

- [54] **INDUCTION COOKING/WARMING APPLIANCE INCLUDING VESSEL SUPPORTING MEANS HAVING AN UNDULANT SURFACE AND TEMPERATURE SENSING MEANS ASSOCIATED WITH SAID SURFACE**

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- [21] Appl. No.: 228,135

- [52] U.S. Cl.....219/10.49, 73/343 R, 73/351,
126/39 J, 219/10.75, 219/504

- [51] Int. Cl. H05b 9/00

- [58] **Field of Search**.....219/10.49, 10.77, 10.79, 502,
219/504, 10.75; 126/39 J; 73/343 R, 351,
362 AR; 340/210, 210 MB; 307/117

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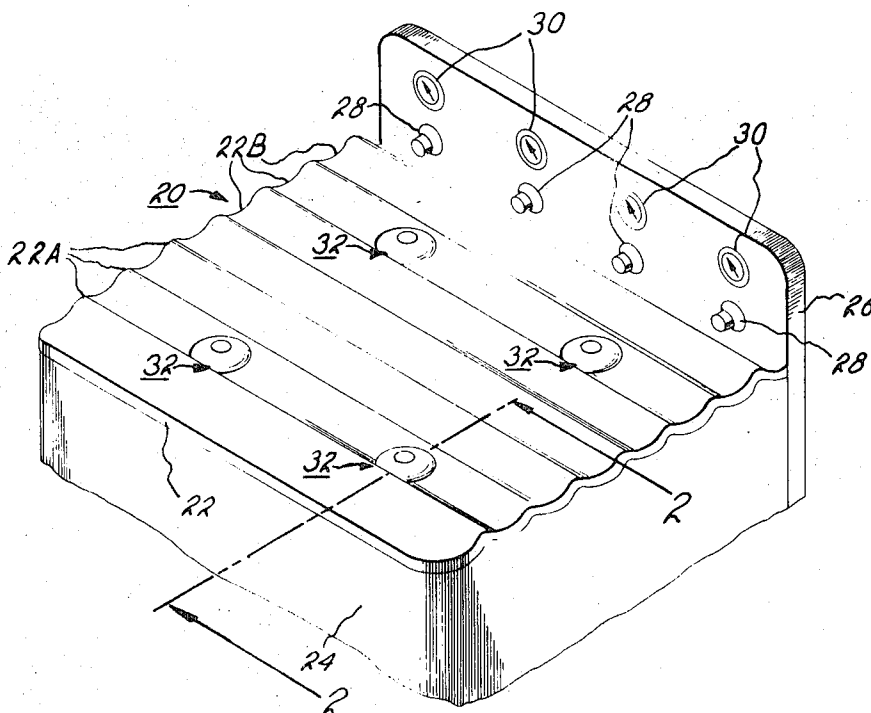
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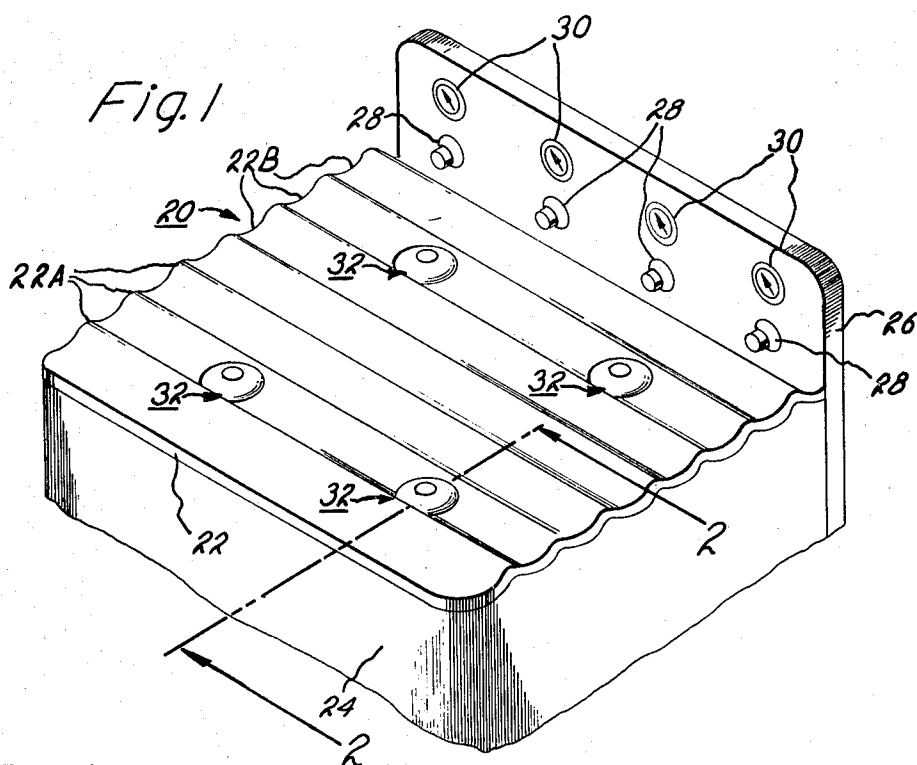
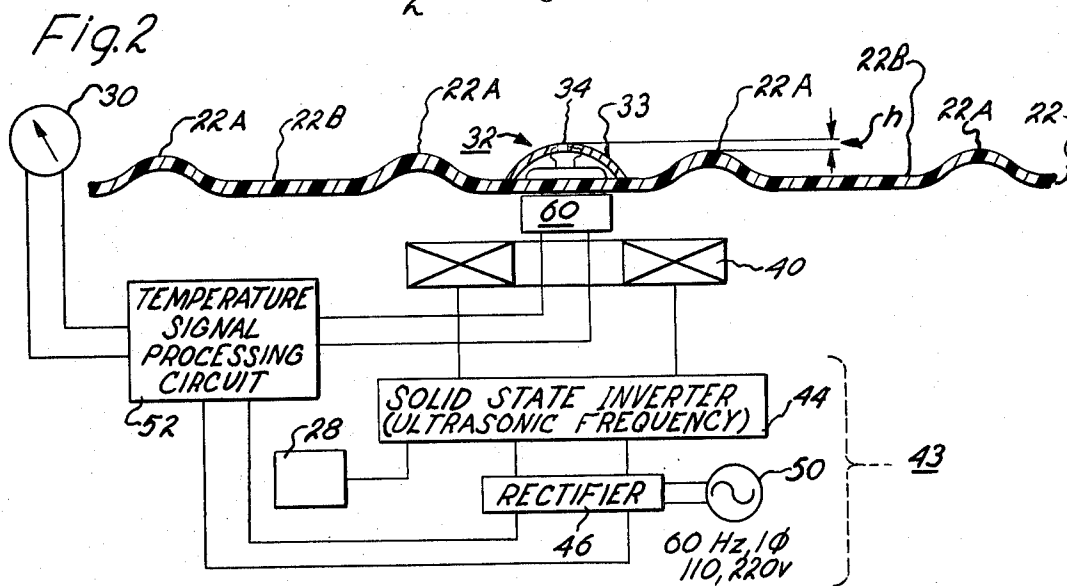
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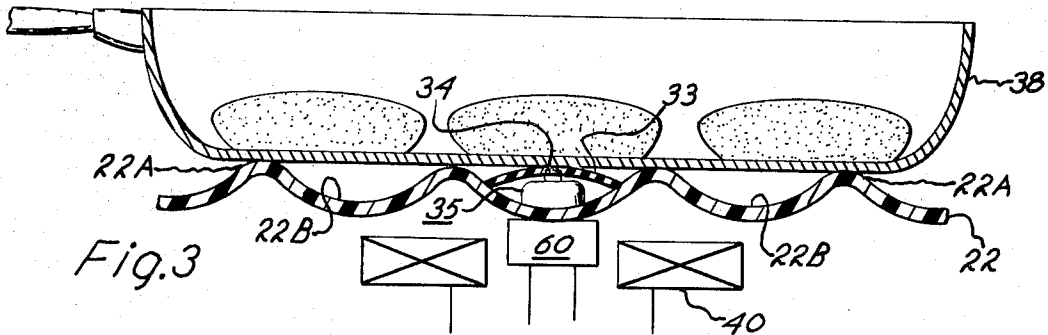
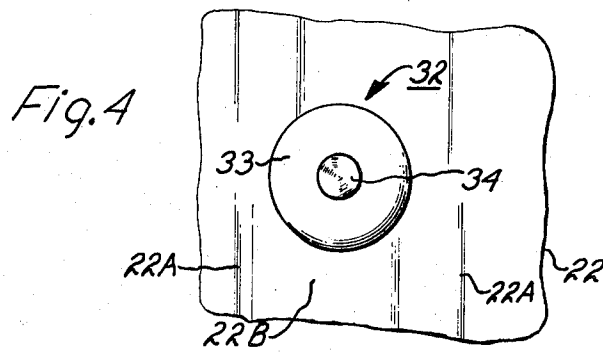
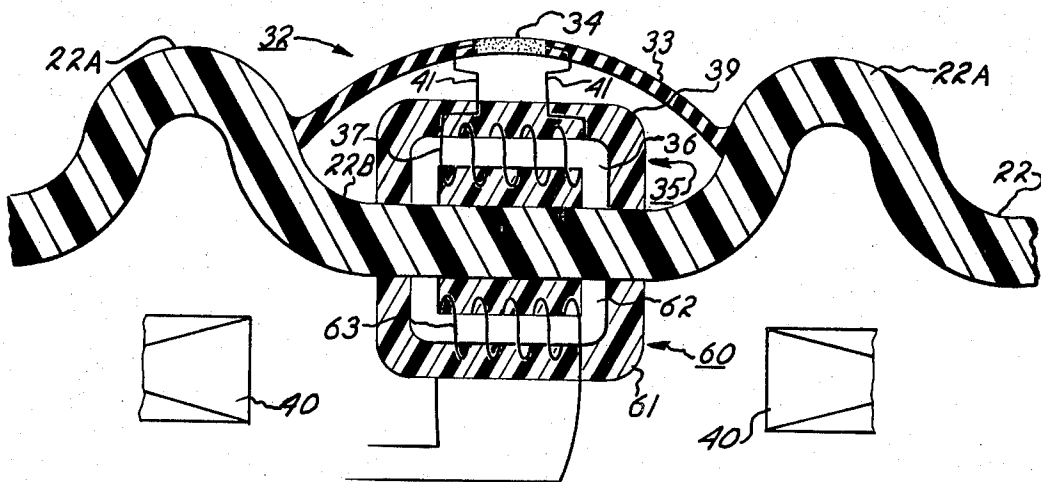
- [57] ABSTRACT

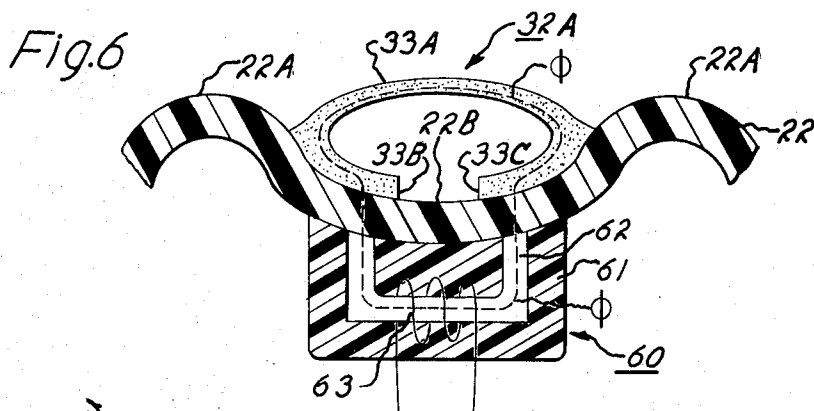
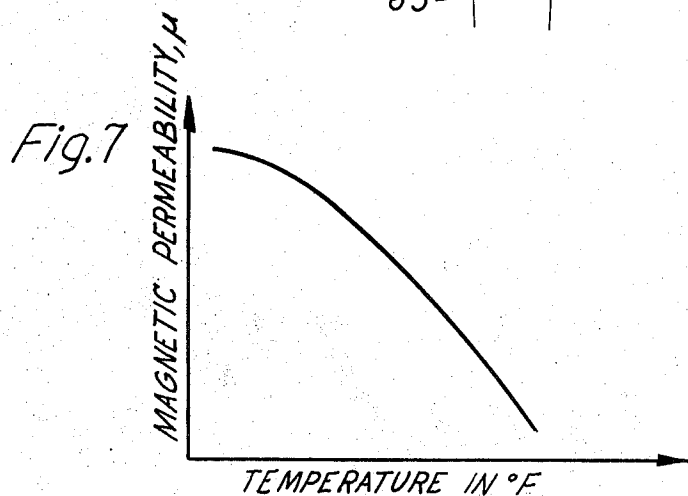
Disclosed herein is an induction range having a counter including an undulant top surface for supporting a cooking vessel. Since the counter is made of a material which is not inductively heatable the counter remains relatively cool during the cooking process, while the vessel is being inductively heated. Although the counter's top surface has undulations therein, it is, nevertheless, an unbroken surface; i.e., there are no openings therethrough. Moreover, even though the counter's top surface has undulations therein, it may, nevertheless, be relatively smooth so that it can be wiped clean, easily. Furthermore, temperature sensing means are arranged on the top surface of the counter between adjacent undulations thereof and said sensing means are adapted to be contacted and easily compressed by the bottom surface of a vessel resting on the counter's top surface; i.e., resting on the undulations.

17 Claims, 7 Drawing Figures









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INCLUDING VESSEL SUPPORTING MEANS
HAVING AN UNDULANT SURFACE AND
TEMPERATURE SENSING MEANS ASSOCIATED
WITH SAID SURFACE**

**CROSS-REFERENCES TO RELATED
APPLICATIONS**

A fuller appreciation of induction cooking appliances, as well as some of the sophistications which may be embodied therein, is to be had by referring to the following U.S. Pat. applications: Ser. No. 200,526, filed 11/19/71, in behalf of David L. Bowers, et al., titled Solid State Induction Cooking Appliance (RD-4675); Ser. No. 200,424, filed 11/19/71, in behalf of J. D. Harnden, Jr. et al., titled Solid State Induction Cooking Appliances And Circuits (RD-4678). The entire right, title and interest in and to the inventions described in the aforesaid patent applications, as well as in and to the aforesaid applications, and the entire right, title and interest in and to the invention herein disclosed, as well as in and to the patent application of which this specification is a part, are assigned to the same assignee.

BACKGROUND OF THE INVENTION

The invention herein disclosed pertains, in general, to induction cooking/warming appliances; and, in particular, to an induction cooking/warming appliance having a vessel supporting means, such as a counter, which is provided with an undulant surface which is adapted for supporting a cooking/warming vessel and for receiving between its undulations temperature sensing means which are adapted to be contacted and easily compressed by a vessel supported on the undulant surface. An important feature of the aforesaid vessel supporting means is that even though it is provided with undulations, it is, nevertheless, relatively smooth and, as a result, may be easily wiped clean. In addition to being undulant and relatively smooth, the surface need have no apertures therethrough so that the surface may be used for food preparation (e.g., cutting, chopping, grating, etc.). Furthermore, since the vessel supporting means is not made of inductively heatable material, the vessel supporting means and its surface remain relatively cool. Thus, easy cleaning and food preparation are facilitated, even during the cooking process.

Certain desiderata with respect to cooking/warming appliances have come to the attention of the manufacturer's of such appliances. For example, the following desideratum, among others, respecting such appliances have been mentioned;

One, the vessel supporting means such as the counter, or cooking surface, of a cooking range should remain relatively cool, even while cooking is taking place. With a cool surface food spilled thereon won't burn or char. Hence, cleaning up such spills of unburned or uncharred foods is relatively easy. Scouring is not required. Moreover, with a cool counter, or cook surface, more food preparation space becomes available in the kitchen. Another advantage of providing a cool counter, or cook surface, is that there becomes available a wider choice of materials from which the counter, or cook surface, may be fabricated. Elevated temperatures are not a restriction.

Two, the surface of the aforementioned counter or cook surface should be relatively smooth and unbroken (no apertures therethrough), as well as relatively cool, so that it can be easily wiped clean with minimum effort after food has been spilled (and contained) thereon.

Three, accurate sensing and display of cooking temperatures, and of rates of temperature rise and fall, should be provided with such appliances.

Prior art electric and gas ranges do not enable achievement of the aforementioned desiderata. Conventional prior art electric ranges employ exposed sheathed resistance heater surface elements which are incorporated in the plane of the counter, or cook surface, and these heater elements are electrically energized so that they can glow to incandescence. Conventional prior art gas ranges employ open flames which emanate from gas manifolds, or burners, which are incorporated in the counter or cook surface. Thus, because of the nature of the primary heat source and its arrangement and proximity with respect to the counter, or cooking surface, temperatures of approximately 1,600° F may occur at or near the cook surface in such prior art cooking ranges. Manifestly, the counter or cook surface in such ranges do not operate at a relatively cool temperature; i.e., near ambient room temperature. In addition to being subjected to elevated temperatures the counter, or cook surface, of such prior art ranges must necessarily be constructed to accommodate resistance heater elements or gas manifolds and nozzles. Hence, such prior art ranges are provided with counters or cooking surfaces which are irregular, unsmooth and broken (apertured). Therefore, food spilled on such counters or cooking surfaces often burns and chars. The result is that extraordinary efforts, such as scouring, must be undertaken in order to clean up after such food spills. Of course, such tasks are not made easier because of the irregular, unsmooth and broken construction of the counter or cooking surface.

Also, another type of electric range (the glass-ceramic electric range) has recently appeared wherein electrical resistance heater elements, or strips, are embedded in a thermally conductive glass-ceramic counter, or cooktop. The counter, or cooktop as it is sometimes called, has a very smooth top surface and the glass-ceramic material from which it is made conducts heat very well. Since the counter, or cooktop, is provided with a very smooth (optically flat) top surface special cooking utensils, or vessels, are recommended for use in conjunction with such a counter or cooktop. The special cooking utensils, or vessels, have a very smooth, optically flat bottom surface so that when rested on the cooktop or counter they are said to be "mated" with the cooktop. Briefly, because of the aforesaid mating of the optically flat utensil with the optically flat cooktop of the glass-ceramic counter, heat transfer from the embedded resistance heater elements is almost exclusively by means of conduction; i.e., heat is conducted from the resistance heater elements, through the counter and directly into the utensil. With such an electric range the cooktop is "temperature restricted" in that it cannot, without destruction, withstand temperatures higher than 600° C (1,112° F). Moreover, if the temperature of the glass-ceramic cookstop cooktop too high electrical leakage

current from the embedded resistance elements becomes of concern and represents a design restraint. Also, the glass-ceramic cooktop represents a relatively large thermal mass and the cooktop does not readily dissipate its stored heat after termination of the cooking operation, i.e., after the resistance heater elements are deenergized it takes a relatively long period of time for the cooktop to cool down to normal room temperature. Thus, in commercially practical embodiments of the aforementioned electric range employing the glass-ceramic cooktop, or counter, a reliable temperature control system is at least required for the important purpose of preventing destruction of the cooktop due to elevated temperatures. Thus, the cooktop, or counter, can be considered to be the primary heat source in the glass-ceramic electric range; i.e., the glass-ceramic counter, or cooktop, is the primary heat source and is the equivalent of the spirally wound electrical surface heaters in the conventional electric range, or equivalent to the gas flames in the conventional gas range.

Thus, the glass-ceramic electric range fails to fulfill the desiderata hereinbefore set forth: a) The counter or cooktop certainly does not remain relatively cool during the cooking process because of the nature of the cooking process; i.e., heat transfer occurs by conduction through the counter, or cooktop, to the special utensil, or vessel, which is "mated" with the cooktop. b) Although the cooktop, or counter, has a smooth surface, food spilled thereon tends to burn or char. As a result, it cannot be said that it can be easily wiped clean. c) Although the cooktop or the surface of the counter is smooth, parts of the cooktop cannot be used for the food preparation operations hereinbefore set forth because of the excessive heat in the cooktop during and after the cooking operation.

With respect to sensing or detecting the true temperature of a cooking vessel or utensil resting on the range counter or cook surface the conventional prior art electric and gas ranges present a number of problems:

First, in prior art electric and gas ranges a temperature sensor unit and its associated components are spuriously heated in some measure by the primary high temperature heating source. In the conventional electric range, for example, a temperature sensor unit is located at the center of a spirally wound resistance heating coil. This heating coil is electrically energized and often glows to incandescence. The heating oil and temperature sensor unit are both located on the top surface of the range counter or cook surface and a cooking vessel or utensil rests upon and contacts the spiral heating coil as well as the temperature sensor unit. Although the temperature sensor unit directly contacts and sensed the temperature of the heated cooking vessel the sensor unit is also subjected to direct spurious heating by the heating coil; e.g., by radiation and convection. In addition, the temperature of the sensor unit is influenced by, among other things, a metallic counter top with which the electric range is provided. Similarly, in prior art gas ranges the open flames directly heat the temperature sensor unit and heated metallic gridirons, as well as a metallic counter top, thermally influence the temperature sensor unit. In brief, with prior art electric and gas ranges the primary

heating source spuriously heats the temperature sensor unit and other heated parts of the range also thermally perturb the temperature sensor unit. Such perturbations tend to frustrate the achievement of accurate temperature measurement.

Second, in prior art electric and gas ranges various component parts of the temperature sensing unit have to be fabricated from materials which are capable of withstanding relatively high temperatures; e.g., up to about 1,600° F, approximately. As a result, certain materials cannot be used. For example, in the conventional electric range wherein the temperature sensing unit is located at the center of the spirally wound resistance heating coil (which is mounted on the metallic counter top of the range) the temperature sensing unit and its associated components are subjected to maximum temperatures of approximately 1,600° F and significant thermal stresses are induced in the temperature sensor unit and its associated components. In addition, the metallic counter is thermally stressed. Clearly, epoxies, plastics and polyimides, among others, are not applicable for use. Similarly, elevated temperatures and consequent severe thermal stresses are present in gas ranges and many materials including those hereinbefore set forth are not applicable for use. In brief, because of the relatively high temperatures involved in prior art electric and gas ranges, the materials from which temperature sensing units including their associated components may be fabricated are quite restricted.

Third, in prior art electric and gas ranges the temperature sensing unit and its associated components are often required to have some thermal shielding, or insulation, to minimize the influences of spurious heating thereof by the high temperature heating source as well as by the heated metallic range counter and the heated gridirons. Without some effective thermal shielding or insulation, the temperature sensing unit will provide a completely false temperature indication, unless temperature compensation is appropriately applied. However, temperature compensation is not feasible over the wide range of cooking conditions. Moreover, without effective thermal shielding severe thermal stresses induced in the various components of the temperature sensing unit will cause a disabling or destruction of the temperature sensing unit. Briefly, because of the relatively high temperatures involved in prior art electric and gas ranges, the temperature sensing units employed therein require effective thermal shielding or insulation.

Fourth, prior art temperature sensing units, especially those employed in the conventional electric range, are rather sophisticated, mechanically, and are of a somewhat complex structure and arrangement. The high temperature environment within which the temperature sensing unit is located permits severe thermal stresses to occur in various components of the temperature sensing unit. These stresses tend to promote warping of the various components. For example, because of the aforesaid severe thermal stresses a relatively massive double spring arrangement is employed in combination with a temperature responsive device. The temperature responsive device, acting against spring restraint, contacts the bottom surface of a cooking vessel which is seated on a flat spiral resistance

heating coil and on the temperature responsive device, both of which are located on the top surface of the metallic range counter. The massive double spring arrangement is rather stiff (i.e., the spring has a relatively high restoring force or a relatively large effective spring constant) due, in large part, to the need to make the arrangement structurally resistant to serious thermal deformation. Such a stiff spring arrangement generally functions satisfactorily to maintain the temperature sensing unit in contact with the more or less regular flat bottom surface of a relatively heavy vessel, such as a cast iron pot, containing foodstuff to be cooked. Since it is in contact with the bottom surface of the vessel, or pot, it is conceptually possible for the temperature sensing unit to detect the temperature of the vessel. However, in the event that a relatively light pot, or vessel, is used or if the foodstuff contained therein is not of sufficient weight, such prior art temperature sensing units employing the aforesaid stiff spring arrangement prove unsatisfactory. Such an arrangement is also unsatisfactory where the vessel has an irregularly contoured bottom surface. For example, if a relatively light cooking vessel is employed, there will be insufficient vessel weight to adequately compress the spring arrangement and one consequence will be that the vessel will not rest on the resistance heating coil in the most intimate contact possible therewith, i.e., the vessel will be raised, or tilted, and thereby cause inefficient heat transfer between the resistance heating coil and the vessel. Suffice it to say that: because of the relatively high temperatures involved and because of the consequent severe thermal stresses created it is not practical to provide temperature sensing units having simple spring arrangements with relatively low effective spring constants; i.e., little spring stiffness or relatively small restoring force.

Also, the so-called glass-ceramic type of electric range, hereinbefore described, would appear to present many of the same problems with respect to sensing, or detecting, the true temperature of the cooking vessel, or utensil, resting on the glass-ceramic cooktop as are presented with the conventional prior art electric and gas ranges:

First, inasmuch as the glass-ceramic cooktop, or counter, containing the embedded electrical resistance elements is, in effect, the primary heating source in such a range, a temperature sensing unit so disposed or arranged as to contact the cooking vessel for the purpose of determining the temperature thereof would tend to be spuriously heated in some measure by the elevated temperature of the glass-ceramic cooktop. Thus, the glass-ceramic type of electric range appears to present the same kinds of problems in this respect as is presented with the conventional electric and gas ranges hereinbefore discussed.

Second, because of the elevated temperatures involved (1,112° F) various component parts of a temperature sensing unit employed in conjunction with the glass-ceramic type of electric range would have to be fabricated from materials which are capable of withstanding such elevated temperatures. Clearly certain materials cannot be used. Epoxies, plastics, polyimides, among others, are not applicable for use. Suffice it to say that: because of the relatively high temperatures involved in the glass-ceramic type of electric

range, the materials from which temperature sensors and their associated components may be fabricated would be quite restricted.

Third, in attempting to determine the temperature of a cooking vessel, a temperature sensing unit and its associated components employed in conjunction with the aforesaid glass-ceramic type of electric range would have to be thermally shielded or insulated, effectively. In brief, most of the same problems encountered with conventional prior art electric and gas ranges would also be encountered with the glass-ceramic type of electric range where effective thermal insulation or shielding is concerned.

Fourth, prior art temperature sensing units employing rather sophisticated and complex structures or arrangements of massive double springs might be employed in conjunction with the glass-ceramic type of electric range. However, it appears that a suitable aperture or apertures would have to be provided through the glass-ceramic cooktop surface. In any event, the same problems as hereinbefore discussed with reference to the conventional prior art electric and gas ranges would appear.

SUMMARY OF THE INVENTION

Although the invention is hereinafter described, and illustrated in the accompanying drawing figures, as being embodied in an induction range, it is, nevertheless, to be understood that the applicability of the invention is not limited to induction ranges but may be embodied in, for example, trivet warmers, portable warming or cooking appliances, as well as in other apparatus which need not, necessarily, be used for cooking food.

One object of the invention is to provide a cooking/warming appliance which includes a vessel supporting means, such as a counter or cooktop, having an unbroken, or non-apertured, top or working surface which remains relatively cool during the cooking or warming process.

Another object of the invention is to provide a cooking/warming appliance which includes a vessel supporting means, such as a counter or cooktop, having an undulated but unbroken or uninterrupted (i.e., without apertures) top or working surface which remains relatively cool during the cooking or warming process; although the top or working surface of the counter has undulations therein, it may, nevertheless, be wiped clean, easily.

Another object of the invention is to provide a cooking/warming appliance which includes a vessel supporting means, such as a counter, or cooktop, having a undulant surface for supporting a cooking/warming vessel or utensil and having between its undulations temperature sensing means for sensing the temperature of said vessel or utensil.

Another object of the invention is to provide a cooking/warming appliance having a temperature sensing unit including a temperature sensor unit and associated components or elements which are free from spurious heating.

Another object of the invention is the provision of a cooking/warming appliance having a temperature sensing unit including a temperature sensor unit and associated components or elements which may be

fabricated from materials which are not usable in the relatively high temperature environments created in the prior art electric, glass-ceramic and gas ranges hereinbefore discussed.

Another object of the invention is to provide a cooking/warming appliance having a temperature sensing unit which includes a temperature sensor unit and associated components or elements which need not be thermally insulated or shielded in the ways, or to the extent, employed in the prior art appliances hereinbefore discussed.

Another object of the invention is to provide a cooking/warming appliance having a temperature sensing unit including, in addition to a temperature sensor unit, components or elements associated with said sensor unit which provide a relatively small spring force (i.e., a relatively low restoring force or relatively low effective spring constant) for maintaining the sensor unit in contact with the surface of a cooking/warming vessel or utensil. The vessel or utensil may be of relatively light weight and may, in addition, have a rather irregularly contoured surface presented for contact with the temperature sensor unit.

Another object of the invention is to provide a cooking/warming appliance including a temperature sensing unit for accurately sensing or detecting the true temperature of a vessel or utensil being heated; said temperature sensing unit being capable of accurately sensing or detecting the temperature of the vessel regardless of the weight of the vessel or weight of the food contained therein, and/or regardless of whether the vessel has or has not an irregular surface or contour.

Another object of the invention is to provide a cooking/warming appliance including a temperature sensing unit which does not require the prior art spring construction or arrangement hereinbefore discussed.

Another object of the invention is to provide a cooking/warming appliance wherein a temperature sensor unit positioned between undulations in the surface of a vessel supporting means is instrumental in enabling data representing the temperature of the vessel supported on said surface to be magnetically coupled through the unbroken or uninterrupted vessel supporting means.

Another object of the invention is to provide a novel temperature sensor unit wherein the magnetic permeability of said unit is a function of temperature.

The aforementioned objects, as well as others, are achieved in accordance with one embodiment of the invention, to wit: an induction cooking/warming appliance, for heating a vessel having at least one portion thereof in which heating currents may be induced, comprising: support means in which no substantial heating current is induced when said support means is subjected to a changing magnetic field, said support means having at least one surface including at least two spaced-apart undulations therein which define a valley portion on said one surface between said two undulations, the vessel being supportable on said support means such that said vessel rests on said two spaced-apart undulations; an induction coil energizable for producing a changing magnetic field in said one portion of the vessel when said vessel is supported on said support means; means for energizing said induction coil;

temperature sensing means disposed in said valley portion between said undulations for sensing the temperature of the supported vessel and for providing a first signal representative of the temperature of the vessel; and, temperature receiving means, magnetically coupled with said temperature sensing means and said first signal, for providing a second signal representative of the temperature of said vessel.

One feature of the invention resides in the use of a vessel supporting means including a surface having undulations therein; the support means being fabricated from a material or materials which will not permit heating currents to be induced therein. Thus, the support means remains relatively cool even during the cooking process. Thus spilled foods will not burn, char or adhere to the support means. Furthermore, the support means may be fabricated from a material or materials which need not withstand temperatures beyond 550° F.

Another feature of the invention resides in the provision of a vessel support means which is relatively smooth and capable of being wiped clean, easily, even though undulations are formed in the surface of said support means.

Another feature of the invention resides in the employment of a temperature sensing unit in combination with the aforesaid undulated vessel support means; e.g., the disposition and arrangement of a vessel-contacting spring means, supporting a temperature sensor unit, between undulations in the aforesaid valley portion of the support means.

Another feature of the invention resides in the use of a temperature sensor unit which changes its electrical impedance, or resistance, as a function of its temperature and using such temperature-correlated impedance or resistance changes in such a way that they are reflected magnetically, without the intervention of tangible physical means; to a relatively remote temperature receiving unit proximate the vessel support means whereat signals representative of the temperature sensed or detected by said sensor unit may be utilized.

Another feature of the invention resides in the employment of a novel temperature sensing unit wherein a plastic magnetic member including temperature responsive material has its magnetic permeability changed as a function of temperature and wherein this change in permeability is reflected magnetically to a relatively remote temperature receiving unit proximate the vessel support means whereat signals representative of the temperature sensed by said sensing unit may be utilized.

Other objects and features, as well as a fuller understanding of the invention, will appear by referring to the following detailed description, claims and drawing FIGURES.

DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a perspective view of an upper part of an induction cooking range illustrating, among other things, a vessel support means, such as a range counter or cooktop, having undulations therein and temperature sensing means arranged between some of the undulations.

FIG. 2 is an enlarged cross section view, taken along the section line 2—2 in FIG. 1, and showing, among

other things, the induction range's undulant counter and temperature sensing means as well as a block diagram of the electric power and temperature signal systems employed with the subject invention.

FIG. 3 is another enlarged cross section view shown in FIG. 2 but showing, however, a fry pan supported on the undulant range counter and contacting the temperature sensing means thereon.

FIG. 4 is a fragmentary plan view showing the temperature sensing means disposed on the surface of the range counter between adjacent undulations therein.

FIG. 5 is a greatly enlarged cross section view similar to the cross section view shown in FIG. 2 but illustrating in more detail the temperature sensing means and temperature receiving means employed in the subject invention.

FIG. 6 is an enlarged cross section view similar to that shown in FIG. 5 but showing an alternate temperature sensing means disposed between adjacent undulations in the top surface of the range counter.

FIG. 7 is a graph showing the variation of the magnetic permeability of the temperature sensing means of FIG. 6 as a function of temperature.

DESCRIPTION OF PREFERRED EMBODIMENTS

Shown in FIG. 1 is an induction cooking range which is designated, generally, by the reference number 20. The range 20 is provided with a counter 22, or vessel support means, which is suitably supported on a range substructure 24. The counter 22, as illustrated, appears as a corrugated member. Fastened to the substructure 24 and located at the rear of the counter 22 is an instrument and control panel 26. On panel 26 is mounted a number of controls 28 and a like number of temperature indicators 30. The temperature indicators 30 are illustrated in the specific embodiment at FIG. 1 as being dial-type thermometers. However, indicators 30 may be digital displays. On the top or working surface of the counter 22 there is illustrated four symmetrically arranged temperature sensing means, each of which is designated generally by the reference number 32. At each of the temperature sensing means 32 a cooking vessel or utensil (e.g., pot, pan, etc.) may be positioned for cooking. It is contemplated that the vessel or utensil will be placed over the temperature sensing means, as suggested in FIG. 3, so that the temperature sensing means 32 is under the bottom surface of the vessel or utensil at the approximate center thereof.

As indicated in FIGS. 1 and 2, there is associated with each cooking position on the range counter 22 the following, among other things: a temperature sensing means 32, a control 28, a temperature indicator 30 and an induction coil 40.

Situated beneath the counter 22 and separated therefrom by an air gap is a flat spirally wound induction coil 40. As shown, the coil 40 includes at the center thereof, an air core. As shown in FIG. 2, the induction coil 40 is electrically coupled to the output of a solid state inverter 44 which, in turn, has an input which is electrically coupled to the output of a rectifier 46. The inverter 44 as combined with rectifier 46 forms a static power conversion circuit designated, generally, by the reference number 43. The rectifier 46 includes an input which is electrically coupled to a conventional A.C. source 50; a 60 Hz, single phase, 110 or 220 volt

source. More details as to the static power conversion circuit 43, including the rectifier 46 and the inverter 44, may be had by referring to the patent applications hereinbefore identified under the heading Cross References to Related Applications.

Also shown in FIG. 2 is a control switch 28, or knob, which is electrically coupled with inverter 44 for the purpose of controlling the flow of power to the induction coil 40. In brief, the control 28 is preferably marked in degree F settings to enable the housewife, for example to "call for" a certain temperature, or temperature range, performance. However, it is the temperature indicator 30 associated with the particular control 28 which provides her with a visible indication of the actual temperature of the vessel 38 or utensil (FIG. 3) as well as of the rate of temperature rise and fall.

As for the conversion circuit 43, the rectifier 46 may be a regulated full-wave rectifier employing solid state devices and operating to convert an A.C. input to a D.C. output and the inverter 44 preferably employs SCR's which, in the performance of their control switching function, enable the inverter 44 to deliver a relatively high frequency (i.e., ultrasonic or higher) output to drive the induction coil 40. The controls 28 and the temperature indicators 30 provide the actuation and visible feedback functions hereinbefore described.

Also shown in FIG. 2 is a temperature signal processing circuit 52 which includes: a first input coupled to the rectifier 46 and deriving therefrom a source of D.C. voltage; a second input in the form of a pair of electrical conductors extending from a magnetic receiving means 60 to the temperature signal processing circuit 52; and, an output directly coupled to a temperature indicator 30. The temperature indicator 30 may be a dial-type thermometer suitably graduated in degrees F or in degree ranges or bands.

As illustrated in FIGS. 1 through 5 the temperature sensing means 32 is comprised of: a relatively thin elastomeric cup-like member 33 such as, for example, a silicone rubber cup; a thermistor unit 34 partially embedded in and supported by the cup-like member 33; a magnetic coupling means 35 including a magnetic core 36 about which there is wound a coil 37 and a cylinder 39 within which the core 36 and coil 37 are embedded or potted. A pair of conductors 41 electrically couple the coil 37 with the thermistor unit 34.

In FIG. 3 the vessel 38 is illustrated as being filled with a food which is to be cooked or heated; e.g., hamburgers. The vessel 38 is a conventional pan which may be made of cast iron, magnetic stainless steel, etc.; i.e., a metal or alloy which is electrically conductive as well as having sufficient magnetic permeability so that sufficient electrical heating current may be induced therein by action of the changing magnetic field produced by the induction coil 40. Because induction heating is employed, the vessel 38, only, and not the counter 22 is heated. The vessel 38 is heated to a maximum temperature of about 500° F. However, 550° F may be considered to be a specification temperature in that the vessel 38 will not actually reach a temperature quite that high but when a safety factor is included 550° F is considered to be a nominal specification temperature. As a result, the counter 22 may be fabricated from

materials which are not employable in the conventional prior art electric or gas ranges; nor in the glass-ceramic electric range hereinbefore discussed. For example, the counter 22 may be fabricated from epoxies, plastics, polyimides, etc. If required for purposes of electrostatic shielding and/or structural enhancement and/or decoration the counter 22 may include some metallic content. However, the inclusion of metallic material is necessarily limited to a small amount in order to enable substantially all of the power developed by the induction coil 40 to be coupled electromagnetically with the cooking vessel 38. In any case, the amount of metallic material included should be so distributed as to prevent the formation of ohmic electrical circuits which would allow significant circulating currents to be induced in the counter 22. In the alternative, the counter 22 may, if desired, be made of a glass which is suitably treated so as to withstand temperatures of 550° F. As another alternative, quartz may be employed in the fabrication of the counter 22. Advantageously, as shown in the drawing figures, the counter 22 presents an uninterrupted or unapertured working or top surface.

As illustrated, the counter 22 is a corrugated member. That is to say it has a number of undulations 22A or crests formed therein; adjacent undulations 22A or crests being separated by a valley 22B.

As shown in FIG. 2 the temperature sensing means 32 is located in a valley 22B between two adjacent undulations 22A. In FIG. 2 the inverted cup-like member 33, or silicone rubber cup, is suitably bonded to the upper surface of the counter 22. Normally, as indicated in FIG. 2, the unstressed or uncompressed cup member 33 projects a short distance *h* above the top of an undulation 22A or crest. However, as shown in FIG. 3 when a cooking vessel 38 is rested on the top surface of counter 22 and is supported by the undulations 22A thereof the cup 33 is compressed so that the top of the cup 33 is substantially at the same height as an undulation 22A or crest. In other words, the dimension *h* (FIG. 2) is reduced to zero.

With respect to the spacing or frequency of undulations 22A and their arrangement in the counter 22, it is to be understood that many changes will occur to those skilled in the art. For example, the undulations 22A need not be run in the direction indicated in the drawing figures. The undulations may run in a transverse direction. In the alternative, the undulations may be arranged in concentric circular patterns. Although in FIG. 3 the vessel 38 is illustrated as being supported by four undulations 22A, it is to be understood that more or less than four undulations may be employed for this purpose.

The thermistor unit 34 is preferably partially embedded in the elastomeric cup member 33 as shown in FIG. 5 so that at least one face thereof is available for making contact with the bottom surface of the vessel 38. The thermistor unit 34 may be comprised of thermistor material which is coated with glass frit. Within the cup 33 and positioned on the valley 22B as indicated in FIG. 5 is the cylinder 39 which, in accordance with the maximum temperatures involved, may be fabricated from epoxies, plastics, polyimides, etc. Embedded within the cylinder 39 is the magnetic core 36 about which there is wound a coil 37. The core 36 constitutes a path of relatively high magnetic

permeability for magnetic flux. The coil 37 is, as shown, electrically coupled with the thermistor unit 34 by the two electrical conductors 41. On the opposite side of the counter 22 (opposite valley 22B) there is mounted a magnetic receiving means which is designated generally by the reference number 60. As indicated in FIG. 5, the receiving means 60 is comprised of a cylinder 61 which, advantageously, may be formed from the same materials as cylinder 39 hereinbefore discussed. Embedded within the cylinder 61 is another magnetic core 62 about which there is wound a coil 63. Since the magnetic field intensity in the region where the temperature sensing means 32, coupling means 35 and magnetic receiving means 60 are located is relatively low (i.e., in a region on an axis through the air core of induction coil 40) relatively insignificant heating currents will be induced in the means 32, 35 and 60. Moreover, the material of vessel 38 will constitute a low reluctance path for most of the magnetic flux produced by the coil 40.

Although the magnetic cores 36 and 62 are illustrated as being U-shaped cores, it is to be understood that cup-shaped cores may be employed to advantage and such cores may have coils similar to the coils 37 and 63 appropriately disposed thereabout. Again, because of the maximum temperatures experienced, the cylinder 61, like cylinder 39, may be made of an epoxy, plastic, polyimide, etc.

Operationally, the temperature signal processing circuit 52 actively drives the coil 63 electrically with energy of a particular predetermined frequency; preferably at a frequency which is substantially different from the ultrasonic or higher frequency at which induction coil 40 is driven by inverter 44. A different frequency for driving the coil 63 is preferred so that signals representative of the vessel temperature may easily be discriminated from the frequency at which coil 40 is driven. For example, the coil 63 may be energized or driven at frequencies which are higher or lower than those at which induction coil 40 is energized. The coil 63 when so energized functions in a manner similar to that of the primary winding of a conventional transformer. The voltage impressed across the coil 63 causes current to flow through coil 63. This current flow is attended by an electromagnetic field about coil 63. Since the voltage impressed across the coil 63 is a changing voltage, the current therethrough also changes as does the attendant magnetic field. Consequently, a changing magnetic flux is introduced into the magnetic core 62 of the receiving means 60. The magnetic flux in the core 62 is coupled across the counter 22 to the magnetic core 36 of the magnetic coupling means 35. The cores 36 and 62 form first and second magnetic flux paths and these flux paths together with the counter 22 interposed therebetween form a magnetic circuit or loop. The changing magnetic flux in the core 36 induces a voltage across the coil 37. Hence, the coil 37 functions in a manner similar to that of the secondary winding of a conventional transformer. As indicated, the thermistor unit 34 is connected across the coil 37 by means of the conductors 41. Hence, the thermistor unit 34 acts as an electrical load on the coil 37. As the vessel 38, which is in contact with the thermistor unit 34, is inductively heated by induction coil 40 heat is transferred to the thermistor unit 34 and the thermistor

material changes the electrical resistance, or impedance, of the thermistor unit as a function of the temperature. In effect, there is connected across the secondary winding or coil 37 a temperature-correlated resistive load. In terms of transformer theory current flow in the coil 37 will produce magnetic flux which reacts with the magnetic flux that is produced by the coil 63, or primary winding. Thus, the temperature-correlated resistive load represented by thermistor unit 34 is "reflected" to the primary winding or coil 63. This reflected resistance or impedance is related to the temperature of the vessel 38. The resistance or impedance reflected to the primary winding or coil 63 is employed, in accordance with the invention, to develop or to modulate a signal in the temperature signal processing circuit 52 so as to provide an output signal for driving the temperature indicator 30. The aforementioned output signal delivered to temperature indicator 30 is representative of the temperature of the vessel 38 as sensed, or detected, by thermistor unit 34.

Advantageously, the temperature sensing unit employing the means and operating in the manner hereinbefore described provides an induction range with the following features: the temperature sensing means 32 is an electrically passive device; the means 32 and 60 as well as the elements comprising these means need not withstand temperatures greater than 550° F and may be fabricated from the materials hereinbefore discussed; the relatively thin elastomer from which the cup-like member 33 is formed exerts a relatively small restoring force against the bottom surface of the vessel 38 thereby eliminating the need for the prior art massive and complicated spring arrangements hereinbefore discussed; being fabricated from a relatively thin elastomer such as silicone rubber, the cup-like member 33 easily contours itself to the bottom surfaces of vessels which may have very irregular bottom surfaces; and, since the cup member 33 is easily stressed (low spring constant) very light weight vessels or partially filled cooking vessels will make adequate contact with thermistor unit 34.

Although the thermistor unit 34 is shown as being but partially embedded in the cup-like member 33, it is to be understood that one or more thermistor units may be wholly embedded in the cup-like member 33. In such case although the thermistor unit or units 34 would not actually contact the vessel 38, the coupling is close enough so that the actual temperature of vessel can be accurately detected.

Illustrated at FIGS. 6 and 7 is an alternative temperature sensing means designated generally by the reference number 32A. With the system shown at FIG. 6, however, the same magnetic receiving means 60 is employed. The temperature sensing means 32A is as indicated at FIG. 6 comprised of an elastomeric magnetic core 33A which resembles an open bladder. The core 33A includes two pole faces 33B and 33C which, as indicated, are separated by an air gap. Those portions of the core 33A which include the pole faces 33B and 33C are arranged on the counter 22 in valley 22B so as to be opposite the corresponding pole faces of the magnetic core 62 of the magnetic receiving means 60. The properties of the elastomeric core 33A are discussed in detail hereinafter. Suffice it to say at this point that the core 33A is fabricated from a material or materials

which, in effect, have a magnetic permeability which is a function of temperature. This relationship is graphically illustrated at FIG. 7. The core 33A is made from an elastomer so that it deforms in the same manner as the cup-like member 33 (FIG. 5) and, in effect, has a low restoring force or spring constant so that it is easily deformed by a vessel 38 resting thereupon.

Operationally, changing current in the coil 63 of the receiving means 60 produces a changing magnetic flux ϕ which traverses the path or circuit shown in FIG. 6. For example, the magnetic flux ϕ passes through the core 62, through the counter 22 and through the elastic core 33A whereat it again passes through the counter 22 returning to the core 62. Thus, the flux ϕ traverses a closed magnetic path or loop. As indicated at FIG. 6, the air gap between the pole faces 33B and 33C should be sufficiently large to prevent significant amounts of magnetic flux from leaking thereacross and, in effect, "short circuiting" the intended flux path through the core 33A. As the temperature of the vessel 38 increases heat is transferred to the elastomeric core 33A. This activity is similar to the activity hereinbefore described with respect to FIG. 3 where heat from the pan 38 is transferred to the cup 33 and thermistor 34. As the transferred heat increases the temperature of the core member 33A, its magnetic permeability decreases in a manner similar to that graphically illustrated at FIG. 7. As a result, the coil 63 of the receiving means 60 is, in effect, loaded, electrically. The effect is similar to that of electrically loading the secondary winding of a transformer so that the primary winding thereof is loaded with a "reflected" impedance. This effect is also similar to the action of a saturable reactor wherein a D.C. winding controls the saturation level of a magnetic core and thereby "loads" an A.C. drive winding disposed on the same core. Hence, the reflected impedance is employed to develop or to modulate a signal in the temperature signal processing circuit 52 in the same manner as hereinbefore described with respect to the discussion relating to FIG. 2.

As indicated in FIG. 6 the elastomeric magnetic core 33A may be fabricated from a relatively thin piece of silicone rubber. Dispersed throughout the silicone rubber, which serves as a matrix, is magnetic material in powder or small granular form. Such magnetic material may, for example, be ferrite powders, or granules, such as nickel-zinc ferrite, manganese-zinc ferrite or manganese-copper ferrite, among others. Such ferrite materials when embedded in the core member 33A will provide a magnetic permeability versus temperature relationship generally like that shown in the graph at FIG. 7. The ferrite materials of the aforementioned nature are identified in published articles. See for example the article The Characteristics of Ferrite Cores with Low Curie Temperature and Their Application by K. Murakami, appearing in the publication IEEE Transactions on Magnetics, June 1965 beginning at page 96; Digital Magnetic Temperature Transducer by D.I. Tchernev et al., appearing in the publication IEEE Transactions on Magnetics, Sept. 1971 beginning at page 450. In the alternative, temperature sensitive first order transition materials may be dispersed in the silicone rubber matrix 33A. For example, such transition materials as the following may be employed: manganese arsenide (Mn_3As_2), iron rhodi-

$um (F_e R_h)$, or chromium doped manganese antimonide ($M_nC_rS_b$). See for example, the U.S. Pat. No. 3,464,225 wherein the magnetic characteristics of such materials and their variation with temperature is discussed. See, also, the publication Some Magnetic First Order Transitions, in the Journal of Applied Physics, supplement to Vol. 33, No. 3, Mar. 1962 beginning at page 1037.

Although the invention has been described and illustrated by way of a specific embodiment with variations thereof, it is to be understood that many changes in details of construction and in the combination and arrangement of parts and components, as well as changes in configurations and materials, may be made without departing from the spirit and scope of the invention which is hereinafter claimed.

The valleys 22B between adjacent undulations 22A provide air gaps, or spaces, which are interposed between the heated bottom surface of the cooking vessel 38 and the surface of the counter 22, or vessel supporting means. The air gaps, or spaces, provide a high thermal impedance between the vessel 38 and counter 22 and thereby retard heat conduction therebetween to allow the vessel support surface of counter 22 to remain relatively cool; i.e., at or near room temperature. For more details see U.S. Pat. application of J. D. Harnden, Jr. and W. P. Kornrumpf, Ser. No. 228,136, filed 2/22/72, on even date herewith, titled Induction Cooking/Warming Appliance Including Vessel Supporting Means With Irregular Vessel Support Surface (RD 5454) and assigned to the same assignee.

What is claimed is:

1. An induction cooking/warming appliance, for heating a vessel having at least one portion thereof in which heating current may be induced by subjecting said one portion to a changing magnetic field, comprising: vessel supporting means in which no substantial heating current is induced when said supporting means is subjected to a changing magnetic field, said supporting means having first and second back-to-back surfaces, said first surface including at least two spaced-apart undulations therein defining a valley therebetween, said vessel being supportable on said two undulations; an induction coil energizable for producing a changing magnetic field in said one portion of said vessel when said vessel is supported on said undulations; means for energizing said induction coil; temperature sensing means located in said valley and comprising spring means, a temperature sensor unit supported by said spring means and having an electrical impedance which varies with temperature, means including a first magnetic flux path and a coil wound about said first flux path and connected to said sensor unit, said spring means being contacted and stressed by said vessel when said vessel is supported on said two undulations and whereby said sensor unit supported by said spring means is subjected to the temperature of said vessel; temperature receiving means supported on said second surface of said vessel supporting means and located opposite said valley of said first surface whereby said vessel supporting means is interposed between said temperature sensing and receiving means, said temperature receiving means comprising means including a second magnetic flux path and a coil wound about said second magnetic flux path whereby said first

and second flux paths together with a portion of the interposed vessel supporting means form a magnetic circuit; and, means for electrically energizing said coil on said second magnetic flux path to introduce a changing magnetic flux into said magnetic circuit whereby the temperature variable impedance of said sensor unit, as reflected to an electric circuit including said coil wound about said second flux path, is representative of the temperature of said vessel.

2. The appliance according to claim 1 further comprising a temperature signal processing circuit and temperature indicator means, said signal processing circuit being electrically coupled to said coil wound about said second flux path and to said temperature indicator means whereby said signal processing circuit in response to said reflected impedance produces a signal representative of the temperature of said vessel for energizing said indicator means whereby said temperature is visibly displayed.

3. The appliance according to claim 1 wherein said induction coil is electrically energized with at least ultrasonic frequency and wherein said coil on said second flux path is electrically energized at a different frequency.

4. The appliance according to claim 1 wherein said first surface including said undulations and valley present a relatively smooth surface which is easily wiped clean.

5. The appliance according to claim 4 wherein said spring means is a cup-like member of relatively thin elastic material having an exposed relatively smooth surface which is easily wiped clean, said cup-like member being secured in said valley and forming together with said first surface including said undulations and valley and enclosure for said first flux path and coil thereabout, said sensor unit being at least partially embedded in said cup-like member, said cup-like member having a relatively low restoring spring force.

6. The appliance according to claim 5 wherein said relatively thin elastic cup-like member of low restoring spring force is adapted for being contoured to the irregular surface of a vessel in contact therewith.

7. An induction cooking/warming appliance, for heating a vessel having at least one portion thereof in which heating current may be induced by subjecting said one portion to a changing magnetic field, comprising: vessel supporting means in which no substantial heating current is induced when said supporting means is subjected to a changing magnetic field, said supporting means having first and second back-to-back surfaces, said first surface including at least two spaced-apart undulations therein defining a valley therebetween, said vessel being supportable on said two undulations; an induction coil energizable for producing a changing magnetic field in said one portion of the vessel when said vessel is supported on said undulations; means for energizing said induction coil; temperature sensing means, located in said valley, comprising means including a first magnetic flux path having a magnetic permeability which varies with temperature, said means including said first flux path being contactable by said vessel when said vessel is supported on said two undulations; and, temperature receiving means supported on said second surface of said supporting means and located opposite said valley of said

first surface whereby said vessel supporting means is interposed between said temperature sensing and receiving means, said temperature receiving means comprising means including a second magnetic flux path and a coil wound about said second flux path whereby said first and second magnetic flux paths together with a portion of the interposed vessel supporting means forms a magnetic circuit, the temperature variable magnetic permeability of said first flux path causing said coil about said second flux path to become electrically loaded with a reflected impedance representative of the temperature of said vessel.

8. The appliance according to claim 7 further comprising a temperature signal processing circuit and temperature indicator means, said signal processing circuit being electrically connected to said coil wound about said second flux path and connected to said temperature indicator means whereby said signal processing circuit in response to said reflected impedance produces a signal representative of the temperature of said vessel for energizing said indicator means whereby said temperature is visibly displayed.

9. The appliance according to claim 7 wherein said induction coil is electrically energized with at least ultrasonic frequency and wherein said coil about said second flux path is electrically energized at a different frequency.

10. The appliance according to claim 7 wherein said first surface including said undulations and valley present a relatively smooth surface and is easily wiped clean.

11. The appliance according to claim 10 wherein said means including first magnetic flux path is an open bladder member of relatively thin elastic material having an exposed relatively smooth surface which is easily wiped clean.

12. The appliance according to claim 11 wherein said relatively thin elastic bladder member has a relatively low restoring spring force and is easily adapted for being contoured to the surface of an irregularly surfaced vessel in contact therewith.

13. The appliance according to claim 7 wherein said means including said first magnetic flux path is comprised of an elastomeric matrix in which there is embedded powdered ferrite material, said matrix including said embedded ferrite powder having a magnetic permeability which varies with temperature.

14. The appliance according to claim 7 wherein said means including said first magnetic flux path is comprised of an elastomeric matrix in which there is embedded powdered temperature sensitive first order transition material, said matrix and embedded powders having a magnetic permeability which varies with temperature.

15. The appliance according to claim 13 wherein said ferrite material is selected from the group consisting of nickel-zinc ferrite, manganese-zinc ferrite, and manganese-copper ferrite.

16. The appliance according to claim 14 wherein said first order transition material is selected from the group consisting of manganese arsenide, iron rhodium, and chromium doped manganese antimonide.

17. An induction cooking/warming appliance, for heating a vessel having at least one portion thereof in which heating current may be induced by subjecting said one portion to a changing magnetic field, comprising: Vessel supporting means in which no substantial heating current is induced when said supporting means is subjected to a changing magnetic field, said supporting means having first and second surfaces, said first surface including at least two spaced-apart undulations therein defining a valley therebetween, said vessel being supportable on said two undulations; an induction coil energizable for producing a changing magnetic field in said one portion of said vessel when said vessel is supported on said undulations; means for energizing said induction coil; temperature sensing means located in said valley and including a first magnetic flux path; temperature receiving means supported on said second surface of said vessel supporting means and located opposite said valley of said first surface whereby said vessel supporting means is interposed between said temperature sensing and receiving means, said temperature receiving means comprising a second magnetic flux path, said first and second flux paths together with a portion of the interposed vessel supporting means forming a magnetic circuit; and means for introducing a changing magnetic flux into said magnetic circuit, the magnetic flux introduced into said magnetic circuit changing in response to the temperature of said vessel; and means for deriving a signal in response to the change of the magnetic flux in said magnetic circuit, said signal being representative of the temperature of said vessel.

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