stream in such conduit an instantaneous ionization of great density in a single dosage, by the said beam or pencil of high voltage electrons.

19. An apparatus for sterilizing by irradiation in accordance with claim 18, wherein the beam or pencil of high voltage electrons has the form of a sheet that is thin in the direction of the flow of the said very thin stream and has its greater dimension extending transversely of the said very thin stream as said beam or pencil penetrates said conduit and effects instantaneous ionization of great density in a single dosage successively to all portions of said very thin stream.

20. An apparatus for sterilizing by irradiation in accordance with claim 18, wherein the said conduit is itself composed of a plurality of thin narrow tubes each having the structure and character of walls stated in claim 18 and arranged close together side by side to constitute in effect a single conduit with thin partitions parallel with the outer side walls of the complete conduit.

21. An apparatus for sterilizing by irradiation in accordance with claim 18, wherein the beam or pencil of high voltage electrons has the form of a sheet that is thin in the direction of the flow of the very thin stream and has its greater dimension extending transversely of the said very thin stream and is of the full width of the said very thin stream as said beam or pencil penetrates said conduit and effects instantaneous ionization of great density in a single dosage successively to all portions of said very thin stream.

22. An apparatus in accordance with claim 18, wherein the beam or pencil of high voltage electrons is initially formed as a beam of small substantially circular cross section and wherein means is provided to focus said beam or pencil into a thin sheet that extends widthwise transversely of the said very thin stream where such thin sheet penetrates the conduit and said very thin stream as an instantaneous dosage.

23. An apparatus in accordance with claim 18 wherein the beam or pencil is initially formed as a thin sheet and in such form penetrates said conduit and said very thin stream as an instantaneous dosage, and with the longer cross dimension of said thin sheet extending transversely of the said very thin stream, in said conduit.

24. Apparatus for sterilizing by irradiation a thin stream of material such as liquids, gases, vapors, liquids having material in suspension, and finely divided solids, comprising in combination, a source of high-energy electrons having means for discharging the same into such thin stream, as an intense, high-energy electron beam in sheet form, and means for passing such thin stream at high velocity through said beam that is in sheet form, in a direction substantially at right angles to the longer dimension of said beam in sheet form.

25. That method of sterilizing by irradiation comprising the following steps: creating a beam of high-voltage electrons forming and forcing at very high pressure a very thin stream of gases, vapors, liquids, liquids with solids in suspension, or materials consisting wholly of finely divided solids, and discharging such beam of electrons as a dosage at a very high instantaneous ionization density through said very thin stream, whereby each portion of the said stream is sterilized as it passes through the said beam of high-voltage electrons.

26. Means for sterilizing liquids of relatively low viscosity, comprising means to create a beam of high energy electrons and to impart thereto a sheet form, means to direct the liquids to be sterilized as a thin liquid stream at high velocity and of substantially the width of the electron sheet, and means so to direct the said electron sheet onto said thin liquid stream that it extends transversely across the surface of said liquid stream as it penetrates the same, whereby the required total dosage is delivered at a very high, instantaneous ionization density.

27. Apparatus for sterilizing by irradiation material projected at very high velocity, such as liquids, gases, vapors, liquids having material in suspension, and finely divided solids, comprising a source of high voltage electrons, means for discharging such electrons as a continuous beam, and means to project such material at very high velocity into the path of said continuous beam of high voltage electrons, so that such continuous beam of high voltage electrons delivers a dosage to each succeeding portion of such material that is projected at very high velocity into its path, whereby there is achieved in each succeeding portion of the said material projected at very high velocity an instantaneous ionization of great density in a single dosage by said continuous beam of high voltage electrons.

28. Apparatus for irradiating by a continuous beam of high-voltage electrons each of the following materials respectively projected at a very high velocity, namely, liquids, gases, vapors, liquids having material in suspension, and finely divided solids, and to which respective material the dosage is delivered at a very high, instantaneous ionization density, comprising a source of high-voltage electrons, means for discharging such electrons as a continuous, intense, high energy beam, and means to project said materials at a very high velocity, at a very high pressure, directly into the high-voltage electron beam, thereby to deliver a high irradiating dosage to each succeeding portion of such material in an exceedingly short time, whereby there is achieved in each succeeding portion of the said material projected at very high velocity an instantaneous ionization of great density in a single dosage, by said continuous beam of high voltage electrons.

29. That method of producing by the direct action of an intensive, continuous beam of high-voltage electrons an increased or maximum percentage yield of chemical reactions in a material or substance, whether in a solid, liquid, gaseous or vaporous state or in a liquid state having material in suspension, or in finely divided solids, in which material or substance it is desired to produce such increased or maximum percentage yield, which method comprises projecting such material or substance at a very high velocity and subjecting such a material or substance while under projection at a very high velocity, to the direct, maximum action of such continuous beam of high-voltage electrons, so that such continuous beam of high-voltage electrons delivers a dosage to succeeding portions of such a material or substance, while the same is under projection at very high velocity, whereby there is achieved in each succeeding portion of such material or substance projected at very high velocity an instantaneous ionization of great density in a single passage through such beam of the material or substance, by said continuous beam of high-voltage electrons, with a minimum of chemical effect due to low energy ionized particles.

30. That method of producing by the direct action of an intensive, continuous beam of high-voltage electrons an increased or maximum percentage yield of chemical reactions in a material or substance, whether in a solid, liquid, gaseous or vaporous state or in a liquid state having material in suspension, or in finely divided solids, in which material or substance it is desired to produce such increased or maximum percentage yield, which method comprises projecting such material or substance at a very high velocity and subjecting such a material or substance while under projection at a very high velocity to the direct maximum action of said continuous beam of high-voltage electrons, so that such continuous beam of high voltage electrons effects in a single passage through such beam of such material or substance an instantaneous ionization of great density.

31. That method of producing by the direct action of an intensive, continuous beam of high-voltage electrons an increased or maximum percentage yield of chemical reactions in a material or substance, whether in a solid, liquid, gaseous or vaporous state or in a liquid state having material in suspension, or in finely divided solids, in which material or substance it is desired to produce such increased or maximum percentage yield, which method comprises projecting such material or substance at a very high velocity and subjecting such a material or substance while under projection at a very high velocity, and as a stream that is very thin in the direction of penetrating travel of such continuous beam, to the direct, maximum action of such continuous beam of high-voltage electrons, so that such continuous beam of high-voltage electrons delivers a dosage to succeeding portions of such a material or substance, while the same is under projection at very high velocity in such a thin stream, whereby there is achieved in each succeeding portion of such material or substance projected at very high velocity in such a thin stream an instantaneous ionization of great density in a single passage through such beam of the material or substance, by said continuous beam of high-voltage electrons, with a minimum of chemical effect due to low energy ionized particles.

32. That method of effecting the generation of and the acceleration and the irradiation by an

accurately focused beam of charged particles, either electrons or ions, of materials or substances while under projection at a very high velocity and as a very thin stream, through the performing of a series of steps involving the creating and injecting of a high velocity beam of charged particles directly and immediately into a substantially uniform, steady and continuous electrostatic field for the purpose of securing the delivery of such high voltage beam of particles as a high voltage beam of charged, swift, accelerated particles throughout the length of such substantially uniform electrostatic field to the point where such high voltage beam penetrates and effects irradiation of such materials or substances while the same are under projection at a very high velocity and as a very thin stream, comprising the following steps: First, removing the gas from within an electronic envelope to such an extent as to create and maintain an extremely high vacuum therein; then creating and maintaining within said vacuum in such electronic envelope throughout the transverse area and lengthwise extent and parallel with the wall thereof, a substantially uniform electrostatic field that is undisturbed and undistorted along the axis of such envelope and for the passage along such axis of such high voltage beam of charged, accelerated particles; and next, creating and injecting directly and immediately into said substantially uniform electrostatic field such high voltage beam of charged particles toward, and then injecting such beam into, and effecting the irradiation of, such materials or substances while the same are under projection at a very high velocity, so that such voltage beam of charged particles delivers a dosage to succeeding portions of such thin stream of such materials or substances, while the same is under projection at very high velocity as such a thin stream, whereby there is achieved in each succeeding portion of such thin stream of materials or substances projected at very high velocity as such thin stream, an instantaneous ionization of great density in a single passage through such beam of the materials or substances, by said beam of high voltage electrons, with a minimum of chemical effect due to low energy ionized particles.

33. That method of effecting the generation of and the acceleration and the irradiation by an accurately focused beam of charged particles, either electrons or ions, of materials or substances while under projection at a very high velocity and as a very thin stream, through the performing of a series of steps involving the creating and injecting of a high voltage beam of charged particles directly and immediately into a substantially uniform, steady and continuous electrostatic field for the purpose of securing the delivery of such high voltage beam of particles as a high voltage beam of charged, swift, accelerated particles throughout the length of such substantially uniform electrostatic field to the point where such high voltage beam penetrates and effects irradiation of such materials or substances while the same are under projection at a very high velocity and as a very thin stream, comprising the following steps: first, removing the gas from within an electronic envelope to such an extent as to create and maintain an extremely high vacuum therein; then creating and maintaining within said vacuum in such electronic envelope throughout the transverse area and lengthwise extent and parallel with the wall thereof, a substantially uniform electrostatic field that is undisturbed and undistorted along the axis of such envelope and for the passage along such axis of such high voltage beam of charged accelerated particles; and next, creating and injecting directly and immediately into said substantially uniform electrostatic field such high voltage beam of charged particles, but having the shape of a thin sheet extending in its longer cross dimension, transversely of said very thin stream of materials or substances and thus penetrating into and effecting the irradiation of, such materials or substances while the same are under projection and at a very high velocity, so that such high voltage beam of charged particles delivers a dosage to succeeding portions of such thin stream of such materials or substances, while the same is under projection at very high velocity as such a thin stream, whereby there is achieved in each succeeding portion of such thin stream of materials or substances projected at very high velocity as such thin stream, an instantaneous ionization of great density in a single passage through such beam of the materials or substances, by said beam of high-voltage electrons, with a minimum of chemical effect due to low energy ionized particles.

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