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(71) Applicant: Kabushiki Kaisha Toshiba
72, Horikawa-cho Saiwai-ku
Kawasaki-shi Kanagawa-ken 210(JP)

(72) Inventor: Saito, Hisao c/o Patent Division
Toshiba Co. Principal Office 1-1, Shibaura 1-chome
Minato-ku Tokyo(JP)

(72) Inventor: Tashiro, Norio c/o Patent Division
Toshiba Co. Principal Office 1-1, Shibaura 1-chome
Minato-ku Tokyo(JP)

(72) Inventor: Mino, Munetaka c/o Patent Division
Toshiba Co. Principal Office 1-1, Shibaura 1-chome
Minato-ku Tokyo(JP)

(72) Inventor: Miura, Heihachi c/o Patent Division
Toshiba Co. Principal Office 1-1, Shibaura 1-chome
Minato-ku Tokyo(JP)

(74) Representative: Shindler, Nigel et al,
BATCHELLOR, KIRK & EYLES 2 Pear Tree Court
Farringdon Road
London EC1R 0DS(GB)

(54) **Magnetron for a microwave oven.**

(57) A magnetron (30) is provided with at least one choke (B_1) for harmonic frequencies of the fourth harmonic or higher and in particular the fifth harmonic etc. in the interior of the metal container (37). The space in the diametric direction inside an opening (37b) of the metal container hermetically sealed from the anode (31) is limited to not more than about 1/2 of the wavelength of this higher harmonic.

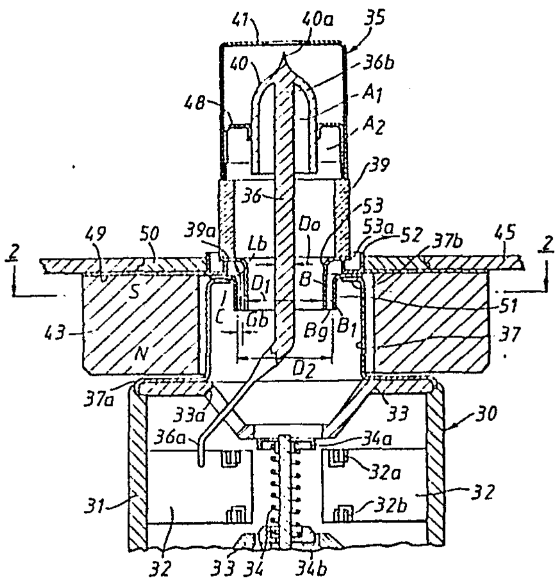

FIG. 1.

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MAGNETRON FOR A MICROWAVE OVEN

This invention relates to magnetrons for microwave ovens and more particularly to a construction such as to suppress radiation of higher harmonics.

A magnetron for a microwave oven generates microwaves in for example the 2540 MHz band in a cavity resonator of the anode. Apart from the power generated at the fundamental frequency in this 2450 MHz band, some power is also generated at so-called "higher harmonics". These higher harmonic components are frequencies which are integral multiples of the fundamental frequency. They are propagated into the heating cavity of the microwave oven. However, shielding of microwave radiation increases in difficulty as the wavelength becomes shorter. Proper electromagnetic shielding of the microwave oven therefore becomes difficult and such higher harmonic components tend to leak to the outside. Even slight microwave leakage causes radio interference and the permitted amount of such leakage is legally prescribed.

A particular problem in recent years, as use of satellite communications has become commonplace, is that of interference with reception if the frequency band used for the satellite down-link coincides with frequencies found in microwave leakage from magnetrons and microwave ovens. This presents few problems if the equipment that receives the communication frequencies transmitted from the satellite is set up at a sufficient distance from users of microwave ovens such as ordinary households. However, in the case of satellite broadcasts such as television, the receiving antennas are often close to sites where microwave ovens are used, so it is particularly necessary to eliminate interference with satellite broadcasts completely. Of the various frequency bands that have been internationally allocated for satellite broadcast downlinks, the 12GHz band coincides with higher harmonics from microwave oven magnetrons generating frequencies in the 2450 + 50MHz band. Specifically, it just about corresponds with the fifth harmonic (i.e. five times) the fundamental frequency of the microwave oven magnetron. The wavelength of this fifth harmonic is about 24.5mm.

Conventionally the output part of the magnetron itself is formed with a 1/4 wavelength choke to suppress higher harmonic generation, and it is already known to suppress radiation of arbitrarily specified higher harmonic components. Examples are disclosed in the specifications of Laid-open Japanese Utility Model No. Sho. 49-80648, Japanese Patent Publication No. Sho. 56-21215, Japanese Patent Publication No. Sho. 54-6862, or Japanese Utility Model Publication No. Sho. 54-18123.

Such a magnetron is constructed essentially as shown in Fig. 24 and Fig. 25. A magnetron body 30 is equipped with an anode cylinder 31, a plurality of anode vanes 32, a pole piece 33, a cathode 34, and an output antenna 35. Output antenna 35 is equipped with an antenna lead 36 that is electrically coupled to an anode vane 32, a tubular metal container 37, an inner metal cylinder 38, a ceramic insulating cylinder 39, a metal exhaust pipe 40, and an output cap 41. A plurality of radiator fins 42 are fixed around the periphery of anode cylinder 31. Ferrite magnets 43 and 44 surrounded by a magnetic yoke 45 are disposed at both ends of body 30. Output antenna 35 extends through magnets 43 and yoke 45. A cathode input terminal 47 is provided in a shielding box 46.

The end of antenna 36 is electrically coupled to metal exhaust pipe 40. An arrangement providing a choking effect on the second and third harmonics is achieved by making the depth L1 of the inside space A of the metal exhaust pipe, that short-circuits the end of the antenna lead, of a dimension corresponding to about 1/4 of the wavelength of for example the second harmonic and by making the depth L2 of the annular groove B formed with the metal container 37 and inner metal cylinder 38 of a dimension corresponding to about 1/4 of the wavelength of for example the third harmonic. The dimensions of such chokes can be set to correspond electrically to 1/4 of the wavelength of any arbitrarily specified higher harmonic. However, conventionally, magnetrons were manufactured incorporating chokes that suppressed the second or third harmonic, since there were the harmonics at which in general relatively most power was generated.

Based on this prior art, it was thought that satisfactory suppression of radiation of higher harmonics could be achieved for example by setting the depth dimension of an annular groove B to about 1/4 of the wavelength of the fifth higher harmonic i.e. to about 6.1 mm. However, in fact, setting the groove to this dimension only results in slight attenuation of the fifth harmonic. The amount of this fifth harmonic in fact far exceeds the radiation level that is presently prescribed for the reasons discussed above. This technique has not therefore given satisfactory results. The reason for this is believed to be that simply setting the depth dimension of annular groove B to about 1/4 of the wavelength of the harmonic that is to be suppressed, for example the fifth higher harmonic, does not prevent this harmonic from being easily propagated to the outside through the space between the antenna lead and metal container and the inner metal cylinder.

Related to this point, in particular the magnetrons that are widely used in domestic microwave ovens, as mentioned above, have a fundamental frequency of about 2450MHz, with microwave output power generally of the order 500-800W. In magnetrons of such rating, the dimensions of the insulating cylinder of the output part and of its vicinity have to be made such as to avoid the possibility of discharge at microwave frequencies due to the microwave electric field when the magnetron is operated under no load conditions. Experience has shown that this implies that the internal diameter of the insulating cylinder should be at least 12mm, and its axial length at least 10mm. If they are made smaller than this there is a considerable risk of microwave discharge in the space between the metal members that are disposed on either side of the insulating cylinder, or between the soldered joint of the metal container to the insulating cylinder and the antenna that passes through inside it. Such discharge tends to cause cracks in the insulating cylinder. Since for this reason the diameters of the insulating cylinder and metal cylinder must be made greater than a certain amount, a large space must be provided between the metal cylinder and the antenna that passes through it. It is therefore inferred that very short wavelength components, such as the fifth harmonic, can be radiated to the outside notwithstanding the presence of a choke formed by the annular groove.

The object of this invention is to provide a magnetron for a microwave oven having a choke construction that is very effective in suppressing radiation of harmonic frequencies of the fourth harmonic or higher.

According to this invention, a magnetron for a microwave oven comprises a cathode; a cylindrical anode having a cavity resonator arranged around the cathode; a cylindrical metal container hermetically sealed to part of the anode to form an evacuated envelope with the anode, defining a part of the space in the evacuated envelope, and having an opening; an output insulating cylinder hermetically coupled to the opening of the metal container; an output antenna lead whereof one end is electrically coupled to the cavity resonator of the anode and which extends through the inside space of the insulating cylinder, passing through the opening of the metal container; and a choke surrounding the antenna lead by means of a cylindrical conductor inside the metal container and comprising an annular groove of depth about 1/4 of the wavelength of a specified higher harmonic, in which the magnetron comprises; means to set the inner diameter of the opening through which the antenna lead passes to a dimension of about 1/2 or less of the wavelength of the specified higher harmonic, which is the fourth or higher harmonic; and a choke having an annular groove suppressing a radiation on the higher harmonic with an opening provided in said inside space of the metal container, the radial width of the choke at or near the opening of the annular groove being formed to be not more than 1/10 of the higher harmonic wavelength.

By this means it is possible to reliably suppress radiation of the fourth or higher harmonics that otherwise tend to leak to the outside from the magnetron, by provision of a choke arranged inside the tubular metal container. If this is combined with formation of a choke for the second and third harmonics at the tip of the antenna lead i.e., near the top end of the insulating cylinder, radiation of both these powerful lower harmonics and the higher harmonics, which, although weak, cause radio interference, can be reliably suppressed.

In order that the invention may be more readily understood, it will now be described, by way of example only, with reference to the accompanying drawings in which:-

Fig. 1 is an axial cross-sectional view of main parts of an embodiment of this invention.

Fig. 2 s a transverse cross-sectional view along the line 2-2 of Fig. 1.

Fig. 3 is a characteristic graph showing a comparison of the levels of higher order harmonic suppression achieved by a construction according an embodiment of this invention and by a prior art construction.

Fig. 4 is a characteristic graph showing the levels of higher order harmonic suppression achieved by an embodiment of this invention.

Fig. 5 is a characteristic graph showing the levels of higher order harmonic suppression achieved by an embodiment of this invention.

Fig. 6 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 7 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 8 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 9 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 10 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 11 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 12 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 13 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 14 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 15 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 16 is perspective view showing a part thereof.

Fig. 17 is an exploded cross-sectional view of main parts showing the method whereby they are assembled.

Fig. 18 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 19 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 20 is an axial cross-sectional view of main parts of a further embodiment of this invention.

Fig. 21 is a cross-sectional view, to a larger scale, of main parts.

Fig. 22 is an exploded perspective view of main parts showing the method whereby they are assembled.

Fig. 23 is an exploded cross-sectional view of main parts of another embodiment of this invention.

Fig. 24 is a side view showing the general construction of a magnetron.

Fig. 25 is an axial cross-sectional view of main parts showing a prior art construction.

Embodiments of the invention are described below with reference to the drawings. Parts which are the same are given the same reference numerals.

The embodiment shown in Fig. 1 and Fig. 2 is constructed as follows. In these Figures, 30 is a magnetron body; 34 is a cathode; 34a and 34b are a pair of end hats; 31 is an anode cylinder; 32 is a plurality of radial anode vanes; 32a and 32b are strap rings; 33 is a funnel shaped pole piece; 33a is a through hole provided in part of the pole piece for passage of the antenna lead; 37 is a cylindrical metal container of the output part, sealed to the end face of the anode at which pole piece 33 is located, to form an evacuated envelope in combination with the anode; 37a is a flange coupled hermetically to the anode cylinder; 37b is an opening provided at its tip, through which antenna lead 36 passes; 39 is a ceramic insulating cylinder of the output part; 40 is a metal exhaust pipe; 40a is a gas-tight sealing pinched-off part; 36 is an output antenna lead; 36a is the bottom end of the antenna lead electrically connected to one of the anode vanes by being pinched flat; 36b is the tip of the antenna lead and is electrically short-circuited by being clamped to the metal exhaust pipe; 41 is an output cap; 48 is a metal cylinder for an external choke coupled hermetically between the periphery of the exhaust pipe and the end face of the opening of the insulating cylinder; 43 is a cylindrical ferrite permanent magnet; 49 is an magnetic shim plate; 45 is an iron yoke; and 50 is a ring-shaped gasket made of electrically conducting mesh. Thus an annular space A1 is formed between metal exhaust pipe 40 electrically connected to the tip of antenna lead 36 and the part of antenna lead 36 that lies inside this metal exhaust pipe. An annular space A2 is formed between this metal exhaust pipe and metal cylinder 48 for the external choke. These annular spaces form 1/4 wavelength chokes principally for the second and third harmonics.

Additionally, an annular groove B of a choke B1 prescribed depth showing a choke effect on the fifth harmonic is formed on the inside of tip opening 37b of metal container 37, whose flange-shaped peripheral edge is gas-tightly coupled to the open end of the anode cylinder. To this end, an intermediate tubular conductor 51 is electrically coupled with the inside of tip opening 37b of metal container 37, a gasket-retaining metal ring is electrically coupled thereto, and in addition an expanded flange 53a of an inner tubular conductor 53 is in turn gas-tightly coupled thereto. This expanded flange 53a is gas-tightly coupled by brazed joint 39a to the bottom end of insulating cylinder 39.

Inner tubular conductor 53 and intermediate tubular conductor 51 are arranged coaxially adjacent around antenna

36, which is formed as a cylindrical rod. Inner tubular conductor 53 is arranged as shown in the drawing to project much further inwards than the relatively large diameter metal container 37. Its internal diameter is formed to a prescribed dimension smaller than the internal diameter of insulating cylinder 39. Specifically, the internal diameter D1 of this inner tubular conductor 53 is about equal to or rather less than 1/2 (= 12.5mm) of the fifth harmonic wavelength that is to be suppressed. It should be noted that this conductor 53 and antenna lead 36 must be separated by a sufficient distance such that electrical discharge is not produced by the high frequency electric field generated between them.

Annular choke groove B for the fifth harmonic is formed by disposing two annular conductors 53 and 51 adjacent each other with a separation. The depth Lb of this annular choke groove B is electrically about 1/4 of the wavelength of the fifth harmonic: that is, it has a choking effect showing high impedance for the fifth harmonic. A groove opening Bg is provided in the inside space surrounded by metal container 37. Its radial dimension (i.e. the width Gb of the groove opening Bg) is no more than 1/10 (= 2.5mm) of the wavelength of the fifth harmonic (that is to be suppressed). In particular,it is preferably not more than 1/20 (= 1.25mm) of the wavelength of the fifth harmonic. By this means, radiation of the fifth harmonic component to the outside can be reliably suppressed by the choke consisting of annular groove B formed by coaxially arranging two tubular conductors 53 and 51 that surround the antenna comparatively closely.

A specific example of the dimensions of these various components will now be given. The microwave oven magnetron of this example has a fundamental frequency in the 2450 MHz band, with output of the order about 800W.

Insulating cylinder 39: cylindrical pipe of internal diameter 13mm, axial length 10mm;

Antenna lead 36: cylindrical copper rod of diameter D0 2.5mm;

Metal container 37: internal diameter 19.0mm, axial height 12mm;

Inner tubular conductor 53: thickness 0.5mm, internal diameter D1 9.5mm, axial length 6.5mm;

Intermediate tubular conductor 51: internal diameter D2 12.0mm, axial length 4.5mm;

Depth Lb of annular groove B formed by the two tubular conductors: 5.8mm, opening width Gb 0.8mm.

The inventors tried various lengths for inside and intermediate tubular conductors 53 and 51 and various depths of the annular groove B formed by them and compared the externally radiated power levels of the fifth harmonic. The results are shown by curve P in Fig. 3. For comparison, the characteristic obtained with the prior art construction of Fig. 25, making the internal annular groove of the metal container, i.e. the internal diametric dimension, greater than 1/2 (in fact it was set to 14mm) of the wavelength of the fifth harmonic and making the groove opening width larger than 1/10 of the wavelength of this harmonic (in fact it was set to 3.0mm) is shown by the dotted line curve R.

It is clear from this Figure that when the depth Lb of annular groove B is in the neighbourhood of 5.8mm with the magnetron of this invention the fifth harmonic component can be reduced to about −20 dB. In contrast, although the characteristic R of the comparative example shows a minimum level when the groove depth is in the neighbourhood of 5.7mm, even at this level too much power is radiated at the fifth harmonic frequency for the construction to be considered satisfactory.

We believe that the beneficial effect which is obtained by this invention is due to the fact that, thanks to the inner tubular conductor provided around the antenna lead for about 1/2 less of the higher harmonic wavelength, radiation of which is to be suppressed, the space between this inner tubular conductor and the antenna lead has a diametric dimension which is less than 1/2 of this higher harmonic wavelength and a choke is constituted consisting of the annular groove that is formed there. In other words, around the antenna lead a coaxial path of small diameter is formed in which unwanted modes of higher order hermonic are not readily excited, and the annular groove choke is of high impedance for practically all higher order harmonic mode components. Thus radiation of these components is reliably suppressed. With the dimensions of the above example, this inner tubular conductor 53 is of smaller diameter than metal container 37 and is provided in a region inside it, forming a narrow space of diametric dimension about 7mm (= D1 − D0) between itself and antenna lead 36. Thus the choke for the fifth harmonic is constituted by this region. The inventors measured the fifth harmonic radiation level for various different internal diameters D1 of this internal tubular conductor 53, keeping the diameter D0 of the antenna lead constant at 2.5mm. The depth Lb of annular groove B was also kept constant at 5.8mm. The results are shown in Fig. 4. From these results, it can be seen that sufficient choking effect is obtained provided the internal diameter D1 is not more than 14mm. This confirms that the internal diameter D1 should be not more than about 1/2 of the wavelength of the fifth harmonic.

Even sharper attenuation can be obtained by making width Gb of the opening of the annular choke groove not more than 1/10 of the higher harmonic wavelength. That is, if, as shown in Fig. 5, the opening width Gb is made about 1/10, preferably about 1/20 or less (but not including zero width) wavelength of the fifth harmonic corresponding to the choke, an excellent choking effect is obtained.

The reason why the groove depth Lb for which the greatest suppression effect is obtained is rather shorter than 1.4 (= 6.1mm) the wavelength of the fifth harmonic is believed to be its interaction with the annular groove C that is provided at its periphery, or its electrical interactions, such as the fringing effect, at the openings of the two tubular conductors. Thus the depth of the annular groove need not necessarily be strictly identical with 1/4 of the spatial wavelength of the higher harmonic wavelength that is to be suppressed, but is to be set thereabouts to the value at which the greatest radiation suppression effect is obtained.

Also in this embodiment the inner tubular conductor projects inwards further than the gas-tight brazed joint at the bottom end of the insulating cylinder, so this brazed joint is screened from the high-frequency electric field between the antenna lead and these conductors, with the result that there is little risk of unwanted microwave discharge and resultant cracking of the brazed joint.

The inventors also recognized that the level of radiation of the fourth harmonic can be considerably reduced by further increasing the depth of the annular groove to in the neighbourhood of 7.1mm. Any desired higher order harmonics such as the forth and higher harmonics can therefore be selectively and reliably suppressed in this way.

A combined choke construction can be achieved by setting annular groove C formed at the periphery of the choke groove for the fifth harmonic to about 1/4 of the wavelength of a specified harmonic. This annular groove C is the annular groove formed by metal container 37 and intermediate tubular conductor 51.

A further embodiment is shown in Fig. 6. This embodiment consists of a magnetron wherein inner tubular conductor 53 that provides the higher order harmonic choke comprising annular groove B is directly gas-tightly soldered to the bottom end face of insulating cylinder 39. The top end of tubular metal container 37 is bent inwards in the form a half cross-section U so that it is integrally formed with intermediate tubular conductor 51. At the top end of the bent portion it is electrically short-circuited by a gas-tight brazed joint with gasket-retaining ring 52 and the end face of inner tubular conductor 53. The inner diameter D1 of inner tubular conductor 53 is of a dimension about 1/2 of, or less than the wavelength of the fifth harmonic. For example, dimension D1 is 13.6mm, D2 is 15.8mm, and Gb is

0.6mm.

This makes it possible to achieve a construction in which a choke for higher order harmonics, surrounding the antenna lead in an inner region of the metal container, can be assembled from a small number of components.

A further embodiment is shown in Fig. 7. In this embodiment, the top end of metal container 37 is bent inwards to serve as intermediate tubular conductor 51, thereby forming an annular groove C of depth Lc corresponding to about 1/4 of the wavelength of the fourth harmonic. The inner diameter D2 of intermediate tubular conductor 51 that forms this annular groove C is about 1/2 of, or less than the wavelength of the fourth harmonic. Inner tubular conductor 53 is coaxially arranged so as to lie adjacent the inner periphery of intermediate tubular conductor 51, thus forming in cooperation with this intermediate tubular conductor 51 an annular groove choke B for the fifth harmonic. The width Gc of annular groove C is less than about 1/10 of the wavelength of the fourth harmonic, and as stated previously opening width Gb of annular groove B is about 1/10 of the wavelength of the fifth harmonic.

These Figures do not show output cap 41 shown in Fig. 1 or Fig. 6, but an output cap of prescribed length is of course affixed to cover the metal exhaust pipe. The same applies to all the following embodiments.

With a magnetron according to this embodiment, reliable suppression of radiation of a plurality of higher order harmonics including the fifth harmonic can be achieved with a comparatively simple construction.

Fig. 8 shows yet a further embodiment of this invention. In this embodiment, a small diameter portion 37c is formed by bending part of metal container 37, that is coupled hermetically to the anode, inwards, and inner tubular conductor 53 is electrically connected on the inside of this small diameter portion. The internal diameter of this inner tubular conductor 53 is of a dimension about 1/2 of, or less than the wavelength of the fifth harmonic. Thus this region provides an annular groove B serving as a choke for the fifth harmonic. The dimensions of this groove B are the same as in the preceding embodiment. By this means a construction can be achieved in which reliable suppression of higher order harmonics can be achieved with an even smaller number of components.

In each of the embodiments described above, the opening of the choke for the fifth harmonic, constituted by the annular groove, is constructed so as to face the anode direction. However, the invention is not restricted to this, and as shown in Fig. 9, opening Bg of annular groove B formed by two tubular conductors 51 and 53 can provide a choke for higher harmonics in the region inside metal container 37 and facing insulating cylinder 39.

It is also possible for the annular groove forming the choke for the higher order harmonics to be bent in L-shaped cross-section as shown in Fig. 9. In this case, the groove depth that gives the choking effect is an electrical length determined by the spatial dimensions of the L shape. By this means therefore the length of the tubular conductor in the antenna direction can be shortened to give a more compact construction.

Still a further embodiment of this invention is shown in Fig. 10. In this embodiment, output part metal container 37 together with insulating cylinder 39 is formed of an internal diameter D3 (=13.6mm) corresponding to about 1/2 of the wavelength of the fifth harmonic, and inner cylinder 53 (internal diameter D1 = 11.0mm) forming choke annular groove B for the fifth harmonic is fixed in a region inside this small-diameter metal container 37c.

In these embodiments, practically the whole of the output part is constructed of a diametric dimension corresponding to about 1/2 of the higher harmonic wavelength corresponding to the higher harmonic choke provided in the internal region of the metal container, so reliable suppression of higher harmonic radiation can be achieved, and cylindrical permanent magnet 43 that is arranged at the periphery of the metal container part can be made of comparatively small dimensions. This increases the utilization of the magnetic field of the magnet and makes it possible to make the overall magnetron construction more compact.

Yet a further embodiment of this invention is shown in Fig. 11. In this embodiment, choke annular groove C for the fourth harmonic and choke annular groove B for the fifth harmonic and a choke annular groove E for the sixth harmonic are mutually coaxially formed at the same location in the region inside metal container 37. Specifically, an approximately U-shaped choke member 61 is fixed to the inside of metal container 37 so as to form two annular grooves C and B arranged with their openings facing mutually opposite directions. A further approximately U-shaped member 62 is fixed to the inside of this choke member 61 so as to form annular groove E. The depth dimensions of these respective annular grooves correspond to about 1/2 of the wavelength of the higher order harmonic that they are intended to stop. The internal diametric dimension D1 of inner cylindrical part 65a of innermost choke member 65 is about 1/2 of or less than the wavelength of the sixth harmonic, but is of such a dimension as not to give rise to microwave discharge between itself and antenna 36.

By means of this embodiment, external radiation of fourth to the sixth harmonic components can be prevented.

A further embodiment of this invention is shown in Fig. 12. In this embodiment, four conductor cylinders 63, 64, 65 and 66 constituting a choke member 74 are fixed mutually coaxially in the inside region of metal container 37. Choke annular grooves C, B, E and F are thereby formed. Choke annular groove C is of a depth dimension corresponding to about 1/4 of the wavelength of the fourth harmonic. Choke annular groove B is of a depth dimension corresponding to about 1/4 of the wavelength of the fifth harmonic. Choke annular groove E is of a depth dimension corresponding to about 1/4 of the wavelength of the sixth harmonic. Choke annular groove F is of a depth dimension corresponding to about 1/4 of the wavelength of the seventh harmonic. The internal diameter D1 of the innermost conductor cylinder 66 is 9mm, corresponding to about 1/2 of the wavelength of the seventh harmonic. By this means suppression of external radiation of a wide range of higher order harmonics, from the forth harmonic to the seventh harmonic, can be achieved.

Still a further embodiment of this invention is shown in Fig. 13. In this embodiment, outermost L-shaped annular groove C constitutes a choke groove of about 1/4 the wavelength of the fourth harmonic, groove B which lies inside it constitutes a choke groove of about 1/4 the wavelength of the fifth harmonic, groove E constitutes a choke groove of about 1/4 the wavelength of the sixth harmonic, and groove F constitutes a choke groove of about 1/4 the wavelength of the seventh harmonic. These choke members are formed by assembling U-shaped conductors 67 and 68, 69.

A further embodiment of this invention is shown in Fig. 14. In this embodiment, choke annular grooves C, B and E for the fourth, fifth and sixth order harmonics are arranged in the inner region of metal container 37 so that their openings respectively face in the direction of insulating cylinder 39. The inside diameter D1 of innermost conductor cylinder 66 is about 1/2 of the wagelength of the sixth harmonic.

In the embodiments shown in Fig. 15 to Fig. 17, integrally formed choke members 70 are provided in the inside region of metal container 37. These choke members 70 consist of a double-skinned thin metal cylinder made for example of copper. This is a single component constructed of an inner cylindrical part 53 and outer cylindrical part 51 formed unitarily by deep drawing using a press. Their opening Bg is directed towards the anode vanes. As shown in Fig. 17, they fit from the bottom onto a step 37d near the upper end of the metal container, being brazed in place around the entire circumference. Extreme end opening 37b of metal container 37 extends further inwards than the brazed joint 39a of insulating cylinder 39, so that it forms an essentially continuous conductive cylinder of the same internal diameter with inner cylinder 53 of choke member 70. The depth dimension Lb of choke member 70, and the internal diametric dimension D1 and opening width Bg of inner cylinder 53 respectively have the same dimensional relationships with the wavelength of the fifth harmonic that is to be suppressed as in the previous embodiments.

With this embodiment, since the choke cylinder consisting of inner and outer cylinders is integrally formed as a single component, the depth Lb of annular groove B can be precisely formed to the prescribed dimension before this component is fitted in the magnetron. This avoids statistical scatter, i.e. manufacturing variations, of the groove depth and therefore permits assembly with the dimension that gives the best possible suppression of any specified higher order harmonic. This enables products with a uniformly good higher order harmonic suppression characteristic to be mass-produced. Handling is also facilitated by the fact that the choke cylinder is a unitary component.

A further embodiment is shown in Fig. 18. In this embodiment, an electromagnetic wave absorber 71 such as carbon or silicon carbide (SiC) is disposed in annular choke groove B for the fifth harmonic. By this means, the higher order harmonic that is practically at the resonant frequency of annular choke groove B is absorbed by absorber 71 as it is reflected within this choke member. External radiation of this higher order component is therefore even more strongly suppressed.

Yet a further embodiment is shown in Fig. 19. In this embodiment, choke member 70 is integrally coated with inner cylindrical part 53 and outer cylindrical part 51, which are formed by a continuous layer of copper plating on the inside and outside faces and one end face of a ceramic dielectric cylinder 72, An end face 53g of the inner cylindrical part is formed as a curved face to prevent microwave discharge. The end face of a thin part 42a of a fixing metal ring 73 is brazed to one end face. Ceramic dielectric 72 essentially constitutes annular choke groove B while its other end part 72a forms the opening of this choke member. Choke member 70 is thus formed from a single integrally constructed component and is mounted in the inside region of metal container 37.

The electrical length of the choke cylinder is thereby increased by the dielectric constant of the ceramic dielectric, so the actual length in the axial direction can be decreased in proportion. Also, since the shape and dimensions of the "annular groove" choke formed by the ceramic dielectric and the conductive layer with which its circumference is coated are fixed, they can be preset accurately, so that the dimensions giving the optimum radiation suppressing effect are easily obtained.

A further embodiment is shown in Fig. 20 to Fig. 22. In this embodiment, a choke member 74 for the fifth harmonic is connected and fixed to antenna lead 36 in the inside region of metal container 37. Metal container 37 is made up of: (i) a flange-shaped circumferential edge portion 37a that is bonded hermetically to the end of the opening of the anode cylinder (ii) a tapered part 37e extending from the flat face of pole piece 33 and at its other end joining (iii) a smaller diameter cylindrical part 37c that extends with constant internal diameter D3 in the direction of insulating cylinder 39. The internal diameter D3 of this smaller diameter cylindrical part 37c corresponds to about 1/2 of the wavelength of the fifth harmonic, and is for example 13mm. Its length Ls in the axial direction is at least 1/4 of the wavelength of the fifth harmonic, and is for example 14mm. A choke cylinder 74 that suppresses radiation of the fifth harmonic to the outside is fixed to the circumferential wall of antenna lead 36 in the region inside this smaller diameter cylindrical part 37c. This higher harmonic choke cylinder 74 is mechanically and electrically fixed in the prescribed position by caulking using a pinching jig 75 that pinches the circumference of a smaller diameter portion 74a of a metal cylinder of prescribed dimensions inserted beforehand from above as shown in Fig. 22 onto antenna lead component 36, which is formed as a round rod. By this means, choke cylinder 74 is set in position such that its opening 74b lies inside smaller diameter portion 37c of the metal container. Thus annular groove B is formed around antenna lead 36 by means of this choke cylinder 74, the depth Lb of this annular groove corresponding to about 1/4 of the wavelength of the fifth harmonic. The distance between this choke cylinder 74 and metal container 37 which coaxially surrounds it is set so that microwave discharge does not occur between them.

In this embodiment, the width Gb in the radial direction of the opening of annular groove B formed by this choke cylinder facing the anode vanes is less than 1/10 (=

2.5mm) of the wavelength of the fifth harmonic that is to be suppressed, and is preferably less than 1/20 (= 1.25mm). Thus external radiation of the fifth harmonic is reliably suppressed by this higher harmonic choke cylinder 74 fixed to the antenna lead.

With a magnetron according to this embodiment, suppression of the fifth harmonic component to -22dB was achieved by making the depth Lb of annular groove B in the neighbourhood of 5.9mm.

In particular in this embodiment, the internal diameter of the metal container of the output part is set to about 1/2 of or less than the harmonic wavelength that is to be suppressed of the higher harmonic choke provided in the inside region, so the antenna lead and metal container smaller diameter portion form a small diameter coaxial path. And since the higher harmonic choke cylinder is arranged on and surrounding the antenna lead in this region, the space between the choke cylinder and the inner circumferential face of the metal container is smaller than 1/2 of this higher harmonic wavelength. And since a choke is formed consisting of an annular groove of small opening width, markedly effective suppression of higher order harmonics is obtained.

It should be noted that when the depth Lb of annular choke groove B is made still deeper, at about the neighbourhood of 7.2mm, it was found to considerably suppress radiation of the fourth harmonic. It is therefore possible to suppress selectively and effectively any desired higher order harmonic of order four or over.

Yet a further embodiment is shown in Fig. 23. In this embodiment, choke cylinder 53 forming annular groove C for suppression of the fifth harmonic is fitted inside smaller diameter portion 37c of output part metal container 37, and choke member 76 for suppression of the sixth harmonic is fixed to antenna lead 36 in the region inside it. That is, cylindrical conductor 53 is fixed to the extreme end of the opening of metal container 37. Metal ring 52 and gasket retaining ring 52a are fixed at the circumference of the extreme end part of the metal container. Annular groove B that is formed between choke cylinder 53 and metal container smaller diameter part 37c is about 1/4 of the wavelength of the fifth harmonic that is to be suppressed. Groove opening width Gb is set to not more than 1/10 of the fifth harmonic as in the previous embodiments. The internal diameter of smaller diameter region 37c of the metal container is likewise set to about 1/2 of the wavelength of the fifth harmonic, or to less than this value. A further choke member 76 formed as a cylinder is provided on antenna lead 36 in the region inside choke cylinder 53. The annular groove E formed by this choke member 76 has a depth dimension Le such as to suppress the sixth harmonic. Thus propagation of both the fifth and sixth harmonics in the region inside the metal container smaller diameter portion is reliably suppressed, propagation of the fifth harmonic being suppressed by the outer annular groove B while propagation of the sixth harmonic is suppressed by the annular groove E formed by the cylinder connected to the antenna lead. In this case, the internal diameter of tubular conductor 53 is about 1/2, or rather less than this, of the wavelength of the sixth harmonic, and its axial length is likewise at least 1/4 of the wavelength of the fifth harmonic.

More than one choke member can be connected to the circumference of the antenna lead and more than one choke member can be connected to the inside of the metal container. These choke members can be used in combination or singly to construct chokes for suppression of higher order harmonics.

CLAIMS

(1) A magnetron for a microwave oven comprising:

a cathode (34);

a cylindrical anode (31) having a cavity resonator arranged around this cathode;

a cylindrical metal container (37) hermetically sealed to part of this anode to form an evacuated envelope with said anode, defining a part of the space in said evacuated envelope, and having an opening (37b);

an output insulating cylinder (39) coupled hermetically to said opening of said metal container;

an output antenna lead (36) whereof one end is electrically coupled to said cavity resonator of said anode and which extends through the inside space of said insulating cylinder, passing through said opening of said metal container; and

a choke surrounding said antenna lead by means of a cylindrical conductor inside said metal container and comprising an annular groove of depth about 1/4 of the wavelength of a specified higher harmonic;

characterized in that:

said magnetron comprises;

means to set the inner diameter (D1) of said opening through which said antenna lead passes to a dimension of about 1/2 or less of said wavelength of said specified higher harmonic, which is the fourth or higher harmonic; and

a choke (B1) having an annular groove (B) suppressing a radiation on said higher harmonic with an opening provided in said inside space of said metal container, the radial width (Gb) of said choke at or near said opening of said annular groove (B) being formed to be not more than 1/10 of said higher harmonic wavelength.

(2) The magnetron for a microwave oven according to claim 1 wherein said choke is fixed to a metal container.

(3) The magnetron for a microwave oven according to claim 1 wherein said metal container forms part of said choke.

(4) The magnetron for a microwave oven according to claim 1 wherein the wall of the opening is defined by a cylinder forming part of said choke.

(5) The magnetron for a microwave oven according to claim 1 wherein said choke is fixed to said antenna lead.

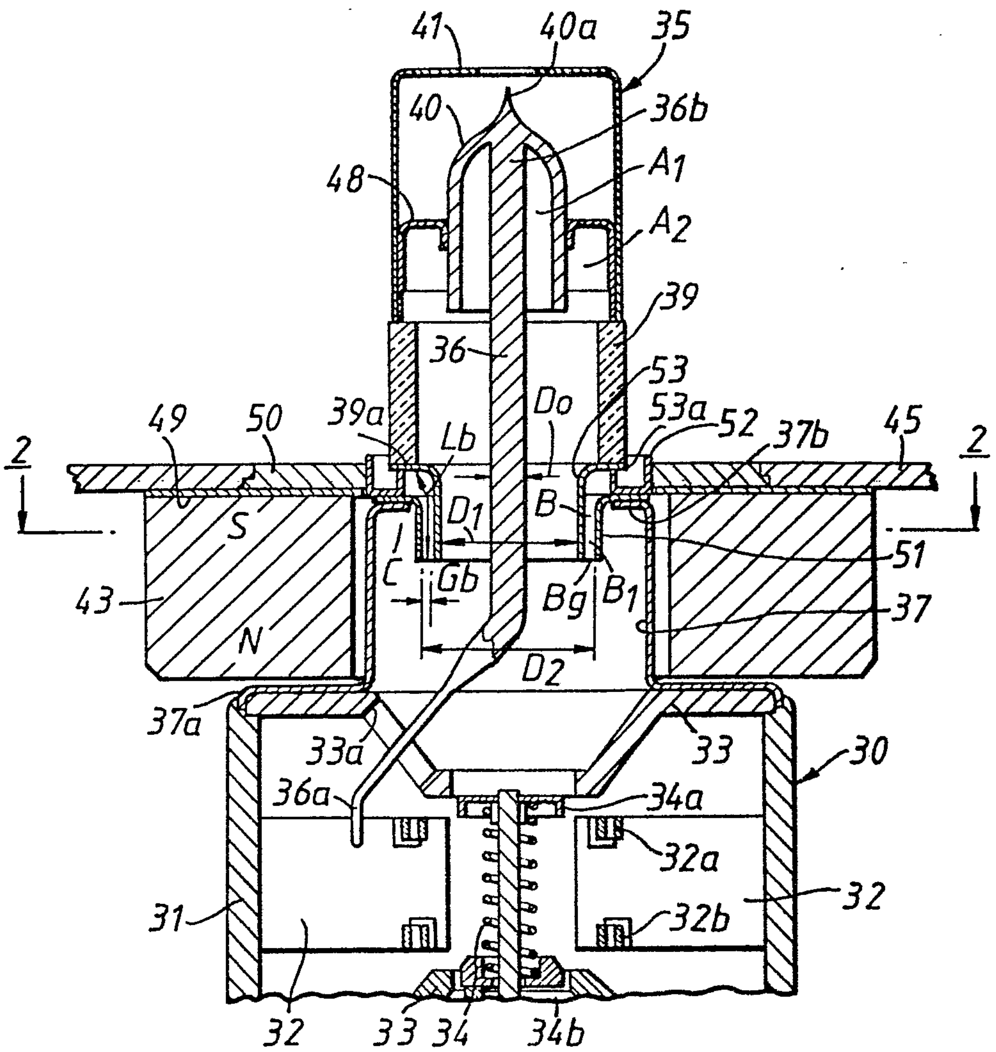

41
40a
35
40
36b
48
A1
A2
39
36
53
Do
53a
39a
Lb
52
37b
45
2
49
50
2
D1
B
S
51
C
Gb
Bg
B1
43
37
N
D2
37a
33a
33
30
36a
34a
32a
32
31
32b
32
33
34
34b

FIG.1.

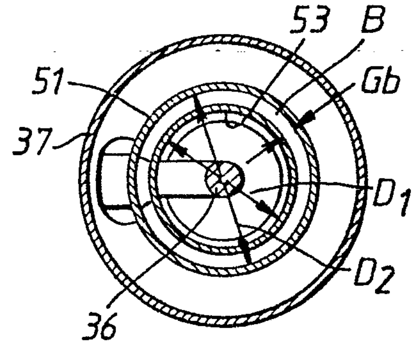

53
B
51
Gb
37
D1
D2
36

FIG.2.

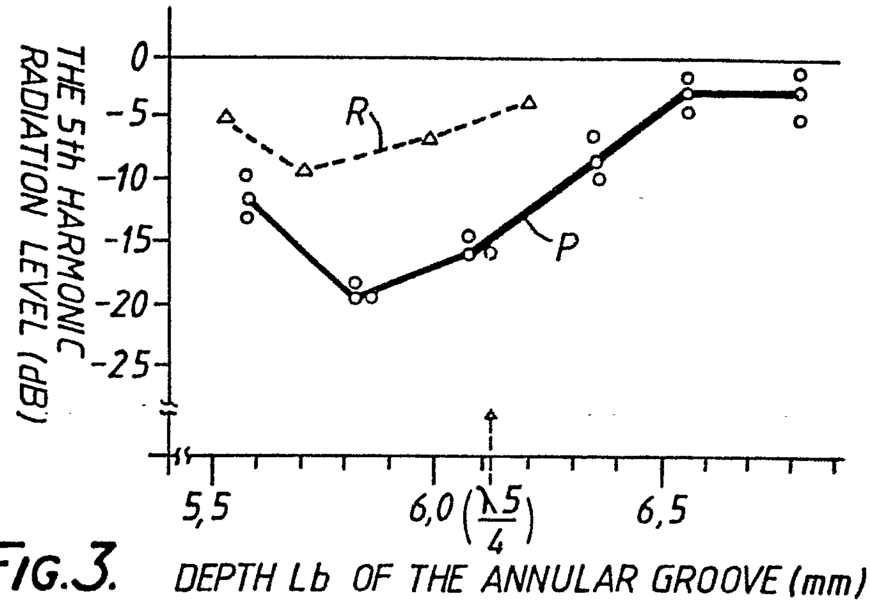
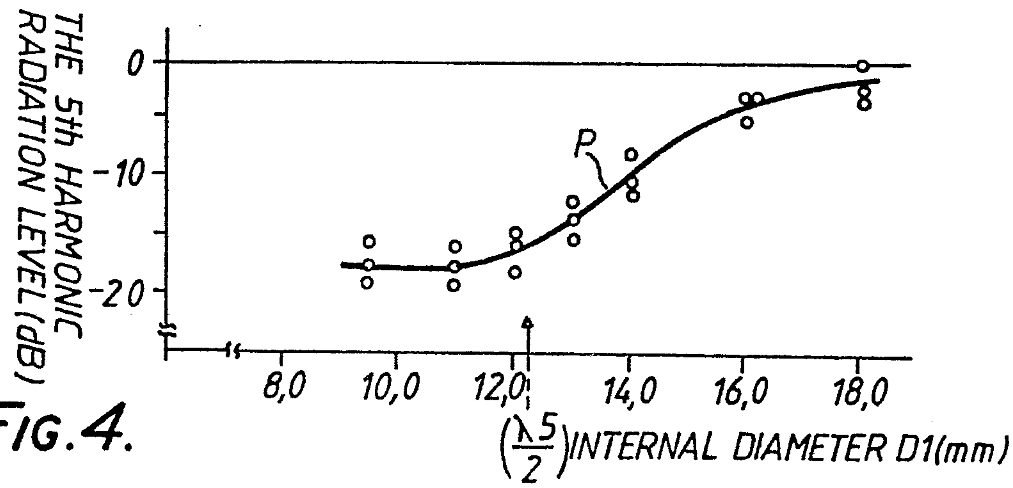


FIG.3.



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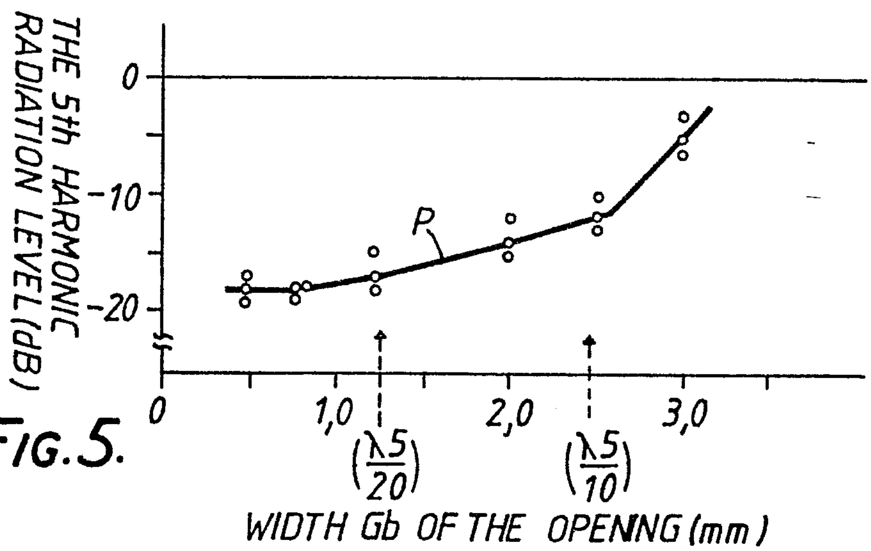


FIG.5.

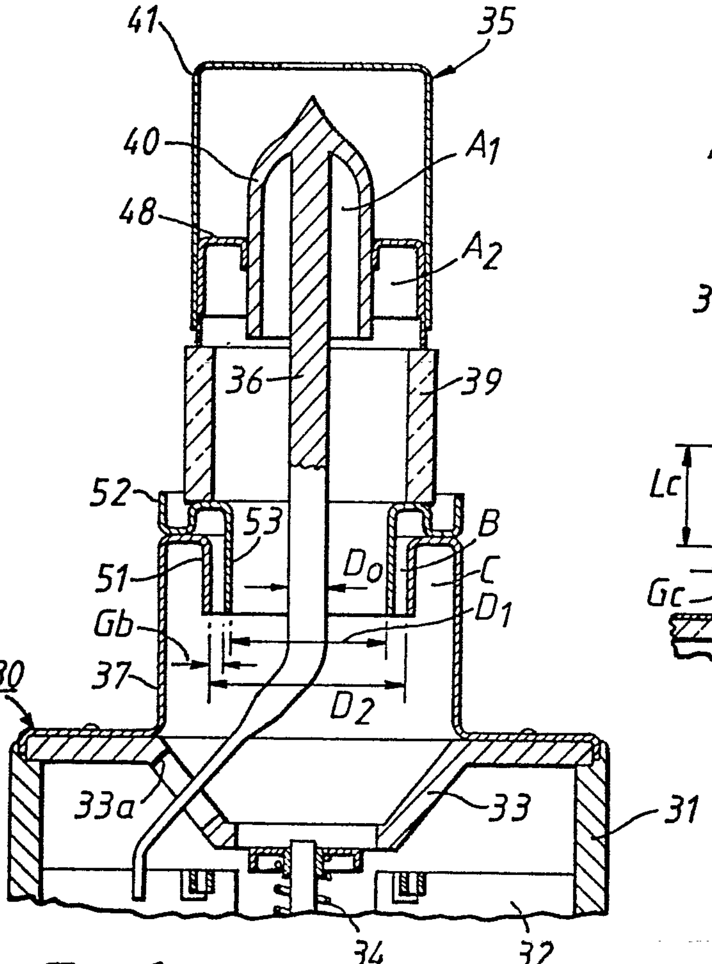


FIG.6.

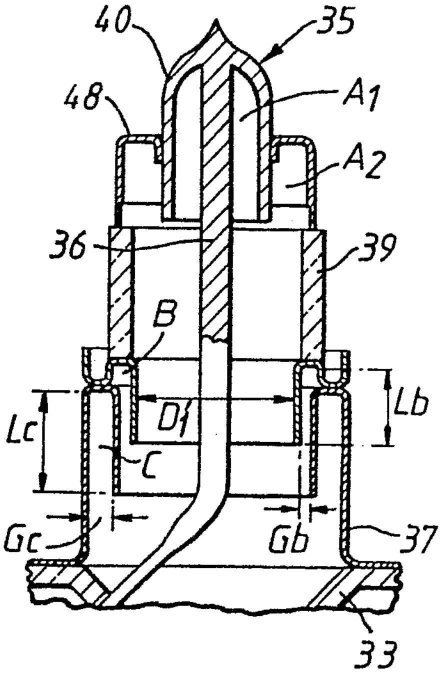


FIG.7.

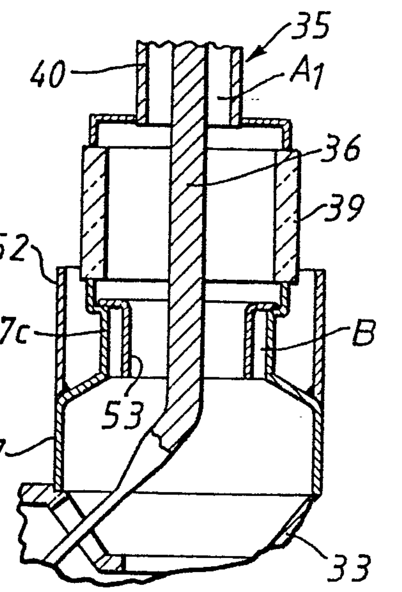


FIG.8.

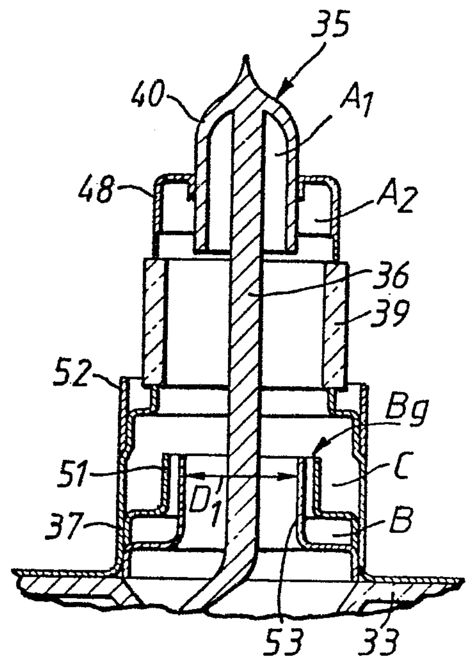
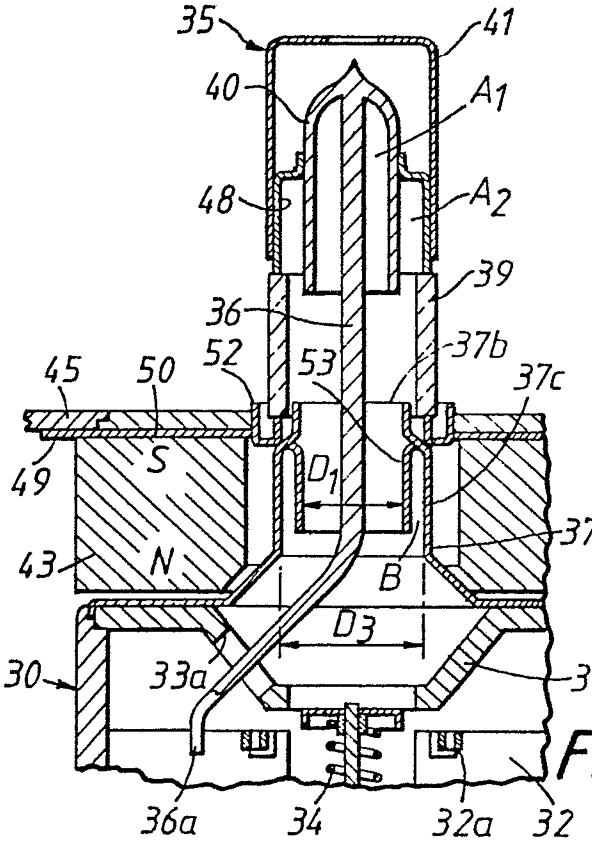


FIG.9.



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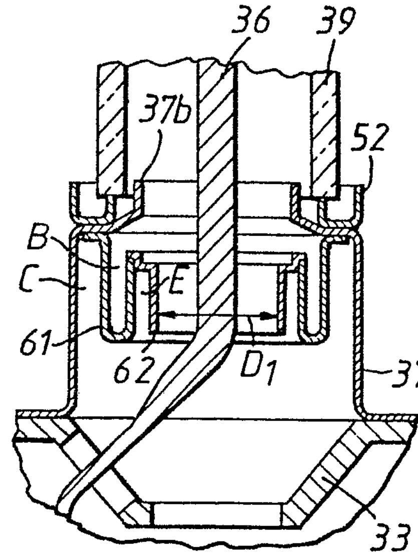
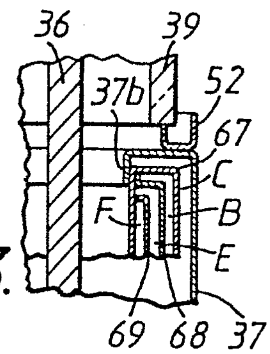


FIG.11.



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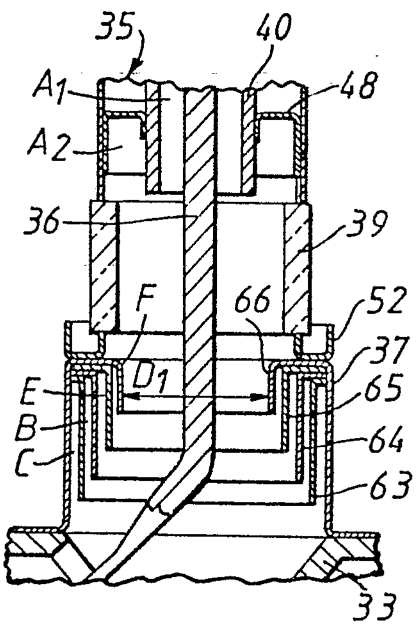


FIG.12.

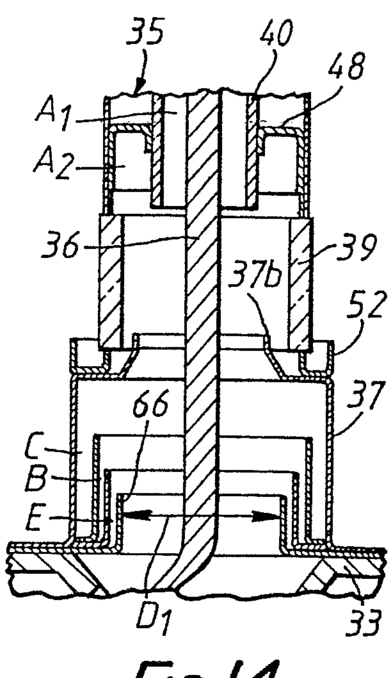
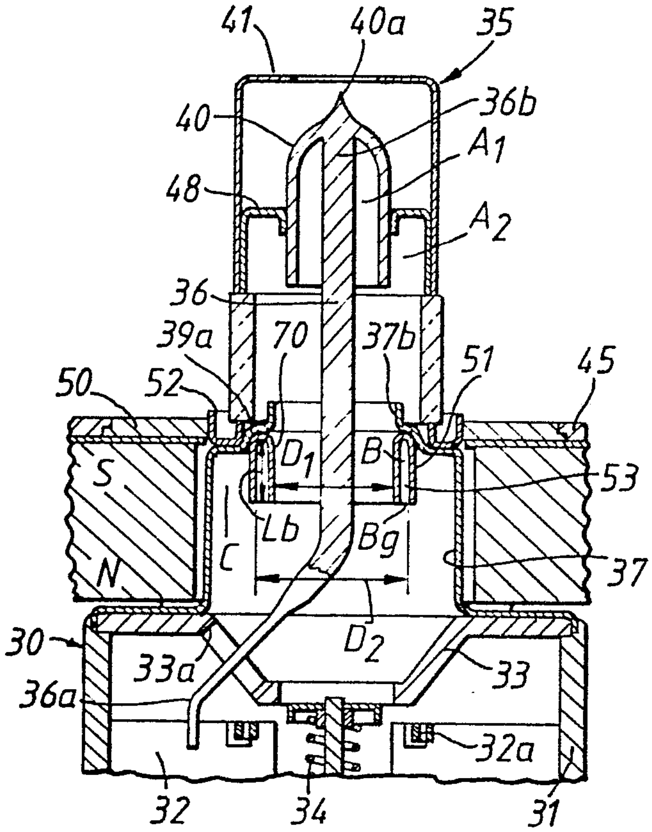


FIG.14.



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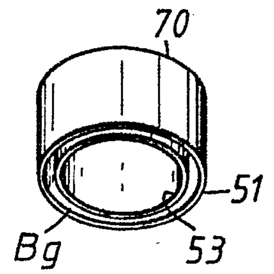

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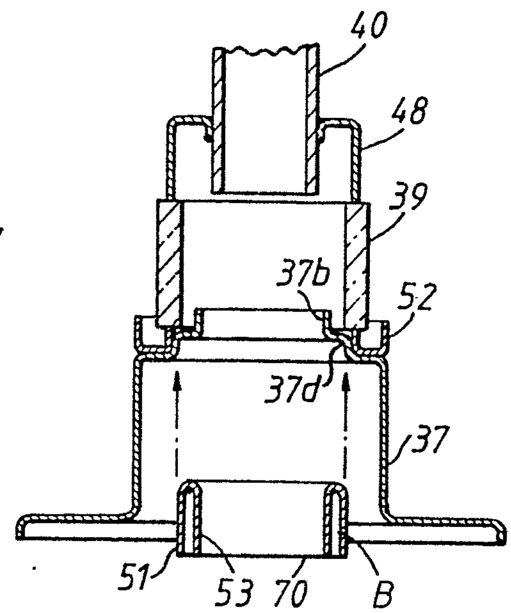

FIG.17.

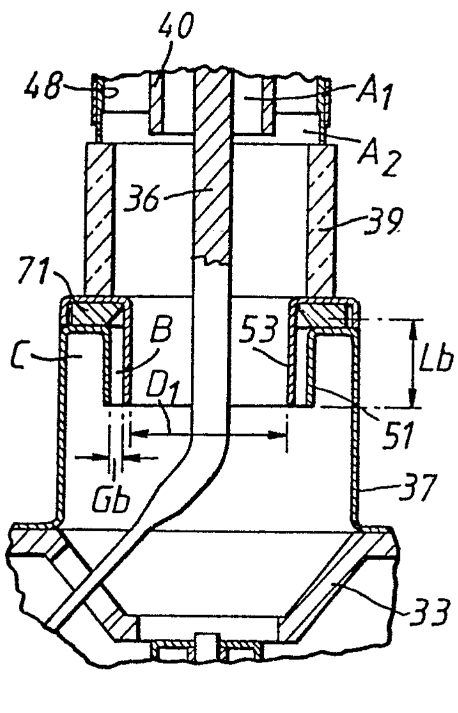

FIG.18.

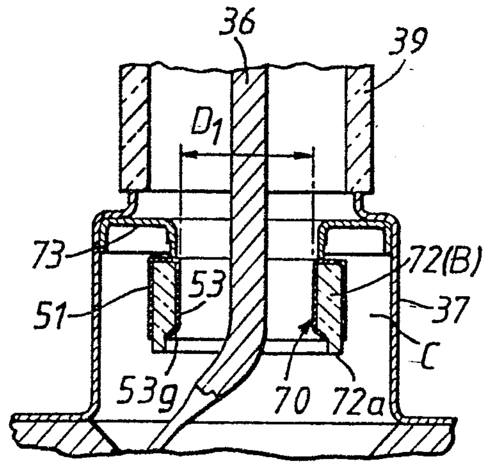

FIG.19.

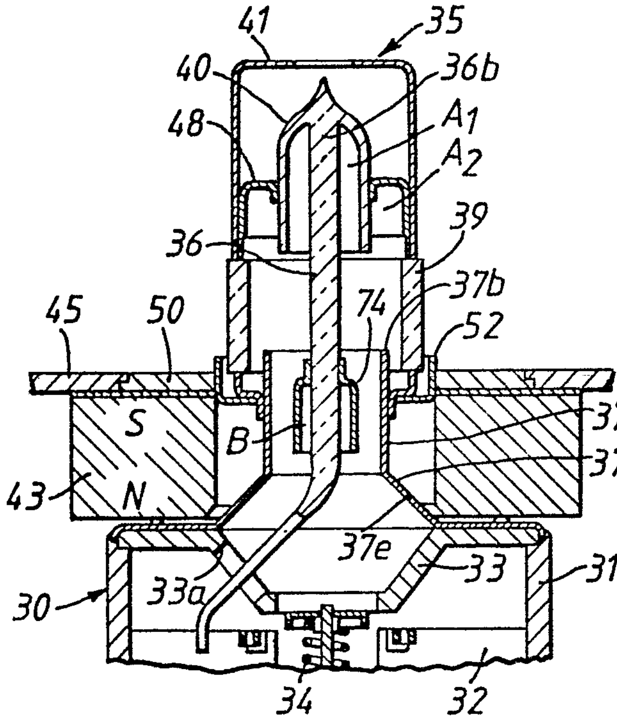

FIG.20.

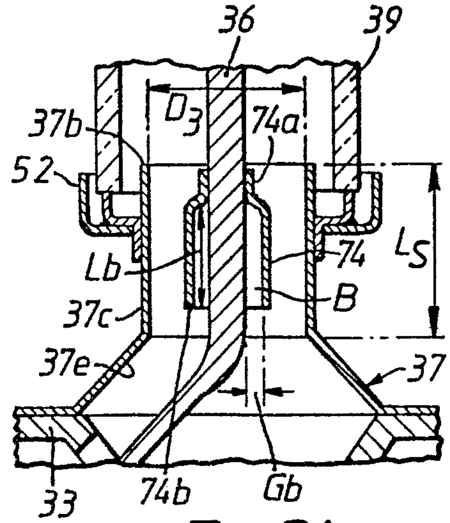

FIG.21.

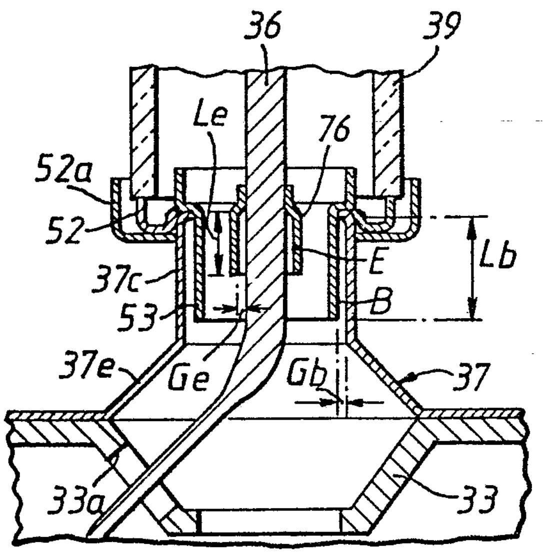

FIG.23.

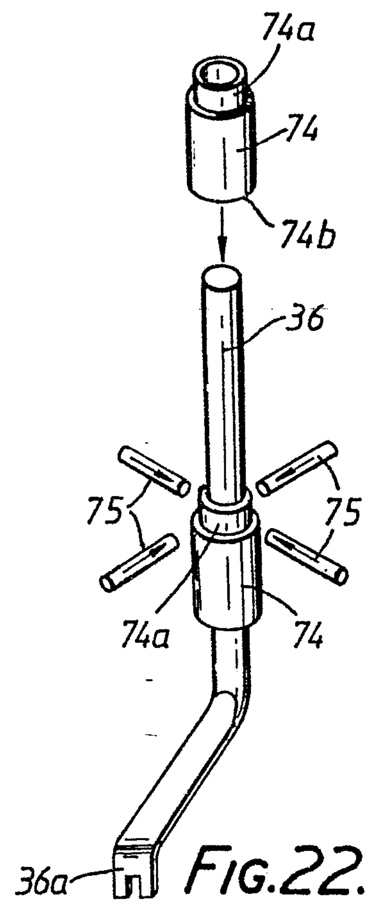

FIG.22.

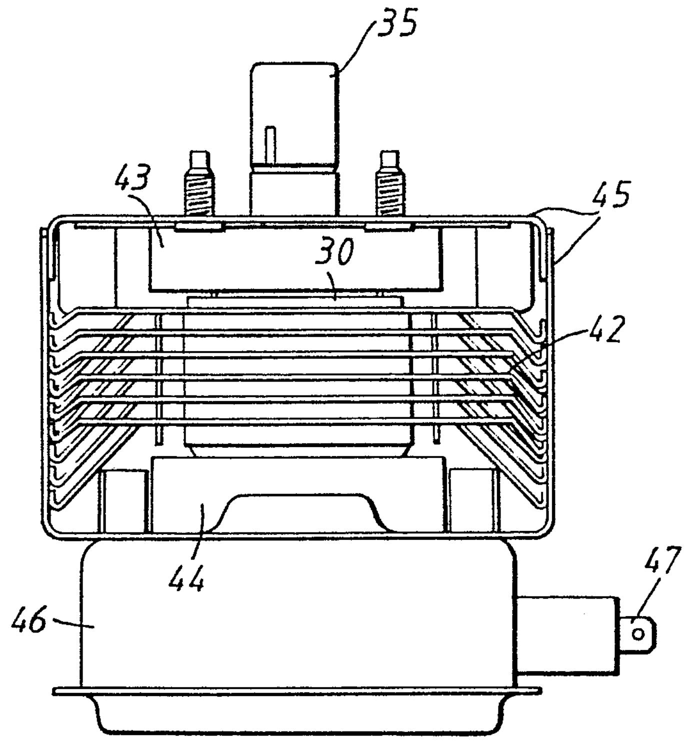

FIG.24.

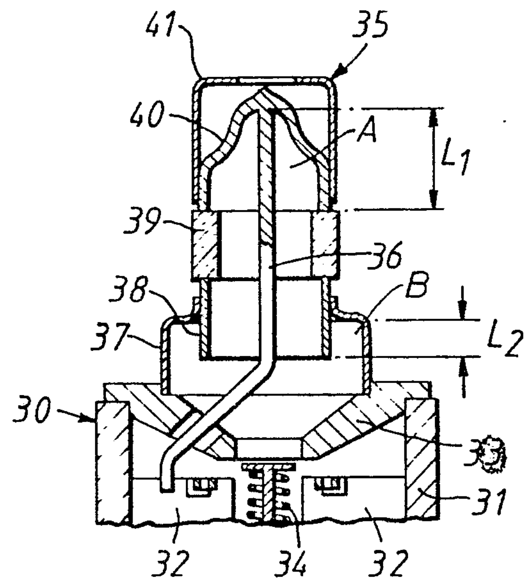

FIG.25.

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EUROPEAN SEARCH REPORT

0205316

Application number

EP 86 30 4299

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
Y	US-A-4 459 563 (T. KAWAGUCHI) * Whole document * ---	1-5	H 01 J 23/54
Y	ELECTRONIC DESIGN, vol. 5, 4th March 1971, pages 50,51, Rochelle Park, US; S.M. PERLOW et al.: "Here's a microwave choke" * Whole document * ---	1-5	
A	US-A-3 537 042 (E. SIMMEN) * Column 2, lines 33-44 * ---	1	
A	US-A-4 006 382 (J.R. BUTLER et al.) * Column 1, lines 28-68; figures * ---	1	TECHNICAL FIELDS SEARCHED (Int. Cl 4)
A	US-A-3 849 737 (T. OGURO) ---		H 01 J H 01 P
A	US-A-4 207 496 (K. NAKAI) ---		
A	US-A-3 872 412 (H. SEIDEL) ---		
A	FR-A-2 377 699 (PHILIPS') --- -/-		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	02-09-1986	LAUGEL R.M.L.

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0205316

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EP 86 30 4299

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
A	FR-A-2 467 479 (PHILIPS')		

			TECHNICAL FIELDS SEARCHED (Int Cl 4)

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