

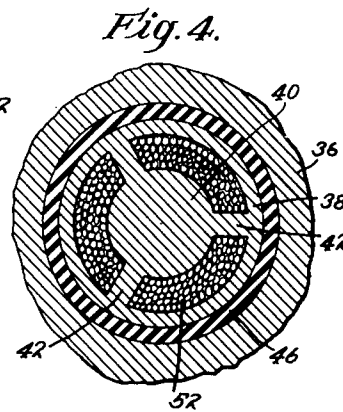
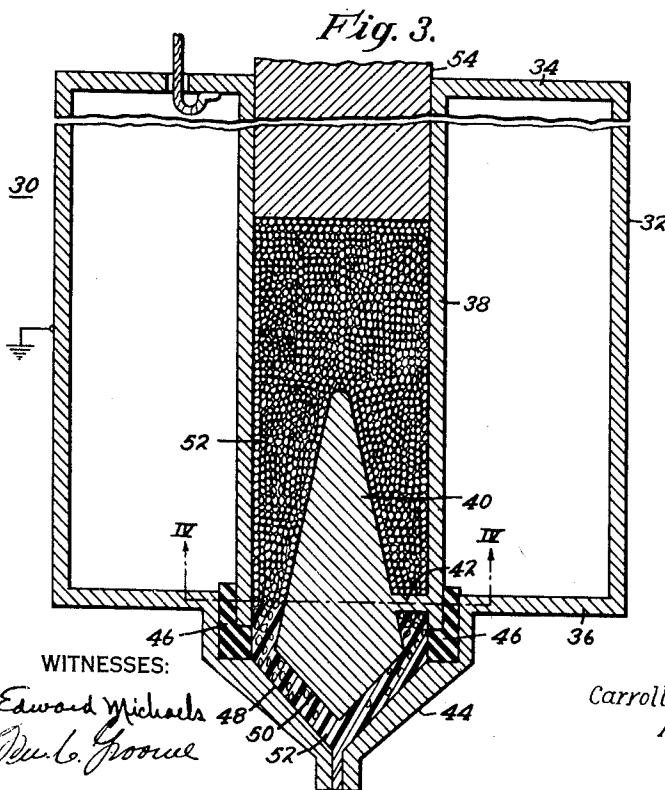
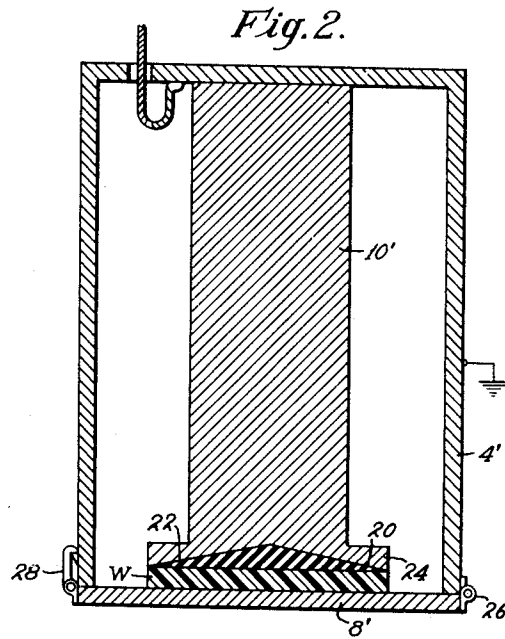
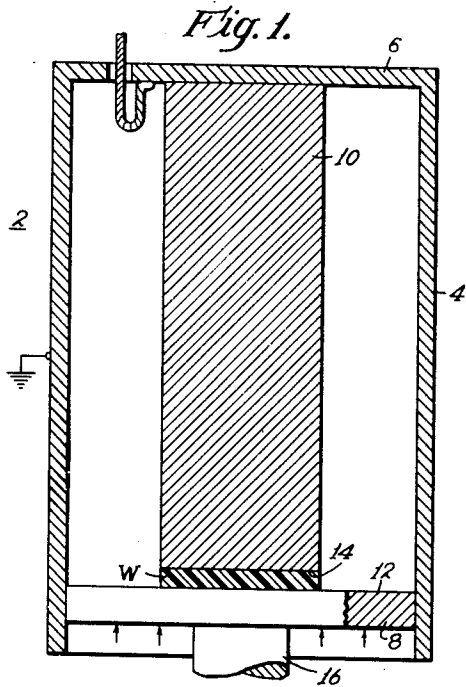
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DIELECTRIC HEATING WITH CAVITY RESONATOR

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DIELECTRIC HEATING WITH CAVITY
RESONATOR

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Our invention broadly relates to dielectric heating apparatus; but more particularly relates to the application of cavity resonators to high-frequency dielectric heating apparatus.

An object of our invention is to provide dielectric heating apparatus including a resonant cavity, more specifically, a reentrant resonant cavity.

Another object of our invention is to provide a dielectric heating apparatus of a type described having a region with a high intensity electric field into which the material to be heat-treated can be readily placed and removed.

A more particular object of our invention is to provide a dielectric heating apparatus comprising a resonant reentrant cavity having an outer shell at ground potential and a readily accessible work-receiving space inside the outer shell. The shell protects an operator against exposure to the high-voltage parts of the equipment.

In one form of our invention, part of the outer shell is movable for loading the work-receiving space of the apparatus. This part must be restored in order to place the apparatus in proper operating condition. In this embodiment, the resonant cavity is provided with an inner central member having a face spaced from a parallel face of an end wall of the shell, the end wall being movable so as to permit the apparatus to be loaded and unloaded. This end wall is at a current nodal point so that the joint between it and the rest of the shell does not carry any considerable current, and a loose joint can be tolerated, although a close fit is recommended.

In another embodiment of our invention, which forms the subject matter of our divisional case, Serial No. 107,442, filed July 26, 1949, the resonant reentrant cavity takes the form of an injecting apparatus suitable for pre-heating or otherwise treating plastic material or the like, which is forced from the apparatus into a mold. In such an embodiment, a part of the resonant cavity is provided with an injection nose or nozzle.

Features, innovations and objects of our invention, in addition to the foregoing, will be discernible from the following description which is to be taken in conjunction with the accompanying schematic drawing in which:

Figure 1 is a central longitudinal view, mostly in section, of apparatus embodying our invention;

Fig. 2 is a longitudinal sectional view of a modified form of our invention;

Fig. 3 is a longitudinal sectional view through

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an injection equipment in accordance with our invention, and

Fig. 4 is a sectional view substantially on the lines IV-IV of Fig. 3.

In the embodiment shown in Fig. 1, a resonant cavity or chamber of the reentrant type is shown. This reentrant resonant cavity is indicated in its entirety by the reference numeral 2 and comprises an outer member or shell having a hollow longitudinal tubular wall 4 and opposite end walls 6 and 8, respectively. The walls are preferably of metal so that the shell constitutes an outer metallic enclosure which can be readily grounded so as to be at ground potential. The end wall 6 is unitary with an edge of the tubular wall 4, and has secured thereto, or is integral with, a solid metallic central member 10 which coaxially extends into the tubular wall 4 and is symmetrically arranged with respect to it. The other end wall 8 is snugly slidable inside the tubular wall 4 and can be forcibly moved to any desired distance from the central member 10 so as to constitute a plunger. The separation between the inner face or work surface 12 of the end wall 8 and the facing transverse face or work surface 14 of the central member 10 provides a work-receiving space in which dielectric work W, comprising a plastic or any other suitable dielectric, may be placed for heat-treatment under a pressure of a value determined by the force exerted on the outer side of the end wall 8. This force is schematically indicated at Fig. 1 by the series of arrows and a plunger or rod 16. In order to resist this force, the other parts of the cavity would, of course, have to be braced.

When the cavity resonator 2 is made to resonate, a current anti-node will be at the end wall 6. A high voltage will exist between the separated faces 12 and 14 at the other end of the cavity resonator, and this high voltage will dielectrically heat any work between the faces.

The portions of the end wall 8 and the central member 10 between which the work is held or pressed can be considered to be relatively insulated heating electrodes, such as are found in more conventional dielectric heating apparatus. The electrode or end wall 8 can be slid into and out of the tubular wall 4 so that the dielectric heating equipment can be loaded and unloaded. However, it is obvious that the upper portion of the equipment could be moved instead, or even the central member only slid through a hole in the end wall 6. This last form, however, has the disadvantage that the sliding joint will be at a current anti-nodal point so that unless an ex-

trementally good conductive connection exists across the joint, power would be lost unnecessarily.

The shell can be made of any suitable material but preferably it should be designed so that it will absorb very little power itself. To this end, the cavity may be of steel and provided with coatings of copper or silver or other metal of high conductivity and low permeability. If desired, however, the entire resonant cavity can be made of copper.

The cavity resonator can be powered by making it part of the tank circuit of an oscillator or by coupling a conductor loop or a capacitor plate to it in a customary manner. The upper limit of the frequency at which the cavity resonator operates is governed by the size of the work to be heat treated between faces 12 and 14. For a given set of conditions, the less the capacity between the faces, the higher will be the frequency at which the resonator will oscillate.

The apparatus has an important advantage in that it provides a high degree of safety for operation because the outer shell constitutes an enclosure which can easily be kept at ground potential. As a further precaution, any suitable safety device could be attached to the movable wall 8 for interrupting the power to the cavity resonator whenever the wall starts to move from the heat-treating position.

The cross-section of the reentrant cavity of the resonator can be selected as desired. The most convenient form is to make both the central member 10 and the tubular member 4 circular and concentric. In such case, the end walls 6 and 8 would necessarily be round discs. However, we have used a cavity resonator in which the central member and outer tubular member were square in cross-section, and had their facing sides parallel.

As an indication of the operation of our invention, we have heated in a matter of seconds, a plastic preform 9" in diameter, 2½" thick and having a loss factor of .6 to 1, in a reentrant resonant cavity, of a type shown in Fig. 1, which was square in cross-section and had the following dimensions: inside overall length 30", central member 12" square on the outside, outer tubular member 18" square on the inside. This reentrant resonant cavity operated at the frequencies from 65 mc. to 80 mc.

With the electrode surfaces or faces 12 and 14 flat, the voltage between them will be greatest at the center and becomes progressively smaller between their circumference or periphery. With flat, circular electrode surfaces, the voltage between any two longitudinally aligned points on the electrode surfaces 12 and 14 will depend on the radial distance from the axis or center. A good approximation of the voltage distribution can be obtained from the following equation:

$$E = E_{\max} \left(1 - \frac{\pi^2 e}{\lambda^2 r^2} \right)$$

where $E_{\max}$ is the voltage across the two center points of the surfaces, e is the dielectric constant of the work, λ is the wave length of the oscillations, and E is the voltage at the distance, r , from the center.

The amount of heating per unit volume of work varies as the square of the voltage so that the radial voltage variation may in some cases cause non-uniform heating. If the variation is large enough to be objectionable, a more uniform heating can be obtained by dishing out one of the electrode surfaces as indicated at 20 in the em-

bodiment shown in Fig. 2, and filling the dished out portion with a solid dielectric material 22 of low power factor. The curvature of the dished out portion could be calculated for any desired voltage distribution across the work to be heated. The voltage across any two longitudinal points at the facing heating surfaces will be partially absorbed in the filling 22, and the remainder in the work W.

Fig. 2 shows other features which have been modified from the embodiment of Fig. 1. Thus, the insulated end of the central member 10' is provided with an annular outwardly projecting portion or flange 24 so as to be able to heat work of larger surface or diameter. Also, the end wall 8' is hinged, by a hinge 26, to the outer tubular wall 4' and can be forcibly latched closed by a latch 28.

Teachings of our invention are also applicable to injection molding, and in Fig. 3 apparatus of this type is schematically indicated in its entirety by the reference numeral 30. It comprises a metallic reentrant cavity having an outer tubular wall 32, an annular end wall 34 and an opposite annular transverse closing end wall 36. Extending from the inner edge of the end wall 34 is a hollow central tubular member 38. A metallic streamlined electrode member 40 is connected to the far or insulated end of the central tubular member 38 by spaced metal connecting bars 42.

The end wall 36 is provided with an outwardly directed metallic nozzle 44 insulated from and spaced from the associated end of the electrode member 38 by a stepped ring 46 of insulation. The inside of the nose 44 is provided with a suitably shaped face or surface 48 which cooperates with a somewhat similarly shaped face or surface 50 on the member 40 to form a work-receiving space across which a high-frequency voltage exists. The inside of the central member 38 is adapted to receive pellets or other suitable plastic material 52 which can be forced by a ram or plunger 54 into the work-receiving space between the faces 48 and 50 of the nose 44 and member 42, respectively, where the work is heated and finally discharged out of the nozzle or nose 44, preferably into a mold.

While we have described our invention in connection with several forms now preferred, it is obvious that the teachings thereof have wide applications and can be embodied in other radically different forms.

We claim as our invention:

1. Dielectric heating means comprising means providing a resonant chamber having means through which it may be electrically excited, said chamber having outer walls including an end wall and having an inner reentrant portion facing said end wall but spaced therefrom to provide a work-receiving space, said end wall being movable with respect to said reentrant portion and to other walls of said chamber so as to provide an opening in said chamber for loading work into said space for heat-treatment and unloading said work after such heat-treatment, and a pressure-exerting means engaging the outside of said end wall for holding work between said end wall and said reentrant portion, said pressure-exerting means comprising a hinge hinging said end wall to a wall of said chamber and a latch for holding said end wall closed.

2. Dielectric heating means comprising means providing a resonant chamber having means through which it may be electrically excited, said chamber having outer walls including an end

5 wall and having an inner reentrant portion facing said end wall but spaced therefrom to provide a work-receiving space, said end wall being movable with respect to said reentrant portion and to other walls of said chamber so as to provide an opening in said chamber for loading work into said space for heat-treatment and unloading said work after such heat-treatment, and a pressure-exerting means engaging the outside of said end wall for holding work between said end wall and said reentrant portion, said pressure-exerting means comprising a member connected to the outside of said end wall and applying pressure on the outside of said end wall.

3. Dielectric heating means comprising means providing a resonant chamber having means through which it may be electrically excited, said chamber having outer walls including an end wall and having an inner reentrant portion facing said end wall but spaced therefrom to provide a work-receiving space, said end wall being movable with respect to said reentrant portion and to other walls of said chamber so as to provide an opening in said chamber for loading work into said space for heat-treatment and unloading said work after such heat-treatment, and a pressure-exerting means engaging the outside of said end wall for holding work between said end wall and said reentrant portion, said outer walls comprising a tubular wall, and said end wall slidably fitting inside of said tubular wall.

4. Dielectric heating means comprising means providing a resonant chamber having means through which it may be electrically excited, said chamber having outer walls including an end wall-portion and having an inner reentrant portion including an end wall-portion facing the first said end wall-portion but spaced therefrom to provide a work-receiving space, one of said end wall-portions being relatively movable with respect to the other and to other walls of said chamber so as to provide an opening in said chamber for loading work into said space for heat-treatment and unloading said work after such heat-treatment, and a pressure-exerting means engaging the outside of said movable end wall-portion for holding work pressed between said end wall-portions during heat-treatment of

6 the work, said pressure-exerting means comprising a member connected to the outside surface of said movable end wall-portion applying pressure to the outside of said movable end wall-portion.

5. Dielectric heating means comprising means providing a resonant chamber having means through which it may be electrically excited, said chamber having outer walls including an end wall-portion and having an inner reentrant portion including an end wall-portion facing the first said end wall-portion but spaced therefrom to provide a work-receiving space, one of said end wall-portions being relatively movable with respect to the other and to other walls of said chamber so as to provide an opening in said chamber for loading work into said space for heat-treatment and unloading said work after such heat-treatment, walls of said resonant chamber providing a tubular portion in which one of said end wall-portions is slidable, and a pressure-exerting member associated with the outside of said slidable end wall-portion applying pressure thereto during heat-treatment of the work in said space.

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