Oct. 12, 1965 S. C. JOHNSON 3,211,880

OVEN

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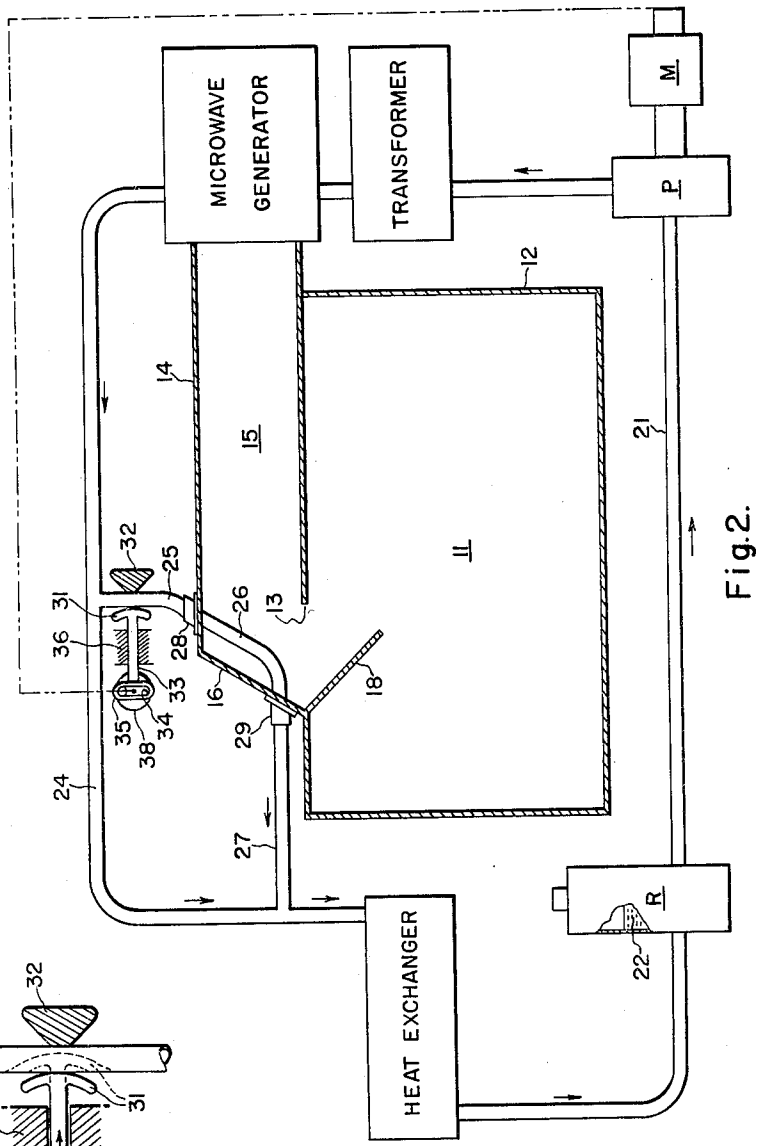


Fig.2.

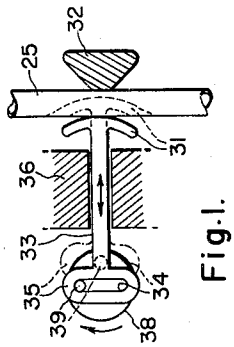


Fig.1.

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This invention relates to heating of materials by exposure to electromagnetic radiation and concerns especially distribution of microwave energy for uniform heating thereby in an oven or similar enclosure.

Increase in temperature of materials exposed to electromagnetic radiation in the microwave portion of the spectrum (from about one thousand to three hundred thousand megacycles per second, corresponding to wavelengths of from about thirty centimeters to one millimeter) is a familiar phenomenon. Microwave generators operating in the lower portion of this range are used to provide energy to cooking ovens or the like. However, the pattern of radiation established in an oven, for example, resembles standing waves to such an extent that the food or other material to be heated is affected non-uniformly. For this reason it is customary to "stir" the pattern or "mix the modes" by means of a rotating fan having electrically conductive blades to reflect the radiation intermittently. However, the added initial cost and upkeep of such a device are unwelcome, and there is a great need for improvement.

A primary object of the present invention is assurance of heating uniformity in a microwave oven or the like without use of moving blades therein.

Another object is provision of means located wholly external to a microwave oven or the like for increasing the degree of uniformity of the energy distribution therein.

A further object is utilization of the cooling system of a microwave generator for evening out the energy pattern in an oven or similar enclosure supplied with energy by the generator.

Other objects of this invention, together with means and methods for attaining the various objects, will be apparent from the following description and the accompanying drawings.

FIG. 1 is a largely schematic representation of apparatus for practicing the present invention; and

FIG. 2 is an enlarged view, in side elevation and partly in section, of a portion of the apparatus of FIG. 1.

In general, the objects of this invention are accomplished, in the heating of materials in an enclosure supplied with microwave energy along a path thereto, by passing a varying quantity of dielectric material across a portion of the path.

The invention contemplates particularly accomplishment of this in a microwave oven comprising a conductive housing adapted to contain microwave energy, a microwave generator, a waveguide interconnecting the microwave generator and an entrance to the housing and thereby defining a path for the energy, a conduit adapted to contain coolant and passing in heat-exchanging relationship with the microwave generator, the conduit having a pair of branch lines, connected in parallel, one of the branch lines crossing a portion of the wave-guide interior at an acute angle, adjacent the housing entrance, an aqueous liquid coolant in the conduit, a pump for circulating the coolant through the conduit, a motor for actuating the pump, and means actauted by the motor for periodically interrupting the circulation of the coolant through the branch line crossing the portion of the waveguide interior.

FIG. 1 shows, largely schematically, apparatus useful

according to the present invention, including a centrally located enclosure or oven 11. Housing 12 defines the oven and is shown in side sectional elevation. Communicating with the oven by way of aperture 13 in the top thereof is energy path 15 defined by waveguide 14. The waveguide terminates in oblique wall 16 adjacent the opening, and oblique vane 18 extends from the junction thereof with the housing wall into the oven, also at an acute angle to the aperture.

Shown in block form at the far end of the wave-guide is a microwave generator, which may comprise a magnetron oscillator. Also shown in block form, just below the microwave generator is a transformer, such as the conventional high-voltage transformer for a magnetron. Visible between and interconnecting the transformer and the microwave generator is a portion of conduit 21, which circulates a coolant in heat-exchanging relationship therewith to maintain them at sufficiently low operating temperature. The coolant is circulated by pump P, driven by motor M, to the transformer and microwave generator, then through a heat exchanger and into reservoir R, partly cut away to show the level of coolant 22 inside, and back to the pump, as indicated by arrows.

Between the microwave generator and the heat exchanger, conduit 21 divides into two branches or parallel lines: branch 24 proceeding directly to the heat exchanger, and branches 25, 26, 27 detouring through a portion of waveguide 14. Portion 26 of the detouring branch crosses energy path 15 at an acute angle to aperture 13 and substantially parallel to oblique end wall 16 of the waveguide. External portions 25 and 27 interconnect it to the rest of the conduit at the ends of parallel branch 24. Collars 28 and 29 surrounding the detouring conduit adjacent the waveguide are constructed as conventional choke joints to prevent escape of microwave energy from the waveguide interior.

Juxtaposed to opposite sides of conduit branch portion 25 are depressor 31 and bumper 32. The depressor is attached to one end of the shaft 33, the other end of which carries slotted member 35, slot 34 therein being oriented perpendicular to the shaft. Bearing member 36, shown sectioned, surrounds the shaft. Wheel 38 located behind the slotted member carries pin 39 mounted off-center thereon and protruding into slot 34 in which it rides. The broken line interconnecting wheel 38 with motor M indicates mechanical linkage whereby rotation of the motor rotates the wheel, as well as pump P shown mounted on the motor shaft.

FIG. 2 shows on a larger scale certain of the apparatus elements shown in FIG. 1 and also illustrates in broken lines an alternative position in which conduit branch portion 25 is compressed between the depressor and the bumper. It will be understood that this portion, at least, of the conduit is made of flexible resilient material, such as rubber, polyethylene, or nylon, for example. The arrows indicate that unidirectional rotation of the wheel causes reciprocation of the shaft and the depressor thereon by reason of the movement of the pin in the slot of the slotted member on the shaft.

It is readily apparent that when conduit branch portion 25 is compressed, as shown in broken lines, the flow of coolant must proceed through parallel branch 24, instead of through both branches simultaneously as when branch portion 25 is not so compressed. This results in periodically discontinuous flow through conduit branch portions 26 and 27, as well, and intermittent propulsion of coolant therethrough. Intermittent injection of coolant in branch portion 26 is important because it crosses the path followed by the microwave energy. Coolant present inside the conduit portion in the energy path will reflect some of the incident microwave energy (and absorb

some), and intermittent energy interception by coolant in the path will provide intermittent reflection, thereby "stirring" the energy pattern. The preferred orientation of branch portion 26 of the coolant conduit, like that of end wall 16 of the waveguide, is at an acute angle such that reflection into the oven will occur. Vane 18 in the oven interior further reflects part of the energy received from the waveguide.

Under ideal conditions the interruption and restoration of flow through conduit branches 25, 26, 27 will result in passage of "slugs" of coolant through branch portion 26. Dimensioning and valving of the various portions of conduit 21 to accomplish this purpose most effectively are well within the capabilities of persons having ordinary skill in the art, in the light of this teaching. The depressor and bumper may be relocated along branch portion 27 or parallel branch 24, or more than one such installation may be made at any of these or other locations along the conduit, to attain the desired result. As in the illustrated example, gravity flow may be employed to supplement the pump pressure at least in part, as may be helpful.

Inasmuch as circulation of a coolant is normally required for the electronic apparatus components of a microwave heating system, advantages of cost and convenience in utilizing it for "mode mixing" are significant despite the slight additional energy consumption. The coolant may be any liquid of suitably lossy dielectric. Water is satisfactory, and aqueous solutions of salts or miscible organic liquids may be employed. Except where flexibility of the conduit is required, as described above, inflexible pipe may be used. A heat exchanger as such may not be required at some temperature ranges and rates of circulation, and in its absence the coolant crossing the microwave energy path may drain directly into the reservoir. Variations in the location, number, and shape of the parts of the suggested apparatus may be made without departing from the invention as defined in the claims.

The claimed invention:

1. Apparatus for heating food materials with microwave energy, comprising a housing defining a microwave cooking oven adapted to contain the energy, a microwave generator, a waveguide interconnecting the microwave generator and the oven and thereby defining a path for the energy, a conduit crossing a portion of the waveguide interior adjacent the oven interior, a dielectric liquid in the conduit, a pump for circulating the liquid through the conduit, and means for circulating the liquid in the form of separated slugs to vary the microwave pattern within the oven.

2. Apparatus for heating materials with microwave energy, comprising a housing defining an enclosure adapted to contain the energy, a microwave generator, a waveguide interconnecting the microwave generator and the housing and thereby defining a path for the energy, the waveguide terminating at the housing in an angled portion adapted to reflect the energy into the housing, a conduit crossing that portion of the waveguide interior and passing also in heat-exchanging relationship with the microwave generator, a dielectric liquid coolant in the conduit, a pump for circulating the coolant through the conduit, a motor for actuating the pump, and means actuated by the motor for periodically interrupting th e circulation of the coolant through that portion of the conduit crossing the portion of the waveguide interior so that the flow through said portion of the conduit is in separated slugs of liquid, whereby the microwave pattern within the enclosure is varied.

3. Apparatus for heating materials with microwave energy, comprising a conductive housing adapted to contain the energy, a microwave generator, a waveguide interconnecting the microwave generator and an entrance to the housing and thereby defining a path for the energy, a conduit adapted to contain coolant and passing in heat-exchanging relationship with the microwave generator, the conduit having a pair of branch lines connected in parallel, one of the branch lines crossing a portion of the waveguide interior, a dielectric liquid coolant in the conduit, a pump for circulating the coolant through the conduit, a motor for actuating the pump, and means actuated by the motor for periodically interrupting the circulation of the coolant through the branch line crossing the portion of the waveguide interior so that the flow therethrough is in separated slugs of liquid, whereby the microwave pattern within the enclosure is varied.

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