June 26, 1962 H. J. CAMERON 3,041,435

DIELECTRIC DRYING OF MATERIALS

Filed Oct. 13, 1958 5 Sheets-Sheet 1

Fig. 1.

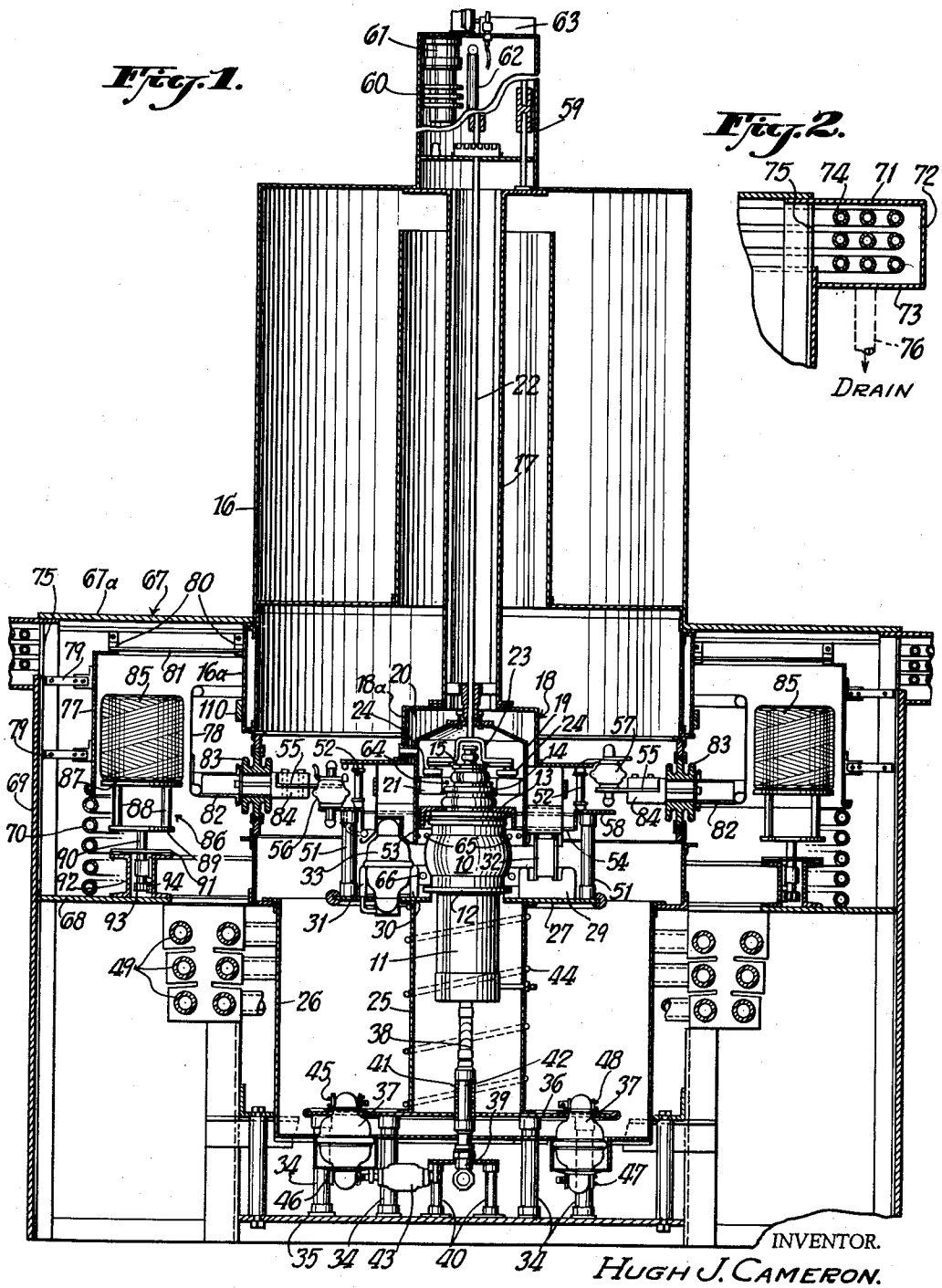


Fig. 2.

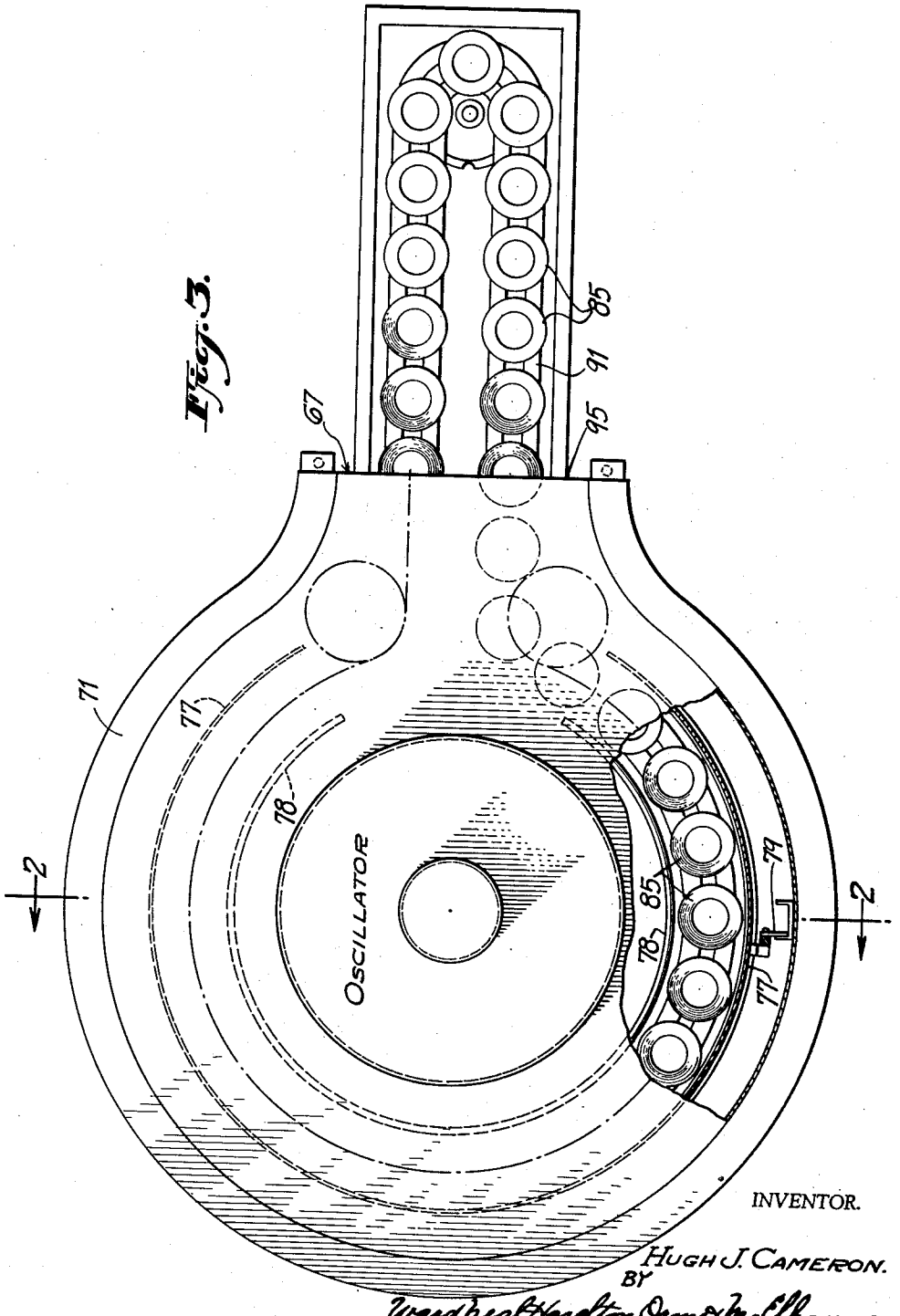
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DIELECTRIC DRYING OF MATERIALS

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Fig. 3.



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DIELECTRIC DRYING OF MATERIALS

Filed Oct. 13, 1958 5 Sheets-Sheet 3

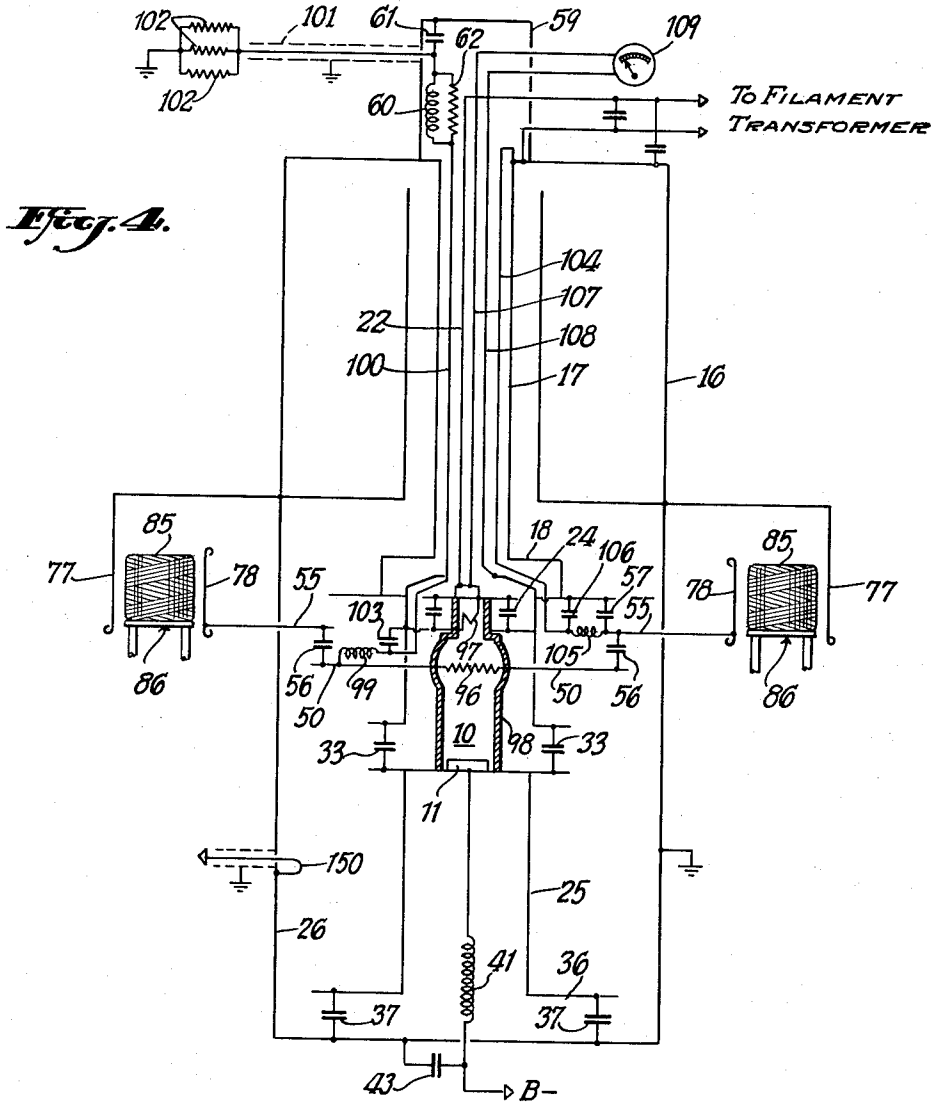


Fig. 4.

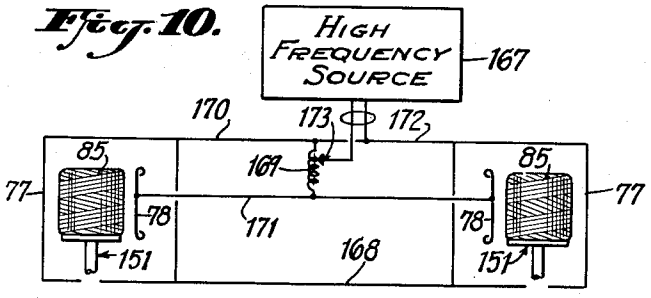


Fig. 10.

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DIELECTRIC DRYING OF MATERIALS

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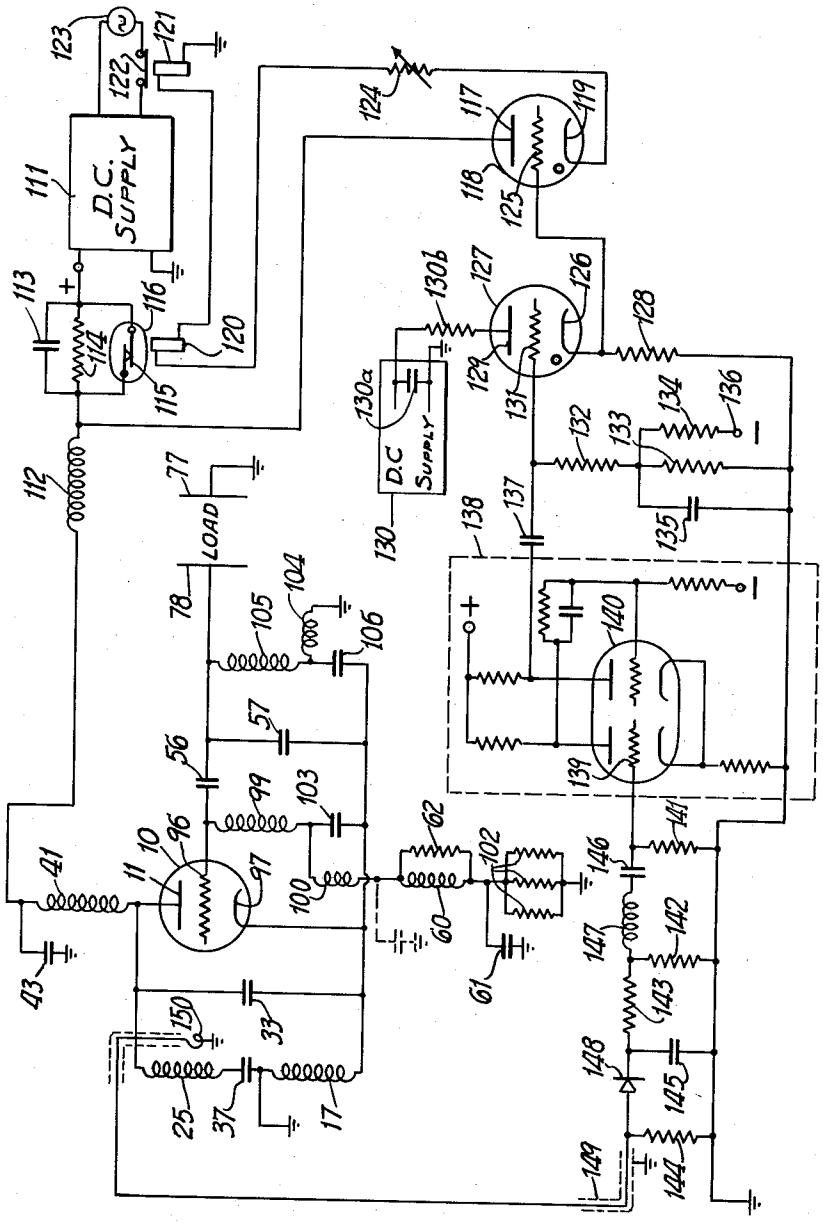


Fig. 5.

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DIELECTRIC DRYING OF MATERIALS

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Fig. 6.

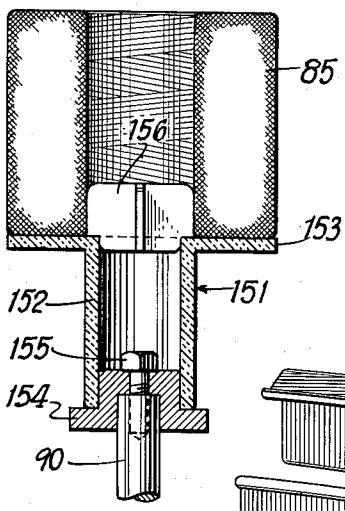


Fig. 7.

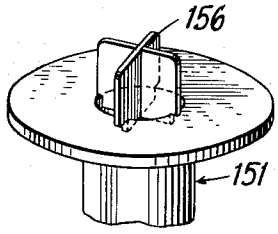


Fig. 9.

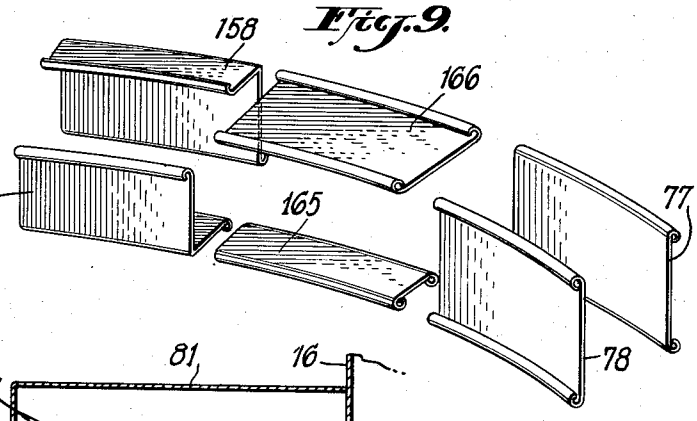
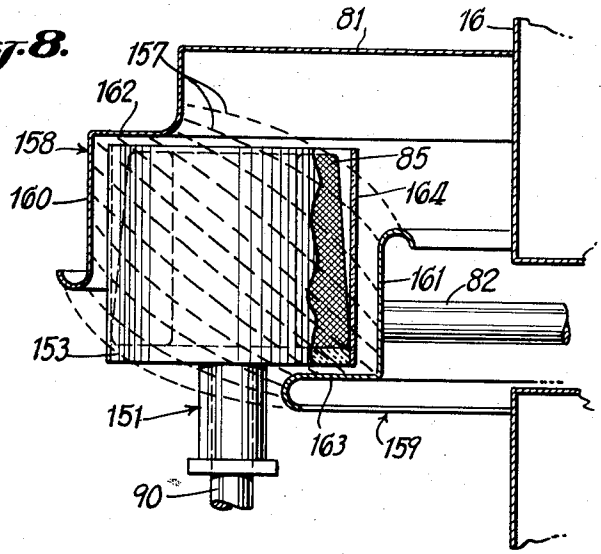


Fig. 8.



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United States Patent Office

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3,041,435
DIELECTRIC DRYING OF MATERIALS

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Filed Oct. 13, 1958, Ser. No. 766,959
16 Claims. (Cl. 219—10.69)

This invention relates to radio frequency heating apparatus and particularly to apparatus for separating volatile liquids from other material by dielectrically heating the material to cause evaporation of the liquid therefrom. The invention is particularly adapted for the removal of water from porous or absorbent solids.

The invention will be herein described in a form particularly adapted for the drying of so-called "cakes" of rayon yarn, but it will be understood that the invention in various of its aspects is well adapted for the heating of various materials and for the drying of other materials, such as textiles, wood, sponge rubber and the like, paper and pulp materials and the baking of articles such as foundry cores.

The drying of materials by dielectric heating involves the reducing of the water content of the material by the internal generation of heat therein, produced by subjecting such material to an electrical field maintained between a pair of spaced electrodes and having a frequency of at least one megacycle per second. In order that such high frequency field may be sufficiently effective for the purpose, it is in practice necessary to apply to the electrodes a potential high enough, e.g. several thousand volts, such as to be liable to generate arcs and cause dielectric breakdown of the air space about the electrodes. The presence of water in the form of mist or as droplets on any conducting surface in the vicinity, greatly increases the liability of arc formations and destructive electrical discharges.

In conventional dielectric heating apparatus, it is frequently desirable that the material to be heated be moved lengthwise of and between a pair of relatively long electrodes which are connected to a high frequency, electrical energy source. The electrodes act as capacitor plates and transfer energy to the material in proportion to the voltage between the plates, the frequency of the energy, the properties of the material, the physical relationship between the plates and the material, the configuration of the plates, etc.

At the relatively high frequencies employed for dielectric heating of materials, the wave length is such that the conductors normally employed, and particularly the electrodes and the lines which connect the electrodes to the source, have a length which is an appreciable fraction of a wave length, and hence, the voltage may vary from point-to-point along the conductors unless care is taken to maintain correct impedance matching. Furthermore, a slight change in impedance at any point along the conductors may produce a relatively large change in electrical potential at other points because the conductors act as transformers at such frequencies. Accordingly, with prior art dielectric heating equipment, it has been difficult to obtain uniform drying of the material due to the fact that the dielectric properties of the material

vary from piece-to-piece or cake-to-cake and with drying thereof and that the loading, and hence heating energy voltage, varies with the number of pieces or cakes within the heating field. In an attempt to overcome these difficulties impedance matching devices, such as tuning stubs, have been employed at various places in the prior art apparatus, and it has been necessary for a skilled operating engineer to supervise or perform the initial setting-up of the apparatus at the beginning of each run. In addition, it has been necessary to make several adjustments of the apparatus from time-to-time to minimize drying variations. Even with such devices and with care on the part of operating personnel, it has been difficult to obtain uniform drying of materials such as, rayon cakes.

I have discovered that if the electrodes between which the material to be dried is passed are arranged so that they extend physically around a substantially centrally located inductor having an impedance substantially equal to the impedance of the electrodes at the heating energy frequency and if the electrodes are connected to such impedance by a plurality of conductors whose lengths are within a small fraction of a wave length of each other, the operation of the heating apparatus is simplified and substantially uniform drying of the material is obtained. Preferably, the centrally located impedance is the source oscillator itself, and the major portions of the conductors which connect the electrodes to the oscillator are substantially parallel, spaced discs extending outwardly from the oscillator. It has been found that with this arrangement the voltage between all portions of the electrodes is substantially the same regardless of the properties of the cakes to be dried and the number of cakes between the electrodes at any given time. Furthermore, small variations in the properties of the cakes of the type normally encountered with rayon cakes produce negligible variations in the loading of the energy source and hence, negligible variations in the voltage between the electrodes. When the oscillator itself is the centrally located impedance, greater variations in the properties of the cakes can be tolerated because such variations produce compensating changes in the oscillator frequency.

In the preferred embodiment of the invention, the material to be dried is rotated as it is passed between the electrodes to obtain uniform drying. With electrodes which are substantially parallel to each other and to the axis of rotation of the material, the uniformity of drying is improved over that obtained with prior art drying apparatus. However, better results can be obtained by successively passing the material between electrodes which are differently disposed with respect to the material and/or which are of different configurations. For example, the material may be passed first, between electrodes which are parallel to each other and the axis of rotation, then, between electrodes which are parallel to each other but perpendicular to the axis of rotation and then between electrodes which are L-shaped in cross-section as described hereinafter. Of course, if desired, a greater or smaller number of these electrodes may be employed, and they may be employed in alternate series.

In order to avoid undesirable effects, materials, such as rayon, should not be exposed to temperatures above the boiling point of water for more than a few minutes.

In order to dry conventional rayon cakes in a short time, the energy input to a cake should be relatively large and may, for example, be twenty kilowatts or more. For mechanical reasons, e.g. variations in cake sizes, conveyor tolerances, etc., the practical minimum spacing between the electrodes and the cakes is about one-half inch. To produce such high energy inputs with conventional rayon cakes, which are from five to ten inches in diameter and in height, requires a voltage between the electrodes of about eight to ten thousand volts. Higher voltages are not practical because of the frequency at which arcs are produced in the equipment and hence, because of the number of production interruptions. In addition, in order to produce uniform heating of the cakes, the electric field should be substantially uniformly distributed within the cakes. I have found that with electrodes of L-shaped cross-section, the legs of the L being perpendicular and parallel respectively to the axis of a cake, a twofold increase in heat generation for a predetermined voltage or a twenty-five percent reduction in electrical stress for a predetermined rate of heat generation, as compared with plane electrodes, can be obtained.

The voltage between the electrodes and a rayon cake therebetween may be of the order of four thousand volts. Damaging arcs may form between the electrodes and the cakes and between the electrodes and other parts of the equipment, particularly when moisture condenses on such other parts. For these reasons, the cakes may be surrounded by a cylindrical shield of dielectric material and sensible heat is supplied to the parts of the equipment exposed to the high voltages so as to maintain such parts above the vapor point of water. However, damaging arcs are still formed from time-to-time, and it is important that some means be provided which will interrupt such arcs within a few milliseconds. The preferred embodiment of the invention includes protective apparatus of my invention which will disable the heating equipment within less than three milliseconds.

It is one object of the invention to provide dielectric heating apparatus which is simple and economical to operate and which will provide uniform drying of low conductivity materials, such as rayon cakes.

Other objects and advantages of the invention will be apparent from the following detailed description of preferred embodiments of the invention, which description should be considered in connection with the accompanying drawings, in which:

FIG. 1 is a cross-sectional, side elevation view of the preferred embodiment of the heating apparatus of the invention;

FIG. 2 is an enlarged fragmentary cross-sectional view of the condensing means forming part of the embodiment shown in FIG. 1;

FIG. 3 is a plan view, partly in cross-section, of the embodiment shown in FIG. 1;

FIG. 4 is a schematic diagram illustrating the electrical components of the embodiment shown in the preceding figures;

FIG. 5 is a circuit diagram of the oscillator forming part of the embodiment shown in the preceding figures and of the protective circuits for the oscillator;

FIG. 6 is a cross-sectional elevation view of an alternative form of support or holding means for the material to be heated;

FIG. 7 is a fragmentary perspective view of the support shown in FIG. 6;

FIG. 8 is a cross-sectional, elevation view of an alternative form of heating electrode arrangement which may be used with the embodiment shown in FIGS. 1–3;

FIG. 9 is a schematic perspective showing heating electrodes which may be employed in the embodiment shown in FIGS. 1–3; and

FIG. 10 is a schematic diagram illustrating an alternative embodiment of the invention.

In the embodiment illustrated in FIGS. 1–3, the oscillator for generating the radio frequency energy is located centrally of the heating apparatus and preferably operates at a frequency of about 30 megacycles per second, although it will be understood that the oscillator may be operated at other radio frequencies. The oscillator comprises a centrally located vacuum tube, such as a type 5682 vacuum tube manufactured by Machlett Laboratories, Inc., Springdale, Conn., which tube can produce 200 kilowatts of radio frequency energy at 30 megacycles per second. The vacuum tube **10** comprises an anode **11** having a connecting ring **12**, a grid connecting ring **13** and a pair of filament or cathode connecting rings **14** and **15**. A folded first co-axial line having a grounded outer conductor **16** and an inner conductor **17** forms an inductor connected between the cathode of the tube **10** and ground. The portion of the inner conductor **17** adjacent the open end of the co-axial line is provided with a conductive extension or member **18** having an outer wall **18***a* and an inner wall **19**. The walls **18** and **19** define an air receiving chamber **20** for purposes hereinafter described, and the inner wall **19** is electrically connected to the cathode ring **14** by means of a conductive terminal or connector **21** which is mounted on the inner wall **19** and which contacts the cathode ring **14**. Filament energizing power is supplied to the filament or cathode of the tube **10** by means of the inner conductor **17** previously described and by means of the conductor **22** which is connected at one end thereof to a terminal or connector **23** which contacts the ring **15**. Radio frequency bypass capacitors **24** are connected between the connectors **23** and **21**.

A second co-axial line comprising an inner conductor **25** and an outer conductor **26** forms an inductor connected between the anode **11** and ground. The portion of the inner conductor **25** adjacent the open end of the second co-axial line is connected to the anode **11** by means of a connector **27** which contacts the ring **12**. The annular connector **27** has a plurality of air passageways **29**, **30**, **31** therein for purposes hereinafter described, and the passageways **29—31** are connected to the air chamber **20** by means of a tube **32**, a plurality of such tubes **32** being provided.

In an oscillator circuit, the magnitude of the impedance between the tank capacitor and the cathode and anode terminals of the oscillator tube affects the efficiency of the oscillator. For maximum efficiency the impedance should be as small as possible, and therefore, in the embodiment shown in FIGS. 1–3 the tank capacitors **33**, only one of which is shown in FIG. 1, are physically as close as possible to the anode ring **12** and the cathode ring **14**, the terminals of the capacitors **33** being received in sockets in the member **18** and in the connector **27** as illustrated in FIG. 1.

The inner conductor **25** is insulated from ground for direct currents and from the outer conductor **26** by means of the insulating supports **34** which are mounted at one end on a base **35** and which engage a conductive disc or plate **36** at the opposite ends, the inner conductor **25** being mounted on and secured to the disc **36**. However, the inner conductor **25** and the outer conductor **26** are coupled together at radio frequencies by means of the capacitors **37** whose terminals are received in sockets in the base of the outer conductor **26** and in the disc **36** as shown in FIG. 1.

Water for cooling the anode **11** is supplied to the tube or pipe **38** through a connector **39** which is mounted on a stand comprising insulating supports **40**. The anode **11** is isolated from ground at radio frequencies by means of a coil **41** wound on an insulating tube **42** and the lower end of the coil **41** which is electrically connected to the connector **39** is bypassed to ground for radio frequencies by means of a capacitor **43**.

The inner conductor **25** is cooled by means of water which is circulated through the encircling tubing **44**. The terminals of the capacitors **37** are water cooled by means of water circulating through the tubing **45—48**. Cooling

water from any suitable source is supplied to the tubing **44—48** and to the connector **39** by conventional means through the water column formed by the insulating tubing **49**.

The vacuum tube **10** is surrounded by an annular conductive ring **50** which is supported from the connector **27** by insulators **51** and which is spaced from the member **18** by insulators **52**. The conductive ring **50** is connected to the grid ring **13** by means of a connector **53** and a plurality of conductive bars or tubes **54**. The vacuum tube **10** is surrounded by a second, conductive, distributor ring **55** which is coupled for radio frequencies to the ring **50** by means of a plurality of capacitors **56**, only one of which is shown in FIG. 1. Radio frequency driving voltage for the grid of the tube **10** is supplied by means of the capacitor **57** connected between the member **18** and the distributor ring **55**.

In the design of a vacuum tube oscillator, the discharge rate of the grid blocking capacitor and the grid leak resistor combination is an important consideration and must be greater than the decrement of the tank circuit of the oscillator but not large compared to the frequency of the oscillator itself. It is common practice to make the time constant of the combination approximately equal to the time required for three to ten cycles of oscillation of the oscillator. If the time constant is too long, the oscillator will "block" and intermittent oscillation will result. Conversely, if it is too short, poor efficiency will result or the oscillator will fail to oscillate. With high power oscillators of the type required for the dielectric drying of materials, the grid resistor must be capable of dissipating large amounts of power, for example, as much as 8,000 watts. Accordingly, relatively large resistors of high power rating are required, and it is undesirable to locate such resistors within the oscillator housing because of the heat radiated and the voltages present, the space within the oscillator being relatively limited at the high frequencies employed. However, if such resistors are located outside of the oscillator housing, the stray or distributed capacitance of the wiring between the grid blocking capacitor and the grid resistors may, in certain cases, prevent the reduction of the size of the blocking capacitor to the value required to obtain the desired time constant. I have found that if a grid biasing circuit of the type described hereinafter in connection with FIGS. 4 and 5 is employed, the high wattage grid resistors may be located outside of the oscillator housing. As illustrated in FIG. 1, a relatively small, conductive housing **59** is mounted on the outer conductor **16** and encloses an inductor **60**, a bypassing capacitor **61** and a relatively low wattage resistor **62**, the inductor **60**, the capacitor **61** and the resistor **62** forming part of the grid biasing circuit. These latter elements are connected to the grid ring **50** by means of the leads (not shown in FIG. 1) which extend through the interior of the inner conductor **17**.

A critical problem in high frequency dielectric heating equipment is the removal of heat from glass-to-metal seals of vacuum capacitors and the oscillator vacuum tube. This heat is generated at points of very high electrical stress and arises from two separate causes. The electrical stress in the glass envelopes causes heating of the glass due to dielectric losses, and the electrical field is greatest in the glass adjacent to the glass-to-metal seal. Furthermore, all of the high frequency current which flows between the vacuum tube electrodes and the exterior terminals or connectors passes over the surface of the metal where it joins the glass producing heating of the metal. Water cooling of all the glass-to-metal seals required in an oscillator illustrated in FIG. 1 is difficult and expensive to provide and mere circulation of air through the oscillator housing is inadequate because an air film of considerable thermal impedance clings tenaciously to all surfaces within the oscillator making it difficult to remove the heat from the glass-to-metal seals by means of low velocity air currents.

I have found that the necessary cooling of the glass-to-metal seals may be obtained by impinging jets of high velocity of air on the surfaces where cooling is required. The orifices from which the air is emitted must be located in close proximity to the heated surfaces because otherwise the necessary impingement velocity will not be obtained. Since the orifices must be in close proximity to the surfaces to be cooled and since relatively high voltages are employed in the oscillator, the member or members containing the orifices should be at substantially the same electrical potential as the surfaces being cooled. I have found that by providing air passageways in the vacuum tube connectors and in the vacuum capacitor sockets, the orifices may be formed in the connectors and sockets themselves and, hence, may be close to the glass-to-metal seals and at the same potential as the surfaces being cooled.

In the embodiment illustrated in FIG. 1, air at about one pound gauge pressure is supplied to the interior of the housing **59** through a conduit **63**. The air flows through the housing **59**, through the interior of the inner conductor **17** into the chamber **20** and from the chamber **20** into the passageways **29**, **30** and **31** described above. The connector **21** is provided with a plurality of orifices **64** extending around the cathode ring **14** and which direct air at high velocity on the glass-to-metal seals between the ring **14** and the glass envelope of the tube **10**. Similarly, the orifices **65** and **66** in the connectors **53** and **27** direct air at high velocity on the glass-to-metal seals between the grid ring **13**, the anode ring **12** and the glass envelope of the vacuum tube **10**. Other orifices (not shown) in the sockets which receive the terminals of the vacuum capacitor **33** similarly direct air at high velocity on the glass-to-metal seals of the capacitors **33**.

A substantially annular enclosure **67** having three walls **67*a***, **68** and **69** extends around the outer conductor **16**, and to minimize condensation within the enclosure **67**, the interior of the enclosure is heated above the boiling point of the liquid evaporated from the material to be dried by means of the heating coils **70** which may, for example, be tubes through which steam is circulated. Condensing means employed for the purposes described in my co-pending application Serial No. 601,050, filed July 30, 1956, now Patent No. 2,949,677, and comprising a plurality of walls **71**, **72** and **73** (see FIGS. 1 and 2) and condensing coils **74** through which a cooling fluid is circulated extends around the upper portion of the enclosure. The condensing means is provided with an inlet **75** which opens into the upper interior portion of the enclosure for the purpose of receiving the vapor which is emitted from the material to be dried. The condensed vapor is removed from the condensing means by means of a drain **76**.

Two conductive, substantially annular, co-axial heating electrodes **77** and **78** are mounted within the enclosure **67** and are substantially co-axial with the vacuum tube oscillator previously described. The heating electrodes **77** and **78** may be substantially continuous or they may be segments of conductive material. The grounded electrode **77** is supported from the walls **67*a*** and **69** of the enclosure by spacers **79** and **80**. The walls of the enclosure as well as the spacers **79** and **80** may provide the electrical connections between the electrode **77** and the outer conductor **16**, but preferably, in order to provide as low an impedance path as possible, the heating electrode **77** is connected to the outer conductor **16** by means of radial strips or a perforated ring **81** of cooper.

The inner heating electrode **78** is supported by a plurality of conductive tubes **82** which are mounted on feed-through insulators **83**, supported by the outer conductor **16**, and which are electrically connected to the terminals **84** secured to the distributor ring **55**. The tubes **82**,

the rings **50** and **55** and the capacitors **56** form a low impedance coupling means between the oscillator and the electrode **78**.

Condensate may form on the portion **16***a* of the outer conductor within the enclosure **67** during the drying of the material within the enclosure **67**, and if this is permitted to drain downwardly on to the insulators **83**, arcing may occur between the tubes **82** and the outer conductor **16**. To aid in the removal of such condensate, an annular absorptive ring **110** of insulating material is mounted on the portion **16***a* of the outer conductor between the heating electrode **78** and the portion **16***a*. The ring **110** may be made of a material such as silicone foam, and it will absorb any condensate which drains downwardly along the portion **16***a*. Also, the ring **110** will be heated dielectrically because of the radio frequency voltage which exists between the heating electrode **78** and the portion **16***a* so that the absorbed condensate will be revaporized and so that accumulation of the condensate on the insulators **83** will be prevented.

The heating apparatus illustrated in FIGS. 1–3 is particularly adapted for the drying of "cakes" **85** of rayon which are filled with moisture. The cakes **85** are supported or held on stands **86** comprising a ceramic plate or disc **87** secured to ceramic insulators **88** which are secured at their opposite ends to a ceramic plate **89**. The plate **89** is carried on the end of a rotatable shaft **90** which is journaled in a conveyor chain **91** which rides on the track **92**. A sprocket **93** mounted on the shaft **90** is engabeable with a sprocket chain **94** mounted on the track **92** so that the stands **86** and, hence, cakes **85** are rotated continuously or intermittently as the stand is moved in a substantially circular path around the oscillator and between the heating electrodes **77** and **78**. Further details of the conveyer mechanism are given in my co-pending application Serial No. 601,050, now Patent No. 2,949,677, and since the particular mechanism employed forms no part of the invention, it will not be described in further detail herein.

The enclosure **67** has an opening **95** therein (FIG. 3) permitting the continuous entrance and exit of the cakes **85** into and out of the enclosure **67**. The outer heating electrode **77** terminates on opposite sides of the opening **95** so as to permit the cakes **85** to enter into and exit from between the heating electrodes **77** and **78**. If desired, the inner heating electrode **78** may also terminate on opposite sides of the opening **95**, but, as used herein, the expression "substantially annular" is intended to apply to the enclosure **67** and to the discontinuous heating electrode **77** illustrated in FIG. 3.

After the heating apparatus is electrically energized, the conveyer **91** is set in operation and the wet cakes **85** are manually loaded on the stands **86** which move into the enclosure **67**. The dry cakes **85** are removed manually from the stands **86** as they exit from the opening **95**. The heating apparatus of the invention is capable of drying at least 250 cylindrical rayon cakes five inches high and five inches in diameter per hour.

It will be noted from an examination of FIGS. 1–3 that the heating electrodes **77** and **78** are closely coupled to the oscillator and are physically only a short distance from the oscillator. It has been found that with such an arrangement a variation in the number of cakes **85** between the electrodes **77** and **78** or a variation in the dielectric properties of such cakes **85** has little effect on the drying of the cakes. Furthermore, it has been found that with such variations the frequency of oscillation changes so that a substantially constant radio frequency voltage is present between the heating electrodes **77** and **78** at all times.

In addition, since all portions of the heating electrode **77** and all portions of the heating electrode **78** are substantially equi-distant from the oscillator and since the heating electrodes **77** and **78** are connected to the oscillator by a plurality of low impedance conductors, the voltage between the electrodes **77** and **78** is substantially the same at all points along the path followed by the cakes **85** even though the properties of individual cakes may differ. This means that substantially all the cakes will be subjected to the same heating field, the heating of one cake will be uneffected by the location or properties of another cake and uniform drying is obtained without adjustment of the heating apparatus.

In the preferred embodiment of the invention, the heating electrodes **77** and **78** extend in concentric circles around the oscillator, as viewed in FIG. 3, but the advantages of the invention may be obtained if the heating electrodes extend around the oscillator in other substantially re-entrant figures, such as an ellipse, provided that all portions of an electrode are spaced from the oscillator by amounts which do not differ by more than a small fraction of a wave length at the operating frequency. For example, the amounts should not differ by more than approximately one-eighth of a wave length.

The spacing between the electrodes **77** and **78** is dependent upon the dimensions of the material to be heated, the voltage between the electrodes and the rate at which heat can be generated within the material. The distance between the electrodes **77** and **78** and the central oscillator is dependent upon the desired power concentration per cubic foot between the electrodes **77** and **78**, the volume of material or number of cakes between the electrodes **77** and **78** at any given time, the maximum permissible voltage between the electrodes **77** and **78**, the total power to be absorbed by the material to be heated in one heating apparatus and the frequency of operation. Since these factors affect the distance between the electrodes **77** and **78** and the central oscillator in different ways, a distance is selected which will provide optimum results under the given conditions. I have found, for example, that when it is desired to process approximately 250 rayon cakes five inches high and five inches in diameter per hour with an oscillator operating at approximately thirty megacycles per second, the radius of the electrode **78** should be approximately twenty-five to twenty-six inches and the radius of the electrode **77** should be approximately thirty-four to thirty-five inches.

FIG. 4 is a schematic diagram of the electrical components of the embodiment shown in FIGS. 1–3 and of the rayon cakes **85** and their supporting or holding stands **86**. The components shown in FIG. 4 and which have been described above are identified by the same reference numerals.

FIG. 4 illustrates the electrodes of the vacuum tube **10** including, an anode **11**, a control grid **96** and a filament or cathode **97**, the electrodes being enclosed in a glass envelope **98**. For the reasons set forth above, the grid **96** is connected to ground through a radio frequency choke **99**, a lead **100** which passes through the interior of the inner conductor **17**, the resistor **62** connected in parallel with the choke **60**, a line **101**, and a plurality of parallel connected, high wattage resistors **102** which are located exteriorly of the oscillator housing. One end of the choke **99** is bypassed to the cathode **97** at radio frequencies by means of a capacitor **103** and one end of the choke **60** is bypassed to ground by the capacitor **61**.

The bias required for the grid **96**, although essentially constant, contains a low amplitude modulation varying in frequency from zero to at least ten megacycles. In order to maintain proper bias on the grid **96**, the biasing voltage should follow the modulated voltage and it is for this reason that when the biasing resistors, such as the resistors **102**, are located outside of the oscillator housing and are connected to the grid of the oscillator tube by a line having substantial capacitance, additional circuit components in positions substantially unaffected by such capacitance should be provided. The choke **60** provides a low resistance path for direct currents and components of less than 1000 cycles per second and has a relatively high impedance for components of higher frequencies.

The resistor **62** has a value of resistance which is relatively low compared to the impedance of the choke **60** at such higher frequencies and the capacitor **61** has a relatively low impedance at such frequencies. The choke **60** has a relatively high impedance at frequencies as low as ten kilocycles per second and the capacitor **61** has a relatively low impedance at frequencies as low as ten kilocycles per second. Therefore, modulation currents having frequency components of from ten kilocycles to several megacycles flow largely through resistor **62** and capacitor **61** dissipating the energy stored in blocking capacitor **56** and thereby maintaining the proper negative bias on the grid of tube **10**. It will be noted that although the choke **99** has a relatively high impedance and the capacitor **103** has a relatively low impedance at the frequency of oscillation, they have relatively low and relatively high impedances, respectively, at the frequencies of the modulating component.

With an oscillator of the type described and a frequency of oscillation of thirty megacycles, proper operation of the oscillator may be obtained when the components of the grid biasing circuit have the following values:

Resistor **62**—500 ohms, 200 watts.
Combined parallel resistance and wattage of resistors **102**—500 ohms, 8 kilowatts.
Choke **60**—30 millihenries.
Choke **99**—self-resonant at 30 megacycles per second.
Capacitor **61**—1000 micromicrofarads.
Capacitor **103**—50 micromicrofarads.

For the purpose of maintaining the distributor ring **55**, and hence, the heating electrode **78**, at ground potential for direct currents, the oscillator includes a lead **104** which extends into the housing **59** and which is connected to the distributor ring **55** through a radio frequency choke **105**. One end of the choke **105** is bypassed for radio frequencies to the cathode **97** by way of the member **18** by a capacitor **106**. Although the lead may be grounded at other points, it preferably extends into the housing **59** for convenience in checking the operation of the oscillator without disassembling the oscillator housing. For example, the existence of short circuits in the capacitors **56**, **57**, **103** and **106** can be determined by applying test voltages between leads **100** and **104** and between the leads **100** and **104** and ground.

For the purpose of measuring the filament energizing voltage, the oscillator may be provided with a pair of leads **107** and **108** which is passed through the inner conductor **17** and which are connected to a voltmeter **109**.

FIG. 5 is a circuit diagram of the oscillator shown in the preceding figures and the circuit of the invention for protecting the oscillator and associated circuits against damage due to arcing within the oscillator. It will be noted from an examination of FIG. 5 that the oscillator circuit is of the Colpitts type, and therefore, its operation is readily apparent to those skilled in the art.

It has been found that during the operation of the heating apparatus previously described, damaging arcs may occur from time to time between the heating electrodes and the material being dried, between the electrodes and other parts within the enclosure **67** and between various parts of the oscillator itself. Such arcs cause an increase in the dissipation of radio frequency energy and are accompanied by a rapid drop in the radio frequency voltage within the oscillator. It has been found that in a dryer of the type described, such arcs produce changes of radio frequency voltage which are more rapid than the changes in radio frequency voltage produced by any other cause of loading variation. It is important to extinguish such arcs within a few milliseconds, and I have invented a protective circuit which will respond within such a short period of time to rapid rates of change of radio frequency voltage caused by arcs but which will not respond to changes of radio frequency voltage caused by low frequency modulation of the radio frequency voltage produced by the low frequency power supply and to the relatively low frequency modulation of the radio frequency voltage which occurs during the time that the oscillator is being put into operation.

In the preferred embodiment of the protective circuit, the anode **11** of the oscillator tube **10** is connected to the positive terminal of a direct current supply **111** through a surge reactor **112** and through a parallel network comprising a surge capacitor **113**, a current limiting resistor **114** and the contacts **115** of a vacuum switch having an envelope **116**. The voltage between the positive terminal of the D.C. supply **111** and ground may, for example, be of the order of fifteen to twenty thousand volts. The anode **117** of a high voltage gas tube **118**, such as a type 5948 hydrogen thyratron having a high current capacity is connected to the junction point of the reactor **112** and the resistor **114**. The cathode **119** of the tube **118** is connected to ground through the operating coil **120** of the vacuum switch and through the operating coil **121** of a relay whose contacts **122** are connected in series between the alternating current source **123** and the input of the direct current supply **111**. The cathode circuit of the tube **118** may optionally include a biasing resistor **124**. The grid **125** of the tube **118** is connected to the cathode **126** of a second gas tube or thyratron **127**, the cathode **126** being connected to ground through a resistor **128**. The anode **129** is connected to the positive terminal of a low voltage direct current supply **130** comprising a capacitor **130***a* through a current limiting resistor **130***b*. Preferably, the impedance of the supply **130** and the value of the capacitor **130***a* are such that when the gas tube **127** conducts, as hereinafter described, the capacitor **130***a* discharges and the potential at the anode **129** becomes less than the ionizing potential of the tube **127**, causing the tube **127** to become non-conducting again.

The control grid **131** is connected to ground through a biasing network comprising resistors **132**—**134** and a capacitor **135**, the terminal **136** being connected to the negative terminal of a low voltage direct current supply (not shown) which provide a biasing potential sufficient to maintain the tube **127** normally non-conducting.

The direct current voltages applied to the gas tubes **118** and **127** are such that these tubes normally are non-conducting, but when a positive pulse is applied to the grid **131** through the capacitor **137**, both of the gas tubes **118** and **127** become conducting. The gas tube **118** will become conducting in less than a millisecond after the positive pulse is applied to the grid **131** and will substantially short circuit the junction point of the reactor **112** and the resistor **114** to ground within this time thereby removing the anode voltage from the oscillator tube **10**.

If the anode **117** were connected to a low voltage supply, the current produced through the operating coil **120** of the vacuum switch when the tube **118** becomes conducting would cause the contacts **115** of the vacuum switch to open in about 20–30 milliseconds after the tube **118** becomes conducting. During this time the tube **118** substantially short circuits the output of the direct current supply **111** and transient currents and voltages may be produced which may damage the direct current supply **111**. However, since the anode **117** is connected to the high voltage supply **111** and since a very large current results when the tube **118** becomes conducting, a strong magnetic field is produced by the coil **120** in a fraction of a millisecond which is sufficient to open the contacts **115** within two to three milliseconds. When the contacts **115** are opened, the resistor **114** is connected in series between the positive terminal of the D.C. supply **111** and the anode **117** of the tube **118** and the undesirable transient currents and voltages are thereby limited in duration to approximately two or three milliseconds.

Shortly after the vacuum switch operates, as described

above, the contacts **122** are opened by virtue of the current flowing through the coil **121** so that the D.C. supply **111** becomes de-energized. At this time the high voltage is interrupted, and the tube **118** becomes non-conducting. The contacts **122** remain open until manually or automatically reset.

The circuit within the dotted rectangle **138** is a well known type of one-cycle, trigger circuit, known as a Schmitt circuit, which supplies a positive output pulse when a positive voltage above a predetermined value is applied to the grid of the vacuum tube **140**. The grid **139** is connected to the output of a rectifying, filtering and differentiating circuit and a positive voltage of sufficient magnitude to operate the trigger circuit **138** is developed across the resistor **141** when a rate of radio frequency energy decrease which normally accompanies the occurrence of a damaging arc in the oscillator occurs. However, radio frequency energy changes of the type encountered during the energization of the high frequency oscillator or which are caused by the alternating current modulation of the radio frequency energy at the frequency of the source **123**, for example 360 cycles per second, will not produce a positive voltage of sufficient magnitude across the resistor **141** to trigger the circuit **138**.

The rectifying, filtering and differentiating network comprises resistors **141**—**144**, capacitors **145** and **146**, a radio frequency choke **147** and a rectifier **148** which is poled so as to produce a negative voltage at the junction point of the resistors **142** and **143** and the choke **147**. Radio frequency energy from the high frequency oscillator comprising the vacuum tube **10** is supplied to the input of the circuit by means of the co-axial line **149** which terminates at the end remote from the circuit in a coupling loop **150** which may be coupled to any portion of the high frequency oscillator which will supply high frequency energy to the rectifying, filtering and differentiating circuit of sufficient amplitude to produce the desired positive voltage at the grid **139**. The loop **150** may, for example, be coupled to the co-axial line which is connected to the anode **11** of the vacuum tube **10** as shown in FIG. 4.

The time constants and magnitudes of the elements of the rectifying, filtering and differentiating circuit are selected in a manner well known to those skilled in the art so as to provide operation of the protective circuit when the magnitude of change and the rate of change of the radio frequency voltage exceed first predetermined values and are less than second predetermined values. It has been found that with the embodiment previously described the desired operation may be obtained if the elements have the following values:

Resistor **141**—12,000 ohms
Resistor **142**—25,000 ohms
Resistor **143**—3,000 ohms
Resistor **144**—73 ohms
Capacitor **145**—20 micromicrofarads
Capacitor **146**—1,500 micromicrofarads
Choke **147**—self-resonant at 30 megacycles per second.

When the elements of the circuit have the values set forth above, the loop **115** may be so oriented and placed with respect to the radio frequency field of the oscillator as to produce a steady state voltage of approximately forty-five R.M.S. volts across the resistor **144**. With the trigger circuit **138** adjusted to operate with a voltage of three volts across the resistor **141**, the voltage being positive at the end of the resistor **141** connected to the grid **139**, it has been found that the protective circuit will not operate when the radio frequency voltage varies about eight percent in magnitude because of modulation thereof at 360 cycles per second by the power supply or because of the transients produced when the oscillator is initially energized. In addition, because of the capacitor **145**, the resistor **143** and the choke **147**, the protective circuit will not be operated by the radio frequency voltage itself or by voltages having frequencies above about a few megacycles per second. However, the protective circuit will operate when the radio frequency voltage varies at intermediate rates and by an amount sufficient to produce a triggering voltage of at least three volts across the resistor **141**.

If it is found that the transients which are produced when the gas tube **118** conducts can be tolerated then the resistor **114**, and the vacuum switch comprising the operating coil **120** and the contacts **115** may be omitted.

Although the stand or holding means **86** for the cakes **85**, shown in FIG. 1, is satisfactory for transporting the cakes **85** between the heating electrodes **77** and **78**, care must be taken to place the cakes **85** centrally of the stand and at times the cakes **85** tend to move sidewise with respect to the stand **86** during the time that they are transported between the heating electrodes. In order to provide uniform drying of the cakes **85** and to prevent arcing between the heating electrodes **77** and **78** and the cakes **85**, the cakes **85** should be spaced from the heating electrodes. The stand **151**, shown in FIGS. 6 and 7, simplifies the loading of the cakes **85** on the stand and holds such cakes **85** in place during the drying cycle.

Since the stand **151** is subjected to the radio frequency field and since losses in the stand should be kept to a minimum, the stand **151** preferably is made of a low loss ceramic material, such as steatite, and comprises a lower tubular portion **152** and an upper flange portion **153**. The lower tubular portion **152** frictionally engages a metal insert **154** which is held on the shaft or spindle **90** by means of a bolt **155**. A removable locator **156**, made of a low loss insulating material such as tetrafluoroethylene, is mounted on top of the flange portion **153** and has a portion which extends within the bore of the tubular portion **152**. The locator **156** maintains the cake **85** in the correct position on the top of the stand **151** and since the locator **156** is made of low loss material and has a relatively small volume, the locator **156** has little effect on the electric field through the cake **85**.

In the embodiment previously described, the heating electrodes **77** and **78** are vertical and extend in planes substantially parallel to the axes of the cakes **85**. When the heating electrodes are so disposed, a substantially uniform electric field is obtained throughout the cakes **85**. With an operating frequency of 30 megacycles per second and an energy input of the order of 20 kilowatts per wet cake, each cake **85** has relatively low impedance. The high energy input is desirable to obtain a fast drying rate, and with vertical heating electrodes and a spacing of about one-half inch between the electrodes and the cakes **85** a voltage between the heating electrodes **77** and **78** of about 8,000–10,000 volts is required to obtain energy inputs of the order of 20 kilowatts. Under these conditions the voltage between diametrically opposite points on the cakes **85** is of the order of 2,000 volts.

With the vertical heating electrodes previously described, the current flux density is relatively high. If the vertical electrodes are merely replaced by horizontal heating electrodes, there is substantially no change in the current flux density, and in addition, the electric field through the cakes is less uniform. Heating electrodes extending transversely to the axis of the cake and substantially parallel to a line drawn between the diagonally opposite corners of the cake, as viewed in cross-section produce an intense concentration of heat at the corners of the cake, and therefore, such electrodes do not produce uniform drying of the cakes.

If the heating electrodes are shaped as shown in FIG. 8, it is possible, with a given voltage, to obtain a 100% increase in the amount of heat generated in a cake **85** as compared with either vertical or horizontal plane electrodes. Furthermore, a substantially uniform electric field through the cake **85**, as indicated by the dotted lines **157**, may be obtained, and hence, with such electrodes it is possible to obtain uniform drying of the cake **85**. The heating electrodes **158** and **159**, shown in FIG. 8, have

vertical portions **160** and **161** which extend parallel to the axes of the cakes **85** and horizontal portions **162** and **163** which extend horizontally and substantially perpendicular to the axes of the cakes **85**. With the use of heating electrodes shaped in this manner, the current flux density for a given voltage may be reduced as compared to plane, vertical or horizontal electrodes. Furthermore, if no increase in the amount of heat generation is desired, a reduction in the electrical stress or voltage of 25% may be obtained for the same rate of heat generation in the cake **85**.

When the material to be heated and dried is rayon wound in cakes, small fibres may extend from the cakes which may brush against the heating electrodes or produce electrical stresses which promote the formation of damaging arcs. Such arcs may be reduced in frequency and the number of arcs terminating at the surface of the cake **85** may be reduced by surrounding the cake **85** by a cylinder or sleeve **164** of insulating material. Since the sleeve **164** also is in the electric field, it should be formed of a low loss material, and it has been found that a sleeve formed from glass cloth impregnated with a silicone resin provides satisfactory results. The sleeve **164** may be secured to the flange portion **153** of the stand **151** in any desired manner and may, for example, be adhesively secured thereto by means of a silicone resin. Alternatively, the stand **151** including the flange portion **153** and the sleeve **164** may be an integral unit molded from fiber glass cloth bonded with a silicone resin.

Although good results are obtained when only one type of heating electrodes extend around the centrally located oscillator, it may in some cases be desirable to employ one or more series of differently disposed and/or shaped electrodes around the periphery of the oscillator. For example, plane vertical electrodes extending parallel to the axis of the cake **85** cause removal of moisture from the peripheral surface of the cake at a rate greater than the rate at which it is removed from the center thereof. Plane horizontal electrodes extending substantially perpendicular to the axis of the cake **85** cause removal of moisture from the bore of the cake at a greater rate than the rate at which the moisture is removed from the outer periphery thereof. Electrodes of the type illustrated in FIG. 8 provide a combination of such results. However, if the electrodes are arranged in a series as illustrated in FIG. 9, and if the cakes **85** are transported successively between such electrodes, then the combined effects of the different electrodes are obtained so that all parts of the cakes **85** receive the same treatment. The arrangement of electrodes illustrated diagrammatically in FIG. 9 comprises a pair of vertical electrodes **77** and **78** of the type illustrated in FIGS. 1 and 3, a pair of horizontal electrodes **165** and **166** and a pair of L-shaped electrodes **158** and **159** of the type illustrated in FIG. 8.

Although heating apparatus of the type illustrated in FIGS. 1–3 in which the oscillator itself is located centrally of the heating electrodes provides the best results because the heating energy voltage is substantially the same between all parts of the heating electrodes and because the heating of the material to be dried is substantially unaffected by the normal loading changes encountered between the electrodes, the former advantage can be obtained with apparatus of the type illustrated in FIG. 10 in which the high frequency oscillator is not located within the heating electrodes **77** and **78**. The heating apparatus, illustrated schematically in FIG. 10, comprises a high frequency source **167** which includes the high frequency oscillator and which may be located remotely from the conductive central housing **168**. The housing **168** encloses an inductor **169**, which is connected or coupled at its opposite ends by means of conductive discs, such as discs of copper, to the electrodes **77** and **78**. Instead of copper discs a plurality of radially extending bars or strips may be employed as long as the ends of the inductor **169** are coupled to the heating electrodes **77** and **78** by conductors of substantial total area which provide low impedance paths between the ends of the inductor **169** and the electrodes **77** and **78**. The inductor **169** has inductance sufficient to provide, in combination with the conductors **170** and **171** and the heating electrodes **77** and **78** a parallel resonant circuit which is resonant at the operating frequency of the source **167**. The inductor **169** is adjustable as indicated so as to permit tuning of the system to resonance, and the source **167** is connected to the inductor **169** by means of a transmission line **172**. Although the transmission line **172** is shown connected to the inductor **169** by an adjustable tap **173**, it will be understood that the transmission line **172** may be coupled to the inductor **169** in any other well known manner.

Having thus described my invention with particular reference to the preferred form thereof and having shown and described certain modifications, it will be obvious to those skilled in the art to which the invention pertains, after understanding my invention, that various changes and other modifications may be made therein without departing from the spirit and scope of my invention, as defined by the claims appended thereto.

What is claimed as new and desired to be secured by Letters Patent is:

1. High frequency heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having a plurality of electrodes, and resonant circuit means coupled in circuit with said electrodes for generating radio frequency energy; an enclosure extending around said oscillator; a plurality of pairs of spaced heating electrodes mounted within said enclosure and extending around said oscillator; material holding means mounted between said heating electrodes, said pairs of heating electrodes having surfaces facing said holding means, said surfaces of one pair of said pairs of heating electrodes being disposed with respect to said holding means at an angle which differs from the angle at which said surfaces of another pair of said pairs of heating electrodes are disposed with respect to said holding means; and low impedance means coupling said heating electrodes to said oscillator.

2. High frequency heating apparatus comprising: a high frequency oscillator comprising a vacuum tube having a plurality of electrodes, and resonant circuit means coupled in circuit with said electrodes for generating radio frequency energy; an enclosure extending around said oscillator; a first pair of spaced heating electrodes mounted in said enclosure; a second pair of spaced heating electrodes mounted in said enclosure and having portions extending transversely to said first pair of heating electrodes, said second pair of heating electrodes being spaced from said first pair of heating electrodes in a direction extending around said oscillator; means for successively passing material to be heated between said first and said second pair of heating electrodes; and low impedance means coupling said heating electrodes to said oscillator.

3. Dielectric heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having at least a cathode, an anode and a grid, a first, tuned, co-axial line having inner and outer conductors and having an open end, means connecting the portion of said inner conductor adjacent said open end to said cathode, a second, tuned, co-axial line having inner and outer conductors and having an open end, said second line being mounted co-axially with said first line and with the open end thereof facing the open end of said first line, means connecting the portion of said inner conductor of said second line adjacent the open end of said second line to said anode and the portion of said outer conductor of said first line adjacent the open end of said first line being connected to the portion of said outer conductor of said second line adjacent the open end of said second line, and a capacitor mounted adjacent said cathode and said anode and connected therebetween; a substantially

annular enclosure extending around one of said outer conductors; a first substantially annular electrode mounted within said enclosure and extending around one of said outer conductors; a conveyer extending around said electrode, said enclosure having an opening therein permitting access to said conveyer; a second electrode extending around said conveyer except for the portion thereof adjacent said opening in said enclosure; low impedance means connecting one of said electrodes to one of said outer conductors; and low impedance means connecting the other of said electrodes to said grid.

4. Dielectric heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having at least a cathode, an anode and a grid, a first, tuned, co-axial line having inner and outer conductors and having open and closed ends, means connecting the portion of said inner conductor adjacent said open end to said cathode, a second, tuned, co-axial line having inner and outer conductors and having open and closed ends, said second line being mounted co-axially with said first line and with the open end thereof facing the open end of said first line, means connecting the portion of said inner conductor of said second line adjacent the open end of said second line to said anode and the portion of said outer conductor of said first line adjacent the open end of said first line being connected to the portion of said outer conductor of said second line adjacent the open end of said second line, a capacitor mounted adjacent said cathode and said anode and connected therebetween, a capacitor mounted adjacent said cathode and said grid and connected therebetween, a conductive ring extending around said vacuum tube and mounted within one of said outer conductors, and means connecting said ring to said grid; a substantially annular enclosure extending around one of said outer conductors; a first substantially annular electrode mounted within said enclosure and extending around one of said outer conductors; a conveyer extending around said electrode, said enclosure having an opening therein permitting access to said conveyer; a second electrode extending around said conveyer except for the portion thereof adjacent said opening in said enclosure; low impedance means connecting one of said electrodes to one of said outer conductors; and low impedance means connecting the other of said electrodes to said ring.

5. Dielectric heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having at least a cathode, an anode and a grid, a first, tuned, co-axial line having inner and outer conductors and having open and closed ends, means connecting the portion of said inner conductor adjacent said open end to said cathode, a second, tuned, co-axial line having inner and outer conductors and having open and closed ends, said second line being mounted co-axially with said first line and with the open end thereof facing the open end of said first line, means connecting the portion of said inner conductor of said second line adjacent the open end of said second line to said anode and the portion of said outer conductor of said first line adjacent the open end of said first line being connected to the portion of said outer conductor of said second line adjacent the open end of said second line, a capacitor mounted adjacent said cathode and said anode and connected therebetween, a capacitor mounted adjacent said cathode and said grid and connected therebetween, a conductive ring extending around said vacuum tube and mounted within one of said outer conductors, and means connecting said ring to said grid; a substantially annular enclosure extending around one of said outer conductors; vapor condensing means having an inlet communicating with the upper interior portion of said enclosure; a first substantially annular electrode mounted within said enclosure and extending around one of said outer conductors; low impedance means connecting said electrode to said ring; a conveyer extending around said electrode, said enclosure having an opening therein permitting access to said conveyer; a second electrode extending around said conveyer except for the portion thereof adjacent said opening in said enclosure; and low impedance means connecting said second electrode to one of said outer conductors.

6. Dielectric heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having at least a cathode, an anode and a grid, a first, tuned, co-axial line having inner and outer conductors and having open and closed ends, means connecting the portion of said inner conductor adjacent said open end to said cathode, a second, tuned, co-axial line having inner and outer conductors and having open and closed ends, said second line being mounted co-axially with said first line and with the open end thereof facing the open end of said first line, means connecting the portion of said inner conductor of said second line adjacent the open end of said second line to said anode and the portion of said outer conductor of said first line adjacent the open end of said first line being connected to the portion of said outer condutor of said second line adjacent the open end of said second line, a plurality of capacitors mounted adjacent said cathode and said anode and connected therebetween, a plurality of capacitors mounted adjacent said cathode and said grid and connected therebetween, a housing mounted on the outer conductor of said first line, a first resistor mounted within said housing, means connecting one end of said first resistor to said grid, a second resistor mounted outside of and remote from said housing, means connecting the other end of said first resistor to one end of said second resistor, means connecting the other end of said second resistor to one of said outer conductors, a conductive ring extending around said vacuum tube and mounted within one of said outer conductors, and means connecting said ring to said grid; a substantially annular enclosure extending around one of said outer conductors; vapor condensing means having an inlet communicating with the upper interior portion of said enclosure; means for heating the interior of said enclosure; a first substantially annular electrode mounted within said enclosure and extending around one of said outer conductors, said electrode having a portion extending substantially parallel to the axes of said lines; low impedance means connecting said electrode to said ring; a substantially annular conveyer extending around said electrode; a second substantially annular electrode extending around said conveyer and having a portion extending substantially parallel to the axes of said lines, said second electrode and said enclosure having aligned openings therein permitting access to said conveyer; and low impedance means connecting said second electrode to one of said outer conductors.

7. High frequency heating apparatus for heating dielectric material comprising a radio frequency oscillator, and a pair of spaced heating electrodes electrically coupled to said oscillator, each said electrode having a pair of electrically connected portions, one of said portions of one said electrode extending substantially parallel to one portion of the other of said electrodes and the other of said portions of said electrodes extending transversely to said one portion thereof and on opposite sides of the space between said one portion of said electrodes.

8. High frequency heating apparatus for heating dielectric material comprising a radio frequency oscillator, and a pair of spaced heating electrodes electrically coupled to said oscillator, each of said electrodes having a pair of electrically connected portions, one of said portions extending substantially perpendicular to the other of said portions and said one of said portions of one electrode extending substantially parallel to said one portion of the other of said electrodes and the other of said portions of said one electrode extending substantially parallel to said other portion of said other electrode, both of said other portions extending intermediate said one portion.

9. High frequency heating apparatus for heating dielectric material comprising a radio frequency oscillator, means for holding material to be heated, and a pair of spaced heating electrodes disposed on opposite sides of said holding means and electrically coupled to said oscillator, each of said electrodes being L-shaped in cross-section, one of said electrodes being disposed with one leg thereof on one side of said holding means and with the other leg thereof extending over said holding means and the other of said electrodes being disposed with one leg thereof on the opposite side of said holding means and with the other leg thereof below said holding means.

10. High frequency heating apparatus comprising a radio frequency oscillator, a pair of spaced heating electrodes electrically coupled to said oscillator, and a rotatable material holding stand disposed intermediate said electrodes, said stand comprising a member of insulating material having a lower portion and a disc-like upper flange portion extending substantially perpendicularly to the axis of rotation of said stand, said upper portion having a centrally disposed opening therein, and a locator of insulating material mounted in said opening and on said upper portion, said locator comprising a pair of intersecting plate-like members mounted with the line of intersection extending substantially coincident with said axis of rotation.

11. High frequency heating apparatus for heating dielectric material comprising a radio frequency oscillator, means for holding material to be heated, a pair of spaced heating electrodes disposed on opposite sides of said holding means and electrically coupled to said oscillator, and fluid absorbing means made of insulating material disposed adjacent one of said electrodes and outside of the space between said electrodes but between said one electrode and a point having a radio frequency potential different from that of said one electrode for absorbing and re-evaporating fluid emitted from said material to be heated.

12. High frequency heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having a plurality of electrodes, and resonant circuit means coupled in circuit with said electrodes for generating radio frequency energy; a substantially annular enclosure extending around said oscillator; a pair of spaced heating electrodes mounted within said enclosure and extending around said oscillator; material holding means mounted between said electrodes; low impedance means coupling said heating electrodes to said oscillator; and fluid absorbing means mounted between one of said electrodes and said enclosure but outside of the space between said electrodes for absorbing and re-evaporating fluid emitted by said material.

13. High frequency heating apparatus comprising: a radio frequency oscillator comprising a vacuum tube having at least a cathode electrode, an anode electrode and a control electrode, a housing for said oscillator comprising a pair of tuned, co-axial lines mounted co-axially with each other, means coupling one of said lines to one of said electrodes, means coupling the other of said lines to another of said electrodes, a radio frequency first choke, a second choke having a value of inductance larger than that of said first choke and a first resistor connected in series in the order named and between said grid and said cathode electrodes, a radio frequency first bypassing capacitor connected between the junction point of said first and second chokes and said cathode electrode, a second bypassing capacitor having a relatively low impedance at frequencies substantially lower than said radio frequency connected between the junction point of said resistor and said second choke and said cathode electrode, and a second resistor having an impedance which is low relative to the impedance of said second choke at frequencies substantially lower than said radio frequency connected in parallel with said second choke, said chokes, said second resistor and said first bypassing capacitor being mounted within said housing and said first resistor being mounted outside of said housing; a substantially annular enclosure mounted co-axially with and extending around one of said lines; a pair of spaced heating electrodes mounted within said enclosure and extending around the major portion of the periphery of one of said lines; material holding means mounted between said electrodes; and low impedance means coupling said heating electrodes to said oscillator.

14. High frequency heating apparatus comprising: a radio frequency oscillator and a pair of spaced heating electrodes electrically coupled to said oscillator, said oscillator comprising a vacuum tube having a plurality of electrodes including a cathode and a grid, resonant circuit means coupled in circuit with said tube electrodes for generating radio frequency energy and means for biasing said tube comprising first and second chokes and a first resistor connected in series in the order named and between said cathode and said grid, one end of said first choke being connected to said grid, a first capacitor connected between the other end of said first choke and said cathode, a second capacitor connected between the junction point of said second choke and said first resistor and said cathode, and a second resistor connected between the ends of said second choke, said first choke and said first capacitor having relatively high and low impedances respectively at said radio frequency, said second choke having a relatively high impedance at predetermined frequencies substantially lower than said radio frequency but having a high impedance at still lower frequencies, said second capacitor having a relatively low impedance at said predetermined frequencies, and said second resistor having a relatively low impedance at said predetermined frequencies.

15. A radio frequency oscillator comprising a vacuum tube having a plurality of electrodes including a cathode and a grid, resonant circuit means coupled in circuit with said tube electrodes for generating radio frequency energy and means for biasing said tube comprising first and second chokes and a first resistor connected in series in the order named and between said cathode and said grid, one end of said first choke being connected to said grid, a first capacitor connected between the other end of said first choke and said cathode, a second capacitor connected between the junction point of said second choke and said first resistor and said cathode, and a second resistor connected between the ends of said second choke, said first choke and said first capacitor having relatively high and low impedances respectively at said radio frequency, said second choke having a relatively high impedance at predetermined frequencies substantially lower than said radio frequency but having a high impedance at still lower frequencies, said second capacitor having a relatively low impedance at said predetermined frequencies, and said second resistor having a relatively low impedance at said predetermined frequencies.

16. A radio frequency oscillator comprising a vacuum tube having a plurality of electrodes including a cathode and a grid, resonant circuit means coupled in circuit with said tube electrodes for generating radio frequency energy and means for biasing said tube comprising a radio frequency first choke, a second choke having an inductance which is higher than that of said first choke, and a first resistor connected in series in the order named and between said cathode and said grid, one end of said first choke being connected to said grid, a radio frequency bypassing, first capacitor connected between the other end of said first choke and said cathode, a second capacitor having a capacitance which is larger than that of said first capacitor connected between the junction point of said second choke and said first resistor and said cathode, and a second resistor connected between the ends of said second choke.

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