

Oct. 27, 1970

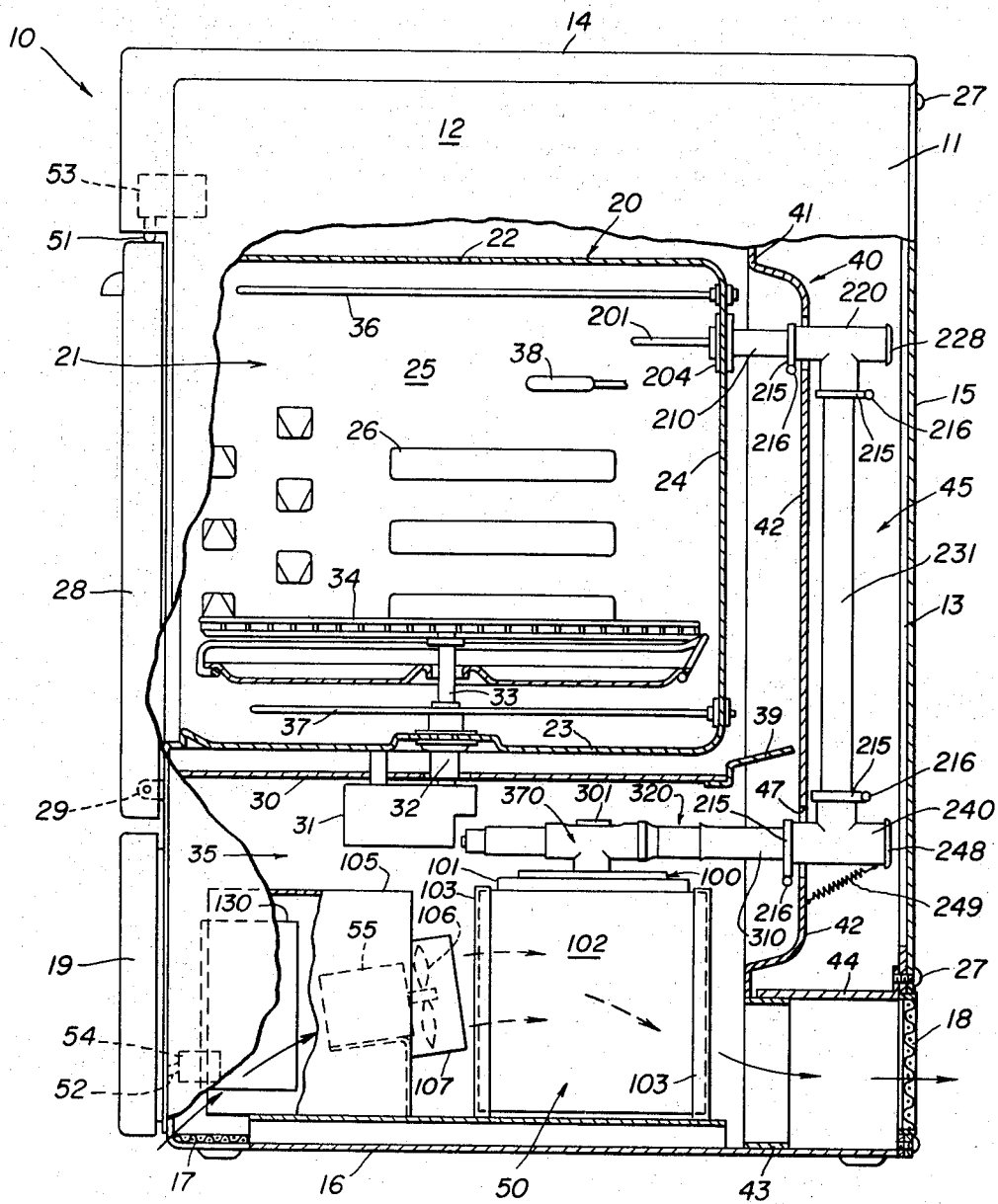
1970	L. H. FITZMAYER ET AL	3,536,8
ELECTRONIC HEATING APPARATUS INCLUDING MICROWAVE COUPLING		
STRUCTURE AND FILTERS THEREFOR		

3,536,878

Filed Dec. 31, 1968

4 Sheets-Sheet 1

FIG. 1



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ATTYS.

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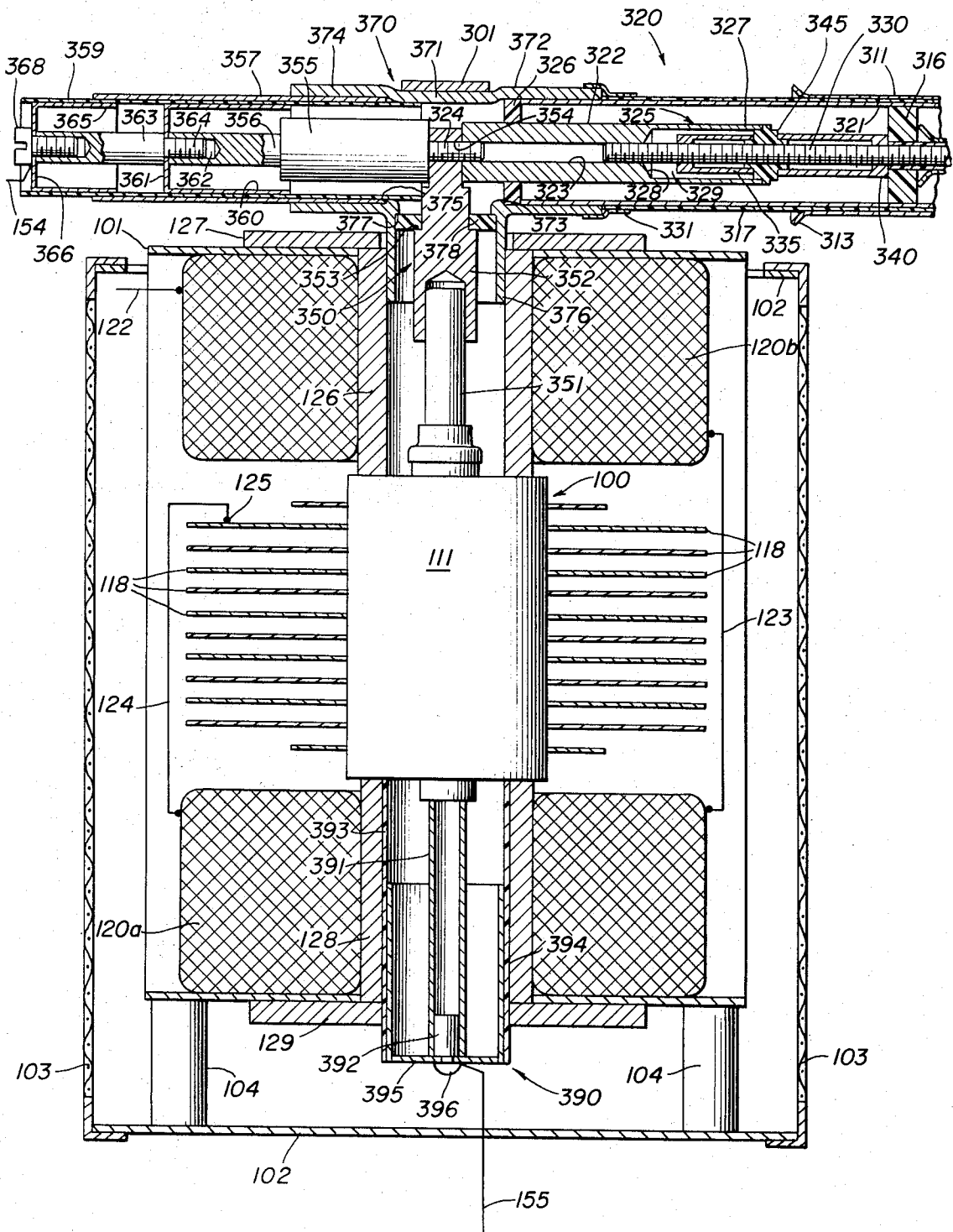
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FIG. 2



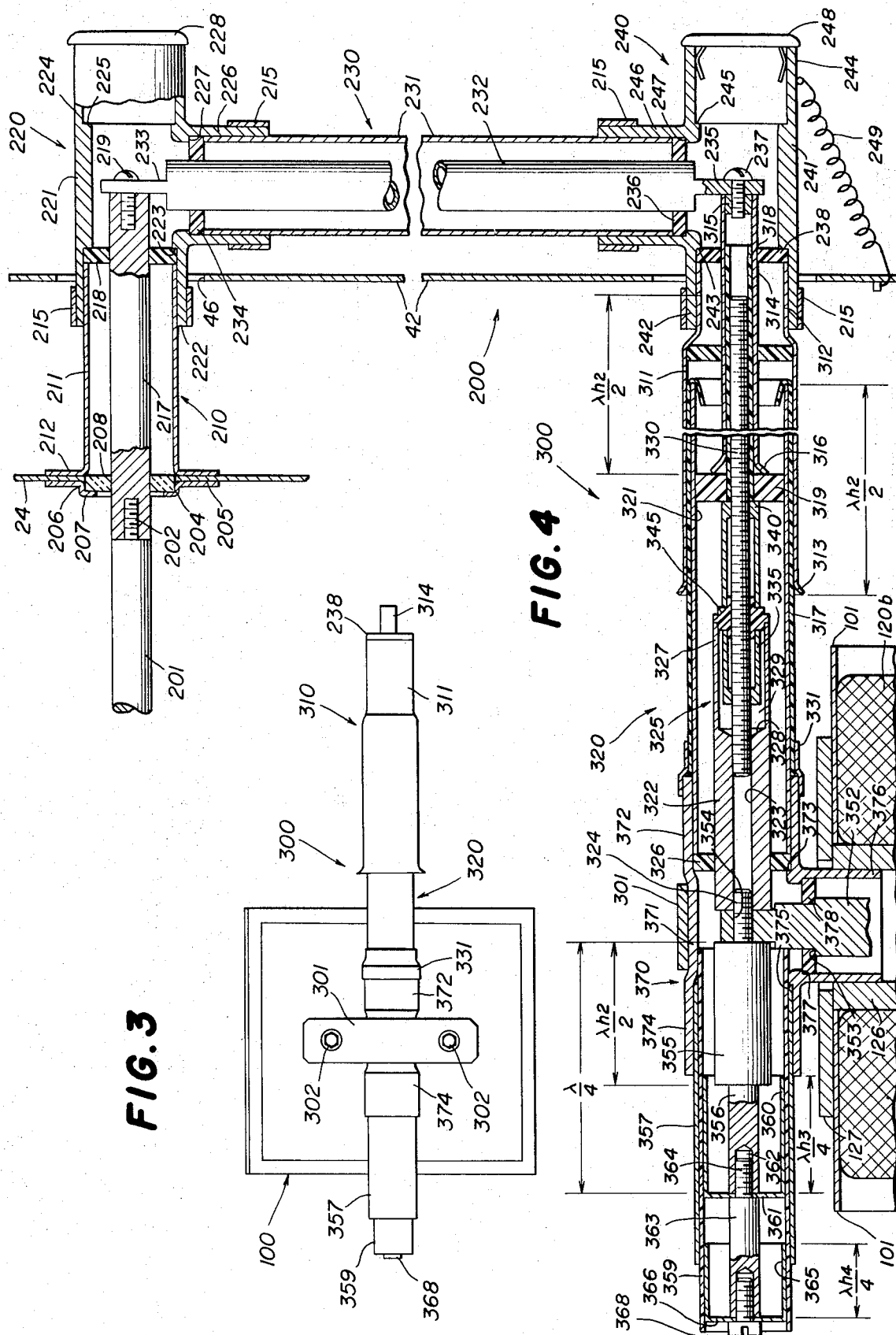
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FIG. 5

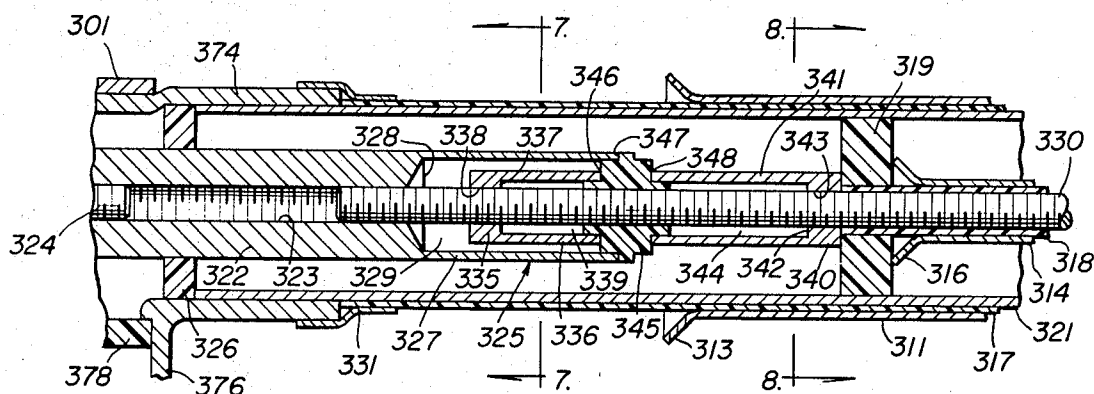


FIG. 7

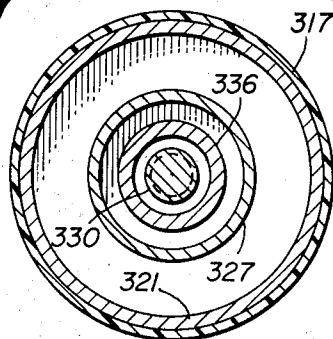


FIG. 8

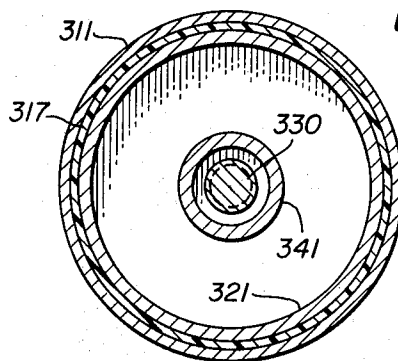


FIG. 6

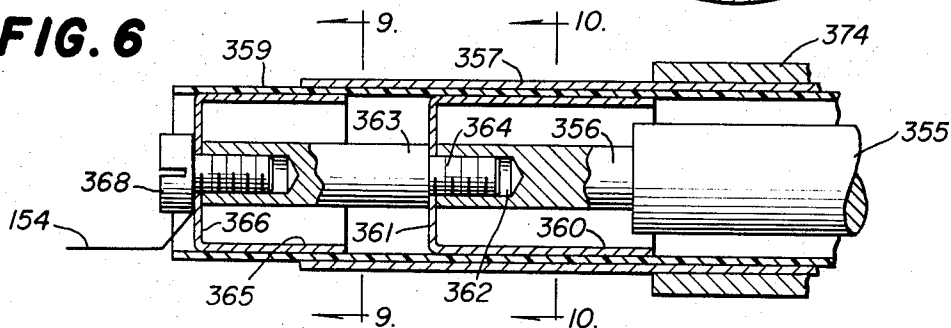


FIG. 9

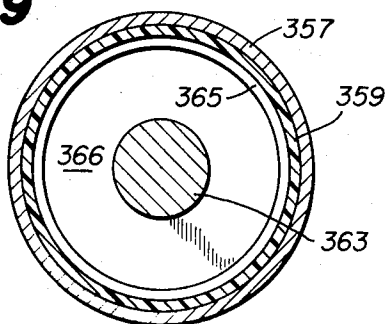
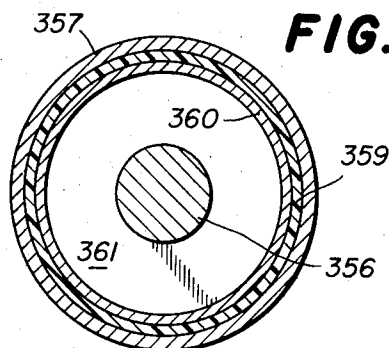


FIG. 10



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ELECTRONIC HEATING APPARATUS INCLUDING MICROWAVE COUPLING STRUCTURE AND FILTERS THEREFOR

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Filed Dec. 31, 1968, Ser. No. 788,214

Int. Cl. H05b 9/06

U.S. Cl. 219—10.55

23 Claims

ABSTRACT OF THE DISCLOSURE

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 a plurality of capacitive bypass filters and resonant cavity rejection filters for preventing the propagation of microwave energy to the source and preventing propagation of harmonics of the predetermined frequency to the cooking cavity, two of the resonant cavity filters, respectively resonant at the second and fourth harmonics of the predetermined frequency, being disposed one within the other.

This invention is concerned with an improved microwave coupling structure and an improved transmission line forming a part of an electronic oven.

More particularly, this invention concerns improved microwave filtering elements for the coupling structure and the transmission line.

It is a general object of this invention to provide an electronic heating apparatus including structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high-frequency and having a pair of output terminals, a transmission line coupling the generator to the cooking cavity and including a hollow outer conductor coupled to one terminal of the generator and an inner conductor coupled to the other terminal of the generator, a plurality of filter sections in the inner conductor for attenuating the second and third and fourth harmonics of the predetermined frequency and a filter section in the transmission line providing a low impedance bypass path for the second and higher harmonics of the predetermined frequency, whereby during the transmission of electromagnetic wave energy along the transmission line the harmonics of the predetermined frequency are highly attenuated by the filter sections while the predetermined frequency is propagated to the cooking cavity substantially without attenuation.

In connection with the foregoing object, it is another object of this invention to provide an electronic heating apparatus of the type set forth wherein each of the filter sections in the inner conductor comprises structure defining a cavity, the cavities having effective electrical lengths respectively equal to one-quarter of the wavelength of the second and third and fourth harmonics of the predetermined frequency and being respectively resonant at the second and third and fourth harmonics of the predetermined frequency to effect high attenuation thereof.

In connection with the foregoing objects, it is yet another object of this invention to provide an electronic heating apparatus of the type set forth and including a filter section in the inner conductor comprising structure defining an inner cavity and an outer cavity disposed about the inner cavity, the filter section structure having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency, the inner cavity having an effective electrical length equal to

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one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, the outer cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, the filter section presenting a high impedance to the transmission of both the second and fourth harmonics of the predetermined frequency along the inner conductor while having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency.

Another object of this invention is to provide an electronic heating apparatus of the type set forth wherein the transmission line includes a first cup-like filter member including a cylindrical sidewall surrounding the adjacent portion of the inner conductor and concentric therewith and spaced therefrom and an end wall closing the sidewall at one end thereof and connected to the inner conductor, the first filter member cooperating with the inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, and a second cup-like filter member including a cylindrical side wall surrounding the cylindrical side wall of the first filter member and concentric therewith and spaced therefrom and an end wall closing the side wall of the second filter member at one end thereof and connected to the inner conductor, the second filter member cooperating with the first filter member and with the inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, the first filter member being disposed within the second filter member and the second filter member having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency while the filter members present a high impedance to the transmission of both the second and fourth harmonics of the predetermined frequency along the inner conductor, whereby during the transmission of electromagnetic wave energy along the transmission line the second and fourth harmonics of the predetermined frequency are highly attenuated by the filter members while the predetermined frequency is propagated to the cooking cavity substantially without attenuation.

In connection with the foregoing object, it is another object of this invention to provide electronic heating apparatus of the type set forth, and further including a third cup-like filter member including a cylindrical side wall surrounding the adjacent portion of the inner conductor and concentric therewith and spaced therefrom and an end wall closing the side wall at one end thereof and connected to the inner conductor, the third filter member cooperating with the inner conductor to define a cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency for highly attenuating the transmission along the transmission line of electromagnetic wave energy at the third harmonic of the predetermined frequency.

It is another object of this invention to provide a transmission line for interconnecting a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and a load wherein the generator has a pair of output terminals, the transmission line comprising a hollow outer conductor coupled to one

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terminal of the generator, an inner conductor disposed within the outer conductor concentric therewith and coupled to the other terminal of the generator, a first filter section in the inner conductor and comprising structure defining a first cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency for effecting high attenuation thereof, and a second filter section in the inner conductor comprising structure defining a second cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency for effecting high attenuation thereof, whereby during the transmission of electromagnetic wave energy along the transmission line the second and fourth harmonics of the predetermined frequency are highly attenuated by the filter section while the predetermined frequency is propagated to the load substantially without attenuation.

In connection with the foregoing object, it is another object of this invention to provide a transmission line of the type set forth, and further including a third filter section in the inner conductor comprising structure defining a third filter cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency for effecting high attenuation thereof.

In connection with the foregoing objects, it is still another object of this invention to provide a transmission line of the type set forth and including a filter section in the inner conductor comprising structure defining an inner cavity and an outer cavity disposed about the inner cavity, the filter section structure having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency, the inner cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, the outer cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, the filter section presenting a high impedance to the transmission of both the second and fourth harmonics of the predetermined frequency along the inner conductor while having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency.

Another object of this invention is to provide a transmission line of the type set forth and including a first cup-like filter member including a cylindrical side wall surrounding the adjacent portion of the inner conductor and concentric therewith and spaced therefrom and an end wall closing the side wall at one end thereof and connected to the inner conductor, the first filter member cooperating with the inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, and a second cup-like filter member including a cylindrical side wall surrounding the cylindrical side wall of the first filter member and concentric therewith and spaced therefrom and an end wall closing the side wall of the second filter member at one end thereof and connected to the inner conductor, the second filter member cooperating with the first filter member and with the inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency,

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the first filter member being disposed within the second filter member and the second filter member comprising a filter section having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency while the filter members present a high impedance to the transmission of both the second and fourth harmonics of the predetermined frequency along the inner conductor, whereby during the transmission of electromagnetic wave energy along the transmission line the second and fourth harmonic of the predetermined frequency are highly attenuated by the filter members while the predetermined frequency is propagated to the load substantially without attenuation.

In connection with the foregoing object, it is another object of this invention to provide a transmission line of the type set forth and further including a third cup-like filter member including a cylindrical side wall surrounding the adjacent portion of the inner conductor and concentric therewith and spaced therefrom and an end wall closing the side wall at one end thereof and connected to the inner conductor, the third filter member cooperating with the inner conductor to define a third cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency for effecting high attenuation thereof.

In connection with the foregoing objects, another object of the invention is to provide a transmission line of the type set forth and further including a filter section comprising a low impedance bypass path between the inner and outer conductors for the second and higher harmonics of the predetermined frequency to effect high attenuation thereof.

It is another object of this invention to provide a coupling structure for interconnecting a generator for generating RF energy of a predetermined ultra-high RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC energy having 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 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, 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 low frequency AC source terminal and the DC source terminal to the outer end of the inner conductor, and a plurality of filter elements disposed in the conductors between the RF output terminals and the outer ends of the conductors and providing low impedance bypass paths for the second and third harmonics of the predetermined frequency and including structure defining cavities respectively resonant at the predetermined frequency and the fourth harmonic thereof for presenting a high series impedance to the transmission of the predetermined frequency and the fourth harmonic thereof along the conductors to the low frequency AC source terminal and the DC source terminal, whereby propagation of RF energy at the predetermined frequency and the second and third and fourth harmonics thereof from the generator to the outer ends of the conductors is highly attenuated without interfering with the transmission of the low frequency AC and the DC operating potentials between the sources thereof and the generator.

In connection with the foregoing object, another object of this invention is to provide a coupling structure of the type set forth including first and second cup-like filter members each including a cylindrical side wall surrounding the adjacent portion of the inner conductor and con-

centric therewith and spaced therefrom and an end wall closing the side wall at one end thereof and connected to the inner conductor, the filter members being telescopically received in and insulated from the outer conductor, and wherein the inner and outer conductors are spaced apart and cooperate to form therebetween a low impedance bypass path at the second harmonic of the predetermined frequency, and the cylindrical side wall of the first filter member cooperates with the outer conductor to form therebetween a low impedance bypass path at the third harmonic of the predetermined frequency, and the first filter member cooperates with the inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the predetermined frequency, and being resonant at the predetermined frequency, and the second filter member cooperates with the inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency.

Another object of the invention is to provide a coupling structure for interconnecting a generator for generating RF energy of a predetermined ultra-high RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC operating potential having at least one terminal and a load for the RF energy, wherein the generator has an annular outer RF terminal and an inner RF terminal, the 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 the first outer conductor and coupled to the inner RF terminal of the generator and extending outwardly therefrom and terminating at an outer end adjacent to the outer end of the first outer conductor, means coupling the DC source terminal and the low frequency AC source terminal to the outer end of the first inner conductor, a second hollow outer conductor coupled to the first outer conductor intermediate the generator RF terminals and the outer ends and coupled to the load, a second inner conductor disposed in the second outer conductor and coupled to the first inner conductor intermediate the generator RF terminals and the outer ends and coupled to the load, filter elements disposed in the first outer conductor between the coupling to the second outer conductor and the outer ends of the first conductors and providing a low impedance bypass path for the second harmonic of the predetermined frequency and including structure defining two resonant cavities respectively resonant at the predetermined frequency and the fourth harmonic thereof for presenting a high series impedance to the transmission of the predetermined frequency and the fourth harmonic thereof along the first conductors to the DC source terminal and the low frequency AC source terminal, whereby propagation of RF energy at the predetermined frequency and the second and fourth harmonics thereof from the generator to the outer ends of the first conductors is highly attenuated without interfering with the transmission of the DC and low frequency AC operating potentials between the sources thereof and the generator, and filter sections in the second outer conductor comprising structure defining two cavities respectively resonant at the second and fourth harmonics of the predetermined frequency to present a high impedance to the transmission of the second and fourth harmonics of the predetermined frequency along the second conductors, whereby propagation of RF energy at the second and fourth harmonics of the predetermined frequency along the second conductors is highly attenuated without interfering with the transmission of microwave energy at the predetermined frequency to the load.

Further features of the electronic heating apparatus pertain to the particular arrangement of the parts of the

transmission line and coupling assembly forming a part thereof, whereby the above-outlined and additional operating features thereof are attained.

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

FIG. 1 is a side elevational view with certain portions broken away of an electronic heating apparatus made in accordance with and embodying the principles of the present invention;

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

FIG. 3 is a top plan view on a reduced scale of the generator of FIG. 2 including a portion of a transmission line for coupling the generator to the cooking cavity in the apparatus of FIG. 1;

FIG. 4 is a fragmentary view in vertical section through the transmission line forming a part of the apparatus of FIG. 1 and interconnecting the device of FIG. 2 to the cooking cavity of the apparatus;

FIG. 5 is an enlarged view in vertical section of a first portion of the transmission line of FIG. 4 including harmonic filters according to the inventions;

FIG. 6 is an enlarged view in vertical section of a second portion of the transmission line of FIG. 4 including RF rejection filters according to the invention;

FIG. 7 is an enlarged view in vertical section along the line 7-7 of FIG. 5;

FIG. 8 is an enlarged view in vertical section along the line 8-8 of FIG. 5;

FIG. 9 is an enlarged view in vertical section along the line 9-9 of FIG. 6; and

FIG. 10 is an enlarged view in vertical section along the line 10-10 of FIG. 6.

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 20 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 diameter portion 33 extending upwardly into the liner 20 and supporting thereon a turntable 34 formed of expanded 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 50 for supplying ultra-high frequency electromagnetic wave energy for electronic cooking within the cooking cavity 21, the generator 50 including a crossed-field electronic discharge device 100 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, it will be seen that the device 100 is disposed within a box-like structure or casing 101 that extends completely about the device 100 but is open on two opposed sides thereof, the sides disposed to the left and right in FIG. 2,

the device 100 and the associated parts therefor being mounted within and electrically connected to the casing 101. As will be explained more fully hereinafter, high operating DC potentials are present on the casing 101, whereby it is desirable electrically to isolate and shield the casing 101, and to this end a second box-like structure 102 has been provided that surrounds the casing 101 and is also provided on an opposed pair of sides thereof with openings in alignment with the opposed open sides of the casing 101, all to accommodate the passage of air through the casing 101 and the box-like structure 102 to cool the device 100 and the associated parts housed therein. However, in order to prevent contact of the user with the casing 101 and the device 100 disposed therein, reticulated metal covers 103 are provided for covering the openings in the opposed sides of the box-like structure 102, the covers 103 permitting passage of air therethrough and thus through the casing 101 and the structure 102 while preventing contact of a user with the casing 101 and the parts disposed therein that carry the high operating DC potentials. Further, the casing 101 is mounted upon insulators 104 carried by the structure 102, thereby electrically to insulate the casing 101 from the structure 102.

As viewed in FIG. 1, the structure 102 and the casing 101 disposed therein are disposed to the rear of the bottom apparatus 35, and are disposed to the right within the bottom apparatus compartment 35 when the range 10 is viewed from the front. In order to provide cooling air for passage through the reticulated covers 103 and across the device 100, there has been provided an open ended housing 105 disposed to the left in FIG. 1 or in front of the structure 102 and housing therein at least a part of a voltage doubler and rectifier circuit 130 that supplies DC operating potentials to the device 100 and also houses therein a fan 106 powered by a motor 55 within the housing 105, an air duct 107 being provided about the fan 106 to direct air therefrom into the structure 102 and into the casing 101 and about the device 100. More specifically, the fan 106 operates to draw air through the screen 17 at the bottom of the apparatus compartment 35, the air being formed into a stream by the housing 105 and passed over the rectifier 130, the motor 55 and through the air duct 107 into the structure 102; the air stream within the structure 102 passes into the casing 101 and about the device 100 and cooling fins 118 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 106 is used to cool all of the various parts of the generator 50, and specifically the crossed-field discharge device 100 and the voltage doubler and rectifier circuit 130 associated therewith. To this end the housing 105 and the air duct 107 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 the generator 50 there illustrated will be described in greater detail. An electron discharge device 100 is contained within a substantially cylindrical metal envelope 111 and includes anode and cathode structure (not shown). Surrounding the envelope 111 and connected thereto is a plurality of cooling fins 118 for dissipating heat from the device 100 as explained above. In order to establish a unidirectional magnetic field within the device 100 there is provided a composite magnetic field winding 120a and 120b respectively disposed at the lower and upper ends of the device 100 and connected in series relation by a conductor 123. A DC operating potential from a voltage doubler and

rectifier 130 is applied to the winding 120b by a conductor 122, and from the winding 120a to the device 100 by a conductor 124 which is connected to one of the cooling fins 118 as at 125. Further details of the construction and operation of the device 100 are disclosed in the previously mentioned Staats application Ser. No. 559,267, 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, Ser. No. 569,006, filed June 27, 1966, now abandoned and Ser. No. 181,144, filed Mar. 20, 1962, the disclosures of all of which applications are incorporated herein by reference.

The device 100 is operative to supply ultra-high 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 300 extends from the device 100 and is coupled to an upper transmission line 200 which extends to the cooking cavity 21, the transmission lines 200 and 300 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 100 are at a substantial voltage DC 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 317 to the adjacent end of the outer output conductor, and the other output terminal is coupled by a capacitor 318 to the adjacent end of the inner output conductor, the remote end of the inner conductor projecting an antenna 201 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 100 is radiated from the antenna 201 into the cooking cavity 21, so as to produce cooking effects upon food arranged therein, all in a conventional manner.

An important feature of the present invention resides in the construction and connection of the transmission lines 200 and 300 interconnecting the crossed-field discharge device 100 and the liner 20, a detailed description of the transmission line 200 and 300 being now presented with particular reference to FIGS. 3 through 5 of the drawings. The cross-field discharge device 100 is provided with a magnet yoke 126 at the upper end thereof which connects to the anode of the device 100 (not shown) and forms an outer conductor and an output terminal for the device 100, the lower end of the magnetic yoke 126 being more particularly connected to the anode of the device 100 and the upper end extending upwardly through the field winding 120b and being connected to a magnet flange 127. The lower end of the device 100 is likewise provided with a magnet yoke 128 having the upper end thereof connected to the anode of the device 100 and the other end extending downwardly through the field winding 120a and being connected at the lower end to a magnet flange 129. The cathode of the device 100 (not shown) has connected thereto a stud 351 forming a part of the upper coupling structure 350, the stud 351 and the magnet yoke 128 forming a coaxial output connection for the device 100.

Referring specifically to FIG. 4, it will be seen that the output from the other end of the upper transmission line 200 is coupled to the antenna 201 disposed in the heating cavity 21, the antenna 201 being essentially a rod having a threaded stud 202 at one end thereof, the antenna 201 extending into the cavity 21 a short distance below the top wall 22 and essentially midway between the side walls 25, see FIG. 1. The stud 202 extends into a complementarily threaded opening at the end of a rod 217 forming an inner conductor that extends into the cavity 21, the

conductor 217 being held in position by a bracket 204 and a cooperating electrical insulator 208. More specifically, the bracket 204 includes an annular mounting flange 205 which is suitably secured as by welding to the rear wall 24 and of the liner 20 and disposed about an opening therein, the flange 205 in turn carrying a forwardly directed annular flange 206 terminating in an inturned holding flange 207 disposed against the forward surface of the insulator 208.

A top section 210 of the transmission line 200 is formed by a first tube 211 forming the outer conductor therefor and the inner conductor 217. The forward edge of the tube 211 has an outwardly directed flange 212 thereon which is suitably secured as by welding on the rear side of the rear wall 24 and surrounding the opening therein and assisting in holding the insulator 208 in the operative position in cooperation with the bracket 204.

The rear end of the tube 211 is received in a T 220, the T 220 including a body 221 and a pair of arms 222 and 224 and a leg or arm 226 all provided with a seat or shoulder 223, 225 and 227, respectively internally thereof. The rear end of the tube 211 is disposed within the arm 222 and in telescopic relationship therewith and has the rearmost end thereof spaced slightly forwardly with respect to the shoulder 223, an insulator 218 being disposed between the tube 211 and the shoulder and held in position thereby, the insulator 218 having a central opening therein receiving the inner conductor 217 therethrough. Preferably the outer end of the arm 222 has longitudinally extending slots (not shown) formed therein and receives therearound a clamp 215 having associated therewith a screw 216 (see FIG. 1) for tightening the clamp 215 about the outer end of the arm 222, thus releasably to clamp the arm 222 about the rear end of the tube 211 to hold it in the operative position. It further is pointed out that the arm 222 extends through an opening 46 in the baffle wall 42, whereby the major portion of the T 220 is disposed to the rear of the baffle wall 42 and thus in the rear machinery compartment 45, whereby the T 220 is accessible for service and maintenance through the removable panel 15 (see FIG. 1 also). The other arm 224 carries on the outer end thereof a dust cover 228 that serves to close the same to prevent the entry of dust, dirt, water and the like into the interior of the T 220.

A rear section 230 for the transmission line 200 is provided by an outer tube 231 and an inner conductor 232 disposed within the outer tube 231. The upper end of the tube 231 extends into the lower arm or leg 226 of the T 220 and is spaced from the shoulder 227 thereof, an insulator 224 being disposed between the upper end of the tube 231 and the shoulder 227 and held in position therebetween. The insulator 234 has an opening therethrough to receive the upper end of the inner conductor 232, the inner conductor 232 having an upper flattened end 233 having an opening therein receiving therethrough a screw 219 engaging in a complementarily threaded opening in the rear end of the rod 217, whereby to interconnect the rear end of the inner conductor 217 and the upper end of the inner conductor 232. There further is provided around the lower portion of the leg 226 one of the clamps 215, the lower end of the leg 226 preferably being slotted (not shown) whereby tightening of the screw 216 associated with the clamp 215 serves to tighten the leg 226 about the upper end of the tube 231 releasably to hold the parts in the assembled telescoping positions.

The lower end of the rear transmission line section 230 is received in a T 240, the T 240 including a body 241 having a pair of arms 242 and 244 and a leg or arm 246 each provided with a cooperating internal seat or shoulder 243, 245 and 247, respectively. More particularly, the leg 246 is positioned upwardly and receives telescopically therein the lower end of the tube 231, the lower end of the tube 231 being spaced upwardly with respect to the seat 247 to receive therebetween an insulator

236 to mount the same within the T 240, the insulator 236 having an opening therethrough receiving the lower end of the inner conductor 232 therethrough. The outer end of the leg 246 is preferably slotted (not shown) and receives therearound one of the clamps 215, whereby by means of the associated screw 216 the clamp 215 can be tightened about the outer end of the leg 246 to clamp it against the lower end of the tube 231 releasably to hold the parts in the assembled position. The arm 244 preferably carries thereon a dust cover 248 which cover serves to prevent the entry of dust, dirt, water and other debris into the interior of the T 240 and the transmission lines 200 and 300.

There is operatively associated with the other arm 242 of the T 240 a rear section 310 of the lower transmission line 300, the rear section 310 including a tube 311 as the outer conductor and a tube 314 as the inner conductor spaced therefrom and electrically insulated therefrom. The tube 311 further has a portion 312 of reduced diameter that extends into and is telescopically associated with the arm 242 of the T 240, the inner end of the tube 311 being spaced from the shoulder 243 and receiving therebetween an insulator 238 that is held in position thereby. One of the clamps 215 is disposed about the outer end of the arm 242 which is preferably slotted (not shown), whereby by means of the associated screw 216 the clamp 215 can be tightened to press the arm 242 about the adjacent end 312 of the tube 311 releasably to hold the parts in the assembled position. The insulator 238 has an opening therein receiving therethrough the inner conductor 314, the rear end of the inner conductor 314 carrying a plug 315 secured thereto and having a threaded opening therein, the lower end of the rear inner conductor 232 having a flattened portion as at 235 having an opening therein receiving a screw 237 that threadedly engages the opening in the plug 315, thus to interconnect the lower end of the inner conductor 232 and the rear end of the inner conductor 314. The forward end (the end disposed to the left of FIG. 4) of the tube 311 is outwardly flared as at 313, and the forward end of the inner conductor 314 is outwardly flared as at 316, all to permit ready assembly with other portions of the transmission line 300 as will be described more fully hereinafter.

The rear lower section 310 cooperates with and is telescopically associated with a front lower transmission line section 320, the front lower section 320 including a tube 321 serving as the outer conductor and an annular inner conductor 322 disposed within the tube 321 and spaced therefrom and electrically insulated therefrom. The tube 321 has an external diameter slightly less than the internal diameter of the main portion of the tube 311 whereby the rear end of the tube 321 is telescopically received therein, a layer of insulation 317 being disposed therebetween to provide a capacitive coupling at certain RF frequencies. The annular inner conductor 322 has received in an opening 323 therethrough and threadedly engaged therewith a probe 330, the probe 330 having an external diameter slightly less than the internal diameter of the inner conductor 314 whereby the rear end of the probe 330 can be disposed therein, a layer of insulation 318 being provided therebetween and forming therewith a capacitive coupling at certain RF frequencies. An annular insulator 319 is disposed about the forward end of the layer of insulation 318 abutting the flared end 316 of the inner conductor 314 positively to position the parts one with the other.

The rearward end of the inner conductor 322 has a hollow portion generally designated 325 including a relatively thin cylindrical side wall 327 and an annular end wall 328. The annular side wall 327 is disposed in surrounding relationship with the adjacent portion of the inner conductor 330 concentric therewith and spaced therefrom and the hollow rearward end 325 of the inner conductor 322 cooperates with the adjacent portion of the inner conductor 330 to define an annular cavity 329 therebetween. Disposed within and surrounded by the

hollow end 325 of the inner conductor 322 is a cup-like electrically conductive member 335 having a cylindrical side wall 336 disposed in surrounding relationship with the adjacent portion of the inner conductor 330 concentric therewith and spaced therefrom and being closed at the forward end thereof by an end wall 337. The end wall 337 of the cup-like member 335 is disposed rearwardly of the end wall 328 of the hollow end 325 of the inner conductor 322 and has an internally threaded opening 338 therethrough along the longitudinal axis thereof. The inner conductor 330 is received through the opening 338 and is threadedly engaged thereat with the cup-like member 335. Disposed about the inner conductor 330 and spaced rearwardly from the inner conductor 322 and the cup-like member 335 is another cup-like electrically conductive member 340 having a cylindrical side wall 341 disposed in surrounding relationship with the adjacent portion of the inner conductor 330 concentric therewith and spaced therefrom, the side wall 341 being closed at the rearward end thereof by an annular end wall 342. The end wall 342 has an internally threaded opening 343 therethrough along the longitudinal axis thereof through which is received the inner conductor 330, the inner conductor 330 being threadedly engaged thereat with the cup-like member 340.

Disposed about the inner conductor 330 and separating the open ends of the inner conductor 322 and the cup-like members 335 and 340 from one another is an annular insulating spacer 345. The spacer 345 has on the outer surface thereof a plurality of shoulders 346, 347 and 348 for respectively supporting the open ends of the cup-like member 335, the inner conductor 322 and the cup-like member 340. More particularly, the rearward end of the cylindrical side wall 336 of the cup-like member 335 overlies the shoulder 346 and is thereby supported and spaced from the inner conductor 330; the rearward end of the cylindrical side wall 327 of the inner conductor 322 similarly overlies the shoulder 347 and is supported thereby and spaced from the side wall 336 of the cup-like member 335; the forward end of the cylindrical side wall 341 of the cup-like member 340 overlies and is supported by the shoulder 348 and is thereby spaced from the inner conductor 330. The shoulders 346, 347 and 348 are arranged stepwise and are dimensioned so as to properly space the open ends of the inner conductor 322 and the cup-like members 335 and 340 from one another to provide the proper reactive impedances at this juncture as will be more fully described hereinafter.

The forward end of the rear lower transmission line section 320 is coupled to the crossed-field discharge device 100 by means of a T 370, the T 370 including a body 371 having a pair of arms 372 and 374 and a leg or arm 376 each provided with a cooperating internal seat or shoulder 373, 375 and 377, respectively. More particularly, the leg 376 is positioned downwardly and is telescopically received in the upper end of the magnet yoke 126 for coupling thereto, the T 370 forming a part of the upper coupling structure 350. Also forming a part of the upper coupling structure 350 is a bullet 352 receiving into the lower end thereof the stud 351 that is coupled to the cathode of the device 100, the bullet 352 having a shoulder 353 thereon that cooperates with the shoulder 377 to hold in operative position an insulator 378 that serves to center the bullet 352 with respect to the leg 376. The upper end of the bullet 352 carries an internally threaded eye 354 through which is threadedly inserted a stud 324, one end of the stud 324 being threadedly received in a complementarily threaded opening in the inner conductor 322, thereby to support the forward end of the inner conductor 322, there also being provided therearound a supporting insulator 326. The forward end of the tube 321 is telescopically received within the leg 372 and is spaced a short distance away from the shoulder 373, thereby to clamp the insulator 326 in the operative position therebetween. Preferably the forward end of the

tube 321 is fixedly secured as by soldering to the arm 372.

A decoupling structure is carried by the other arm 374 of the T 370, and more particularly comprises an inner conductor 355 having a rearward end connected to the forward end of the stud 324 by means of a threaded connection therebetween, the inner conductor 355 having a reduced forward portion 356. Fixedly mounted on the arm 374 and telescopically received therein is an outer conductor 357 within which is disposed an insulating sleeve 359. The outer conductor 357 and the sleeve 359 both extend outwardly beyond the outer end of the inner conductor 355. A cylindrical inner conductor 363 having an external diameter substantially equal to the external diameter of the reduced forward portion 356 of the inner conductor 355, is disposed forwardly of the inner conductor 355 along the longitudinal axis thereof. The rearward end of the inner conductor 363 has a reduced diameter externally threaded portion 364 which is threadedly engaged with a complementary threaded opening 362 in the outer end of the reduced forward portion 356 of the inner conductor 355. Disposed within the insulating sleeve 359 is a cup-like inner conductor 360 surrounding the reduced portion 356 of the inner conductor 355 and having an outer end closed by an end wall 361 which abuts the reduced diameter portion 356 of the inner conductor 355 at the outer end thereof, the threaded portion 364 of the inner conductor 363 passing through an opening in the wall 361. Another cup-like conductor 365 is disposed in surrounding relationship with the adjacent portion of the inner conductor 363, the cup-like conductor 365 being telescopically received within the outer ends of the sleeve 359 and the outer conductor 357 and having the outer end thereof closed by an end wall 366, the end wall 366 having an opening therein through which is received a screw threadedly engaged with a complementarily threaded opening in the outer end of the inner conductor 363 fixedly to interconnect the parts and to provide an input terminal 368.

In operation the inner conductors 322 and 330 and the cup-like members 335 and 340 and the insulating spacer 345 cooperate to define a plurality of resonant cavities for filtering predetermined harmonics of the operating frequency of the device 100. More particularly, the cylindrical side wall 327 of the outer end 325 of the inner conductor 322 has a length corresponding to about one-quarter of the wavelength of the second harmonic of the operating frequency of the device 100. The side wall 327 and the end wall 328 are so dimensioned that the cavity 329 defined thereby has an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the operating frequency of the device 100 and is resonant at this second harmonic. Similarly, the cup-like member 335 is so dimensioned that the cavity 339 defined thereby in cooperation with the inner conductor 330 has an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the operating frequency of the device 100 and is resonant at this fourth harmonic. In like manner, the cup-like member 340 is of such dimensions that the cavity 344 defined thereby in cooperation with the inner conductor 330 has an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the operating frequency of the device 100 and is resonant at this third harmonic. The three resonant cavities thus provided respectively present a high series impedance to the transmission of the second and third and fourth harmonics of the operating frequency of the device 100 along the transmission line 300 thereby to provide high attenuation of these harmonics and to minimize the propagation thereof to the cooking cavity 21. Furthermore, the inner conductor 314 overlaps the inner conductor 330 a distance equivalent to about one-quarter of the wavelength of the frequency of operation of the device 100 and the outer conductors 311 and 321 overlap a distance equal to about one-quarter of the wavelength of the frequency of opera-

tion of the device 100, thereby to provide a half-wave coaxial transmission line section at the second harmonic of the frequency of operation of the device 100 to provide a high impedance path between the inner conductors 330 and 314 and the outer conductors 321 and 311 of the transmission line 300 for the second and higher even harmonics of the frequency of operation of the device 100.

In actual construction, the above-described resonant cavity filters for the second and third and fourth harmonics of the frequency of operation of the device 100 and the high impedance filter for the second and higher even harmonics of the frequency of operation of the device 100 are all contained in a portion of the transmission line 300 having an overall length of about 6½ inches, which at the frequency of operation of the device 100 (915 mHz.) represents about one-half wavelength. Accordingly, advantageous compaction of a large number of filters into a relatively small space has been achieved.

It is noted that the transmission of energy at the frequency of operation of the device 100 to the cooking cavity 21 along the transmission line 300 is not substantially impeded by the above-described harmonic filters. The various parts of the forward section 320 of the transmission line 300 have been so arranged and are of such dimensions that any capacitive reactance at 915 mHz. at the junction of the cup-like member 340, the inner conductor 314 and the insulator 319 is substantially canceled by inductive reactance at 915 mHz. at the junction of the inner conductor 322, the cup-like members 335 and 340 and the insulator 345.

Because of the effective filtration of the second, third and fourth harmonics of the operating frequency of the device 100 in the transmission line 300, it is necessary that these harmonics, as well as the frequency of operation itself be effectively filtered in the coupling structure described above to prevent their propagation to the Edison supply network and the voltage doubler and rectifier circuit 130. To this end, the cup-like inner conductor 360 cooperates with the inner conductor 355 to define a cavity having an effective electrical length equal to one-quarter of the wavelength of the frequency of operation of the device 100 and being resonant thereat to provide a high series impedance to the transmission of this frequency along the conductors 355 and 357. The conductors 355 and 357 cooperate with each other to provide a capacitive low impedance bypass path therebetween for the second harmonic of the frequency of operation of the device 100. Similarly, the cup-like inner conductor 360 cooperates with the outer conductor 357 to provide therebetween a low impedance bypass path at the third harmonic of the frequency of operation of the device 100. Finally, the cup-like conductor 365 cooperates with the inner conductor 363 to define a cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the frequency of operation of the device 100 and being resonant thereat to provide a high series impedance to the transmission thereof along the conductors 363 and 357.

In effect, the inner conductor 355, the outer conductor 357 and the cup-like conductors 360 and 365 are so arranged and dimensioned that there is provided along the inner conductor 355 capacitive loading on the second harmonic of the frequency of operation of the device 100. There is also provided at the inner end of the inner conductor 355 an open circuit reflection at the frequency of operation of the device 100 between the inner conductor 355 and the outer conductor 357; there is provided at the inner end of the cup-like conductor 360 a short circuit reflection at the third harmonic of the frequency of operation of the device 100 between the conductors 360 and 357; and there is provided at the inner end of the cup-like conductor 365 an open circuit reflection at the fourth harmonic of the frequency of operation of the device 100 between the conductors 365 and 363. Accordingly, the above-described RF filters provide

a high attenuation for the frequency of operation of the device 100 and for the second and third and fourth harmonics thereof to minimize the propagation of RF energy to the Edison supply network and the voltage doubler and rectifier circuit 130.

In the transmission line 300, the bullet 352, the T 370, the inner conductor 322 and the tube 321 are shaped and arranged to provide a quarter wave transformer section at the frequency of operation of the device 100. More particularly, the shouldered portions of the bullet 352 and the conductor 322, the inner conductor 330 and the cup-like member 335 have dimensions such that the impedance of the device 100 is matched to the impedance of the transmission lines 200 and 300 that is in turn matched to the impedance of the heating cavity 21. Likewise, the bullet 352, the inner conductor 355, the outer conductor 357 and the inner conductor 360 are all shaped and arranged to provide a quarter wave transformer section that assists in decoupling RF energy from the input terminal 368 to prevent the propagation of RF energy into the power supply. It is noted that the stepped configuration of the inner conductor 355 permits a shorter mechanical connection while maintaining an electrical characteristic equivalent to one-quarter wavelength of the operating frequency of the device 100.

Because the potentials for operating the device 100 are derived from the voltage doubler and rectifier circuit 130, neither the stud 351 forming the inner conductor or any of the parts such as the yoke 126 and the T 370 forming the outer conductor of the coupling structure 350 can be grounded. However, it is highly desirable to ground the portion of the transmission line 200 disposed to the rear of the rear baffle 40, and to this end the capacitive coupling at 317 and 318 has been provided between the rear lower transmission line portion 310 and the front lower transmission line portion 320. Furthermore, the outer conductors 311 and 321 overlap a distance equivalent to one-quarter wavelength at the frequency of operation of the device 100 and the inner conductor 314 overlaps the probe 330 a distance equivalent to one-quarter wavelength of the frequency of operation of the device 100, thereby to provide a filter for the second and higher harmonics as well as providing a DC insulation between the parts named. Accordingly, the outer conductor 311 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 310 and 320, the device 100 and the front portion 320 of the transmission line 300 may be easily disengaged from the rear portion 310 of the transmission line 300 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 T 220, the entire rear transmission line section 230, the T 240 and the rear lower transmission line section 310 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 clamp 215, about the leg 222 which frees the T 220 from the tube 211 and removing the screw 219 to free the inner conductor 232 from the inner conductor 217. Due to the telescoping arrangement of the lower transmission line portions 310 and 320, there is no need to remove or disconnect any parts other than by the relative sliding movement of the portions 310 and 320 with respect to each other. Reassembly of the parts is facilitated by the flared ends 313 and 316 on the outer conductor 311 and the inner con-

ductor 314 for re-engagement over the conductors 321 and 330, respectively. It further is necessary to hold the removable transmission line assembly in the assembled position, and to this end a spring 249 under tension has been provided interconnecting the T 240 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 200 and 300 resides in the fact that the tubes 211, 231, 311, 321 and 357 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 inner conductors 232 and 314 also can be formed essentially of standard tubing shaped as required and cut to length, this tubing also preferably being formed of copper, brass or the like. The T's 220, 240 and 370 are also of standard configuration and are all identical one to the other, the T' preferably being formed of copper, brass or other material having good electrical conductivity. Finally, the insulators 218, 234, 236, 238, 317-319, 326, 359 and 378 are preferably all formed of a polytetrafluoroethylene resin such as that sold under the trademark "Teflon."

A lower coupling structure 390 cooperates with the magnet yoke 128 serving as an outer conductor of a transmission line and a tube 391 connected at the upper end to one end of the heater of the device 100 (not shown) and serving as an inner conductor of a coaxial transmission line, the lower end of the tube 391 carrying an insert 392 therein and receiving the screw 396 serving as an input terminal. Disposed within and essentially lining the magnet yoke 128 is a sleeve 393 of electrically insulating material, an inner conductor 394 being disposed against the sleeve 393 and telescopically overlapping a portion of the yoke 128 and having the outer end thereof closed by an end wall 395, the end wall 395 having an opening therethrough receiving the shank of the screw 396 that engages in a complementarily threaded opening in the insert 392. The yoke 128, the tube 391, the insulating sleeve 393, the inner conductor 394 and the end wall 395 cooperate to provide a parallel resonant circuit including a reactive impedance and a capacitive impedance, the structure comprising a high impedance to RF energy to prevent propagation thereof onto the conductor 155. More specifically, the distance between the lower adjacent end of the anode of the device 100 and the inner surface of the end wall 395 is equivalent to a quarter wavelength at the operating frequency of the device 100, and the yoke 128 and the inner conductor 394 telescopically overlap a distance equivalent to one-eighth wavelength at the operating frequency of the device 100.

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 100 and the voltage doubler and rectifier circuit 130 therefor are housed within the bottom machinery compartment 35 which provides a protecting housing therefor. The fan 106 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 100 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 members 30 and 40. Also, the improved coupler structure and transmission line 200 has been provided, the major portion of which can be readily removed from the assembled relation with the liner 20 and the device 100 for repair and services purposes through the removable panel 15, and can thereafter be readily reassembled therewith.

Further, it can be seen that there has been provided in the forward section 320 of the transmission line 300 a

plurality of filters for the second and third and fourth and higher harmonics of the frequency of operation of the device 100, all of which filters have been disposed within a section of transmission line having a length equal to only about one-half of the wavelength of the frequency of operation of the device 100, all without substantially impeding the propagation of energy at the frequency of operation of the device 100 to the cooking cavity 21. Also, RF filters for filtering the frequency of operation of the device 100 and the second and third and fourth harmonics thereof have been provided in the coupling structure between the device 100 and the Edison supply network and the voltage doubler and rectifier circuit 130 to provide high attenuation of RF energy while not interfering with the transmission of the DC and low frequency AC operation potentials from the Edison supply network and the voltage doubler and rectifier circuit 130 to the device 100.

From the above it will be seen that there has been provided an improved electronic heating apparatus 10 and microwave coupling structure 350-390 and improved transmission lines 200 and 300 therefor and improved harmonic filters in the transmission line 300 which fulfill all of the objects and advantages set forth above.

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 can 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. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and having a pair of output terminals, a transmission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, a first filter section in said inner conductor and comprising structure defining a first cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency to effect high attenuation thereof, a second filter section in said inner conductor and comprising structure defining a second cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency to effect high attenuation thereof, whereby during the transmission of electromagnetic wave energy along said transmission line the second and fourth harmonics of the predetermined frequency are highly attenuated by said filter sections while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

2. The electronic heating apparatus set forth in claim 1, and further including a third filter section in said transmission line including a high impedance path in said inner and outer conductors for the second and higher even harmonics of the predetermined frequency to effect high attenuation thereof.

3. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and having a pair of output terminals, a transmission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, a first filter section in said inner conductor and comprising structure defining a first cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency to effect high attenuation thereof, a second filter section in said inner conductor and comprising structure defining

a second cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency to effect high attenuation thereof, and a third filter section in said inner conductor and comprising structure defining a third cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency to effect high attenuation thereof, whereby during the transmission of electromagnetic wave energy along said transmission line the second and third, and fourth harmonics of the predetermined frequency are highly attenuated by said filter sections while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

4. The electronic heating apparatus set forth in claim 3, and further including a fourth filter section in said transmission line including a high impedance path in said inner and outer conductors for the second and higher even harmonics of the predetermined frequency to effect high attenuation thereof.

5. The electronic heating apparatus set forth in claim 4, wherein the portion of said transmission line including said first and second and third and fourth filter sections has a length corresponding to about one-half of the wavelength of the predetermined frequency.

6. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency having a pair of output terminals, a transmission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, and a filter section in said inner conductor and comprising structure defining an inner cavity and an outer cavity disposed about said inner cavity, said filter section structure having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency, said inner cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, said outer cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, said filter section presenting a high impedance to the transmission of both the second and fourth harmonics of the predetermined frequency along said inner conductor while having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency, whereby during the transmission of electromagnetic wave energy along said transmission line the second and fourth harmonics of the predetermined frequency are highly attenuated by said filter section while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

7. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and having a pair of output terminals, a transmission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, a first filter section in said inner conductor and comprising structure defining an inner cavity and an outer cavity disposed about said inner cavity, said filter section structure having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency, said inner cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predeter-

mined frequency, said outer cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, and a second filter section in said inner conductor and comprising structure defining a cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency, said first and second filter sections presenting a high impedance to the transmission of the second and third and fourth harmonics of the predetermined frequency along said inner conductor, whereby during the transmission of electromagnetic wave energy along said transmission line the second and third and fourth harmonics of the predetermined frequency are highly attenuated by said filter sections while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

8. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and having a pair of output terminals, a transmission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, a first cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor, said first filter member cooperating with said inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, and a second cup-like filter member including a cylindrical side wall surrounding the cylindrical side wall of said first filter member and concentric therewith and spaced therefrom and an end wall closing said side wall of said second filter member at one end thereof and connected to said inner conductor, said second filter member cooperating with said first filter member and with said inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, said first filter member being disposed within said second filter member and said second filter member having a length equal to about one-quarter of the wavelength of the second harmonic of the predetermined frequency while said filter members present a high impedance to the transmission of both the second and fourth harmonics of the predetermined frequency along said inner conductor, whereby during the transmission of electromagnetic wave energy along said transmission line the second and fourth harmonics of the predetermined frequency are highly attenuated by said filter members while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

9. The electronic heating apparatus set forth in claim 8, wherein the end walls of said first and second cup-like filter members are both disposed toward the same end of said transmission line.

10. The electronic heating apparatus set forth in claim 9, wherein the end walls of said first and second cup-like filter members are both disposed toward said generator.

11. The electronic heating apparatus set forth in claim 8, wherein the end walls of said first and second cup-like filter members each has an internally threaded opening therethrough, said inner conductor being disposed through said internally threaded openings and threadedly engaged thereat with said first and second cup-like filter members.

12. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and having a pair of output terminals, a transmission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, a first cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor, said first filter member cooperating with said inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, a second cup-like filter member including a cylindrical side wall surrounding the cylindrical side wall of said first filter member and concentric therewith and spaced therefrom and an end wall closing said side wall of said second filter member at one end thereof and connected to said inner conductor, said second filter member cooperating with said first filter member and with said inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, and a third cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor, said third filter member cooperating with said inner conductor to define a cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency, whereby during the transmission of electromagnetic wave energy along said transmission line the second and third and fourth harmonics of the predetermined frequency are highly attenuated by said filter members while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

13. The electronic heating apparatus set forth in claim 12, wherein the end walls of said first and second cup-like filter members are both disposed toward one end of said transmission line and the end wall of said third cup-like filter member is disposed toward the other end of said transmission line.

14. The electronic heating apparatus set forth in claim 13, wherein the end walls of said first and second cup-like filter members are disposed toward said generator and the end wall of said third cup-like filter member is disposed toward said load.

15. The electronic heating apparatus set forth in claim 13, and further including an annular insulating spacer disposed around said inner conductor and separating said first and second cup-like filter members from said third cup-like filter member, said insulating spacer having three pairs of shoulders thereon respectively abutting the ends of said first and second and third cup-like filter members opposite to the end walls thereof.

16. The electronic heating apparatus set forth in claim 12, wherein the end walls of said first and second and third cup-like filter members each has an internally threaded opening therethrough, said inner conductor being disposed through said internally threaded openings and threadedly engaged thereat with said first and second and third cup-like filter members.

17. In an electronic heating apparatus, structure defining a cooking cavity, a generator for generating electromagnetic wave energy of a predetermined ultra-high frequency and having a pair of output terminals, a trans-

mission line coupling said generator to said cooking cavity and including a hollow outer conductor coupled to one terminal of said generator and an inner conductor coupled to the other terminal of said generator, a first cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor, said first filter member cooperating with said inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth harmonic of the predetermined frequency, a second cup-like filter member including a cylindrical side wall surrounding the cylindrical side wall of said first filter member and concentric therewith and spaced therefrom and an end wall closing said side wall of said second filter member at one end thereof and connected to said inner conductor, said second filter member cooperating with said first filter member and with said inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency, a third cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor, said third filter member cooperating with said inner conductor to define a third cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency, and a filter section in said transmission line including a low impedance bypass path between said inner and outer conductors for the second and higher harmonics of the predetermined frequency to effect high attenuation thereof, whereby during the transmission of electromagnetic wave energy along said transmission line the second and third and fourth and higher harmonics of the predetermined frequency are highly attenuated by said filter members and said filter section while the predetermined frequency is propagated to said cooking cavity substantially without attenuation.

18. The electronic heating apparatus set forth in claim 17, wherein said inner and outer conductors each comprise a pair of segments insulated from each other and telescopically overlapping each other a distance equal to about one-quarter of the wavelength of the predetermined frequency thereby providing a high impedance path in said inner and outer conductors for the second and higher even harmonics of the predetermined frequency.

19. 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, 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 low frequency AC source terminal and the DC source terminal to the outer end of said inner conductor, a first filter element disposed in said conductors between said RF output terminals and the outer ends of said conductors and providing a low impedance bypass path for the second

harmonic of the predetermined frequency, a second filter element disposed in said conductors between said RF output terminals and the outer ends of said conductors and providing a low impedance bypass path for the third harmonic of the predetermined frequency, a third filter element disposed in said conductors between said RF output terminals and the outer ends of said conductors and including a cavity resonant at the predetermined frequency and presenting a high series impedance to the transmission of the predetermined frequency along said conductors to the low frequency AC source terminal and the DC source terminal, and a fourth filter element disposed in said conductors between said RF output terminals and the outer ends of said conductors and including a cavity resonant at the fourth harmonic of the predetermined frequency and presenting a high series impedance to the transmission of the fourth harmonic of the predetermined frequency along said conductors to the low frequency AC source terminal and the DC source terminal, whereby propagation of RF energy at the predetermined frequency and the second and third and fourth harmonics thereof from the generator to the outer ends of said conductors is highly attenuated without interfering with the transmission of the low frequency AC and the DC operating potentials between the sources thereof and the generator.

20. 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 said 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, 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 low frequency AC source terminal and the DC source terminal to the outer end of said inner conductor, a first cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor intermediate the ends thereof, said first filter member being telescopically received in and insulated from said outer conductor, and a second cup-like filter member including a cylindrical side wall surrounding the adjacent portion of said inner conductor and concentric therewith and spaced therefrom and an end wall closing said side wall at one end thereof and connected to said inner conductor at the outer end thereof, the cylindrical side wall of said second filter member being telescopically received in and insulated from the outer end of said outer conductor, said inner and outer conductors being spaced apart and cooperating to form therebetween a low impedance bypass path at the second harmonic of the predetermined frequency to effect high attenuation thereof, the cylindrical side wall of said first filter member cooperating with said outer conductor to form therebetween a low impedance bypass path at the third harmonic of the predetermined frequency to effect high attenuation thereof, said first filter member cooperating with said inner conductor to define a first cavity having an effective electrical length equal to one-quarter of the wavelength of the predetermined frequency and being resonant at the predetermined frequency to present a high impedance to the transmission of the predetermined frequency along said inner conductor, said second filter member cooperating with said inner conductor to define a second cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the

fourth harmonic of the predetermined frequency to present a high impedance to the transmission of the fourth harmonic of the predetermined frequency along said inner conductor, whereby propagation of RF energy at the predetermined frequency and the second and third and fourth harmonics thereof from said generator to the outer ends of said conductors is highly attenuated without interfering with the transmission of the low frequency AC and the DC operating potentials between the sources thereof and the generator.

21. The coupling structure set forth in claim 20, wherein the end walls of said first and second cup-like filter members are both disposed toward said sources.

22. A coupling structure for interconnecting a generator for generating RF energy of a predetermined ultra-high RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC operating potential having at least one terminal and a load for the RF energy, wherein the generator has an annular outer RF terminal and an inner RF 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 first outer conductor and coupled to the inner RF terminal of the generator and extending outwardly therefrom and terminating at an outer end adjacent to the outer end of said first outer conductor, means coupling the DC source terminal and the low frequency AC source terminal to the outer end of said first inner conductor, a second hollow outer conductor coupled to said first outer conductor intermediate the generator RF terminals and said outer ends and coupled to the load, a second inner conductor disposed in said second outer conductor and coupled to said first inner conductor intermediate the generator RF terminals and said outer ends and coupled to the load, a first filter element disposed in said first outer conductor between the coupling to said second outer conductor and the outer ends of said first conductors and providing a low impedance bypass path for the second harmonic of the predetermined frequency, a second filter element disposed in said first outer conductor between said coupling to said second outer conductor and the outer ends of said first conductors and including a cavity resonant at the predetermined frequency and presenting a high series impedance to the transmission of the predetermined frequency along said first conductors to the DC source terminal and the low frequency AC source terminal, a third filter element disposed in said first outer conductor between said coupling to said second outer conductor and the outer ends of said first conductors and including a cavity resonant at the fourth harmonic of the predetermined frequency and presenting a high series impedance to the transmission of the fourth harmonic of the predetermined frequency along said first conductors to the DC source terminal and the low frequency AC source terminal, whereby propagation of RF energy at the predetermined frequency and the second and fourth harmonics thereof from the generator to the outer ends of said first conductors is highly attenuated without interfering with the transmission of the DC and the low frequency AC operating potentials between the sources thereof and the generator, a first filter section in said second outer conductor and comprising structure defining a first cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency to present a high impedance to the transmission of the second harmonic of the predetermined frequency along said second conductors, and a second filter section in said second outer conductor and comprising structure defining a second cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and being resonant at the fourth har-

monic of the predetermined frequency to present a high impedance to the transmission of the fourth harmonic of the predetermined frequency along said second conductors, whereby propagation of RF energy at the second and fourth harmonics of the predetermined frequency along said second conductors is highly attenuated without interfering with the transmission of RF energy at the predetermined frequency to the load.

23. A coupling structure for interconnecting a generator for generating RF energy of a predetermined ultra-high RF frequency and a source of DC operating potentials having at least one terminal and a source of low frequency AC operating potential having at least one terminal and a load for the RF energy, wherein the generator has an annular outer RF terminal and an inner RF 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 first outer conductor and coupled to the inner RF terminal of the generator and extending outwardly therefrom and terminating at an outer end adjacent to the outer end of said first outer conductor, means coupling the DC source terminal and the low frequency AC source terminal to the outer end of said first inner conductor, a second hollow outer conductor coupled to said first outer conductor intermediate the generator RF terminals and said outer ends and coupled to the load, a second inner conductor disposed in said second outer conductor and coupled to said first inner conductor intermediate the generator RF terminals and said outer ends and coupled to the load, a first filter element disposed in said first outer conductor between the coupling to said second outer conductor and the outer ends of said first conductors and providing a low impedance bypass path for the second harmonic of the predetermined frequency, a second filter element disposed in said first outer conductor between said coupling to said second outer conductor and the outer ends of said first conductors and including a cavity resonant at the predetermined frequency and presenting a high series impedance to the transmission of the predetermined frequency along said first conductors to the DC source terminal and the low frequency AC source terminal, a third filter element disposed in said first outer conductor between said coupling to said second outer conductor and the outer ends of said first conductors and including a cavity resonant at the fourth harmonic of the predetermined frequency and presenting a high series impedance to the transmission of the fourth harmonic of the predetermined frequency along said first conductors to the DC source terminal and the low frequency AC source terminal, a fourth filter element disposed in said first outer conductor between the coupling to said second outer conductor and the outer ends of said first conductors and providing a low impedance bypass path for the third harmonic of the predetermined frequency, whereby propagation of RF energy at the predetermined frequency and the second and third and fourth harmonics thereof from the generator to the outer ends of said first conductors is highly attenuated without interfering with the transmission of the DC and the low frequency AC operating potentials between the sources thereof and the generator, a first filter section in said second outer conductor and comprising structure defining a first cavity having an effective electrical length equal to one-quarter of the wavelength of the second harmonic of the predetermined frequency and being resonant at the second harmonic of the predetermined frequency to present a high impedance to the transmission of the second harmonic of the predetermined frequency along said second conductors, a second filter section in said second outer conductor and comprising structure defining a second cavity having an effective electrical length equal to one-quarter of the wavelength of the fourth harmonic of the predetermined frequency and

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being resonant at the fourth harmonic of the predetermined frequency to present a high impedance to the transmission of the fourth harmonic of the predetermined frequency along said second conductors, and a third filter section in said second outer conductor and comprising structure defining a third cavity having an effective electrical length equal to one-quarter of the wavelength of the third harmonic of the predetermined frequency and being resonant at the third harmonic of the predetermined frequency to present a high impedance to the transmission of the third harmonic of the predetermined frequency along said second conductors, whereby propagation of RF energy at the second and third and fourth harmonics of the predetermined frequency along said second conductors is highly attenuated without interfering with the transmission of RF energy at the predetermined frequency to the load.

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U.S. Cl. X.R.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,536,878 Dated October 27, 1970

Inventor(s) Louis H. Fitzmayer et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 26, line 10, "3,448,386" should read
-- 3,440,386 --.

Signed and sealed this 13th day of April 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents