June 21, 1955 C. E. ELLSWORTH 2,711,468

DIELECTRIC HEATING TUNNELS

Filed Dec. 28, 1951 3 Sheets-Sheet 1

Fig. 1

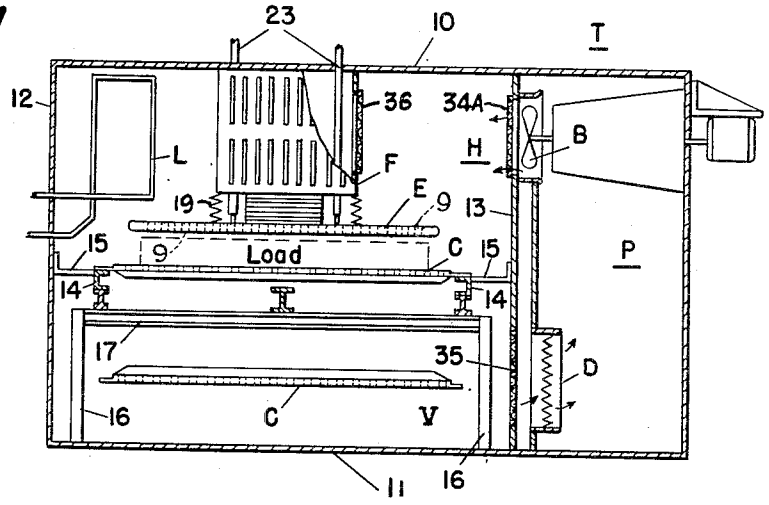
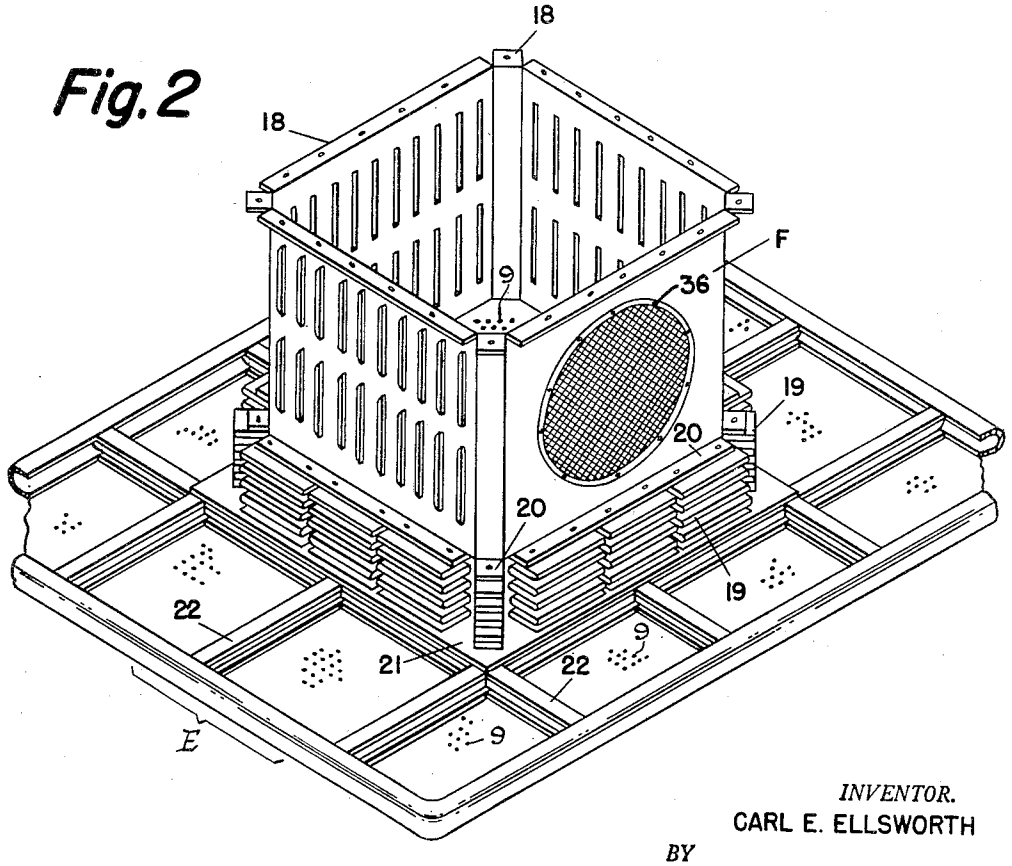


Fig. 2



INVENTOR.
CARL E. ELLSWORTH

BY

Woodcock and Phelan

ATTORNEYS

June 21, 1955 C. E. ELLSWORTH 2,711,468

DIELECTRIC HEATING TUNNELS

Filed Dec. 28, 1951 3 Sheets-Sheet 2

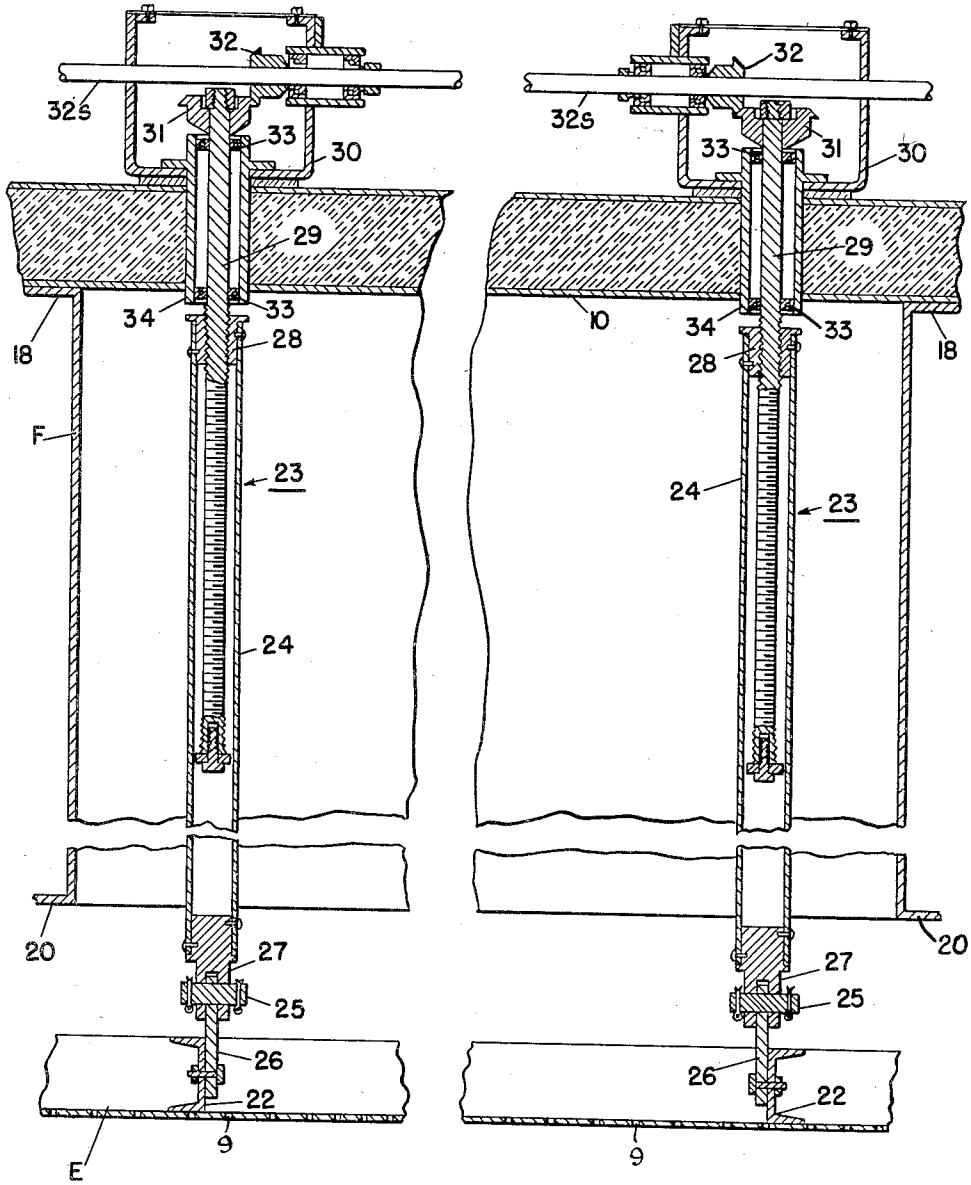


Fig.3

INVENTOR.
CARL E. ELLSWORTH
BY
Woodcock and Phelan
ATTORNEYS

June 21, 1955 C. E. ELLSWORTH 2,711,468

DIELECTRIC HEATING TUNNELS

Filed Dec. 28, 1951 3 Sheets-Sheet 3

Fig. 4

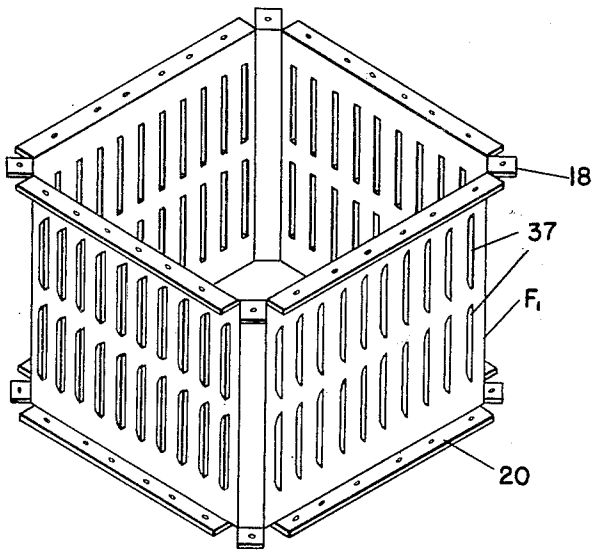
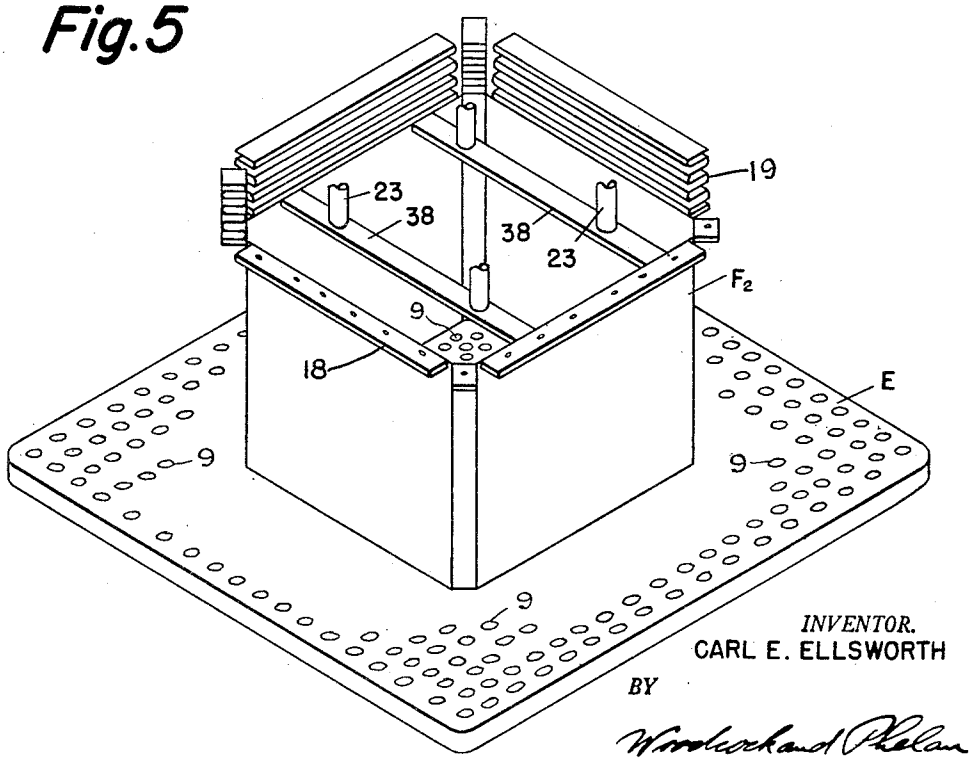


Fig. 5



INVENTOR.
CARL E. ELLSWORTH

BY

Woodcock and Phelan

ATTORNEYS

United States Patent Office 2,711,468 Patented June 21, 1955

2,711,468

DIELECTRIC HEATING TUNNELS

Carl E. Ellsworth, Louisville, Ky., assignor, by mesne assignments, to National Cylinder Gas Company, Chicago, Ill., a corporation of Delaware

Application December 28, 1951, Serial No. 263,803

14 Claims. (Cl. 219—10.55)

This invention relates to dielectric heating systems and particularly to modifications of tunnel type applicators such as disclosed in copending Warren application Serial No. 138,628, filed January 14, 1950, now abandoned in favor of continuation-in-part application, Serial No. 419,633, filed March 26, 1954.

In one embodiment of a tunnel applicator, a high-frequency heating electrode is attached to the free end of a conductive fin or inductor whose opposite end is attached to one wall of a metallic tunnel, an opposite wall usually serving as an associated heating electrode. The fin or inductor forms the inductance of a resonant circuit whose capacitance, or at least most of it, is that between the heating electrodes, the tunnel walls serving as a conductor of insubstantial resistance and reactance which completes the resonant tunnel circuit. The fin electrode of many tunnel applicators may be raised or lowered to vary the potential gradient through the load to be heated and/or to apply pressure to the load.

In accordance with one aspect of the present invention, the inductance fin is in the form of a hollow metallic box having blunted corners in avoidance of excessively high current density at the corners otherwise there occurring because of the distribution of the high-frequency magnetic field in the tunnel space which encircles the fin.

In accordance with another aspect of the invention, when the fin electrode is perforated for passage of air or other gases or vapors generically termed air, at least one and preferably all sides of the box fin are provided with passages for forcible circulation of air through all portions of the fin electrode and in avoidance of strain upon the fin as subjected to a blast of ventilating air.

The invention further resides in features of construction, combination and arrangement having features of novelty and utility hereinafter described and claimed.

For a more detailed understanding of the invention and for illustration of several forms thereof, reference may be had to the accompanying drawings in which:

Fig. 1 is a transverse sectional elevational view of one form of a dielectric heating tunnel embodying the present invention;

Fig. 2 is a perspective view of the fin and fin electrode assembly of Fig. 1;

Fig. 3 is a detail view showing electrode-raising mechanism of Fig. 1 on enlarged scale;

Fig. 4, in perspective, shows a modification of the box fin of Figs. 1 and 2; and

Fig. 5 illustrates, in perspective, a modification of the fin and electrode assembly of Fig. 2.

Referring to Fig. 1, electrically conductive walls **10—13** of a tunnel or reentrant resonator T are of sheet metal of suitably high-electrical conductivity, for example, aluminum or aluminum alloy, reinforced by external beams not shown. An upper flight of a conveyor C, which transports load objects to be dielectrically heated, divides the tunnel T into an upper heating compartment H and a lower ventilation duct V. The

conveyor C, as more fully disclosed in copending application Serial No. 263,781, filed December 28, 1951, now U. S. Patent No. 2,684,432, comprises a series of perforated metallic plates whose opposite ends, or extensions thereof, rest upon a pair of guide rails **14, 14**, or contact strips in the upper face thereof, which are electrically bonded by wide straps **15, 15** to the side walls **12, 13** of the tunnel T. The guide rails **14, 14** are supported by a framework comprising uprights **16** and cross-beams **17**.

An upper heating electrode E is disposed in compartment H above the conveyor C which serves as a lower heating electrode. The electrode E is attached to the lower end or edge of a box-fin inductance F whose upper end is attached to the top wall **10** of the tunnel. In the particular arrangement shown in Figs. 1 to 3, the upper end or edge of the box-fin is directly attached, as by bolts, extending through its flanges **18**, to the under face of the top wall **10** and the lower edge of the fin is attached to the upper face of the heating electrode E through a plurality of accordion-folded strips **19** of high-conductivity metal, such as aluminum, copper or alloys thereof. The upper ends of strips **19** are attached to flanges **20** of the lower edge of the box-fin and the lower ends of the strips are fastened to a metal plate **21** welded or otherwise fastened to frame members **22** of the upper electrode. The plate **21**, for reasons which later appear, may be provided with a large central opening.

The resonant tunnel circuit is excited by a coupling loop L suitably supported in the tunnel space which encircles the box-fin inductance F, thus to produce a high-voltage, high-frequency field between the upper heating electrode E and the lower heating electrode which in the particular arrangement shown is the upper flight of the metallic conveyor C. To vary the potential gradient through the load, the electrode E is raised or lowered by mechanism generically represented in Fig. 1 by a plurality of members **23** which enter the tunnel and are attached to the electrode E within the field-free space afforded by the box-fin inductance F. The arrangement of electrode lifting mechanisms disposed within a hollow flexible inductor is claimed in a copending application Serial No. 419,070, filed March 26, 1954, which is a continuation-in-part of the aforesaid Warren application now abandoned. As there are no strong high-frequency fields within the box-fin even when the tunnel may be delivering 200 kw. of high-frequency power to the load, the actuating members **23** may be of metal throughout and may be conductively attached to the electrode E and also may be in metallic contact with wall **10** of the tunnel. There is avoided need to use interposed insulators subject to mechanical or electrical breakdown.

A suitable form of electrode-raising mechanism **23** is shown in Fig. 3. A metal tube or hollow rod **24** is conductively connected at its lower end to the electrode E by an arrangement comprising a pin **25** which passes through eye-members **26, 27**, the former being a link fastened to the frame member **22** of electrode E and the latter being a plug or end-closure for tube **24**. A plug **28** for an upper end of tube **24** threadably receives a vertical shaft **29** which extends through the top wall of the tunnel into a gear-box **30**. A bevel gear **31** fastened to an upper end of shaft **29** is driven by gear **32** on shaft **325** suitably coupled to a motor (not shown).

The shaft **29** is electrically connected to the top wall of the tunnel through its bearings **33** and their casing **34**. There is thus provided a conductive path from the electrode E to the wall, but no appreciable current flows in this path despite the fact the potential-difference between electrode E and the wall **10** may be in excess of 30,000 volts and despite the fact that currents of the order of thousands of amperes may flow in the box-fin also con-

nected between electrode E and wall 10. As there is substantially no current flow between the relatively movable parts of the electrode-raising mechanism 23, they will not be welded together and rendered inoperative despite the absence of insulators or suffer other effects normally due to high-current flow. In brief, by such arrangement of the box-fin inductance and the electrode-raising mechanism, the latter may be mechanically strong by use of an all-metal construction conductively attached to the electrode and to the tunnel.

For removal of moisture or gases released from the load during its dielectric heating, provision is made for forcible circulation of air or other gas, generically termed air, through the heating compartment H. Specifically, the wall 13 is provided with electrically shielded openings 34A, 35 respectively above and below the perforated conveyor C. A fan B forces air through opening 34A into the heating compartment H, the air and entrapped moisture passing through the conveyor into duct V and thence outwardly through opening 35. Before recirculation, the air passes through a heater D which maintains its temperature above the dew point. Make-up air moves into the ventilating duct V from the ends of the tunnel and exhaust air leaves a compartment or passage P through a top duct (not shown).

The plate 21 has an enlarged central opening for air flow through the perforations 9 of electrode E. To avoid stress upon the large box-fin structure and also to insure passage of ventilating air through all portions of the perforated electrode E, at least that side wall of the box-fin inductance which faces the fan opening 34A is perforated, as by a large opening 36 (Fig. 2) or by a multiplicity of louvres 37 (Fig. 4). Preferably, all of the other side walls are louvred (Figs. 2 and 4) in avoidance of dead air zones in the heating compartment H. In the Fig. 2 construction, the opening 36 is provided with a screen which may be removed to afford access to the interior of the box-fin.

When the heating electrode is not too large and heavy, sufficient rigidity is possible by attaching the lifting rods 23 to or near the top of a fin and electrode assembly (Fig. 5) in which the rigid portion of a fin F_2 is rigidly attached to the electrode, with the flexible portion formed by conductors 19 connected to the upper tunnel wall. Specifically, the lower ends of the actuating rods 23 are attached to cross-members 38 within the box-fin so that they are in a field-free space permitting, as with the arrangement of Fig. 2, an all-metal construction without interposed insulation.

For dielectric-heating applications which do not require movement of the electrode E, the box-fin inductance of all figures may be rigidly attached at its opposite edges respectively to the electrode E and to a wall of the tunnel without interposition of flexible strips 19, or equivalent. Also for some uses, the side walls of the box-fin F may be imperforate. In all cases, however, the corners of the box-fin should be blunted in avoidance of localized high-current density due to the shape or distribution of the high-frequency electromagnetic field which encircles the fin. The diagonal corner blunting provides current paths spaced inwardly from the intersection of the planes of the adjacent flat side walls of the inductor. Moreover, the diagonal corner blunting shown is preferred because substantially facilitating a low-resistance connection to the flexible corner straps 19.

It shall be understood the invention is not limited to the embodiments shown and that equivalents thereof are within the scope of the appended claims.

What is claimed is:

1. A high-frequency heating device comprising an applicator having conductive walls, at least one of said walls having an air opening, a hollow metallic structure electrically connected at one end to one of said walls and projecting into the interior of said applicator, said structure having perforations in the sides thereof, a pair of high-frequency heating electrodes providing a space within the applicator for receiving work to be heated by an electric field between the electrodes, means supporting one of said electrodes at the inwardly projecting opposite end of said hollow structure in spaced relation to said walls of the applicator, said one electrode being electrically connected through said structure to said one of said walls, said other of said electrodes being electrically connected by way of said conductive walls to said one end of said metallic structure, means forming an air passage for flow of air from said air opening into the interior of said hollow structure, and means for creating a forced circulation of air through said air opening by way of said passage into the interior of said hollow structure and outwardly through said perforations in the sides of said structure and into the surrounding space within the applicator.

2. The high-frequency heating device of claim 1 in which said metallic structure has at least two diametrically opposed perforated areas for permitting the circulation of air from said air opening to pass through said metallic structure into the surrounding areas of said applicator.

3. The high-frequency heating device of claim 1 in which said perforated metallic structure is of sheet metal and substantially rectangular in cross-section with blunted corners for reduction of current density therein.

4. A resonant high-frequency heating device comprising a tunnel applicator having conductive walls whose resistance and reactance are negligible, a flat-sided hollow metallic inductor attached and electrically connected to and extending inwardly from one of said walls in spaced relation to the remainder of said walls, and a heating electrode attached to the free end of said inductor and spaced from all of said walls, said inductor providing substantially all the inductance and said heating electrode and an associated grounded electrode providing substantially all the capacitance of said tunnel applicator, the sides of said inductor meeting in blunted corners which form current paths spaced inwardly from the intersection of the planes of the adjacent side walls in avoidance of localized high-current density in said blunted corners due to circulation about the inductor of a high-frequency magnetic field.

5. The high-frequency heating device of claim 4 in which the walls of said metallic inductor are perforated, and means for creating a circulation of air through the interior of said metallic inductor and through said perforated walls.

6. The high-frequency heating device of claim 4 in which said heating electrode and the walls of said metallic inductor are perforated, and means for creating a circulation of air through the interior of said metallic inductor, through said perforated walls, and through said perforated heating electrode.

7. A high-frequency heating device comprising an applicator having conductive walls, at least one of which has an opening for passage of air, a hollow metallic structure projecting into the interior of said applicator and electrically connected at one end thereof to one of said walls, a pair of high-frequency electrodes providing a work-heating space within the applicator for receiving work to be heated by an electric field between said electrodes, means supporting one of said electrodes at the inwardly projecting opposite end of said hollow structure in spaced relation to said applicator walls, said one electrode being electrically connected to said one of said walls through said structure and having perforations affording communication between said work-heating space and the interior of said hollow structure, said other of said electrodes being electrically connected by way of said conductive walls to said one end of said metallic structure, and means for creating a forced circulation of air through said air opening, the interior of said hollow structure, and through said perforations between the in-

terior of the hollow structure and said work-heating space, thereby to remove gases and vapors from said space.

8. A resonant high-frequency heating device comprising an applicator having conductive walls, at least one of said walls having an air opening, upper and lower perforated high-frequency heating electrodes between which load-objects to be dielectrically heated are disposed, a hollow inductor conductively attached at its opposite edges respectively to one of said electrodes and to a wall of the applicator, the sides of said inductor being perforated, and fan apparatus for forcing air through said opening for flow through the perforated inductor and the perforated upper and lower electrodes.

9. A resonant high-frequency heating device comprising conductive walls defining an applicator having an air opening in one side wall, a coupling loop disposed within said applicator adjacent the opposite side wall, a perforated hollow inductor conductively attached at one edge to a horizontal wall of the applicator and extending therefrom between said coupling loop and said air opening, a perforated high-frequency electrode attached to the other edge of said inductor, and fan apparatus for forcing air through said opening for flow through said perforated inductor and said high-frequency electrode.

10. A high-frequency heating device comprising an applicator having conductive walls, a hollow metallic structure electrically connected at one end to one of said walls and projecting into the interior of said applicator in spaced relation to all adjacent walls of said applicator and in variable spaced relation at least to one of said walls, a pair of high-frequency heating electrodes providing a space within said applicator for receiving work to be heated by an electric field between said electrodes, means supporting one of said electrodes at the inwardly projecting opposite end of said hollow structure in spaced relation to said walls and movable with said structure relative to one of said walls, said one electrode being electrically connected through said structure to said first-named one of said walls, said other of said electrodes being electrically connected by way of said conductive walls to said first-named end of said metallic structure, said structure being of sheet metal and having a substantially rectangular cross-sectional configuration, at least two opposite sides of said structure being provided with louvres to permit the circulation of air therethrough while maintaining the interior of said structure free from magnetic fields, a plurality of flexible straps mounted in spaced relation along the entire periphery of one end of said structure for electrical connection to said heating electrode or to one of the walls of the applicator, and means for creating a circulation of air through the interior of said metallic structure.

11. The high-frequency dielectric heating device of claim 10 in which at least three sides of said structure are provided with louvres and the remaining side is provided with an enlarged aperture covered by a screen.

12. A resonant high-frequency heating device comprising an applicator having conductive side walls and a top wall, at least one of said walls having an air opening, a

metallic perforated conveyor for transporting load-objects through said applicator and for serving as a lower heating electrode, a perforated upper electrode disposed within said applicator above said conveyor and in spaced relation to said top wall and to said side walls, a hollow metallic inductor conductively attached at its upper edge to said top wall of said applicator and at its lower edge to said electrode, the sides of said inductor being perforated, and fan apparatus for forcing air through said opening for flow through said perforated inductor, said upper electrode and said conveyor.

13. A high-frequency heating device comprising conductive walls defining an applicator having an air opening in a wall thereof, a metallic perforated conveyor extending through said applicator beneath said air opening for transport of load-objects, a perforated high-frequency heating electrode above said conveyor and spaced from all walls of said applicator, a perforated metallic supporting structure attached at its upper and lower edges respectively to a top wall and to said heating electrode, and ventilating means for forcibly circulating air through said opening for flow through the perforated supporting structure, heating electrode, and conveyor.

14. A resonant high-frequency heating device comprising conductive walls defining an applicator having air openings vertically spaced in a side wall thereof, a metallic perforated conveyor extending into said applicator at a level between said air openings for transport of load-objects and dividing the applicator into an upper heating compartment and a lower ventilating compartment, a perforated high-frequency electrode above said conveyor and spaced from the top and side walls of the heating compartment, a perforated inductance attached at its upper and lower edges respectively to said top wall and to said electrode, and ventilating means for forcibly circulating air through said perforated inductance and said electrode in said heating compartment, and through said perforated conveyor, the air entering and leaving said applicator through said wall openings above and below said conveyor.

References Cited in the file of this patent

UNITED STATES PATENTS

2,109,323	Smith	Feb. 22, 1938
2,215,582	Goldstine	Sept. 24, 1940
2,218,223	Usselman	Oct. 15, 1940
2,342,897	Goldstine	Feb. 29, 1944
2,504,109	Dakin et al.	Apr. 18, 1950
2,506,814	Sayre	May 9, 1950
2,521,808	Taylor	Sept. 12, 1950
2,532,460	Phillips, Jr.	Dec. 5, 1950
2,546,004	Kinn	Mar. 20, 1951
2,551,756	Mittelmann	May 8, 1951
2,563,585	Dallenbach	Aug. 7, 1951
2,632,090	Rivercomb	Mar. 17, 1951

FOREIGN PATENTS

619,398	Great Britain	Mar. 9, 1949