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ELECTRIC DISCHARGE APPARATUS

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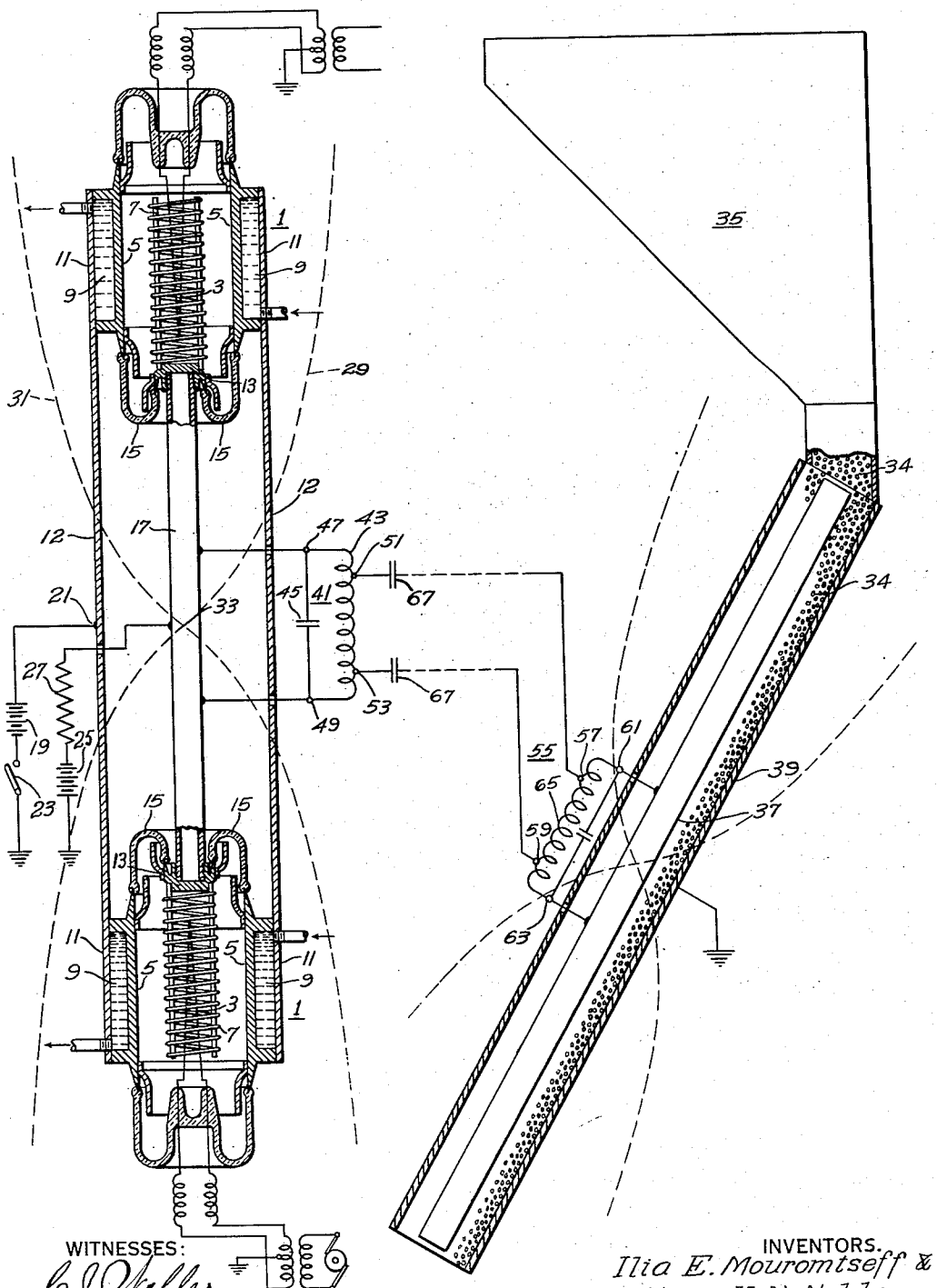

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ELECTRIC DISCHARGE APPARATUS

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Our invention relates to electric discharge apparatus and it has particular relation to apparatus utilized in the treatment of impurity-infested products, such as insect-infested grain, to destroy the impurities.

It is an object of our invention to provide apparatus for efficiently destroying the impurities in an impurity-infested product.

Another object of our invention is to provide apparatus for cheaply and efficiently destroying the impurities in an impurity-infested product of the type which, when pure, is substantially a non-conductor, the impurities being substantially conductive.

A further object of our invention is to provide apparatus for destroying the impurities of the type having high frequency dielectric losses in an impurity-infested product of the type which, when pure, has low high frequency dielectric losses.

A more specific object of our invention is to provide apparatus for treating insect-infested grain to destroy the insects in the grain.

More concisely stated, it is an object of our invention to provide apparatus for bringing an impurity-infested product in such intimate relationship with a high frequency electrical field that the impurities in the product are substantially destroyed.

According to our invention, we provide a plurality of co-axial tubes between which the product to be treated is projected. The tubes are substantially of equal length and a high frequency electrical potential is impressed on one or both of the tubes. The length of the tubes is equal to

$$\frac{n}{2}\times\lambda,$$

where n is an integer and λ is the wave length corresponding to the frequency impressed on the tube. Consequently, when the potential is impressed on one of the tubes, a standing potential wave and a corresponding current wave are set up along the tube and correspondingly potential and current waves are induced in the other tube. The potential of both tubes is thus periodically varied and, the medium between the tubes is correspondingly stressed.

The impurities that infest the products of the type treated by apparatus constructed in accordance with our invention, in general, either have high dielectric losses when subjected to a high frequency electrical field, or are substantially conductive. In either case, the effect of the field is to so heat the impurities as to effectively destroy them. The product on the other hand, if in a substantially pure condition, has only comparatively low dielectric losses when subjected to a high frequency electrical field. The high frequency field impressed on the impurity-infested product, therefore, has substantially no deleterious effect on the pure product.

With reference specifically to the example which has been mentioned hereinabove, the insects which generally infest grain are moist, and in consequence thereof, have considerable electrical conductivity, or manifest high dielectric losses, or both when subjected to a high-frequency alternating electrical field. The pure grain itself, on the other hand, is substantially non-conductive when dry and its losses when it is subjected to a high frequency field are comparatively low. Consequently, if insect-infested grain is projected between the tubes and thus subjected to the high frequency field the insects are destroyed.

From the above consideration, it should be apparent that the electrical field required for producing the desired results should have considerable magnitude. For this reason, we provide an electrical oscillation generator that is capable of delivering the necessary power. The generator comprises a plurality of electric discharge devices, each device being equipped with a cathode that is capable of delivering considerable current, a cylindrical anode enclosing the cathode and a cylindrical grid or control electrode interposed between the cathode and the anode. Since the electric discharge devices are constructed to deliver considerable power, their electrodes are rather large and in consequence thereof, the interelectrode capacity is considerable. As a result, it is substantially impossible to attain the ultra high frequency that is necessary for the destruction of the impurities by utilizing a simple tuned circuit.

In the practice of our invention, the tuned circuit is replaced by a plurality of co-axial tubes, the inner tube extending between the grids and the outer tube extending between the anodes of the electric discharge devices.

For the purpose of simplifying the explanation of the operation of the system it may be assumed that it comprises a single electric discharge device with coaxial tubes extending from its control electrode and from its anode. The function of the other electric discharge device is merely to increase the power output of the system. When a high potential is impressed between the anode and the cathode of one of the electric discharge devices, an electrical impulse is generated

which travels along the anode tube as it would travel along a transmission line and is reflected from the terminal of this tube. It is apparent that the time required for the impulse to travel from one end of the tube to the other is a function of the length of the tube. On the other hand, as the impulse travels along the tube a corresponding impulse of opposite polarity to the generated impulse is induced in the tube extending from the control electrodes.

The anode and the control electrode tubes are substantially of equal length and the impulse which originated at the anode returns to the anode after an interval of time predetermined by the length of the anode tube while at the same time a corresponding wave of opposite polarity reaches the control electrode. The potentials that are now impressed between the cathode and the anode and control electrode are such that another impulse is transmitted which is in turn also reflected and produces the condition necessary for further impulses.

By reason of the successive transmission of impulses standing potential waves and corresponding current waves are set up along the tubes. The potential waves have nodes at the electrical center of the tubes and anti-nodes at the terminals of the tubes. The nodes of the current waves are at the terminals of the tubes while the loops are in the region of the electrical center of the tubes. The voltage waves impressed on the tube projecting from the control electrode is in opposite phase to the voltage waves impressed in the tube projecting from the anode and it is to be noted that just as in the ordinary oscillator when the control electrode potential swings positive the anode potential swings negative and when the anode potential swings positive the control electrode potential swings negative.

Since the maximum amplitudes of the potentials impressed by the standing waves at points along the tubes vary in magnitude and polarity in accordance with the displacements of the points from the anti-nodes, at the center of the tubes, a difference in potential will be impressed between two terminals connected to two displaced points on one of the metal tubes and this difference of potential will have a maximum magnitude for a predetermined spacing if the terminals are on either side of the center. A similar result will also be attained if the terminals are connected respectively to proper points on the two tubes, the preferred arrangement being in this case one in which one terminal is connected to one tube at a predetermined point displaced from the anti-node and the other terminal is connected to the other tube at the same corresponding point along this tube. In the preferred practice of our invention the terminals of an impedance are connected one on each side of the center of one of the tubes and a difference of potential is thus set up between the terminals of the impedance. The impedance is equipped with output terminals and a plurality of conductors are connected to the output terminals and to the input terminals of a similar impedance cooperating with the tubes between which the product to be purified is projected. The output terminals of the latter impedance are connected at two points symmetrically spaced about the electrical center of one of the latter tubes and an electrical field is thus impressed on these tubes. To provide for the proper maintenance of the magnitude of the field impressed on the tubes each of the above impedances is tuned to the frequency of the output of the oscillator generator. Since the tubes through which the product is projected have a length of

$$\frac{n\lambda}{2},$$

standing waves corresponding to the waves impressed on the tubes associated with the electric discharge devices are set up along them when the electromotive force is impressed thereon and the medium through which the product is projected is stressed.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which the single figure is a view, partly in section and partly diagrammatic, showing an embodiment of our invention.

The apparatus shown in the drawing comprises a plurality of electric discharge devices 1, each of the devices being equipped with a hot cathode 3 that is suitably energized, a cylindrical anode 5 enclosing the cathode 3 and a cylindrical control electrode 7 interposed between the anode 5 and the cathode 3. The anode 5 of each electric discharge device is provided with a cylindrical water jacket 9 and a conducting cylinder 12 extends from the outer wall 11 of one water jacket 9 to the outer wall of the other and is integral with the walls. The control electrode 7 of each electric discharge device 1 is mounted on a plug 13 which is suitably sealed in its glass walls 15, and a cylindrical bar 17 is screwed into the plugs 13 and thus extends between the two electric discharge devices. When the above described system is utilized as an oscillator, the effective lengths of the cylindrical tubes are the lengths of the tubes 12 and 17 extending between the electrodes 5 and 7 plus the lengths of the electrodes. It will be noted that the cylindrical tubes are substantially of equal effective lengths.

One terminal of a power source 19 of large magnitude is connected to the electrical center 21 of the cylinder 12 that extends between the anodes 5, and when a switch 23 connected to the cathodes 3 through ground connections is closed, a high electromotive force is impressed between the anodes 5 and the cathodes 3, and a potential impulse is transmitted from each anode to the end of the tube which extends from it. The cylindrical bar 17 that extends between the control electrodes 7 is connected to the cathodes 3 through a suitable biasing battery 25 and through a suitable impedance 27, and as the impulse travels along the outer cylinder 12, a corresponding impulse is generated in the cylinder extending between the control electrodes 7 of each electric discharge device 1.

As has been explained hereinabove, the time required for the impulse to travel away from the anode and to be reflected back to the anode determines the frequency of a standing potential wave which is impressed on the cylinders. The potential waves impressed on the two tubes are represented in the drawing, respectively, by two broken line curves 29 and 31 that intersect at the common electrical center 33 of the tubes. The anti-node of the current waves is at the center point 33. The length of the wave, as is apparent from the above explanation and from

the drawing, is equal to twice the length of either tube and it is seen that by proper construction, an electrical disturbance having a wave length of the order of a few meters may be produced. We have constructed several systems that produce a high frequency disturbance having a wave length of less than five meters.

Our invention has been applied with considerable success to the treatment of insect-infested grain. In this application of our invention, the grain 34, deposited in a funnel shaped container 35 open at the lower end, is projected by air pressure or by other means in the region between a plurality of coaxial tubes 37 and 39.

A tuned circuit 41 comprising an inductor 43 and a capacitor 45 in parallel therewith and so related thereto that the frequency of the circuit is substantially equal to the frequency generated by the oscillation generator, is connected to the cylindrical rod 17 that is secured to the control electrodes 7 of the electric discharge device. One terminal 47 of the circuit 41 is connected above the electrical center 33 of the rod 17, while the other terminal 49 is connected an equal distance below the electrical center of the rod. When an electrical potential is generated along the rod 17 a difference of potential is established between the two terminals 47 and 49 connected to the rod and a corresponding difference of potential is established across the inductor 43. The inductor 43 is equipped with output terminals 51 and 53 that are disposed between its ends 47 and 49 and its electrical center.

A corresponding tuned circuit 55 is correspondingly connected to the inner cylinder 37 of the system through which the grain 34 is projected, and the output terminals 51 and 53 of the inductor 43 associated with the oscillation generator, are connected respectively to a plurality of input terminals 57 and 59 which are provided intermediate the electrical center and the ends 61 and 63 of the inductor 65 associated with the tuned circuit 55. The output terminals 51 and 53 of the former inductor 43 are not directly coupled to the input terminals 57 and 59 of the latter conductor but they are coupled to each other through a plurality of capacitors 67 that prevent the direct current high potential which is applied to the anodes 5 of the oscillation generator from becoming impressed on the tubes 37 and 39 between which the grain 34 is projected.

When the frequency produced in the oscillation generator is impressed across the inductor 43 associated with the generator, a corresponding frequency is impressed across the inductor 65 associated with the system through which the grain 34 is projected. The length of the tubes 37 and 39 between which the grain 34 is projected is an integral multiple of the length of the tubes of the oscillator, and when the high frequency disturbance is impressed on the inner tube 37 of the system through which the grain is projected, a standing wave is set up on this tube, and a corresponding wave is induced on the outer tube 39. The medium between the tubes 37 and 39 is correspondingly stressed and the grain is, therefore, subjected to the high frequency influence of the electrical field.

It is to be noted that we have described hereinabove one specific system whereby our invention may be practiced. The system may be modified in a number of respects. For example, instead of being symmetrically disposed about the electrical center 33 of the oscillation generator, the terminals 47 and 49 of the tuned circuit 41 associated with the generator may be connected at points in the two cylinders 12 and 17 that are at substantially equal distances above or below the center 33. That is to say, one terminal may be connected to the cylinder 17 to which the control electrodes 7 are connected at a predetermined point above the center 33, while the other terminal may be connected to the cylinder 12 to which the anodes 5 are connected at an equal distance above the center. In such a case, a potential is impressed across the inductor 43, since the potential wave set up along the inner cylinder 17 of the oscillation generator is in opposite phase to the potential wave set up along the outer cylinder 12 of the oscillation generator.

The tubes 37 and 39 between which the grain 34 is projected may be correspondingly connected, that is to say, instead of being connected at equally spaced points above and below the electrical center of the inner cylinder 37, the terminals 61 and 63 of the tuned circuit 55 may be connected to two points, one on the inner cylinder 37 and one on the outer cylinder 39, that are spaced a predetermined distance above the center or below the center.

Moreover it is to be noted that other types of excitable cathodes than hot cathodes might be utilized for the electric discharge devices of the oscillation generator. For example the cathodes might be of the mercury pool type. Again it is well to keep in mind that while the cylindrical capacitor of the type described hereinabove is utilized in the preferred practice of our invention, capacitors of other structures may be utilized. Thus it may be found desirable to utilize a plane plate condenser or a spherical condenser and to dispose or project the substance to be purified between the plates. In certain applications of our invention the capacity may also be replaced by an induction coil in which the material may be disposed.

Finally there are situations in which it may not be possible to project the material into the electromagnetic field. Such a contingency might arise, for example, if a tree were treated in accordance with our invention. In such a case, the capacitor or conductor may be built up around the material.

Although we have shown and described certain specific embodiments of our invention, we are fully aware that many modifications thereof are possible. Our invention, therefore, is not to be restricted, except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. Apparatus for treating an impurity-infested product of the type that has, when non-infested, low dielectric losses when it is subjected to a high-frequency electrical field for impurities of the type that have high dielectric losses when they are subjected to a high-frequency electrical field; comprising a hollow cylinder, another cylinder of cross-sectional area smaller than the cross sectional area of the first-named cylinder, disposed within said first-named cylinder, means for projecting said product in the region between said cylinders and means for impressing a high frequency electrical field on said region, the wave length corresponding to the frequency of said field being substantially

$$\frac{2}{n}l$$

where n is an integer and l is the length of at least one of said cylinders.

2. Apparatus for treating an impurity-infested product of the type that has when non-infested, low dielectric losses when it is subjected to a high-frequency electrical field for impurities of the type that have high dielectric losses when they are subjected to a high frequency electrical field: comprising a hollow cylinder, another cylinder of cross-sectional area smaller than the cross sectional area of the first-named cylinder, disposed within said first-named cylinder, said cylinders being substantially equal in length, means for projecting said product in the region between said cylinders and means for impressing a high frequency electrical field on said region, the wave length corresponding to the frequency of said field being substantially

$$\frac{2}{n}l$$

where n is an integer and l is the length of said cylinders.

3. In combination, an electrical oscillator comprising a plurality of cylinders, one cylinder extending longitudinally within the other, said cylinders being of substantially equal length, and means for generating electrical impulses along said cylinders disposed at one terminal thereof, a plurality of additional cylinders, one of said last-named cylinders extending longitudinally within the the other and the length of at least one of said last-named cylinders being substantially nl, where l is the length of said first-named cylinders and n is an integer, and means for impressing the oscillations generated by said oscillator on said last-named cylinders.

4. In combination, an electrical oscillator comprising a plurality of cylinders, one cylinder extending longitudinally within the other, said cylinders being of substantially equal length, and means for generating electrical impulses along said cylinders disposed at one terminal thereof, a plurality of additional cylinders, one of said last-named cylinders extending longitudinally within the other and the length of both of said last-named cylinders being substantially nl, where l is the length of said first-named cylinders and n is an integer, and means for impressing the oscillations generated by said oscillator on said last-named cylinders.

5. In combination, an electric discharge device comprising a control electrode and a plurality of principal electrodes, a cylinder connected to one of said principal electrodes, another cylinder connected to said control electrode, said last-named cylinder extending longitudinally within said first-named cylinder, and said cylinders being of equal length, means for applying a potential between said principal electrodes to generate a series of impulses along said cylinders, a plurality of additional cylinders, one of said last-named cylinders being disposed within the other and both of said cylinders having a length given by the quantity nl, where n is an integer and l is the length of the first-named cylinders, and means for impressing the impulses generated along said first-named cylinders on said last-named cylinders.

6. In combination, a plurality of electric discharge devices, each of said devices having a control electrode and a plurality of principal electrodes, a hollow cylinder, the ends of said cylinder being connected respectively to the principal electrodes of said electric discharge devices, a second cylinder of length substantially equal to said first-named cylinder, the ends of said cylinder being connected, respectively, to the control electrodes of said electric discharge devices, means for impressing potentials between the principal electrodes of said devices to generate electrical impulses along said cylinders, a plurality of additional cylinders of substantially equal length, one of said cylinders extending longitudinally within the other and the length of said cylinders being given by the expression nl, where n is an integer and l is the length of said first-named cylinders, and means for impressing the impulses generated along said first-named cylinders on said last-named cylinders.

7. In combination, an electric discharge device of the type having an excitable cathode, a cylindrical principal electrode surrounding said cathode to cooperate therewith, and a cylindrical control electrode interposed between said cathode and said cylindrical principal electrode, a cylinder secured to said cylindrical principal electrode and extending therefrom, a second cylinder secured to said cylindrical control electrode and extending therefrom, means for impressing a potential on said cylinder extending from said principal electrode to generate an electrical impulse along said cylinder and to induce a corresponding electrical impulse in the cylinder extending from said control electrode, a plurality of additional cylinders, one of said cylinders being disposed within the other and both of said cylinders having a length given by the expression nl, where l is the length of said first-named cylinder plus the length of said cylindrical principal electrode to which it is secured, and n is an integer, and means for impressing the electrical impulses generated along said first-named cylinders on said additional cylinders.

8. In combination, a plurality of electric discharge devices, each of said devices being equipped with an excitable cathode, a cylindrical anode to cooperate with said cathode and a cylindrical control electrode interposed between said cathode and said anode, a cylinder, the ends of said cylinder being secured to an anode of each of said electric discharge devices, another cylinder, the ends of said last-named cylinder being secured to the control electrodes of each of said devices, means for impressing a potential on said first-named cylinder to generate an electrical impulse along both of said cylinders, a plurality of additional cylinders, one of said last-named additional cylinders being disposed within the other, and said cylinders having a length given by the expression nl, where l is the length of the tube formed by said first-named cylinders and the anodes of said electric discharge devices, and n is an integer, and means for impressing the electrical impulses generated along said first-named cylinders on said last-named cylinders.

9. Apparatus for treating material infested with impurities of the type which have high dielectric losses when subjected to a high frequency field comprising means for generating high frequency electrical oscillations of wave length λ, a plurality of longitudinal bodies, at least one of which has a length l given by the expression

$$\lambda=\frac{2}{n}l$$

where n is an integer, said bodies being adapted to have the material disposed between them for treatment, and means for impressing said electrical oscillations on said bodies.

10. Apparatus according to claim 9 characterized by the fact that both bodies have the same length l.

11. Apparatus according to claim 9 characterized by the fact that both bodies have the same length l and are insulated from each other.

12. Apparatus according to claim 9 characterized by the fact that the electrical oscillations are impressed on the bodies by a plurality of conductors symmetrically disposed about an imaginary plane passing transversely through the body having the length l and dividing its length into two equal halves.

13. Apparatus according to claim 9 characterized by the fact that the electrical oscillations are impressed on the bodies through a tuned circuit tuned to the frequency of said oscillations.

14. Apparatus according to claim 9 characterized by the fact that the electrical oscillations are impressed on the bodies through a parallel tuned circuit tuned to the frequency of said oscillations.

15. Apparatus for treating material infested with impurities of the type which have high dielectric losses when subjected to a high frequency field comprising a pair of treating bodies having a space therebetween adapted to receive said material for treatment, an electrical oscillation generator comprising an electron emissive cathode, an anode, and a grid electrode interposed between said cathode and said anode, a linear conductor projecting from said grid electrode, a linear conductor substantially parallel thereto extending from said anode, and electrical connections from two points spaced apart on said linear conductors to two points spaced apart on said treating bodies, said electrical connections including at least one tuned circuit, tuned to frequency of the oscillations of said oscillation generator.

16. Apparatus for treating material infested with impurities of the type which have high dielectric losses when subjected to a high frequency field comprising a pair of treating bodies having a space therebetween adapted to receive said material for treatment, an electrical oscillation generator comprising a plurality of principal electrodes and a control electrode, a linear conductor projecting from said control electrode, a linear conductor substantially parallel thereto extending from one of said principal electrodes, and electrical connections from two points spaced apart on said linear conductors to two points spaced apart on said treating bodies, said electrical connections including at least one tuned circuit, tuned to frequency of the oscillations of said oscillation generator.

17. Apparatus for treating material infested with impurities of the type which have high dielectric losses when subjected to a high frequency field comprising a pair of treating bodies having a space therebetween adapted to receive said material for treatment, an electrical oscillation generator comprising a plurality of principal electrodes and a control electrode, a linear conductor projecting from said control electrode, a linear conductor substantially parallel thereto extending from one of said principal electrodes, and electrical connections from two points spaced apart on said linear conductors to two points spaced apart on said treating bodies, said electrical connections including a tuned circuit, tuned to frequency of the oscillations of said oscillation generator and connected by short conductors to said points on said one linear conductor and another tuned circuit, tuned to the frequency of the oscillations of said oscillation generator and connected by short conductors to said bodies.

18. Apparatus according to claim 17 characterized by the fact that the tuned circuits are parallel tuned circuits.

19. Apparatus for treating material infested with impurities of the type which have high dielectric losses when subjected to a high frequency field comprising means for generating high frequency electrical oscillations of wave length λ, a plurality of longitudinal bodies, at least one of which has a length l given by the expression

$$\lambda=\frac{2}{n}l$$

where n is an integer, said bodies being adapted to have the material disposed between them for treatment, and means for impressing said electrical oscillations on said bodies, the last said means being tuned to the frequency of said oscillations.

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