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MODE-SHIFTING DEVICES

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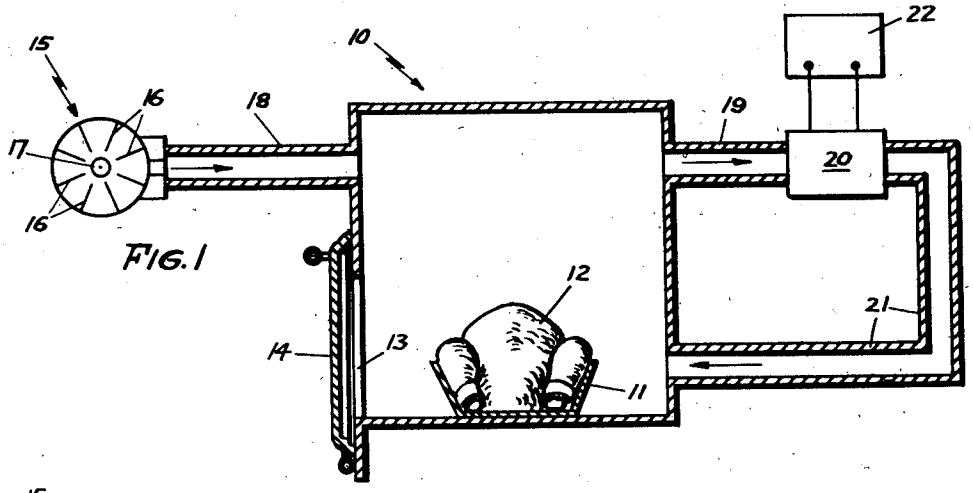


FIG. 1

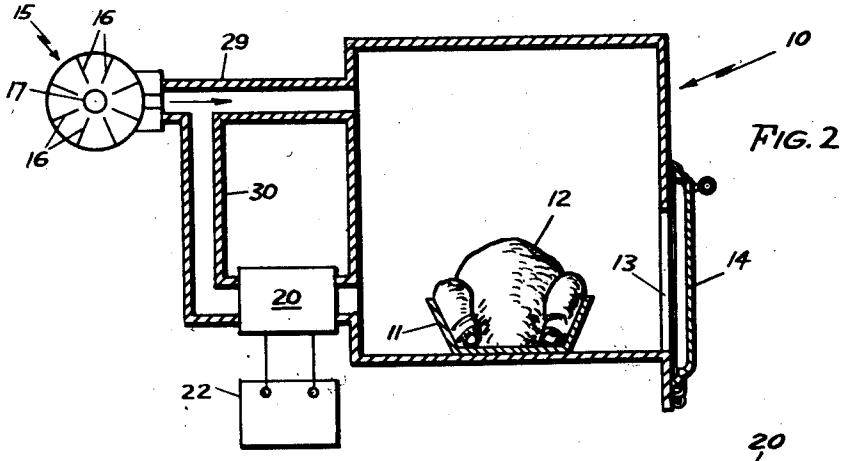


FIG. 2

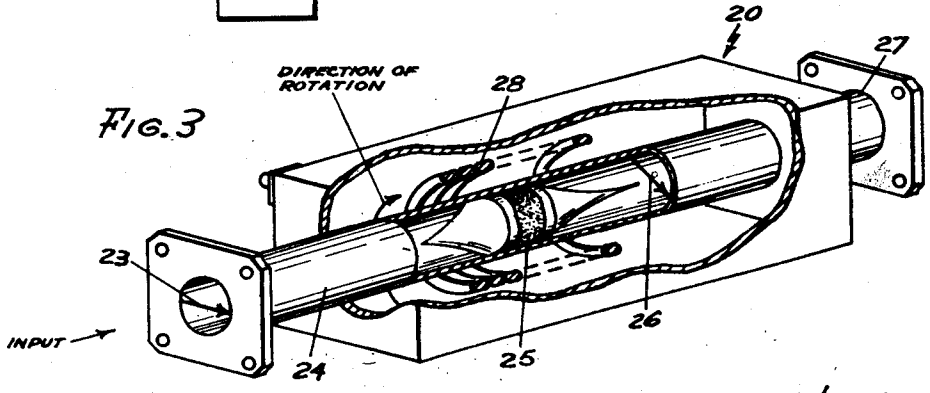


FIG. 3

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MODE-SHIFTING DEVICES

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This invention relates to a mode-shifting device, and more specifically to a device that will shift the mode characteristics of the heating cavity without using mechanical means.

In the microwave cooking art, the object to be heated, usually foodstuff, is placed in a cavity wherein microwaves are inserted for the purpose of causing an even distribution of the voltage gradient lines. The containers or cavities used to hold the foodstuff will operate at a certain mode of operation, thereby causing voltage gradient lines to appear in said cavity. Since heating takes place by the stretching of molecules at the applied microwave frequency, and since the amount of heat generated depends on the voltage gradient fields, it can be seen that uneven heating will occur if the cavity is allowed to operate at any specific mode. The problem, therefore, is to continually change the mode of operation in said cavity, thereby producing an even voltage gradient distribution throughout said cavity. Heretofore, mode shifting has been accomplished by means of mechanical rotating devices usually located within the heating cavity.

It is an object of this invention to disclose a fully electronic method for changing the mode of operation in a heating cavity. It is to be understood that electronic method refers to a system that does not use mechanical rotating devices.

Further objects and advantages of this system will be apparent as the disclosure progresses, reference being made to the accompanying drawing wherein:

Fig. 1 is a view illustrating a first embodiment of a high frequency oven according to this invention;

Fig. 2 is a view illustrating a second embodiment of a high frequency oven according to this invention; and

Fig. 3 is a view illustrating an electronic method for changing the polarization of microwaves.

In microwave cooking devices, the problem arises in cooking foodstuff having a rather large total area or volume. In order to accomplish the desired heating result, it is necessary to energize large regions of space with microwave energy, and for proper cooking this energization should be substantially uniform throughout the space. Also, it is desirable to accomplish such energization with a minimum expenditure of power. In such a space the wavelength of the microwave energy is small in comparison to the linear dimension of the oven, or in comparison to the linear dimensions of the foodstuff to be cooked or heated.

At any single frequency only one mode of oscillation can exist in such a shape. In other words, there can be only one distribution of regions of high electric field intensity and regions of high magnetic intensity. Unless the walls are made high absorbing so that substantially all incident radiation is absorbed, the difference in field intensity will be very great. The problem presented, therefore, is to minimize or eliminate the effect

that such field distribution may have on the heating of the material to be cooked.

The electrical load which is presented to the microwave energy source will change if this field distribution changes. This will occur if the frequency of the source is changed, or if the quantity or nature of the food which is being heated is changed. Heretofore, the field distribution within the heating cavity has been changed by mechanical methods whereby mechanically rotating devices are placed within the cavity for the purpose of reradiating energy. These mechanical methods accomplish the result of even heat distribution by continually changing the operating mode of the container.

In this patent there is accomplished a continual change of the operating mode of the heated container by electronic means which are preferably external to the heated container.

Referring now to Fig. 1, there is shown an oven **10** constructed of a suitable metal having relatively thin walls formed in the shape of a cavity or container. A container **11** is located within said oven **10** for the purpose of holding the foodstuff **12** which is to be heated. In order to allow access to the interior of oven **10** for the placing of foodstuff **12** therein, an opening **13** in oven **10** is provided. Opening **13** is capable of being closed by means of a hinged metal door **14** for the purpose of sealing said oven **10**. Magnetron **15** is the source of microwave energy used for heating foodstuff **12** located in oven **10**. Magnetron **15** is of the fixed frequency type, having a plurality of vanes **16** and a central cathode **17**, said magnetron supplying the microwave energy for oven **10**. The microwave energy from magnetron **15** is directed along waveguide **18** into oven **10**. Also connected to oven **10** is waveguide **19** connected to the input of a ferromagnetic gyrator **20**. A gyrator is hereby defined as a device containing a core located in a magnetic field. The gyrator exhibits the property of changing the polarization of a wave passing through said core in accordance with a principle known as the Faraday effect. The output of said gyrator **20** is connected by waveguide **21** back to oven **10** at a still different point. A modulator source **22**, preferably in the audio range, is connected to the gyrator **20** for the purpose of continually shifting the polarization of the microwave energy emanating from waveguide **21**, as compared to the energy emanating from waveguide **19**.

It will be seen, therefore, that the energy arriving from magnetron **15** will cause a certain mode of operation to exist in oven **10**. A portion of this energy will be fed by waveguide **19** to gyrator **20**, which will change the polarization of the microwave energy in waveguide **21**, as compared to the microwave energy in waveguide **19**, at a rate depending on the modulating source **22**. This shifted microwave energy in waveguide **21** is then directed back into oven **10**, causing the mode of operation of oven **10** to continually change at a rate determined by modulator **22**.

By continually changing the operating mode of oven **10**, there is obtained a uniform heating effect through the foodstuff **12**, since the voltage gradient fields will have an even voltage distribution. Since the field distribution, or the mode pattern, inside oven **10** is periodically changing, and since this is a complex mode pattern, the total or integrated heat provided in any one area of the oven during a period of time will be substantially the same as that provided in any other equal area of the oven during the same time, no matter where in the oven the two comparable areas are located. Due to this heat uniformity the oven is made very effective for cooking purposes.

Referring now to Fig. 3, there is shown an embodi-

ment of the ferromagnetic gyrator **20**, illustrated in Figs. 1 and 2. Speaking generally, a transmission line having conventional geometry will transmit microwave power as freely in one direction as another. Power losses that may occur in such a line will not be due to the direction of energy propagation, but rather to inherent line characteristics. A phenomenon known as the Faraday effect has been applied to produce a unidirectional transmission line section, which permits microwave power to be transmitted with negligible attenuation in one direction, but which functions to absorb power in the opposite direction. The Faraday effect at optical frequencies was discovered by Michael Faraday in 1845. He demonstrated that the plane of vibration was rotated when plane-polarized light was sent through certain materials in a direction parallel to an applied magnetic field. This same effect is also evident at microwave frequencies. Here the plane of polarization of a plane polarized wave is roated when passing through certain ferromagnetic materials which exhibit the desired properties. Of significance is the fact that the direction of rotation is determined by the direction of the applied magnetic field, not by the direction of propagation of the microwave energy.

Regardless of the direction of travel, left to right, or right to left, microwaves passing through a material exhibiting the Faraday effect will have their plane of polarization rotated in the same direction in space. Fig. 3 illustrates how the ferromagnetic gyrator **20** operates. By considering propagation in a forward direction, the plane polarized energy **23** passes through a cylindrical waveguide **24**. Since the microwave energy passes through a ferromagnetic material **25** exhibiting the Faraday effect, its plane of polarization is shifted by 45 degrees as shown by arrow **26**. The polarized energy is then fed from cylindrical waveguide **27**.

Energy propagated in the reverse direction is oriented 45 degrees with respect to that of the input. The ferromagnetic material **26** in conjunction with the applied magnetic field **28** then rotates the field an additional 45 degrees, resulting in a total shift of 90 degrees with respect to the initial plane of polarization. By applying an alternating current to the magnetic field-producing coil **28**, the resulting magnetic field causes the plane of polarization of the microwave field to be rotated first in one direction and then the other, resulting in an increase or decrease in the amplitude of the transmitted component. At the crest of the positive half cycle of the applied alternating current, the resultant polarization is such that the amplitude of the transmitted microwave energy is increased from its zero signal current value to 90%, or more, of the original input level. At the crest of the alternating current negative half cycle the corresponding change will reduce the microwave energy output to nearly zero. The microwave output may, therefore, be amplitude modulated at the audio frequency by means of a suitable modulating source **22** applied to the external coil **28**.

Referring now to Fig. 2, there is illustrated an oven and microwave source similar to that shown in Fig. 1. Fig. 2 merely shows another embodiment of the use of ferromagnetic gyrator **20** feeding the oven **10**. The microwave energy for magnetron **15** is directed along waveguide **29** and thence to oven **10** and also from waveguide **29** through waveguide **30** to the input of the ferromagnetic gyrator **20**. The output of the ferromagnetic gyrator **20** is then directed to the oven **10** in a similar manner as shown in Fig. 1.

This completes the description of the embodiment of the invention illustrated herein. However, many modifications and advantages thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. It is to be understood that any form of gyrator that uses the Faraday effect may be used for changing the operating mode of the oven. Accordingly, it is desired that this invention not be limited to the particular details of the embodiment disclosed herein except as defined by the appended claims.

What is claimed is:

1. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, a first means for feeding the microwave energy from said source to said oven, a gyrator external to said oven coupled to said oven for changing the operating mode of said oven, and a second means for feeding said microwave energy to said gyrator.

2. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, a first means for feeding the microwave energy from said source to said oven, a core external to said oven located in a magnetic field for changing the polarization of microwave energy passing through said core, means for coupling said core to said oven for changing the operating mode of said oven, and a second means for feeding said microwave energy to said core.

3. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, a first means for feeding the microwave energy from said source to said oven, a core external to said oven located in a magnetic field for changing the polarization of microwave energy passing through said core, means for coupling said core to said oven for changing the operating mode of said oven, means for modulating the field intensity of said magnetic field, and a second means for feeding said microwave energy to said core.

4. In combination, an oven for heating foodstuff by microwave energy, a first means for feeding the microwave energy from said source to said oven, a core external to said oven located in a magnetic field for changing the polarization of microwave energy passing through said core, means for coupling said core to said oven for changing the operating mode of said oven, means for modulating the field intensity of said magnetic field at a rate susbtantially less than the operating frequency of the microwave energy, and a second means for feeding said microwave energy to said core.

5. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, a first means for feeding the microwave energy from said source to said oven, a ferromagnetic core external to said oven located in a magnetic field for changing the polarization of microwave energy passing through said core, means for coupling said core to said oven for changing the operating mode of said oven, and a second means for feeding said microwave energy to said core.

6. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, a first means for feeding the microwave energy from said source to said oven, a ferromagnetic core external to said oven located in a magnetic field for changing the polarization of microwave energy passing through said core, means for coupling said core to said oven for changing the operating mode of said oven, means for modulating the field intensity of said magnetic field at a rate substantially less than the operating frequency of the microwave energy, and a second means for feeding said microwave energy to said core.

7. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, means for feeding the microwave energy from said source to said oven, means for feeding the microwave energy from within said oven through a ferromagnetic core external to said oven located in a magentic field for changing the polarization of said microwave energy, and means for feeding said polarized microwave energy back into said oven for changing the operating mode of said oven.

8. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, means for feeding the microwave energy from said source to said oven, means for feeding the microwave energy from within said oven through a ferromagnetic core external to

said oven located in a magnetic field for changing the polarization of said microwave energy, means for modulating the field intensity of said magnetic field, and means for feeding said polarized microwave energy back into said oven for changing the operating mode of said oven.

9. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, means for feeding the microwave energy from said source to said oven, means for feeding said microwave energy from said source through a ferromagnetic core external to said oven located in a magnetic field for changing the polarization of said microwave energy, and means for feeding said polarized microwave energy from said ferromagnetic core to said oven for changing the operating mode of said oven.

10. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy, means for feeding the microwave energy from said source to said oven, means for feeding said microwave energy from said source through a ferromagnetic core external to said

oven located in a variable magnetic field for changing the polarization of said microwave energy, means for modulating the field intensity of said magnetic field, and means for feeding said polarized microwave energy from said ferromagnetic core to said oven for changing the operating mode of said oven.

11. In combination, an oven for heating foodstuff by microwave energy, a source of microwave energy a first means for feeding the microwave energy from said source to said oven, means external to said oven and coupled to said oven for changing the operating mode of said oven, and a second means for feeding said microwave energy to said external mode shifting means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,618,735	Hall	Nov. 18, 1952
2,644,930	Luhrs et al.	July 7, 1953

FOREIGN PATENTS

511,649	Belgium	June 14, 1952