

- [54] **ELECTRONIC OVEN WITH FERRITE RF REJECTION FILTERS**
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Related U.S. Application Data

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[52] U.S. Cl. 333/70 S, 333/73 C, 333/79
[51] Int. Cl. H03h 7/04
[58] Field of Search. 333/70 S, 79, 73 C, 333/81 A

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[57] **ABSTRACT**

There is disclosed an electronic oven comprising a generator of microwave energy of a predetermined frequency coupled to a cooking cavity and to a source of DC and 60 cycle operating potentials by a coupling structure, the coupling structure including an RF rejection filter comprising coaxial inner and outer conductors insulated from each other, the inner conductor having a cylindrical ferrite member and a cylindrical metal slug therein of such diameter that the filter operates as a lossy transmission line, terminated in a capacitance for highly attenuating the predetermined frequency and all harmonics thereof up to the seventh harmonic.

14 Claims, 7 Drawing Figures

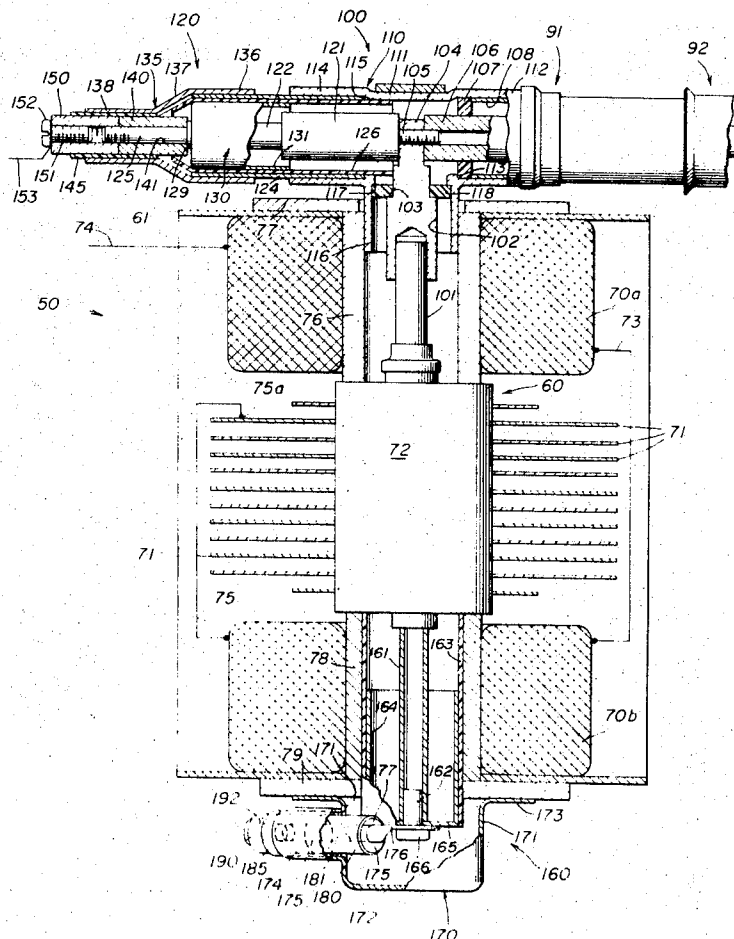


FIG. 1

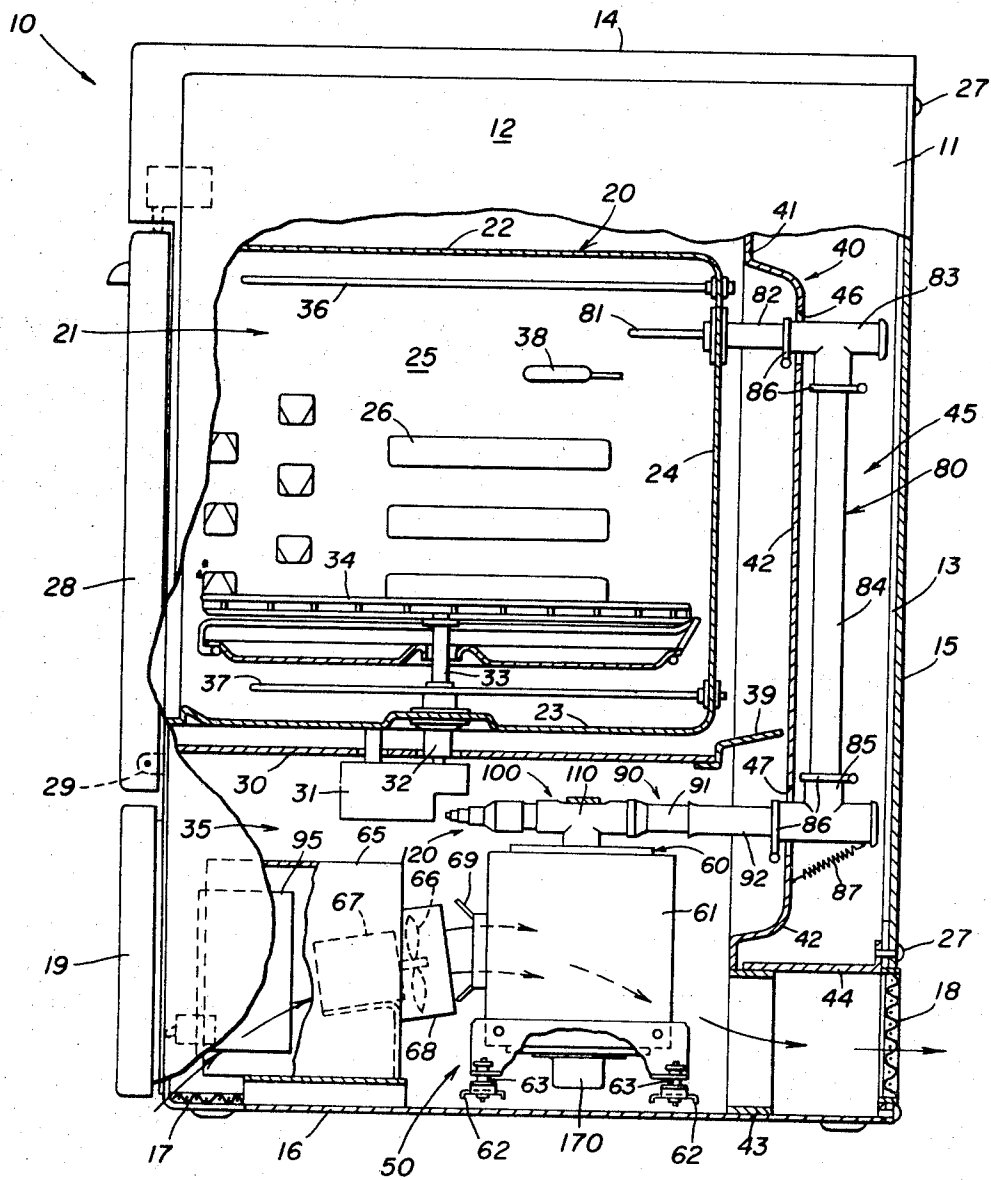


FIG. 2

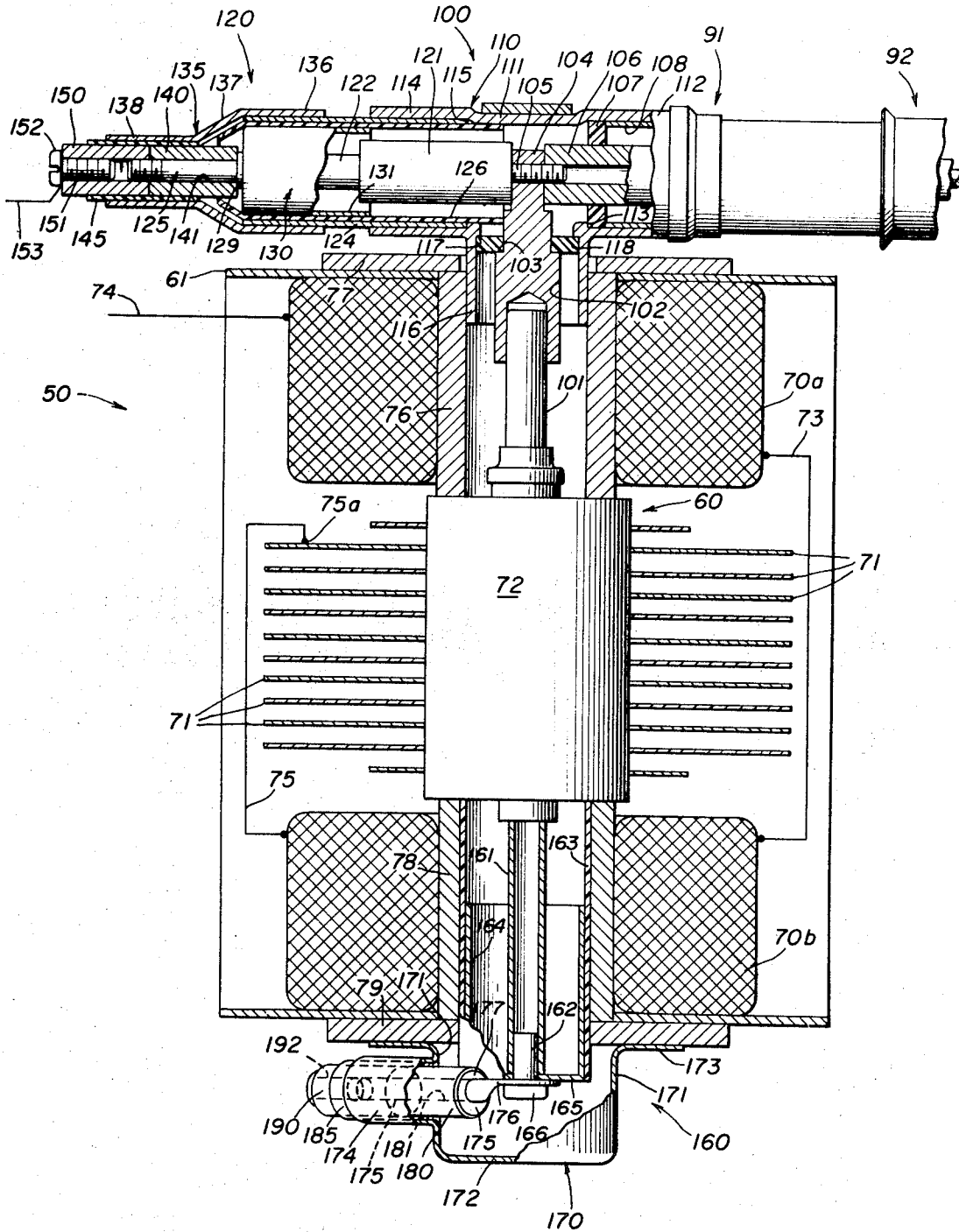


FIG. 3

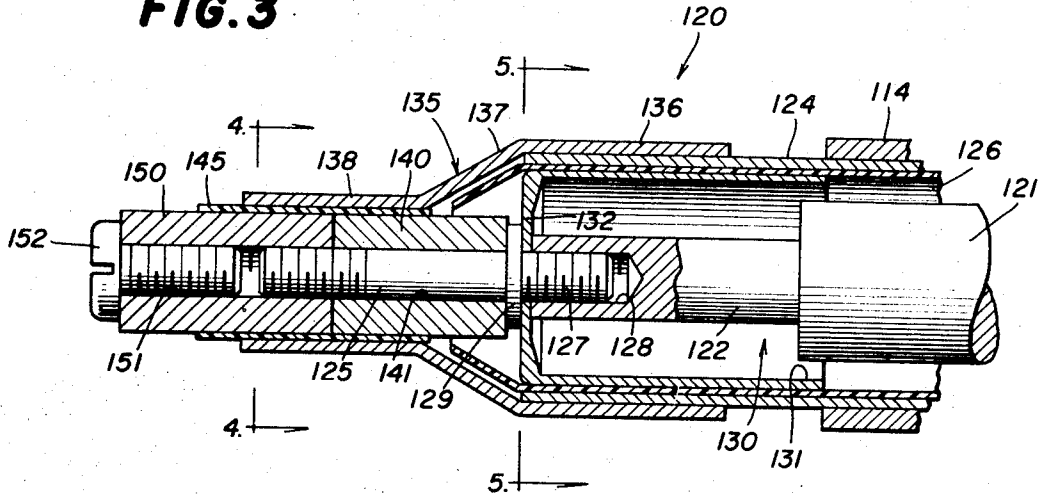


FIG. 4

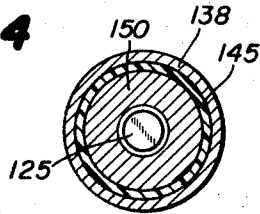


FIG. 5

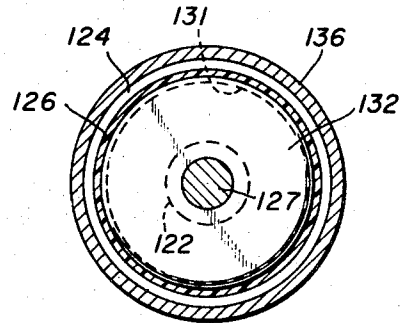


FIG. 6

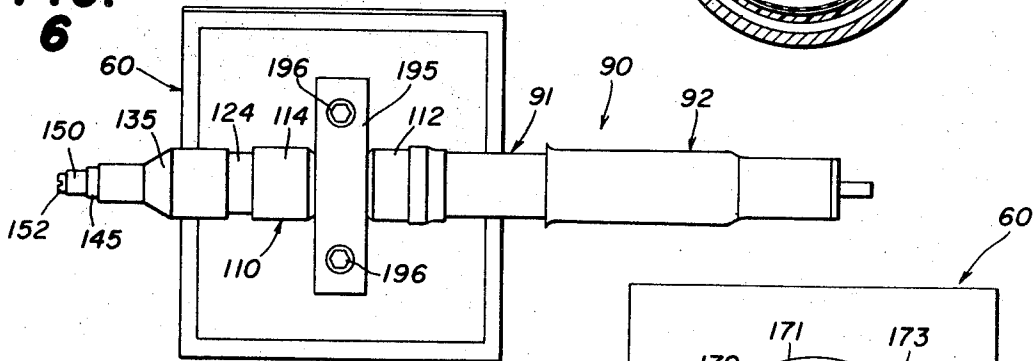
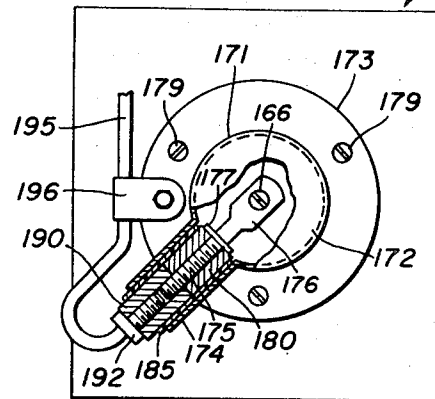


FIG. 7



ELECTRONIC OVEN WITH FERRITE RF REJECTION FILTERS

This application is a division of co-pending application Ser. No. 877,989, filed Nov. 19, 1969, now U.S. Pat. No. 3,626,135, issued Dec. 7, 1971, for ELECTRONIC OVEN WITH FERRITE RF REJECTION FILTERS.

This invention is concerned with an improved microwave coupling structure and an improved RF rejection filter therefore forming a part of an electronic oven.

More particularly, this invention concerns an improved microwave rejection filter for microwave coupling structure in an electronic oven.

It is a general object of this invention to provide an RF rejection filter of simple and economical construction and which affords high attenuation of the frequency of operation of the microwave generator in an electronic oven and also provides high attenuation of the harmonics of this frequency of operation up to and including the seventh harmonic.

It is an important object of this invention to provide a coupling structure for interconnecting a generator for generating RF energy of a predetermined ultrahigh RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC energy having at least one terminal, wherein the generator has an annular outer RF terminal and an inner RF terminal, the coupling structure comprising a hollow outer conductor coupled to the outer RF terminal of the generator and extending outwardly therefrom and terminating in an outer end, an inner conductor disposed in the outer conductor and coupled to the inner RF terminal of the generator and extending outwardly therefrom and terminating in an outer end adjacent to the outer end of the outer conductor, an insulating sleeve disposed within the outer conductor in surrounding relationship with the inner conductor, a pair of RF output terminals respectively coupled to the outer conductor and the inner conductor intermediate the generator RF terminals and the outer ends, means coupling the DC source terminal and the low frequency AC source terminal to the outer end of the inner conductor, a ferrite filter element disposed in the inner conductor intermediate the outer end thereof and the generator output terminals and being constructed and arranged to provide high transmission losses at selected harmonics of the predetermined frequency, and a conductive filter element disposed in the inner conductor adjacent to the outer end thereof and connected to the ferrite filter element and being constructed and arranged to cooperate with the insulating sleeve and the outer conductor for providing a low impedance bypass path between the inner and outer conductors at the predetermined frequency, whereby propagation of ultrahigh frequency energy at the predetermined frequency and selected harmonics thereof from the generator to the outer ends of the conductors is highly attenuated without interfering with the transmission of the DC operating potentials and the low frequency AC energy from the sources thereof to the generator.

In connection with the foregoing object, it is a further object of this invention to provide a coupling structure of the type set forth wherein the source of low frequency AC energy has a pair of terminals and the generator has a low frequency AC terminal, and further including a second hollow outer conductor coupled to the one output terminal of the generator and disposed

adjacent to the low frequency AC input terminal and extending outwardly therefrom and terminating in an outer end, a second inner conductor disposed in the second outer conductor and coupled to the low frequency AC input terminal of the generator and extending outwardly therefrom and terminating in an outer end adjacent to the outer end of the second inner conductor, a second insulating sleeve disposed within the second outer conductor in surrounding relationship with the second inner conductor, means coupling the other of the low frequency AC source terminals to the outer end of the second inner conductor, a second ferrite filter element disposed in the second inner conductor intermediate the outer end thereof and the generator low frequency AC input terminal and being constructed and arranged to provide high transmission losses at selected harmonics of the predetermined frequency, and a second conductive filter element disposed in the second inner conductor adjacent to the outer end thereof and connected to the second ferrite filter element and being constructed and arranged to cooperate with the second insulating sleeve and the second outer conductor for providing a low impedance bypass path between the second inner and outer conductors at the predetermined frequency, whereby propagation of ultra-high frequency energy at the predetermined frequency and selected harmonics thereof from the generator to the outer ends of the first and second conductors is highly attenuated without interfering with the transmission of the DC operating potentials and the low frequency AC energy from the sources thereof to the generator.

Yet another object of this invention is to provide a RF rejection filter for highly attenuating a predetermined ultrahigh frequency and selected harmonics thereof, the filter assembly comprising a coaxial transmission line section including a hollow outer conductor and an inner conductor disposed in the outer conductor, a ferrite filter element disposed in the inner conductor and being constructed and arranged to provide high transmission losses at selected harmonics of the predetermined frequency, a conductive filter element disposed in the inner conductor and connected to the ferrite filter element and being constructed and arranged to provide a low impedance bypass path between the inner and outer conductors at the predetermined frequency, and an insulating sleeve disposed between the filter elements and the outer conductor, the filter elements cooperating with each other and with the inner and outer conductors to form a filter for highly attenuating the predetermined frequency and selected harmonics thereof.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof will best be understood by reference to the following specification taken together with the accompanying drawings, in which:

FIG. 1 is a side elevational view of an electronic heating apparatus made in accordance with and embodying the principles of the present invention with the sidewall partly broken away to show the internal components;

FIG. 2 is an enlarged fragmentary view in vertical section of a crossed-field discharge device forming a part of the generator for the heating apparatus of FIG. 1;

FIG. 3 is a further enlarged fragmentary sectional view of the left-hand end of the microwave coupling structure shown in FIG. 2;

FIG. 4 is a sectional view taken along the line 4—4 in FIG. 3;

FIG. 5 is a sectional view taken along the line 5—5 in FIG. 3;

FIG. 6 is a reduced top plan view of the crossed-field discharge device and microwave coupling structure shown in FIG. 2; and

FIG. 7 is a bottom plan view of the crossed-field discharge device shown in FIG. 2 with the RF rejection filter shown in cross section.

Referring now to FIG. 1 of the drawings, the electronic heating apparatus 10 there illustrated, and embodying the features of the present invention, is in the form of a combination electric and electronic range that is especially designed for home use. More particularly, the range 10 comprises an upstanding substantially box-like casing 11 formed of steel and including a pair of side walls 12, a rear wall 13 having a removable closure member or panel 15 disposed therein, and a top wall 14 and a bottom wall 16, the removable panel 15 being removably held in place by a plurality of screws 27. The casing 11 houses in the upper central portion thereof a metal liner 20 defining a heating or cooking cavity 21 therein, the metal liner 20 preferably being formed of steel, and essentially comprising a box-like structure provided with a top wall 22, a bottom wall 23, a rear wall 24, and a pair of opposed side walls 25; whereby the liner 20 is provided with an upstanding front opening into the heating cavity 21 defined therein. Further, the casing 11 is provided with a front door 28 arranged in a front opening formed therein and cooperating with the front opening provided in the liner 20, the front door 28 being mounted adjacent to the lower end thereof upon associated hinge structure 29; whereby the front door 28 is movable between a substantially vertical closed position and a substantially horizontal open position with respect to the front opening provided in the liner 20.

An electric heating unit 36 is arranged in the upper portion of the heating cavity 21 adjacent to and below the top wall 22, and an electric heating unit 37 is arranged in the lower portion of the heating cavity 21 adjacent to and above the bottom wall 23; which electric heating units 36 and 37 are utilized in the carrying out of conventional baking and broiling cooking operations in the heating cavity 21, as explained more fully hereinafter. Also, a temperature sensing bulb 38 is arranged in a pocket provided in one of the side walls 25; which temperature sensing bulb 38 forms a part of an oven switch and temperature controller and is utilized in carrying out the previously mentioned conventional baking and broiling operations in the heating cavity 21. The side walls 25 of the liner 20 further carry thereon a plurality of shelf supports 26 for the supporting of shelves (not shown) that in turn support items to be cooked within the heating cavity 21. There also is provided below the front door 28 a lower front panel 19 that closes a front opening in the lower portion of the casing 11, the bottom wall 16 further being provided with a reticulated member or screen 17 and the lower portion of the rear wall 13 being provided with a reticulated member or screen 18, the screens 17 and 18 permitting the passage of air through the lower portion of

the casing 11 to cool the electronic apparatus therein as will be described more fully hereinafter.

Disposed below the liner 20 and spaced therefrom is a generally horizontally arranged lower baffle 30 extending laterally across the casing 11 between the side walls 12 thereof and extending rearwardly from the front of the casing 11 to a point spaced forwardly of the rear wall 13, the baffle 30 in cooperation with the casing 11 defining a bottom machinery compartment 35 in the lower portion of the casing 11, the lower front panel 19 being removable to provide access to the bottom machinery compartment 35.

Mounted on the underside of the baffle 30 is an electric motor 31 having an output drive shaft 32 including a reduced portion 33 extending upwardly into the liner 20 and supporting thereon a turntable 34 formed of perforated sheet metal and arranged in the lower portion of the heating cavity 21. The turntable 34 is mounted for rotation and upon operation of the motor 31 is adapted to support food to be heated or cooked in the electronic operation that is carried out in the heating cavity 21, as explained more fully hereinafter. The motor 31 has an associated gear train (not shown) that reduces the speed of the shaft 33 to approximately 6 r.p.m.

A rear baffle 40 is provided to the rear of the liner 20 and extends across the casing 11 between the side walls 12 thereof, the baffle 40 including a main wall 41 carrying centrally thereof a rearwardly offset wall 42 that is in general horizontal alignment with the rear of the liner 20 and spaced rearwardly therefrom. Disposed in the lower portion of the main wall 41 is an opening around which is disposed a flange 43 connecting with an air duct 44 that communicates with the screen 18 in the rear wall 13 of the casing 11. It further will be noted that the bottom baffle 30 carries on the rear thereof an upwardly and rearwardly extending baffle section 39 that extends toward the offset wall 42 but is spaced therefrom, the baffles 30 and 40 being formed of metal, such as steel, whereby the spacing between the baffle section 39 and the rear baffle 40 minimizes the conduction of heat therebetween during the operation of the range 10. The rear baffle 40 cooperates with the casing 11 to provide a rear machinery compartment 45, the rear machinery compartment 45 being disposed behind the liner 20 and access thereto being provided through the removable panel 15 that covers the opening in the rear wall 13 described above.

There is arranged to the right (as viewed in FIG. 1) of the bottom machinery compartment 35 a generator, generally designated by the numeral 50, for supplying ultra-high frequency electromagnetic wave energy for electronic cooking within the cooking cavity 21, the generator 50 including a crossed-field electron discharge device, generally designated by the numeral 60, of the construction and arrangement disclosed in the copending application of James E. Staats, Ser. No. 559,267, filed June 21, 1966, now U. S. Pat. No. 3,458,755. Referring to FIGS. 1 and 2 of the drawings, it will be seen that the device 60 is disposed within a box-like structure or casing 61 that extends completely about the device 60 but is open on two opposed sides thereof, the sides disposed to the left and right in FIG. 2, the device 60 and the associated parts therefor being mounted within and electrically connected to the casing 61. As will be explained more fully hereinafter, high operating DC potentials are present on the casing 61,

whereby it is desirable electrically to isolate and shield the casing 61, and to this end a pair of mounting rails 62 are provided in the bottom of the machinery compartment 35 for supporting the device 60 and the casing 61. The mounting rails 62 each carry a pair of insulators 63 adjacent to the opposite ends thereof, the casing 61 being mounted on the insulators 63 by a pair of angle brackets 64, only one of which is shown, which span the mounting rails 62 adjacent to the ends thereof. Thus, the casing 61 is insulated from the mounting rails 62 and from the casing 11.

As viewed in FIG. 1, the mounting rails 62 and the casing 61 mounted thereon are disposed to the rear of the bottom machinery compartment 35, and are disposed to the right within the bottom machinery compartment 35 when the range 10 is viewed from the front. In order to provide cooling air for passage across the device 60, there has been provided an open ended housing 65 disposed to the left in FIG. 1 or in front of the casing 61 and housing therein at least a part of a voltage doubler and rectifier circuit 95 that supplies DC operating potentials to the device 60 and also houses therein a fan 66 powered by a motor 67 within the housing 65. An air duct 68 is provided about the fan 66 to direct air therefrom into a cooperating air duct 69 mounted on the casing 61, the ducts 68 and 69 cooperating to facilitate direction of the air stream over the device 60. More specifically, the fan 66 operates to draw air through the screen 17 at the bottom of the machinery compartment 35, the air being formed into a stream by the housing 65, and passed over the rectifier 95, the motor 55 and through the air ducts 68 and 69 into the casing 61; the air stream within the casing 61 passes about the device 60 and cooling fins 71 disposed thereon and passes therefrom and into the air duct 44 to be discharged through the screen 18 in the rear wall 13 of the casing 11.

In accordance with the present invention, the air stream generated by the fan 66 is used to cool all of the various parts of the generator 50, and specifically the crossed-field discharge device 60 and the voltage doubler and rectifier circuit 95 associated therewith. To this end the housing 65 and the air ducts 68 and 69 and the air duct 44 have been provided so as to concentrate the air stream upon the parts noted, all while attempting to deflect the air stream away from the baffles 30 and 40. The baffles 30 and 40 further protect the liner 20 and the cooking cavity 21 disposed therein from the air stream thus generated so as to maintain more uniform cooking conditions within the cooking cavity 21 and thus to improve the cooking therein.

Referring now particularly to FIG. 2 of the drawings, the generator 50 there illustrated will be described in greater detail. An electron discharge device 60 is contained within a substantially cylindrical metal envelope 72 and includes anode and cathode structure (not shown). Surrounding the envelope 72 and connected thereto is a plurality of cooling fins 71 for dissipating heat from the device 60 as explained above. In order to establish a unidirectional magnetic field within the device 60, there is provided a composite magnetic field winding 70a and 70b disposed at the upper and lower ends of the device 60 and connected in series relation by a conductor 73. A DC operating potential from the voltage doubler and rectifier 95 is applied to the winding 70a by a conductor 74, and from the winding 70b to the device 60 by a conductor 75 which is connected

to one of the cooling fins 71 as at 75a. Further details of the construction and operation of the device 60 are disclosed in the previously mentioned Staats application Ser. No. 559,267, now U. S. Pat. No. 3,458,755, the disclosure of which is incorporated herein by reference.

The generator 50 is arranged to be advantageously operated in connection with suitable control and power supply apparatus, details of the construction and operation of which are disclosed in the copending U.S. applications of James E. Staats, Ser. No. 656,977, filed June 12, 1967, now U. S. Pat. No. 3,421,115; and Ser. No. 181,144, filed Mar. 20, 1962; and in the copending U. S. application of James E. Staats and Robert D. Ogburn, Ser. No. 676,584, filed Oct. 19, 1967, and now U. S. Pat. No. 3,445,784, the disclosures of all of which applications are incorporated herein by reference.

The crossed-field discharge device 60 is provided with a magnet yoke 76 at the upper end thereof which connects to the anode of the device 60 (not shown) and forms an outer conductor and an output terminal for the device 60, the lower end of the magnetic yoke 76 being more particularly connected to the anode of the device 60 and the upper end extending upwardly through the field winding 70a and being connected to a magnet flange 77. The lower end of the device 60 is likewise provided with a magnet yoke 78 having the upper end thereof connected to the anode of the device 60 and the other end extending downwardly through the field winding 70b and being connected at the lower end to a magnet flange 79. The cathode of the device 60 (not shown) has connected thereto a stud 101 forming a part of an upper coupling structure 100, the stud 101 and the magnet yoke 78 forming a coaxial output connection for the device 60.

The device 60 is operative to supply ultrahigh frequency energy of about 915 mc, with a power output at the output terminals in the general range 50 to 800 watts. The device is arranged to supply the RF power for cooking and to this end a lower transmission line, generally designated by the numeral 90, extends from the device 60 and is coupled to an upper transmission line, generally designated by the numeral 80, which extends to the cooking cavity 21, the transmission lines 80 and 90 being of the coaxial type including an inner conductor and an enclosing outer conductor electrically insulated therefrom. Both of the output terminals of the device 60 are at a substantial DC voltage with respect to ground potential, so that the output terminals are electrically insulated from ground potential, as well as from each other. One of the output terminals is coupled by a capacitor (not shown) to the adjacent end of the outer output conductor, and the other output terminal is coupled by a capacitor (not shown) to the adjacent end of the inner output conductor, the remote end of the inner conductor projecting as an antenna 81 into the oven cavity 21. The remote end of the outer conductor is electrically connected to the metal liner 20. Thus the RF power produced by operation of the device 60 is radiated from the antenna 81 into the cooking cavity 21, so as to produce cooking effects upon food arranged therein, all in a conventional manner.

The antenna 81 is essentially a rod connected at one end thereof to the inner conductor of the upper transmission line 80, the antenna 81 extending into the cavity 21 a short distance below the top wall 22 and essen-

tially midway between the side walls 25, as shown in FIG. 1. A top coaxial transmission line section 82 of the upper transmission line 80 is disposed adjacent to the antenna 81, the inner conductor of the transmission line section 82 being connected to the antenna 81 and the outer conductor of the transmission line section 82 being connected to the rear wall 24 of the cooking cavity liner 20. The rear end of the transmission line section 82 is received in the forward arm of a tee 83 in telescopic relationship therewith, the rear arm of the tee 83 carrying on the outer end thereof a dust cover that serves to close the same to prevent the entry of dust, dirt, and water or the like into the interior of the tee 83. It further is pointed out that the forward arm of the tee 83 extends through an opening 46 in the baffle wall 42, whereby the major portion of the tee 83 is disposed to the rear of the baffle wall 42 and thus in the rear machinery compartment 45, whereby the tee 83 is accessible for service and maintenance through the removable panel 15. A rear coaxial section 84 for the upper transmission line 80 is disposed in the rear machinery compartment 45, the upper end of the section 84 extending into the lower arm or leg of the tee 83 in telescopic relationship therewith. The inner conductors of the transmission line sections 82 and 84 are connected together within the tee 83, preferably by means of a screw (not shown). The lower end of the rear transmission line section 84 is received in the upper arm or leg of a tee 85 in telescopic relationship therewith. The rear arm of the tee 85 preferably carries at the outer end thereof a dust cover similar to the dust cover on the tee 83, the forward arm of the tee 85 extending through an opening 47 in the baffle wall 42 and receiving therein a telescopic relationship therewith the rearward end of the lower transmission line 90. Preferably, clamps 86 are provided around the arms of the tees 83 and 85 coupled to the various sections of the transmission lines 80 and 90, these arms preferably being slotted (not shown) whereby tightening of the associated clamps 86 serves to tighten the arms about the associated ends of the respective transmission lines 80 and 90 to hold the parts in the assembled telescoping positions. The inner conductor of the coaxial transmission line 90 is connected to the inner conductor of the rear section 84 of the upper transmission line 80 within the tee 85, preferably by a screw (not shown).

Both the inner and outer conductors of the lower transmission line 90 are divided into forward and rearward sections 91 and 92, respectively, separated from each other by insulating sleeves (not shown) to provide the capacitive coupling between the generator 50 and the oven liner 20 to prevent the high DC potentials existing at the output terminals of the generator 50 from existing on the oven liner 20 or the casing 11. Preferably, the forward end of the outer conductor of the rear section 92 is flared to facilitate reception thereof into the rearward end of the forward section 91. The rear section of the inner conductor is similarly flared (not shown). Further, a plurality of microwave filters (not shown) are provided in the lower transmission line 90 for highly attenuating the harmonics of the frequency of operation of the device 60 and preventing propagation of these harmonics to the oven cavity 21. Details of the construction and operation of the transmission lines 80 and 90 are disclosed in the copending U. S. application of James E. Staats, Ser. No. 788,204, filed Dec. 31, 1968 and now U.S. Pat. No. 3,511,958, the

disclosure of which application is incorporated herein by reference.

An upper coupling structure, generally designated by the numeral 100, is provided at the upper end of the device 60 for coupling the terminals thereof to the lower transmission line 90 and to the voltage doubler and rectifier power supply 95. The forward end of the lower transmission line 90 is coupled to the crossed-field discharge device 60 by means of a tee 110, the tee 110 including a body 111 having a pair of arms 112 and 114 and a leg or arm 116 each provided with a cooperating internal seat or shoulder 113, 115 and 117, respectively. More particularly, the leg 116 is positioned downwardly and is telescopically received in the upper end of the magnet yoke 76 for coupling thereto, the tee 110 forming a part of the upper coupling structure 100. Also forming a part of the upper coupling structure 100 is a bullet 102 receiving into the lower end thereof the stud 101 that is coupled to the cathode of the device 60, the bullet 102 having a shoulder 103 thereon that cooperates with the shoulder 117 to hold in operative position an insulator 118 that serves a center the bullet 102 with respect to the leg 116. The upper end of the bullet 102 carries an internally threaded eye 104 through which is threadedly inserted a stud 105, one end of the stud 105 being threadedly received in a complementarily threaded opening in an inner conductor 106 of the transmission line 90, thereby to support the forward end thereof, there also being provided therearound a supporting insulator 107. The forward end of the outer conductor 108 of the transmission line 90 is telescopically received within the leg 112 and is spaced a short distance away from the shoulder 113, thereby to clamp the insulator 107 in the operative position therebetween. Preferably the forward end of the outer conductor 108 is fixedly secured as by soldering to the arm 112.

A decoupling structure, generally designated by the numeral 120, is carried by the other arm 114 of the tee 110, and more particularly comprises an inner conductor 121 having a rearward end connected to the forward end of the stud 105 by means of a threaded connection therebetween, the inner conductor 120 having a reduced forward portion 122. Fixedly mounted on the arm 114 and telescopically received therein is an outer conductor 124 within which is disposed an insulating sleeve 126. The outer conductor 124 and the sleeve 126 both extend outwardly beyond the outer end of the inner conductor 121. A cylindrical inner conductor 125 having an outer diameter slightly less than the outer diameter of the reduced forward portion 122 of the inner conductor 121, is disposed forwardly of the inner conductor 121 along the longitudinal axis thereof. The inner conductor 125 is externally threaded adjacent to each end thereof and is provided intermediate the ends thereof with a radially outwardly extending circular bearing flange or collar 129. The rearward end 127 of the inner conductor 125 is threadedly engaged with a complementarily threaded opening 128 in the outer end of the reduced diameter forward portion 122 of the inner conductor 121. Disposed within the insulating sleeve 126 is a cup-like inner conductor 130 having a cylindrical side wall 131 surrounding the reduced portion 122 of the inner conductor 121 and having an outer end closed by an end wall 132 which abuts the reduced portion 122 of the inner conductor 121 at the outer end thereof, the threaded por-

tion 127 of the inner conductor 125 passing through an opening in the wall 132.

Connected to the outer end of the outer conductor 124 in coaxial surrounding relationship with the inner conductor 125 is a hollow cylindrical outer conductor 135 including a relatively large diameter inner section 136, a relatively small diameter outer section 138 and a tapered section 137 interconnecting the inner and outer sections 136 and 138. The outer end of the outer conductor 124 is disposed within the large diameter inner section 136 of the outer conductor 135 in telescoping relationship therewith and is preferably fixedly secured thereto as by clamping. The outer end of the insulating sleeve 126 extends outwardly beyond the end of the outer conductor 124 and into the tapered section 137 of the outer conductor 135 and is shaped conformably therewith. Mounted on the outer end of the inner conductor 125 is a cylindrical ferrite member 140 having an opening 141 extending axially there-through for receiving therein the threaded outer end of the inner conductor 125 whereby the filter member 140 is mounted on the inner conductor 125 in surrounding relationship therewith. In its assembled position, the inner end of the ferrite member 140 abuts against the bearing flange 129 on the inner conductor 125 and the outer end of the ferrite member 140 extends into the reduced diameter portion 138 of the outer conductor 135. Disposed outwardly of the ferrite member 140 and adjacent thereto is a cylindrical metal slug 150 having an internally threaded opening 141 extending axially therethrough for receiving therein and threadedly engaging with the threaded outer end of the inner conductor 125 for mounting the slug 150 thereon in surrounding relationship therewith. In use, the metal slug 150 is threaded onto the inner conductor 125 until it abuts against the outer end of the ferrite member 140 for holding the ferrite member 140 in its assembled position against the bearing flange 129. Disposed within the reduced diameter section 138 of the outer conductor 135 in surrounding relationship with the ferrite member 140 and the metal slug 150 is an insulating sleeve 145. A terminal screw 152 is preferably received in the outer end of the internally threaded opening 151 of metal slug 150 forming a terminal for connecting a power supply lead 155 thereto.

Because of the effective filtration of harmonics of the operating frequency of the device 60 in the lower transmission line 90, it is necessary that these harmonics, as well as the frequency of the operation itself, be effectively filtered in the coupling structure 120 described above to prevent their propagation to the Edison supply network and to the voltage doubler and rectifier circuit 95. To this end, the cup-like inner conductor 130 cooperates with the inner conductor 121 to define a cavity having an effective electrical length equal to one quarter of the wavelength of the frequency of operation of the device 60 and being resonant thereat to provide a high-series impedance for the transmission of this frequency along the conductors 121 and 124. The conductors 121 and 124 cooperate with each other and with the insulating sleeve 126 to provide a capacitive low-impedance bypass path therebetween for the second harmonic of the frequency of the operation of the device 60. Similarly, the cuplike inner conductor 130 cooperates with the outer conductor 124 to provide therebetween a low impedance bypass path at the third

harmonic of the frequency of operation of the device 60.

In effect, the inner conductor 121, the outer conductor 124 and the cuplike conductor 130 are so arranged and dimensioned that there is provided along the inner conductor 121 capacitive loading on the second harmonic of the frequency of operation of the device 60. There is also provided at the inner end of the inner conductor 121 an open circuit reflection at the frequency of operation of the device 60 between the inner conductor 121 and the outer conductor 124; there is provided at the inner end of the cup-like conductor 130 a short circuit reflection at the third harmonic of the frequency of operation of the device 60 between the conductors 130 and 124. Accordingly, the above described RF filters provide high attenuation of the frequencies of operation of the device 60 and of the second and third harmonics thereof to minimize the propagation of RF energy to the Edison supply network and to the voltage doubler and the rectifier circuit 95.

However, to insure that there is no appreciable RF leakage to the power supply circuitry, additional rejection filters are preferably provided in the decoupling structure 120. To this end, the ferrite member 140 and the metal slug 150 are provided in order to improve filtration of the frequency of the operation of the device 60 and the harmonics thereof and further to extend the effective range of this filtration over a band of frequencies including all harmonics up to the seventh harmonic. In operation, the ferrite member 140 acts like a section of lossy transmission line in the coaxial mode at frequencies above the frequency of operation of the device 60, thereby producing high attenuation of the harmonics of the frequency of operation of the device 60, the attenuation increasing with frequency. Preferably, the outer diameter of the ferrite member 140 is such as to produce high attenuation of all harmonics up to the seventh harmonic of the frequency of operation. The metal slug 150 preferably has an outer diameter substantially equal to the outer diameter of the ferrite element 140 for ease of manufacture, this outer diameter being such that both the ferrite element 140 and the metal slug 150 will operate in the coaxial mode, yet allow for cooperation between the metal slug 150 and the outer conductor 135 to provide a low-impedance capacitive bypass path therebetween at the frequency of operation of the device 60.

Thus, in essence, the outer portion of the decoupling structure 120 includes the inner conductor 125, the reduced diameter portion 138 of the outer conductor 135, the insulating sleeve 145, the ferrite member 140 and the metal slug 150, all cooperating to form an RF rejection filter which operates like a lossy transmission line terminated by a capacitive reactance, the capacitive reactance providing a low impedance shunt path for the frequency of operation of the device 60 and the lossy line providing high attenuation of the harmonics of that frequency up to the seventh harmonic. It is necessary for this purpose that the decoupling structure 120 operate in the coaxial mode, whereby it is essential that the outer diameter of the metal slug 150 and the ferrite member 140 be maintained below a predetermined upper limit at which they will begin to operate in a wave guide mode thereby propagating the harmonics of the frequency of operation. Further, the outer diameter of these filter elements must be maintained above a predetermined lower limit at which the metal

slug 150 will cease to provide a capacitive coupling to the outer conductor 135 for the frequency of operation of the device 60. Thus, in order to achieve the desired results, it is necessary that the outer diameters of the metal slug 150 and the ferrite member 140 be small enough to insure coaxial mode operation to provide good filter response at RF frequencies including all harmonics up to the seventh harmonic, but large enough to provide a good capacitive loading by the metal slug 150. Constructional models of the RF rejection filter formed by the ferrite member 140 and the metal slug 150 according to this invention have produced attenuation values in excess of 50 DB per inch above 5 GHz.

A lower coupling structure, generally designated by the numeral 160, is connected at the lower end of the device 60. A tube 161 is disposed within the magnet yoke 78, coaxial therewith, and is connected at the upper end thereof to one end of the heater of the device 60 (not shown) and serves as an inner conductor of a coaxial transmission line, the lower end of the tube 161 carrying an internally threaded insert 162 therein. The outer conductor of this coaxial transmission line is provided by the magnet yoke 78. Disposed within and essentially lining the magnet yoke 78 is a sleeve 163 of electrically insulating material, an inner conductor 164 being disposed against the inner surface of sleeve 163 and telescopically overlapping a portion of the yoke 78 and having the outer end thereof closed by an end wall 165, the end wall 165 having an opening therethrough for receiving the shank of a screw 166 that engages in the complementarily threaded opening in the insert 162. The yoke 78, the tube 161, the insulating sleeve 163, the inner conductor 164 and the end wall 165 cooperate to provide a parallel resonant circuit including an inductive impedance and a capacitive impedance, the structure comprising a high impedance to RF energy to prevent propagation thereof from the terminal 166 to the power supply lead. More specifically, the distance between the lower adjacent end of the anode of the device 60 and the inner surface of the end wall 165 is equivalent to a quarter wavelength at the operating frequency of the device 60, and the yoke 78 and the inner conductor 164 telescopically overlap a distance equivalent to one-eighth wavelength at the operating frequency of the device 60.

Disposed at the lower end of the device 60 is a conductive cap or cover, generally designated by the numeral 170, having a cylindrical side wall 171 disposed substantially concentric with the magnet yoke 78 and surrounding the outer ends of the conductor 164 and the insulating sleeve 163 and being closed at the lower end thereof by an end wall 172. Extending outwardly from the upper end of the cylindrical side wall 171 substantially normal thereto is an attachment flange 173 attached to the outer surface of the magnet flange 79 by suitable fastening means such as screws 179. Extending outwardly from the side wall 171 substantially normal thereto is a hollow cylindrical outer conductor 174 communicating with the interior of the cover 170 through a complementarily shaped opening in the side wall 171. A generally cylindrical inner conductor 175 is disposed in the outer conductor 174 and extends into the interior of the cover 170, the inner conductor 175 having an externally threaded outer end and having a flattened inner end 176 having an opening therethrough for receiving the terminal screw 166 whereby the inner conductor 175 is securely fastened to the end

wall 165 of the conductor 164. The inner conductor 175 is provided with a circular bearing flange 177 extending radially outwardly therefrom intermediate the ends thereof. Disposed within the tube 174 is a cylindrical ferrite element 180 having an opening 181 extending axially therethrough for receiving therein the externally threaded inner conductor 175 whereby the ferrite element 180 is mounted on the inner conductor 175 in surrounding relationship therewith. Preferably, when assembled on the inner conductor 175, the inner end of the ferrite member 180 abuts against the bearing flange 177. Also coupled to the outer end of the inner conductor 175 and disposed within the tube 174 is a cylindrical metal slug 190 having an internally threaded opening extending axially therethrough for receiving therein and threadedly engaging with the outer end of the externally threaded outer conductor 175 whereby the metal slug 150 is securely mounted on the inner conductor 175 in surrounding relationship therewith. When assembled on the inner conductor 175, the inner end of the metal slug 190 abuts against the outer end of the ferrite member 180, thereby holding the ferrite member 180 in the assembled position against the bearing flange 177. Disposed within the tube 174 in surrounding relationship with the slug 190 and the ferrite member 180 is an insulating sleeve 185. A terminal screw 192 has the shank thereof received within the outer end of the internally threaded opening 191 in the metal slug 190 providing a filament terminal for the device 60 for connection of a lead 195 from the source of low frequency AC operating potentials. The lead 195 may be held against the underside of the device 60 by means of a clamp 196 (see FIG. 7) to prevent interference with other parts of the electronic oven apparatus. In operation, the inner conductor 175, the outer conductor 174, the ferrite member 180, the metal slug 190 and the insulating sleeve 185 cooperate to form an RF rejection filter for the frequency of operation of the device 60 and the harmonics thereof up to the seventh harmonic for preventing the propagation of RF energy to the power supply circuitry over the lead 195. This filament lead rejection filter is identical in operation to the rejection filter formed by the conductors 125 and 135, the insulator 126, the ferrite member 140 and the metal slug 150 in the coupling structure 120 in the cathode lead of the device 60, whereby the detailed description of the operation of this filament lead filter will not now be repeated.

In a constructional example of an RF rejection filter constructed in accordance with the present invention, the inner conductors 125 and 175 were made of nickel-plated brass or aluminum alloy and were approximately 1.3 inches in length and had a diameter of approximately 0.15 inch, the bearing flanges 129 and 177 having a diameter of approximately 0.38 inch; the outer conductor 135 was formed of copper and had an overall length of approximately 1.75 inches, the reduced diameter section 138 having an inner diameter of approximately 0.463 inch and the section 136 having an inner diameter of approximately 0.879 inch; the outer conductor 174 has an inner diameter of approximately 0.46 inch and is also formed of nickel-plated steel; the insulating sleeves 145 and 185 are formed of a polytetrafluoroethylene resin such as that sold under the trademark "Teflon;" the ferrite members 140 and 180 are formed of a suitable ferrite material and have a length of approximately 1 inch, an outer diameter of

approximately 0.38 inch and an inner diameter of approximately 0.15 inch; the metal slugs 150 and 190 were formed of an aluminum alloy and had a length of approximately 0.75 inch, an outer diameter of approximately 0.438 inch and an inner diameter of approximately 0.15 inch.

In the transmission line 90, the bullet 102, the tee 110, the inner conductor 106 and the tube 108 are shaped and arranged to provide a quarter wave transformer section at the frequency of operation of the device 60. More particularly, the shouldered portions of the bullet 102 and the conductor 106, and the filter members in the transmission line 90 have dimensions such that the impedance of the device 60 is matched to the impedance of the transmission lines 80 and 90 that is in turn matched to the impedance of the heating cavity 21. Likewise, the bullet 102, the inner conductor 121, the outer conductor 124 and the inner conductor 130 are all shaped and arranged to provide a quarter wave transformer section that assists in decoupling RF energy from the input terminal 152 to prevent the propagation of RF energy into the power supply. It is noted that the stepped configuration of the inner conductor 121 permits a shorter mechanical connection while maintaining an electrical characteristic equivalent to one-quarter wavelength of the operating frequency of the device 60.

Because the potentials for operating the device 60 are derived from the voltage doubler and rectifier circuit 95, neither the stud 101 forming the inner conductor or any of the parts such as the yoke 76 and the tee 110 forming the outer conductor of the coupling structure 100 can be grounded. However, it is highly desirable to ground the portion of the transmission line 80 disposed to the rear of the rear baffle 40, and to this end capacitive couplings have been provided between the rear lower transmission line section 92 and the front lower transmission line section 91, all as described in detail in the aforementioned copending U. S. application Ser. No. 788,214. Accordingly, the outer conductor of the rear transmission line section 92 can be grounded as on the casing 11 and the baffle member 40, thereby to present only grounded parts to workmen gaining access to the rear machinery compartment 45 through the removable panel 15.

It is noted that the front panel 19 of the electronic heating apparatus 10 is preferably removable. Due to the telescoping arrangement of the lower transmission line portions, the device 60 and the front portion 91 of the transmission line 90 may be easily disengaged from the rear portion 92 of the transmission line 90 and removed from the lower machinery compartment 35 through the front end thereof. Thus, the electron discharge device is readily accessible from the front of the range for easy servicing.

It further is pointed out that the tee 83, the entire rear transmission line section 84, the tee 85 and the rear lower transmission line section 92 form a removable transmission line assembly that can be bodily moved rearwardly through the opening provided by the removable panel 15 for maintenance and repair of the parts. Such movement of the transmission line assembly rearwardly is accomplished by simply loosening the clamps 86, about the forward or inner legs of the tees 83 and 85 which frees the tees 83 and 85 respectively from the transmission line sections 82 and 92 and removing the screws holding the inner conductors of the

line sections 82, 84 and 92 together. Due to the telescoping arrangement of the lower transmission line portions 91 and 92, there is no need to remove or disconnect any parts other than by the relative sliding movement of the portions 91 and 92 with respect to each other. Reassembly of the parts is facilitated by the flared ends on the outer conductor and the inner conductor of the transmission line section 91, respectively. It further is necessary to hold the removable transmission line assembly in the assembled position, and to this end a spring 87 under tension has been provided interconnecting the tee 85 and the baffle wall 42, thus continually to urge the removable transmission line assembly into the assembled operative position.

Another important feature of the transmission lines 80 and 90 resides in the fact that the tubes forming the inner and outer conductors thereof can all be formed essentially of standard tubing shaped as required and cut to length, the tubing preferably being formed of copper, brass or other good electrically conductive metal. The tees 83, 85 and 110 are also of standard configuration and are all identical one to the other, the tees preferably being formed of copper, brass or other material having good electrical conductivity. Finally, the insulators 126 and 145 are preferably all formed of a polytetrafluoroethylene resin such as that sold under the trademark "Teflon."

From the above it will be seen that the liner 20 is effectively isolated from the bottom machinery compartment 35 and the rear machinery compartment 45 by the baffle members 30 and 40, respectively, thereby to provide a more uniform distribution of heat within the liner 20 and thus to permit good cooking therein. The entire generator 50, including the crossed-field discharge device 60 and the voltage doubler and rectifier circuit 95 therefor, are housed within the bottom machinery compartment 35 which provides a protecting housing therefor. The fan 66 serves to cool all of the electrical components of the generator 50 by drawing air inwardly through the screen 17 into the bottom machinery compartment 35 and across the crossed-field discharge device 60 and outwardly through the screen 18. The stream of air thus created is effectively prevented from coming into contact with the liner 20 due to the presence of the baffle member 30 and 40. Also, the improved coupler structure and transmission line 90 has been provided, the major portion of which can be readily removed from the assembled relation with the liner 20 and the device 60 for repair and service purposes through the removable panel 15, and can thereafter be readily reassembled therewith.

Also, RF filters for filtering the frequency of operation of the device 60 and the harmonics thereof up to the seventh harmonic, have been provided in the coupling structure 120 between the device 60 and the Edison supply network and the voltage doubler and rectifier circuit 95 to prevent propagation of RF energy thereto while not interfering with the transmission of the DC and low frequency AC operation potentials, therefrom to the device 60.

More particularly, there has been provided an improved RF rejection filter adaptable for use both in the cathode lead and the filament lead of a crossed-field electron discharge device. Referring to the cathode lead application of the improved rejection filter, this filter includes the inner conductor 125, the outer conductor 135, the ferrite member 140, the metal slug 150

and the insulating sleeve 145, all cooperating to provide high attenuation for the frequency of operation of the device 60 and all harmonics thereof up to the seventh harmonic for preventing the propagation of these frequencies to the voltage doubler and rectifier 95 and the source of low frequency AC operating potentials for the device 60 over the lead 155. Referring to the filament lead application, this improved rejection filter includes the inner conductor 175, the outer conductor 174, the ferrite member 180, the metal slug 190, and the insulating sleeve 185 all cooperating to provide high attenuation for the frequency of operation of the device 60 and all harmonics thereof up to the seventh harmonic to prevent the propagation of these frequencies to the source of low frequency operating potential for the device 60 over the lead 195.

In addition, there has been provided an improved RF rejection filter of simple and economical construction and specially adapted for use with the microwave generator of an electronic oven for providing high attenuation over a broad band of RF frequencies.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A coupling structure for interconnecting a generator for generating RF energy of a predetermined ultrahigh RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC energy having at least one terminal, wherein the generator has an annular outer RF terminal and an inner RF terminal, said coupling structure comprising a hollow outer conductor coupled to the outer RF terminal of the generator and extending outwardly therefrom and terminating in an outer end, an inner conductor disposed in said outer conductor and coupled to the inner RF terminal of the generator and extending outwardly therefrom and terminating in an outer end adjacent to the outer end of said outer conductor, an insulating sleeve disposed within said outer conductor in surrounding relationship with said inner conductor, a pair of RF output terminals respectively coupled to said outer conductor and said inner conductor intermediate the generator RF terminals and said outer ends, means coupling the DC source terminal and the low frequency AC source terminal to the outer end of said inner conductor, a ferrite filter element disposed between said insulating sleeve and said inner conductor and in contact with each intermediate the outer end of said inner conductor and said generator output terminals and being constructed and arranged to provide high transmission losses at selected harmonics of the predetermined frequency, and a conductive filter element disposed between said insulating sleeve and said inner conductor and in contact with each adjacent to the outer end of said inner conductor and connected to said ferrite filter element and being constructed and arranged to cooperate with said insulating sleeve and said outer conductor for providing a low impedance bypass path between said inner and outer conductors at the predetermined frequency, whereby propagation of ultrahigh frequency energy at the predetermined frequency and selected harmonics thereof from the generator to the outer ends of said conductors

is highly attenuated without interfering with the transmission of the DC operating potentials and the low frequency AC energy from the sources thereof to the generator.

2. The coupling structure set forth in claim 1, wherein said inner and outer conductors and said ferrite filter element are each cylindrical in shape and circular in cross section, the outer diameter of said ferrite filter element being such as to provide high attenuation of all of the harmonics of the predetermined frequency up to the seventh harmonic.

3. The coupling structure set forth in claim 1, wherein said inner and outer conductors and said conductive filter element are each cylindrical in shape and circular in cross section, the outer diameter of said conductive filter element being such as to provide a capacitive bypass path between said inner and outer conductors at the pre-determined frequency.

4. The coupling structure set forth in claim 1, wherein said inner and outer conductors and said ferrite filter element and said conductive filter element are all cylindrical in shape and circular in cross section, the outer diameters of said ferrite filter element and said conductive filter element being substantially equal to each other.

5. The coupling structure set forth in claim 1, wherein said outer conductor overlaps said conductive filter element a distance not greater than one-quarter of the wavelength of the predetermined frequency.

6. The coupling structure set forth in claim 1, wherein said inner conductor comprises an externally threaded rod, said ferrite filter element and said conductive filter element each being cylindrical in shape and having an internally threaded opening extending axially therethrough, said inner conductor being threadedly engaged with the internally threaded openings through said ferrite filter element and said conductive filter element for coupling said filter elements to said inner conductor.

7. A coupling structure for interconnecting a generator for generating RF energy of a predetermined ultrahigh RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC energy having a pair of terminals, wherein the generator has an annular outer RF terminal and an inner RF terminal and a low frequency AC terminal, said coupling structure comprising a first hollow outer conductor coupled to the outer RF terminal of the generator and extending outwardly therefrom and terminating in an outer end, a first inner conductor disposed in said outer conductor and coupled to the inner RF terminal of the generator and extending outwardly therefrom and terminating in an outer end adjacent to the outer end of said outer conductor, a first insulating sleeve disposed within said outer conductor in surrounding relationship with said inner conductor, a pair of RF output terminals respectively coupled to said outer conductor and said inner conductor intermediate the generator RF terminals and said outer ends, means coupling one of said low frequency AC source terminals and one of said DC source terminals to the outer end of said inner conductor, a first ferrite filter element disposed between said first insulating sleeve and said inner conductor and in contact with each intermediate the outer end of said inner conductor and said generator output terminals and being constructed and arranged to provide high transmission losses at selected

harmonics of the predetermined frequency, a first conductive filter element disposed between said first insulating sleeve and said inner conductor and in contact with each adjacent to the outer end of said inner conductor and connected to said ferrite filter element and being constructed and arranged to cooperate with said insulating sleeve and said outer conductor for providing a low impedance bypass path between said inner and outer conductors at the predetermined frequency, a second hollow outer conductor coupled to said one output terminal of said generator and disposed adjacent to said low frequency AC input terminal and extending outwardly therefrom and terminating in an outer end, a second inner conductor disposed in said second outer conductor and coupled to said low frequency AC input terminal of said generator and extending outwardly therefrom and terminating in an outer end adjacent to the outer end of said second inner conductor, a second insulating sleeve disposed within said second outer conductor in surrounding relationship with said second inner conductor, means coupling the other of said low frequency AC source terminals to the outer end of said second inner conductor, a second ferrite filter element disposed between said second insulating sleeves and said second inner conductor and in contact with each intermediate the outer end of said second inner conductor and said generator low frequency AC input terminal and being constructed and arranged to provide high transmission losses at selected harmonics of the predetermined frequency, and a second conductive filter element disposed between said second insulating sleeve and said second inner conductor and in contact with each adjacent to the outer end of said second inner conductor and connected to said second ferrite filter element and being constructed and arranged to cooperate with said second insulating sleeve and said second outer conductor for providing a low impedance bypass path between said second inner and outer conductors at the predetermined frequency, whereby propagation of ultrahigh frequency energy at the predetermined frequency and selected harmonics thereof from the generator to the outer ends of said first and second conductors is highly attenuated without interfering with the transmission of the DC operating potentials and the low frequency AC energy from the sources thereof to the generator.

8. The coupling structure as set forth in claim 7, wherein said first ferrite filter element is identical in construction to said second filter element, and wherein said first conductive filter element is identical in construction to said second conductive filter element.

9. An RF rejection filter for highly attenuating a predetermined ultrahigh frequency and selected harmonics thereof, said filter assembly comprising a coaxial

transmission line section including a hollow outer conductor and an inner conductor disposed in said outer conductor, a ferrite filter element disposed in contact with said inner conductor and being constructed and arranged to provide high transmission losses at selected harmonics of the predetermined frequency, a conductive filter element disposed in contact with said inner conductor and connected to said ferrite filter element and being constructed and arranged to provide a low impedance bypass path between said inner and outer conductors at the predetermined frequency, and an insulating sleeve disposed between said filter elements and said outer conductor and in contact with each, said filter elements cooperating with each other and with said inner and outer conductors to form a filter for highly attenuating said predetermined frequency and selected harmonics thereof.

10. The RF rejection filter set forth in claim 9, wherein said inner and outer conductors and said ferrite filter element are each cylindrical in shape and circular in cross section, the outer diameter of said ferrite filter element being such as to provide high attenuation of all of the harmonics of the predetermined frequency up to the seventh harmonic.

11. The RF injection filter set forth in claim 9, wherein said inner and outer conductors and said conductive filter element are each cylindrical in shape and circular in cross section, the outer diameter of said conductive filter element being such as to provide a capacitive bypass path between said inner and outer conductors at the predetermined frequency.

12. The RF rejection filter set forth in claim 9, wherein said inner and outer conductors and said ferrite filter element and said conductive filter element are all cylindrical in shape and circular in cross section, the outer diameters of said ferrite filter element and said conductive filter element being substantially equal to each other.

13. The RF rejection filter set forth in claim 9, wherein said outer conductor overlaps said conductive filter element a distance not greater than one-quarter of the wavelength of the predetermined frequency.

14. The RF rejection filter set forth in claim 9, wherein said inner conductor comprises an externally threaded rod, said ferrite filter element and said conductive filter element each being cylindrical in shape and having an internally threaded opening extending axially therethrough, said inner conductor being threadedly engaged with the internally threaded openings through said ferrite filter element and said conductive filter element for coupling said filter elements to said inner conductor.

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