

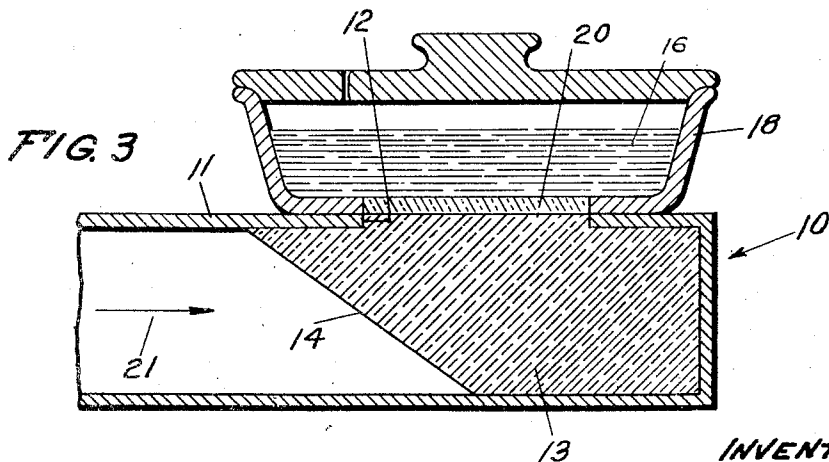
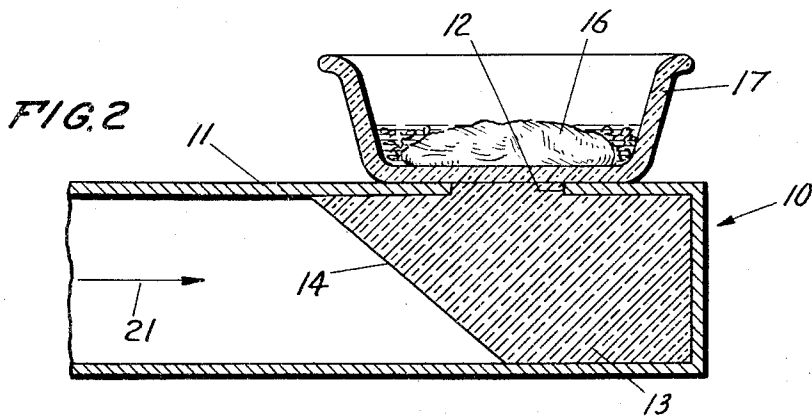
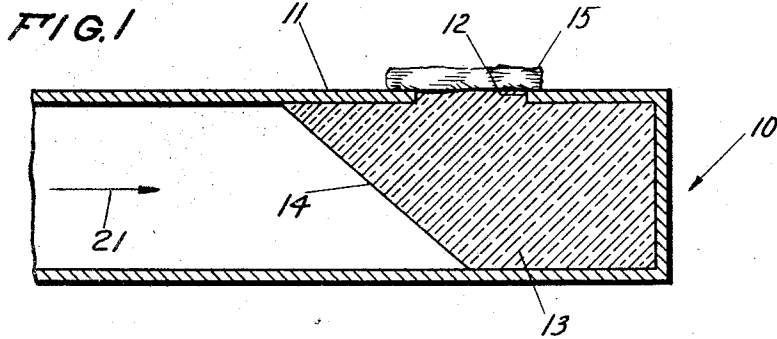
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DIELECTRIC MATCHING DEVICES

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DIELECTRIC MATCHING DEVICES

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This invention relates to devices for matching the impedance of a source of radio frequency energy to that of material to be irradiated with such energy, and more particularly to such devices having a dielectric constant close to that of the material to be irradiated and positioned in that part of a transmission line that is in juxtaposition to the material.

In heating by means of radio frequency, a problem of impedance matching arises particularly when heating substances have a considerable water content. Water has a high dielectric constant and thus causes a mismatch when used with an air-filled transmission line. Such a mismatch results in loss of energy. Furthermore, when the wave length of the propagated energy is of the same order of magnitude as the object to be heated, unequal application of heat to different parts of the object will result due to standing waves. In the case of material to be dried, the solid material may absorb more energy than that still wet, and there is thus a danger that part of the mass will be burned before the rest is completely dried.

In the invention, that portion of the transmission line, usually a wave guide, in closest proximity to the load is filled with insulating material having a dielectric constant as close as possible to that of the load material. This may be done by forming an opening near the end of the wave guide and filling the end portion with a suitable insulating material. In the case of a device of this sort to be used with a load material having a high water content, this material will most conveniently be titanium dioxide, a titanate or other titanium compound. In cooking certain foods, such as a steak, the food can be applied directly to the opening. The device then operates as a hot plate. If the material to be heated or dried is a liquid or a semi-liquid, it may be held in a container having a dielectric constant close to that of the material of the matching device. A metallic container can be used for this purpose if it is fitted with an insert of material having the appropriate dielectric constant in the region that will be in closest proximity to the opening in the wave guide. The result is a more efficient and even distribution of energy throughout the load.

Other and further advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawing wherein:

Fig. 1 is a longitudinal sectional view of an embodiment of the invention;

Fig. 2 is a longitudinal sectional view of another embodiment of the invention; and

Fig. 3 is a longitudinal sectional view of a third embodiment of the invention.

In Fig. 1, the reference numeral 10 designates a wave guide having a top wall 11 in which is formed an opening 12. The wave guide is shown in Fig. 1 as rectangular in cross section. However, it may be circular or elliptical. A portion of the wave guide 10 near one end is filled with a solid piece 13 of insulating material having approximately the same dielectric constant as the mate-

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rial to be heated. In the case of food having a high water content, this material will preferably have the dielectric constant of water. A suitable ceramic for this purpose is one consisting largely of titanium oxide or one or more of the titanates or other titanium compounds. The matching piece is formed with a taper 14 at the end nearest the generator. The dimension of the block in the direction of propagation should be long relative to the wave length of the propagated energy at the operating frequency. The material 15 to be heated or dried, if it is of a consistency that makes it self-supporting, such as a piece of steak, can be placed directly on the opening 12 as shown in Fig. 1. Best results are obtained if the opening 12 is approximately the same size and shape as the object to be heated. If the material to be heated is a liquid or a semi-liquid, such as soup, it may be placed in a container of a material presenting little or no impedance to the passage of radio frequency energy. Such a material 16 is shown in Fig. 2 in a container 17. The material of this container may also be the same as that of the matching block 13. Fig. 3 shows another embodiment of the invention in which the material to be heated, 16, is contained in a metal container 18 having an insert 20 of the same material as the matching block 13 inserted in that part of the container 18 which will be in closest proximity to the matching block 13. Best results are obtained if this insert 20 is of the same dimensions as the opening 12.

In operation, radio frequency energy from a generator proceeds down the guide 10 in the direction indicated by the arrow 21 in each of the figures. As the energy penetrates the block 13 of insulating material, reflections are prevented by the taper 14 formed in the block 13. The dimensions of the block 13 are chosen with respect to the wave length of the radio frequency energy at the operating frequency so that, over a narrow band of frequencies near the operating frequency, a large number of resonant modes appear. Since the dielectric constant of the material from which the block is made is high, these modes are obtained with relatively small dimensions for the block. These many modes result in a relatively even distribution of energy throughout the opening 12. With the dielectric constant of the material of the block chosen to approximate that of the material to be irradiated, the impedance of the block approximates that of the material to be irradiated and there is little or no energy lost by reflections at the boundary between the block and the material. The high dielectric constant of the material of the block has the further effect that any energy propagated from the block into space or into a surrounding shielding box will be reflected back into the block by the mismatch between the impedance of the block and that of air. Due to the taper formed on that end of the block nearest the generator, the impedance of the generator may be matched to that of the transmission line by well-known means without this match being affected by the impedance of the load.

It is also possible to cause the energy propagated through the block to be concentrated within the load by an appropriate shaping of the metal and dielectric surfaces of the matching device, the same way as light is concentrated by an optical lens.

Due to the low heat conductivity of dielectric material, the block may act as a "hot plate" for frying or other cooking of foods placed directly in contact with it. A rod of the same material as the block may be inserted into an object to be heated to heat the interior of the object, as shown in the United States patent, No. 2,540,036, to Percy L. Spencer. In this case, the rod is brought into contact with the block of this invention.

When the matching device of this invention is used for drying material wet with a liquid having the dielectric

constant of the matching block, quite different from that of the solid portion of the material, the good match to the liquid in the material will cause it to dry rapidly while the mismatch to the solid portion of the material will prevent the dried portions of the material from being burned during the drying process.

As an example of the efficiencies to be obtained with this invention, a wave guide, terminated in such a matching device and having a $2\frac{1}{2}$ inch circular opening in its upper wall, heated water with a loss of only 20% of the energy generated and propagated down the guide without a shielding box. A standing wave ratio of as low as 1.5 to 1.7 was measured on the generator side of the matching device.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is, accordingly, desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. In combination, a waveguide for radio frequency energy having an opening in one wall, material having a high water content to be irradiated with said energy, and means to couple energy from said transmission line to said material comprising a tapered block of insulating material containing a titanate positioned within the waveguide at the opening in the wall of the waveguide.

2. In combination, a transmission line for radio frequency energy comprising a wave guide having an opening in one wall, material having a high water content to be irradiated with said energy, and means to couple energy from said wave guide to said material comprising a tapered block of insulating material containing titanium dioxide positioned within the waveguide at the opening in the wall of the wave guide.

3. In combination, a waveguide for radio frequency energy having an opening in one wall, material having a high dielectric constant to be irradiated with said energy, and means to couple energy from said waveguide to said material comprising a tapered block of insulating material having a dielectric constant approximating that of the material to be irradiated positioned within the waveguide at the opening in the wall of the waveguide and extending into the opening, said block being formed with a taper in the direction from which the energy is propagated.

4. In combination, a waveguide for radio frequency energy having an opening in one wall, material having a high dielectric constant to be irradiated with said energy, and means to couple energy from said waveguide to said material comprising a tapered block of insulating material having a dielectric constant approximating that of the material to be irradiated positioned within the waveguide at the opening in the wall of the waveguide and extending into the opening and a container for said material to be irradiated formed of a material presenting a minimum impedance to the passage of radio frequency energy.

5. In combination, a waveguide for radio frequency energy having an opening in one wall, material having a high dielectric constant to be irradiated with said energy, and means to couple energy from said waveguide to said material comprising a tapered block to insulating ma-

terial having a dielectric constant approximating that of the material to be irradiated positioned within the waveguide at the opening in the wall of the waveguide and extending into the opening, and a container for said material to be irradiated formed of a material having the same dielectric constant as the material to be irradiated.

6. In combination, a transmission line for radio frequency energy, material having a high dielectric constant to be irradiated with said energy, and means to couple energy from said transmission line to said material comprising a tapered block of insulating material having a dielectric constant approximating that of the material to be irradiated positioned at the output of the transmission line and a metallic container for said material to be irradiated fitted with an insert in the region of proximity to the block, said insert being formed of a material having the same dielectric constant as the material to be irradiated.

7. A waveguide for transmitting radio frequency energy having an opening in one wall near one end, a block of insulating material containing a titanate having a dielectric constant approximating that of material to be irradiated, said block being positioned within the waveguide behind the opening and extending into the opening.

8. A waveguide for transmitting radio frequency energy having an opening in one wall near one end, a block of insulating material containing titanium dioxide having a dielectric constant approximating that of material to be irradiated, said block being positioned within the waveguide behind the opening and extending into the opening.

9. A waveguide for transmitting radio frequency energy having an opening in one wall near one end, a tapered block of insulating material containing a titanate having a dielectric constant approximating that of material to be irradiated, said block being positioned within the waveguide behind the opening and extending into the opening.

10. A waveguide for transmitting radio frequency energy having an opening in one wall near one end, a tapered block of insulating material containing titanium dioxide having a dielectric constant approximating that of material to be irradiated, said block being positioned within the waveguide behind the opening and extending into the opening.

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