May 4, 1965 R. IRONFIELD 3,182,164

ELECTROMAGNETIC ENERGY SEAL

Filed Feb. 28, 1962 2 Sheets-Sheet 1

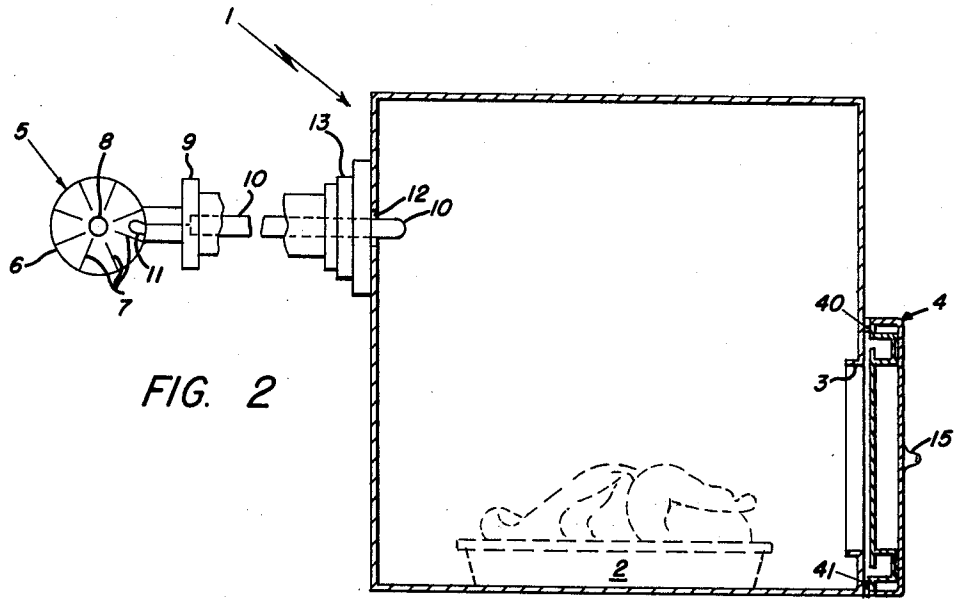



FIG. 2

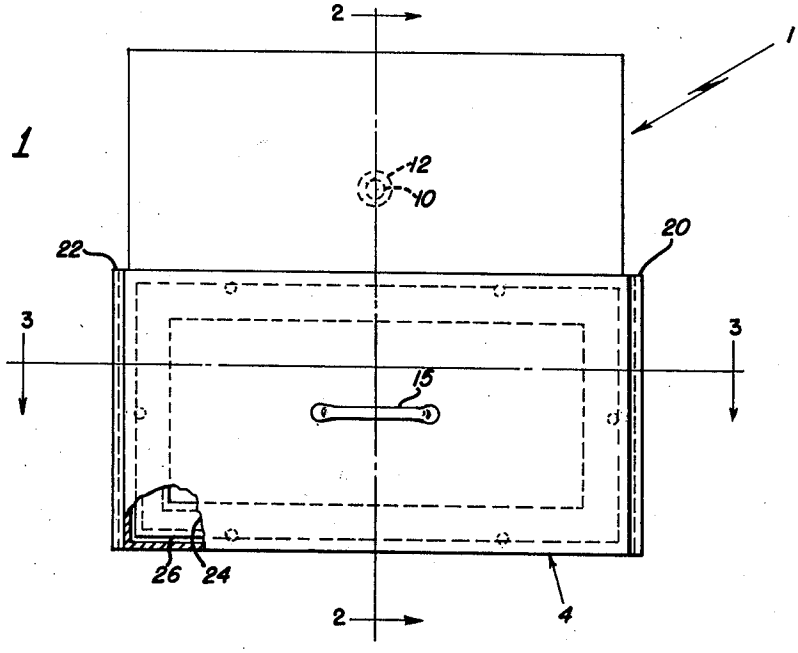



FIG. 1

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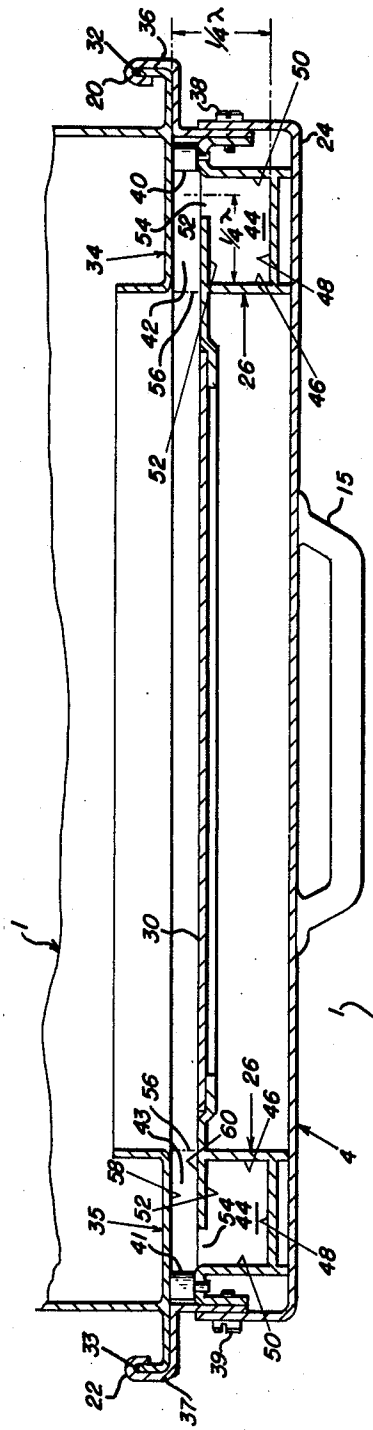


FIG. 3

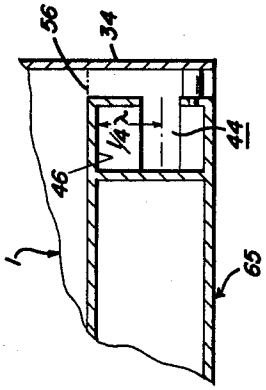


FIG. 6

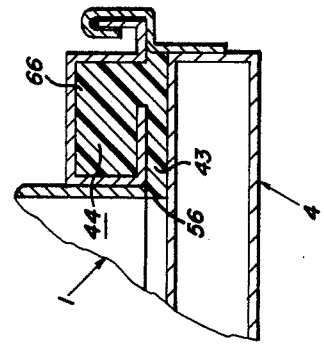


FIG. 7

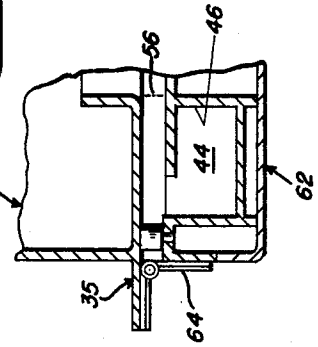


FIG. 4

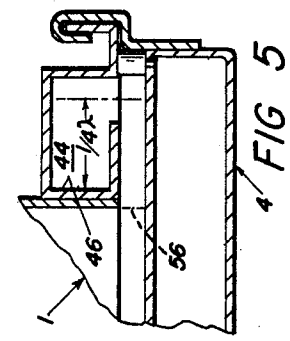


FIG 5

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3,182,164
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3,182,164

# ELECTROMAGNETIC ENERGY SEAL

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8 Claims. (Cl. 219—10.55)

This apparatus relates to an electromagnetic energy seal, and, more particularly, to an energy seal for electronic heating apparatus which seal may be mounted on either the doors or walls of the electronic heating apparatus to permit access therein when the electronic heating apparatus is not radiating and to provide a seal to prevent leakage of radiation from the electronic heating apparatus.

Prior energy seals in connection with electronic heating apparatus in the main comprise spring contacts on the door or front of the electronic heating apparatus oven or cavity. The spring contact method has been found to have serious inherent shortcomings in that over a period of time, particularly if the springs are not kept meticulously clean, contact becomes poor and leakage of R-F radiation occurs. In addition, wherever metal-to-metal contact occurs and there is any appreciable discontinuity in the mating surfaces, arcing has been known to occur and rapid deterioration of the seal takes place.

The present invention eliminates the aforementioned problem in the following manner. A nonmetallic spacer is provided between the walls defining an access opening into the electronic heating apparatus and the cover or door enclosing said access opening. This spacing creates a gap between the walls defining the access opening and the cover or door enclosing said access opening so that there is no metallic contact in a planar area surrounding the access opening, thus eliminating objectionable arcing difficulties inherent in metal-to-metal seals. This gap can be looked upon as the interior of a parallel plate transmission line, one plate being the wall surface adjacent to the door surface, the other plate comprising the door surface. The origin of the parallel plate transmission line structure is the point at which the wall surface is no longer parallel to the door surface, that is, where the wall surface turns inward to the interior of the electronic heating apparatus. The present invention prevents escape of electromagnetic energy through this gap by providing a cavity in one or more surfaces of the parallel plate transmission line, said cavity having a terminating conducting surface located an integral number of one-half wavelengths from the origin of the gap. The terminating conducting surface thus presents a low impedance across the transmission line at approximately one-half wavelength from the gap origin. This low impedance, which is essentially a short circuit, is reflected or transformed a quarter-wavelength back into an extremely high impedance. In turn, the high impedance is reflected or transformed back another one-quarter wavelength into a low impedance at the origin of the transmission line, thereby approximating a short circuit at the origin which provides an energy seal without need for an actual metallic contact and thus prevents leakage of electromagnetic energy from the interior or oven portion of the electrical heating apparatus, while still providing a convenient access thereto when the heating apparatus is not radiating.



It should be noted that the term "wavelength" used here and as used hereafter refers to the wavelength of the electromagnetic energy originating in the electronic heating apparatus as it travels down the medium in the gap between the walls of the heating apparatus and the door or cover. For example, this invention utilizes a magnetron heating apparatus which radiates at a frequency of substantially 2450 megacycles per second, corresponding to a wavelength of approximately five inches in air. However, since it may be desirable for compactness, etc., to fill the aforementioned gap and cavity with a dielectric medium which will decrease the effective wavelength of the radiating energy, the term "wavelength" herein is not thus limited to the wavelength of the radiation source as propagated only in air.

Further objects and advantages of this invention will become more evident from examination of the drawing, wherein:

FIG. 1 is a front elevation view of a heating apparatus embodying the present invention;

FIG. 2 is a cross-sectional view taken along the line 2—2 of the heating apparatus of FIG. 1;

FIG. 3 is an enlarged section view taken along the line 3—3 of the heating apparatus of FIG. 1;

FIG. 4 shows an alternate embodiment of the present invention as used on a hinged door frame;

FIG. 5 shows an alternative embodiment of the present invention in which the cavity is mounted in the electronic heating apparatus wall surface;

FIG. 6 shows an alternative embodiment of the present invention in which the door extends into the interior of the electronic heating apparatus; and

FIG. 7 shows an alternative embodiment of the present invention wherein the gap between the wall and the door is filled with a dielectric medium having a dielectric constant greater than unity, thereby allowing the dimensions of the cavity to be proportionately decreased.

Now referring to FIGS. 1 and 2, a hollow rectangular oven-like enclosure is made of a suitable metal and has rather thin walls; enclosure **1** is adapted to serve as the oven of the cooking apparatus. Oven **1** is adapted to have a container **2** of food placed therein, said container resting on the bottom wall of the oven, while the food therein is being cooked. In order to allow access to the interior of the oven for placing the food therein and for removing the food therefrom, a rectangular aperture **3** is provided in the front wall of the oven **1** near the lower end of said wall, this aperture being closable by means of a sliding metal door **4** attached to tracking mechanisms **20** and **22**, to be described more in detail hereinafter. When door **4** is closed, the enclosure **1** is entirely closed, except for the opening **12** for the exciting means to be described hereinafter.

Numeral **5** generally designates an electron discharge device of the magnetron type, which includes, for example, an evacuated envelope **6**, made of highly conductive material, such as copper, and provided with a plurality of inwardly directed, radially disposed anode vanes **7**. The arrangement is such that each pair of adjacent anode vanes **7** forms, together with that portion of the envelope lying therebetween, a cavity resonator whose natural frequency is as is well known to those skilled in the art, a function of the geometry of the physical elements making up the same. For the purposes of

the present invention it is desirable that the dimensions of each such cavity resonator be such that the wavelength of the electrical oscillations adapted to be generated therein has a predetermined value, for example, of the order of five inches. Wavelengths of this order lie in the microwave region of the frequency spectrum. However, this invention is equally applicable to radio frequency energy of longer or shorter wavelengths, such wavelengths lying within or without the microwave region.

Centrally located in envelope 6 is a highly electron-emissive cathode member 8, for example, of the well-known alkaline-earth metal oxide type, said cathode member being provided with conventional means (not shown) for raising the temperature thereof to a level sufficient for thermionic emission.

The electron discharge device 5 is completed by magnetic means (not shown) for establishing a magnetic field in a direction transversely of the electron path between the cathode and anode members thereof.

Magnetron 5 is energized from any suitable source (not shown) and when so energized delivers microwave energy or high frequency electromagnetic waves to a coaxial transmission line 9, the inner conductor 10 of which is coupled to oscillator 5 by a loop 11, and the outer conductor of which is connected to envelope 6. The inner conductor 10 of line 9 extends directly into the interior of oven 1 through a suitable opening 12 provided in the rear wall thereof, while the outer conductor of said line is connected to the rear wall of the oven 1 by a suitable fastening means 13. Opening 12 is preferably centered with respect to the vertical side walls of the oven, as shown in FIG. 1, and is preferably somewhat above the horizontal mid-plane of the oven, as shown in FIGS. 1 and 2. A "stirrer," not shown, as described in United States Patent 2,700,092 issued to W. M. Hall, et al., January 18, 1955, may be mounted on the ceiling structure of oven 1.

The door 4 is comprised of an outer skin of aluminum 24 wrapped around a frame 26, which consists of four sections of aluminum channel cut at 45-degree angles and seam-welded together to form a picture framelike structure completely encompassing the cooking oven aperture 3. A handle 15 is attached to door 4 to enable manual opening and closing thereof.

As best shown in FIG. 3, a second skin of aluminum 30 extends across the inner surface of the door structure to reinforce the door 4 and completely enclose the inside of the frame 26. Still referring to FIG. 3, the track mechanism of FIG. 1, items 20 and 22, can be seen to comprise nylon-bearing surfaces 32 and 33 inserted on the outer flange of the cooking oven walls 34 and 35, around which are wrapped guide rails 36 and 37 which are coupled between the aluminum skin 24 and the frame 26 and secured thereto by sheet metal screws 38 and 39. Guide rails 36 and 37 are provided with slotted holes, not shown, at the screw securing points to allow adjustment of the sliding mechanism as required, to compensate for tolerance buildup. In accordance with this invention, dielectric spacers 40 and 41 are inserted into frame 26, thereby preventing metal-to-metal contact between the metallic door 4 and the metallic oven walls 34 and 35, and accordingly creating gaps 42 and 43 between the two surfaces.

The details of the metal frame 26 can best be illustrated with reference to the lower portion of FIG. 3, but it should be remembered that this frame extends completely around the periphery of door 4 and corresponding surfaces of frame 26 will be numbered in the upper portion of FIG. 3 accordingly. The metal frame 26 has a cavity 44 therein, defined by the interior wall surfaces 46, 48, 50 and 52. In accordance with this invention, wall surface 46 is adapted to be disposed a distance of approximately an integral number of one-half wavelengths from the origin 56 of the gap between the door 4 and the oven 1. Furthermore, the opening 54 into the cavity 44 is located so that the midpoint of the opening 54 is approximately one-quarter wavelength from wall surface 46. The surface 46 thus presents a conductive termination to electromagnetic wave energy emanating from the oven heating apparatus. This effective short circuit is reflected back as an open circuit to the midpoint of opening 54, a quarter wavelength away, and again another quarter wavelength away to a short circuit, until the origin 56 of the gap 43 is reached an integral number of one-half wavelengths from the terminating conducting surface 46, at which point a short circuit is created between the parallel plate transmission line formed by exterior oven wall surface 58 and door frame surface 60. It can thus be seen that an effective electronic heating apparatus seal has been provided in accordance with this invention, which allows a gap between the electronic heating apparatus metallic walls and the metallic door or cover thereto, in order to prevent arcing, while at the same time providing a non-metallic effective short circuit at the gap origin to prevent egress of the electromagnetic energy permeating the oven chamber.



One embodiment of the invention, as shown in FIGS. 1, 2 and 3, utilized the following dimensions for optimum results on a microwave cooking oven witha magnetron heating device operating at substantially 2450 megacyles: six nylon buttons, as shown in FIG. 1 were displaced about the circumference of frame 26, having a thickness of .050 inch providing a .050 inch gap between the wall and door surfaces, surface 50 was 1.2 inches wide, thus providing substantially a one-quarter wavelength distance between surface 48 and exterior oven wall surface 58. Surface 48 was 1.562 inches wide and surface 52, .875 inch wide, the opening 54 being thus .687 inch wide and the midpoint thereby located 1.2185 inches from terminating conducting surface 46 or substantially one-quarter wavelength therefrom. Surface 46 was disposed laterally adjacent to the origin 56 of gap 43, as shown in FIG. 2, so that the distance from the origin 56 to surface 46 was substantially one-half wavelength. The resultant configuration was found to provide an effective seal under all operating conditions and was shown to have maintained the radiation leakage below 10 mw./cm.$^2$ (the accepted level of radiation) in all cases.

In accordance with this invention, therefore, it has been found that in order to achieve the maximum leakage prevention it is preferable to define the cavity interior surfaces with more specificity than merely locating the terminating conducting surface an integral number of ½ wavelength from the origin 56. For example, the width and location of the opening 54 contributes in establishing the required energy sealing properties. This dimension has been specified by locating the mid-point of the opening substantially a ¼ wavelength from the terminating conducting surface 46. The width of said opening has been specified in proportion to the other cavity dimensions by requiring the inner cavity cross-sectional perimeter comprising the width of surfaces 52, 46, 48 and 50 to be equal to or less than one wavelength, in addition the distance between surface 48 and the oven wall 58 is less than or equal to ¼ wavelength.

FIG. 4 shows a portion of a cross-section of an alternative embodiment of the present invention wherein the cavity seal 44 is mounted on a hinged door 62 provided with a spring-loaded hinge 64. FIG. 5 shows an alternative embodiment wherein the cavity seal 44 is mounted or enclosed in the oven walls 34 and 35, and FIG. 6 shows another alternative embodiment in which the cavity seal is enclosed in a flush-mounted door frame 65, each of said embodiments operating in substantially the same manner. FIG. 7 shows a further embodiment wherein the cavity 44 and the gap 43 is filled with a dielectric material 66, such as polystyrene, which acts to shorten the physical length of the one-half wavelength with respect to a similar structure having air therein. Thus, the cavity dimensions may be correspondingly decreased

in order to make the seal more compact for ease in fabrication and appearances. Accordingly, it is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Accordingly, it is desired that the invention not be limited to particular details of the embodiment disclosed herein except as defined in the appended claims.

What is claimed is:

1. In combination;
an enclosure;
means for supplying electromagnetic waves to the interior of said enclosure, said enclosure having an access aperture therein;
a door for closing said aperture;
spacing means preventing metallic contact between said door and said enclosure in a planar area surrounding said access aperture, upon closure thereof, said spacing means thereby providing a gap between said door and said enclosure;
and a cavity situated in one of the gap defining surfaces having a top, bottom, and a plurality of side walls, said top wall having an opening at one end which is located substantially ¼ wavelength from one of said side walls defining a terminating conducting surface, said terminating surface being located substantially an integral number of ½ wavelengths from the origin of said gap.

2. In combination:
an enclosure;
means for supplying electromagnetic waves to the interior of said enclosure, said enclosure having an access aperture therein;
a door for closing said aperture;
spacing means preventing metallic contact between said door and said enclosure in a planar area surrounding said access aperture, upon closure thereof, said spacing means thereby providing a gap between said door and said enclosure;
a cavity having a inner cross-sectional preimeter substantially equal to one wavelength, a terminating conducting surface therein which is located substantially an integral number of ½ wavelengths from the origin of said gap, a surface substantially perpendicular to said terminating conducting surface and located less than or equal to ¼ wavelength from the gap defining surface opposite the gap defining surface in which said cavity is situated.

3. High frequency apparatus comprising:
a metallic enclosure;
means for supplying high frequency electromagnetic waves to the interior of said enclosure, said enclosure having an access aperture therein;
a metallic door for closing said aperture, said door, upon closure thereof, being prevented from contacting the metallic enclosure in a planar area surrounding said access aperture by non-metallic spacing means, said spacing means thereby providing a gap between said door and said metallic enclosure;
and a dielectric filled metallic cavity situated in one of the gap defining surfaces having a terminating conducting surface therein which is located substantially an integral number of ½ wavelengths from the origin of said gap.

4. High frequency apparatus comprising:
a metallic enclosure;
means for supplying high frequency electromagnetic waves to the interior of said enclosure, said enclosure having an access aperture therein;
a metallic door for closing said aperture, said door, upon closure thereof, being prevented from contacting the metallic enclosure in a planar area surrounding said access aperture by non-metallic spacing means, said spacing means thereby providing a gap between said door and said metallic enclosure, said gap being filled with a dielectric medium having a dielectric constant greater than air;
and a metallic cavity filled with a dielectric medium having a dielectric constant of greater than air situated in one of the gap defining surfaces, said cavity having a terminating conducting surface therein which is located substantially an integral number of ½ wavelength from the origin of said gap.



5. An electromagnetic energy seal comprising:
a box-like metallic cavity having a slit along one surface and extending transverse thereto, said box-like cavity being formed in the manner of a picture frame to define a structure co-extensive with the shape of the surface to be sealed, said box-like metallic cavity having a first surface positioned perpendicular with respect to said slit and located a distance approximately equal to ¼ wavelength from the midpoint of said slit, said box-like cavity having a cross-sectional perimeter excluding said slit dimension substantially equal to one wavelength, said box-like cavity having a non-conductive spacer coupled to the exterior of the slotted surface, said non-conducting spacer so dimensioned as to provide a gap between the surface to be sealed and the metallic cavity, the start of said gap being located a distance approximately equal to an integral number of ½ wavelengths from said first recited surface.

6. In a high frequency apparatus:
a sliding door;
an electromagnetic energy seal comprising;
a box-like metallic cavity having a slit along one surface and extending transverse thereto, said box-like cavity being formed in the manner of a picture frame to define a structure co-extensive with the shape of the surface to be sealed, said box-like metallic cavity having a first surface positioned perpendicular with respect to said slit and located a distance approximately equal to ¼ wavelength from the midpoint of said slit, said box-like cavity having a cross-sectional perimeter excluding said slit dimensions substantially equal to one wavelength, said box-like cavity having a non-conductive spacer coupled to the exterior of the slotted surface, said non-conducting spacer so dimensioned as to provide a gap between the surface to be sealed and the metallic cavity, the start of said gap being located a distance approximately equal to an integral number of ½ wavelengths from said first recited surface, said seal mounted on the periphery of said sliding door.

7. In a high frequency apparatus:
a hinged door;
an electromagnetic energy seal comprising;
a box-like metallic cavity having a slit along one surface and extending transverse thereto, said box-like cavity being formed in the manner of a picture frame to define a structure co-extensive with the shape of the surface to be sealed, said box-like metallic cavity having a first surface positioned perpendicular with respect to said slit and located a distance approximately equal to ¼ wavelength from the midpoint of said slit, said box-like cavity having a cross-sectional perimeter excluding said slit dimension substantially equal to one wavelength, said box-like cavity having a non-conductive spacer coupled to the exterior of the slotted surface, said non-conducting spacer so dimension as to provide a gap between the surface to be sealed and the metallic cavity, the start of said gap being located a distance approximately equal ot an integral number of ½ wavelengths from said first recited surface, said seal mounted on the periphery of said hinged door.

8. In a high frequency apparatus an electromagnetic energy seal comprising:

a box-like metallic cavity having a slit along one surface and extending transverse thereto, said box-like cavity being formed in the manner of a picture frame to define a structure co-extensive with the shape of the surface to be sealed, said box-like metallic cavity having a first surface positioned perpendicular with respect to said slit and located a distance approximately equal to ¼ wavelength from the midpoint of said slit, said box-like cavity having a cross-sectional perimeter excluding said slit dimension substantially equal to one wavelength, said box-like cavity having a non-conductive spacer coupled to the exterior of the slotted surface, said non-conducting spacer so dimensioned as to provide a gap between the surface to be sealed and the metallic



cavity, the start of said gap being located a distance approximately equal to an integral number of ½ wavelengths from said first recited surface, said seal mounted on the periphery of an access opening to an electron heating apparatus.


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