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[45] Feb. 5, 1974

[54] INDUCTIVE HEATED BAKE OVEN

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[73] Assignee: **Environment/One Corporation,** Schenectady, N.Y.

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[52] U.S. Cl......... **219/10.49,** 219/10.75, 219/10.79, 219/398
[51] Int. Cl. **H05b 5/04**
[58] Field of Search..........219/10.49, 10.67, 10.75, 219/10.79, 407, 395, 398, 399; 13/26, 27, 32

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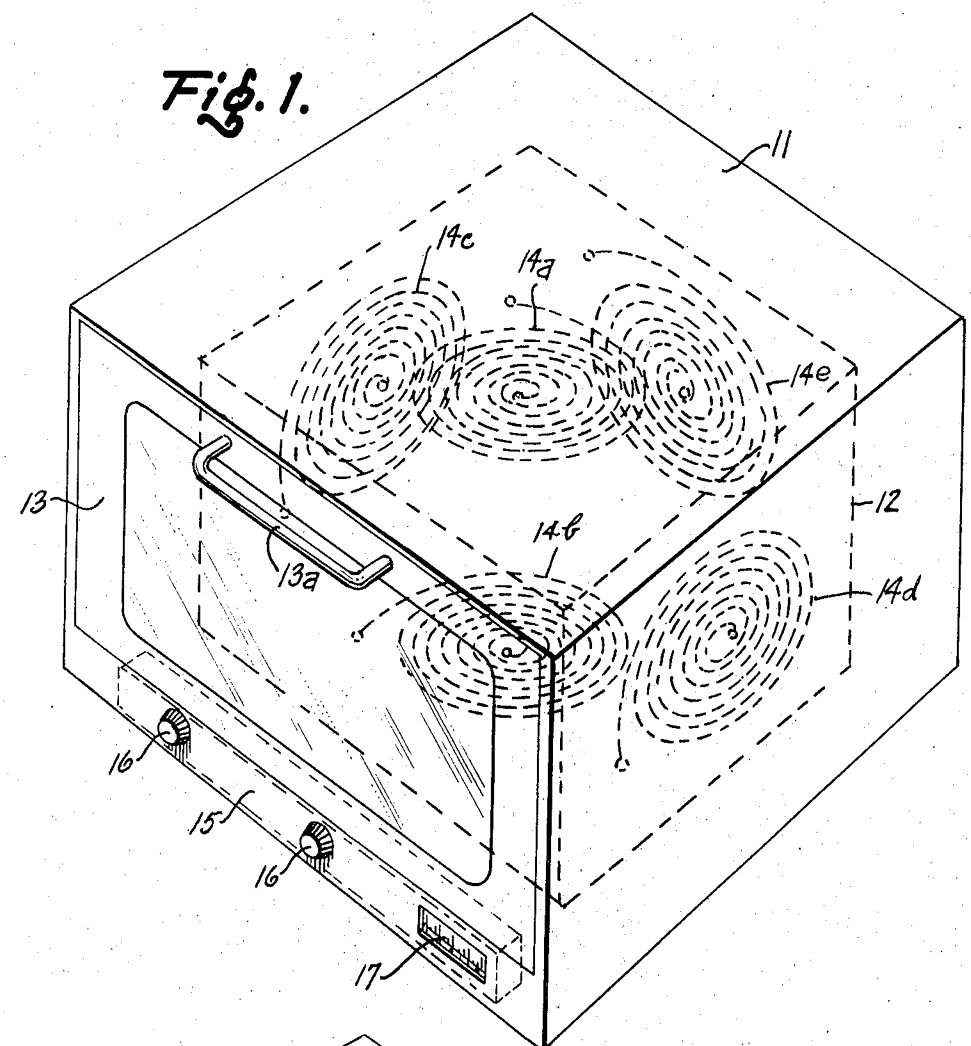
Primary Examiner—Bruce A. Reynolds
Attorney, Agent, or Firm—Charles W. Helzer

[57] **ABSTRACT**

An inductively heated bake oven for heating and warming cookware disposed in the oven comprising an outer housing fabricated from a magnetically non-permeable material and having a plurality of different sides joined together to form an enclosed space with one of th sides forming a door to provide access to the enclosed space. An inner housing is supported within the outer housing and may be fabricated from magnetically susceptible metal material or insulating material and have a plurality of different sides joined together to form an enclosed oven space. The inner housing is spaced from and supported within the sides of the outer housing with the side of the inner housing facing the door of the outer housing being open or accessible to provide access to the interior of the inner housing. A plurality of inductive heating coils preferably of planar, helically wound, pancake-shaped heating coil design are supported within the space intermediate the respective confronting sides of the inner and outer housings and arranged to maximize the inductive coupling to magnetically susceptible metal material either comprising the inner housing or supported within the inner housing if it is of insulating material. Electric circuit means is provided for electrically exciting the inductive heating coils at relatively high frequency of the order of 20 kilohertz to thereby magnetically induce the generation of heat in the inner housing or a metal based cookware disposed within the inner housing if it is of insulating nature. The outer housing may be formed of aluminum, copper or other highly conductive metal material which serves as an effective magnetic shield to confine the magnetic induction field to the space within the outer housing, and the inner housing may be formed of iron, stainless steel, titanium or the like or of an insulating material. If the inner housing is formed of a magnetic susceptible metal material, such as iron, stainless steel, insulation is placed in the space between the induction heating coil and the inner housing and the interior of the inner housing may be porcelainized or otherwise provided with an attractive, easy to clean interior surface similar to known oven interiors. If the inner housing is fabricated from insulating material, a pyroceramic insulating material, high temperature glass, etc. may be used. Preferably, individual excitation circuits are provided for each induction heating coil and the individual excitation circuits can be individually controlled to excite any desired number of coils. Preferably, a plurality of coils are provided one on each of five different sides of the oven so as to assure uniform and even heating of the interior of the oven. Temperature sensor units may be employed for sensing the actual temperature of the inner housing, or a metal base cookware disposed in the inner housing space. Cooling vents may be formed in either the inner or the outer housing or both to provide for removal of moisture in the oven space as well as to provide a flow of cooling air across the induction heating coils thereby maintaining their resistance at a low value and improving the overall efficiency of operation of the bake oven. If desired, self-cleaning of the oven can be provided for the inner housing member, if formed of a magnetically susceptible metal material, by raising its temperature to sufficiently high value to achieve self-cleaning action. The inductive heating coils may be a helix wound from electrically insulated Litz wire or the like, or may be fabricated from a helix cut out of sheet metal.

24 Claims, 23 Drawing Figures

Fig. 1.


11
14c
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14e
12
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13a
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Fig. 1A.

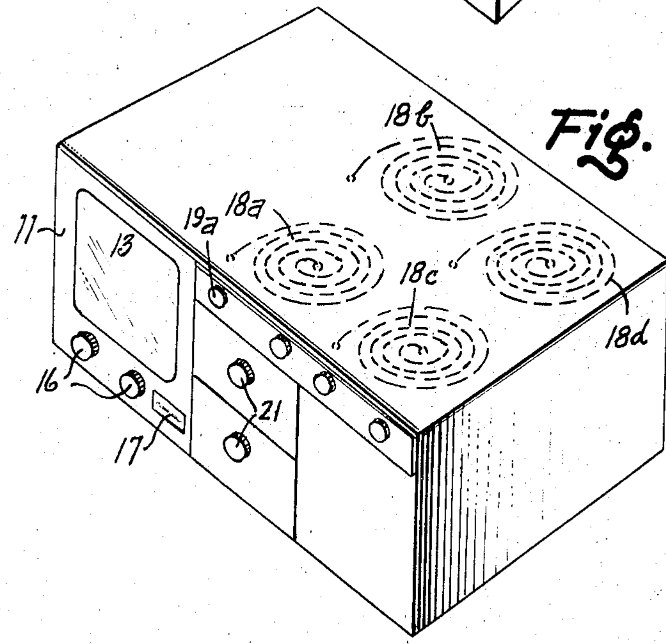
18b
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Fig. 2.

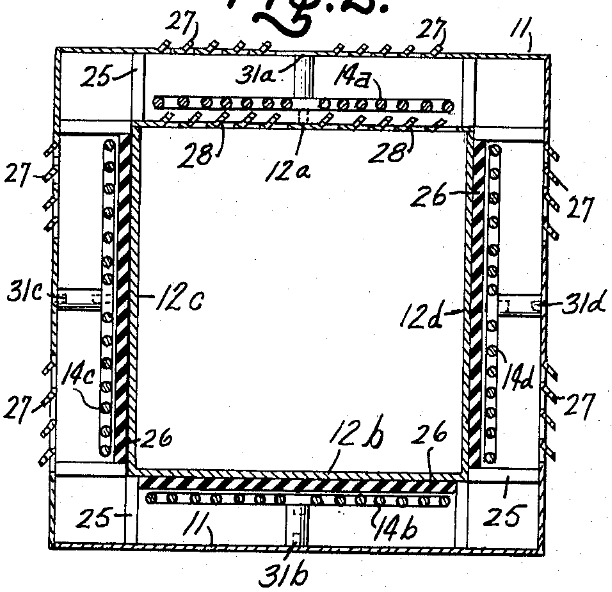


Fig. 3.

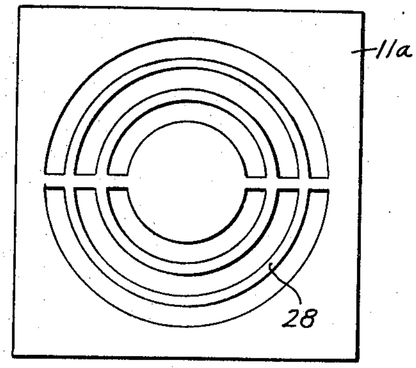
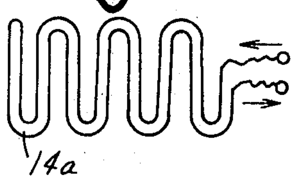


Fig. 6.



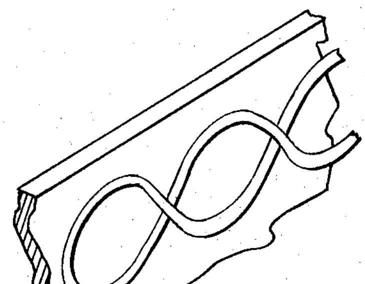


Fig. 6B.

Fig. 4.

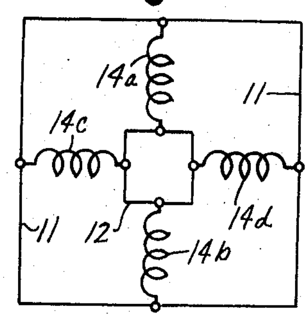


Fig. 5.

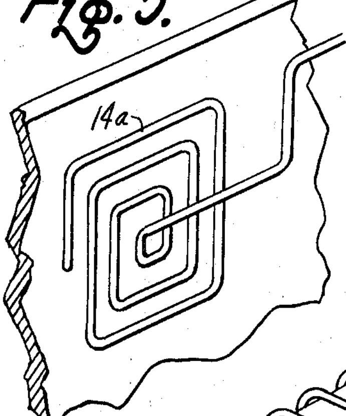


Fig. 4A.

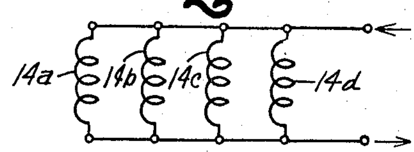


Fig. 6A.

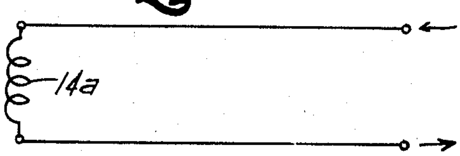


Fig. 7.

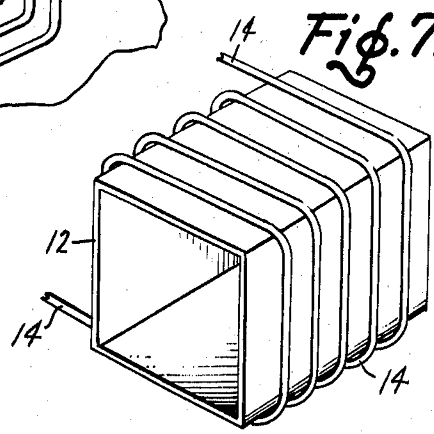


Fig. 5A.

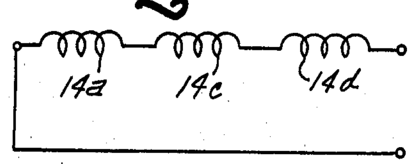


Fig. 8.

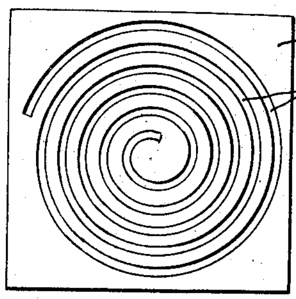


Fig. 8A.

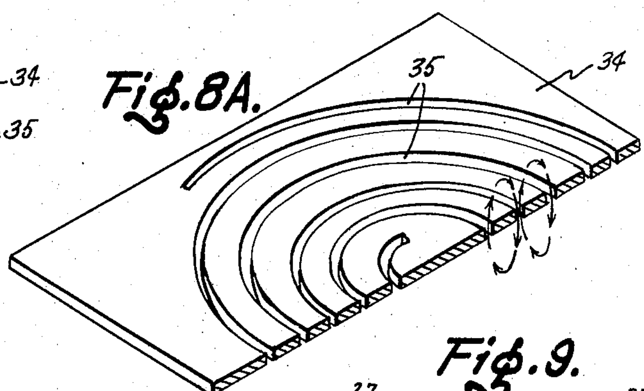


Fig. 9.

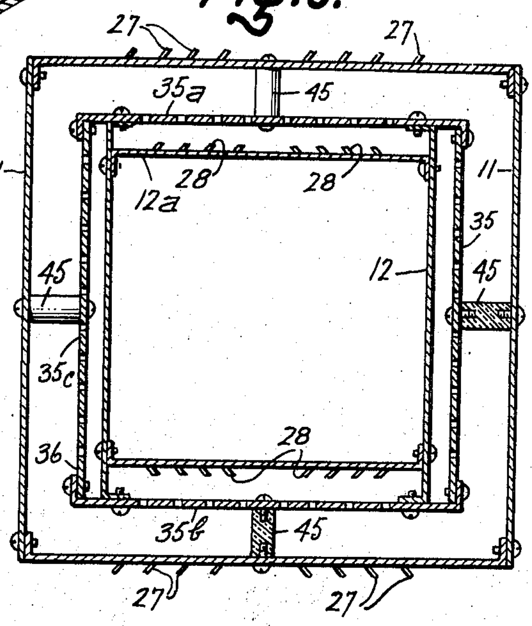
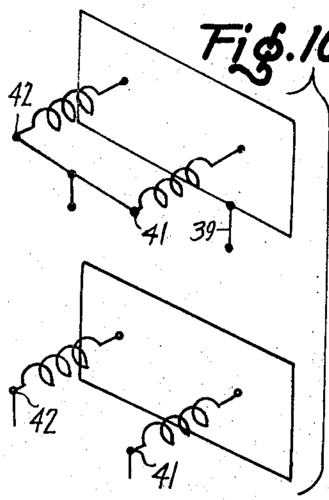


Fig. 10B.



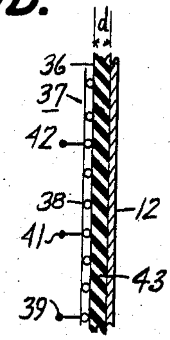


Fig. 10A.

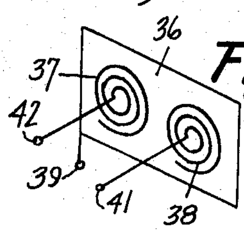


Fig. 10.

Fig. 11A.

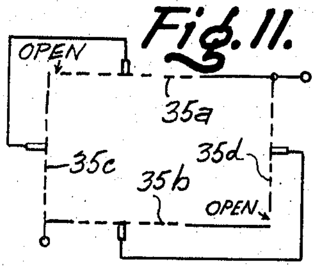


Fig. 11.

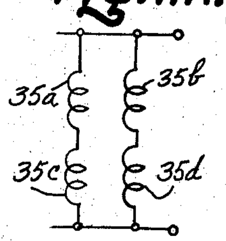


Fig. 13.

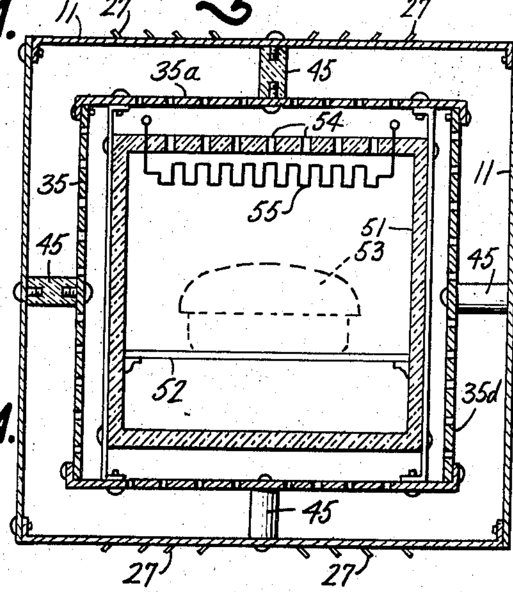
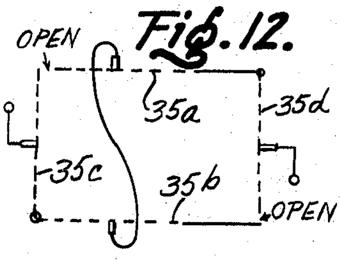


Fig. 12.



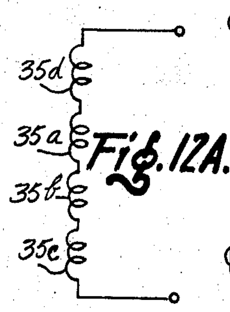


Fig. 12A.

INDUCTIVE HEATED BAKE OVEN

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to new and improved inductively heated bake ovens.

More specifically, the invention relates to new and improved inductively heated bake ovens which are more efficient in operation than existing bake ovens which employ radiant heating elements, and which provide more uniform heating and improved temperature control.

2. Background Problem

Bake ovens of the type which employ a radiant heating element inside an oven cavity, produce convection heating currents of air which cause foods placed in the upper region of the oven to heat very rapidly, sometime drying and burning the food long before the entire oven cavity becomes stabilized thermally and the walls of the oven become warm enough to give forth anything like the uniform heat required for good baking. Food placed closely and just above a radiant heating element likewise is easily over-heated by direct radiation from the element. Thus, bake ovens of this type require a relatively large cavity to handle roasts and bake goods which must be placed approximately in the center of the large cavity to achieve uniform heating. Generally, it is necessary to heat this relatively large oven cavity for a substantial period of time in advance of placing the food in it. This is done to avoid unnecessary evaporation of moisture from the food at low temperatures during the warm-up period as the walls of the oven and the air in the interior of the oven cavity are heated. The faster the walls and the interior of the oven cavity can be brought up to temperature, the sooner the food can be placed in the oven.

SUMMARY OF THE INVENTION

It is therefor a primary purpose of the invention to provide a new and improved induction-heated oven that can be heated rapidly and by heating all of the walls or sides of the oven cavity, it can be heated uniformly in a minimum time period. By thus heating all of the walls of the oven cavity, hot convection currents at start-up can be minimized. Rapid initial heating can be achieved by the use of high power levels at the start which then can be reduced smoothly to holding levels that would depend upon the food load and the heat loss. The rate at which moisture is removed from the oven cavity can be controlled by the use of a small cooling fan which causes air to move slowly out of small vent openings that may be formed in the oven cavity wall, for example. Such openings can increase the electrical resistance of the wall surfaces and make these surfaces easier to heat with lower levels of magnetic induction fields. Thus, oven wall structures compatible both with moisture removal and rapid heat generation are feasible.

The oven cavity may be made of suitable ferrous alloys such as stainless steel, iron, porcelainized steel, or titanium and the like. Titanium in thin **30** milli-inch sheet thicknesses is exceptionally strong and easily heated by magnetic induction fields. It is also highly corrosion resistant and of relatively low density so that the oven structure can be relatively light-weight for a given baking capability.

An outer housing made of a low loss metal such as aluminum, copper or of a composite structure such as stainless steel clad on the inside with a thin layer of aluminum or copper surrounds the induction heating coils and the inner oven cavity. Such an outer housing would not be heated significantly by the magnetic induction field and would serve primarily to protect and support the inner oven cavity and coils. The outer housing could, of course, contain louvers or vents to permit air circulation around induction heating coils thereby helping to maintain the induction heating coils cool so that they have relatively low electrical resistance and improve the efficiency of the oven. To further improve the bake oven efficiency, insulating material is preferably disposed between the induction heating coils and the inner magnetically susceptible oven that is inductively heated. Any such insulation must, of course, be transparent to magnetic lines of flux so as to permit induction heating of the inner housing forming the oven cavity.

The magnetic induction heating coil may be formed of planar, helically wound, pancake-shaped coils of wound Litz wire, or other similar insulated wire, or it may be fabricated by cutting a spiral opening in a thin sheet metal member and by attaching excitation terminals to the inner terminal of the spiral and to an outer portion of the sheet metal member. The resulting structure provides a preferred flat spiral coil that is best adapted to the heating of the flat metal surfaces of the inner oven cavity. A laminated material made up of layers of metal and insulation to achieve minimium coil loss also can be used.

It is also desirable to employ an infrared temperature sensor now available in the art for sensing and controlling the heating of materials in the induction-heated bake oven. The temperature sensor could be designed to look directly into the oven through a small port at the food being cooked. A known sensor of this type employs a small chopper to chop the sensing beam to provide a contrast between the infrared radiation coming from the metal surfaces of the inductively heated oven and the radiation coming from the port through which the food being cooked is viewed. If the food is at a low temperature, the contrast would be large, and if the food is at or near the wall temperature, then the contrast becomes smaller and system logic is arranged to remove heating power when the radiation differential is at a desired low level.

It is also possible for such an induction heated oven to be made self-cleaning by causing it to be heated sufficiently to vaporize all spattered foodstuffs in a manner similar to that employed in known self-cleaning ovens. The fact that all walls are heated directly by the magnetic induction field can result in less energy being required to achieve self-cleaning. In this manner, all surfaces can be kept free of condensible materials possibly on a continuous basis in which a cleaning cycle automatically occurs after each use of the oven.

It is also possible by appropriate design of the inner oven cavity so that it is insulating in nature, to employ a metal-base cooking utensil in which the food is placed, and which is susceptible to being magnetically heated directly through the action of the magnetic induction field. Direct heating of the utensil may prove desirable to achieve more rapid cooking or even a combination of frying and baking at the same time. In such an arrangement, the inner housing is made insulating and serves to insulate the induction heating coils from back heating effects from the metal-base cookware disposed within the oven cavity.

These and other objects, features and many of the attendant advantages of this invention will be appreciated more readily as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings, wherein like parts in each of the several Figures are identified by the same reference character, and wherein:

FIGS. **1** and **1**A of the drawings are overall perspective views of inductively heated bake ovens constructed in accordance with the invention, and which illustrate certain features of construction of the inductively heated bake oven in phantom;

FIG. **2** is a cross-sectional view of one preferred form of construction of the inductively heated bake oven shown in perspective in FIG. **1**, and illustrates certain details of internal construction of the bake oven;

FIG. **3** is a diagrammatic sketch illustrating one form of construction to provide venting slots or louvers in one of the sides of the bake oven, preferably the top, to allow venting of the oven cavity;

FIGS. **4** and **4**A of the drawings illustrate suitable electrical connections for the inductive heating coil, and illustrate one manner of exciting the inductive heating coil in a parallel circuit configuration;

FIG. **5**A illustrates a series of three planar inductive heating coils each similar in construction to that shown in FIG. **5**. connected in series circuit relationship, and which can be used to provide electrical excitation for the inductive heating coils;

FIGS. **6** and **6**B illustrate still different forms for constructing the inductive heating coils and FIG. **6**A is the equivalent schematic circuit diagram for each of these forms;

FIG. **7** is a perspective view of still another form of inductively heated bake oven according to the invention showing a spirally wound solenoid coil surrounding an inner, magnetically susceptible, oven housing or cavity;

FIGS. **8** and **8**A illustrates still another manner of constructing a planar, pancake-shaped inductive heating coil according to the invention by cutting a helical slot or opening in a thin planar metal member of aluminum or copper, or the like;

FIG. **9** is a cross-sectional view of an overall inductively heated bake oven employing sheet metal inductive heating coils of the type illustrated in FIG. **8**;

FIGS. **10**, **10**A and **10**B show different techniques for electrically interconnecting and exciting inductive heating coils of the type illustrated schematically in FIG. **8**;

FIGS. **11**, **11**A **12** and **12**A illustrate two different, mechanical and electrical connections for the sheet metal, inductive heating coils of the bake oven shown in FIG. **10** as well as their equivalent electrical circuit diagrams; and

FIG. **13** illustrates still a different form of the invention employing an insulating inner housing to form the oven cavity wherein metal-base cookware can be placed within the cavity for the purpose of baking or simultaneously baking and frying foodstuffs contained in the metal-base cookware.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** is an overall perspective view of a new and improved inductively heated bake oven constructed in accordance with the invention and also illustrates in phantom (dotted outline form) certain parts of the inductively heated bake oven (while omitting others) in order to better depict the overall construction and relationship of these elements in a completed, inductively heated bake oven assembly according to the invention. The inductively heated bake oven is comprised by an outer housing **11** which is fabricated from a highly conductive, magnetically non-permeable material such as copper, aluminum or some other highly conductive material and preferably has an attractive exterior appearance. If desired, the exterior of outer housing **11** can be porcelainized, provided with a ceramic coating or otherwise treated to provide the desired attractive exterior appearance. Alternatively, housing **11** may be fabricated from stainless steel, titanium, iron, or suitable alloys of these or other metals with the interior surface thereof being provided with a layer of copper, aluminum, or other highly conductive, magnetically non-permeable material. An inner housing as shown at **12** is mechanically supported within the outer housing **11** by suitable thermal insulating and mechanically strong structural supports (not shown). The inner and outer housings each have a plurality of different sides joined together to form an enclosed oven space with one of the sides of the outer housing shown at **13** forming a door to provide access to the oven space. That side of the inner housing **12** which confronts the door **13** also is open to provide access to the interior of the enclosed oven space provided by inner housing **12**. For convenience, it will be assumed that the inner and outer housings **12** and **11** are formed in the shape of cubes having five closed sides and one open side that forms the access door **13**. Door **13** may have a Pyrex glass front in order to allow the interior of the oven space to be viewed and includes a handle **13***a* to facilitate opening and closing of the door.

A plurality of planar, helically-wound, pancake-shaped inductive heating coils shown at **14a-14e** are physically supported (by means not shown in FIG. **1**) within the space intermediate the respective confronting sides of the inner and outer housings **11** and **12**, and are arranged to maximize the inductive coupling between the coils **14***a*–**14***e* to the respective associated sides of the inner housing **12**. The sides of the inner housing **12** are fabricated from sheet members of iron, stainless steel, titanium, alloys of these metals or other magnetically susceptible metal material capable of being inductively heated through the action of relatively high frequency magnetic induction fields of the order of 20 kilohertz which magnetically induces the generation of heat in the inner housing member **12**. For convenience, the physical and thermally insulating supports for the various conductive heating coils **14a-14e** have not been illustrated in order not to unduly complicate the Figure, and for the same reason the electrical interconnections to the respective coils from a source **15** of relatively high frequency, electrical excitation signals, have not been shown. The source **15** of relatively high frequency (of the order of 20 kilohertz), electrical, excitation signals preferably comprises a chopper-inverter power supply circuit of the type described and claimed more fully in co-pending United States Pat. No. 3,710,062 issued Jan. 9, 1973 entitled "Metal Base Cookware Induction Heating Apparatus Having Improved Power Supply and Gating Control Circuits Using IR Temperature Sensors and Improved Heating Coil Arrangement "-P. H. Peters, Inventor, assigned to the Environment/One Corporation. The various controls for controlling the electronic circuitry are shown at **16** along with a temperature indicator **17** for providing an indication of the temperature of the oven cavity defined by inner housing **12.**

In the particular inductively heated bake oven arrangement shown in FIG. **1**, a single, pancake-shaped, planar inductive heating coil **14***a*–**14***e* has been provided for each of the five walls of the inner housing **12** defining the oven cavity. With this construction, the oven cavity will be heated from all five walls by circulating currents induced in the surfaces of these walls from their associated induction heating coils. The induction heating coils **14***a*–**14***e* are physically displaced from the sides of inner housing **12** and are supported within the space intermediate the associated confronting walls of the inner and outer housing **12** and **11,** respectively. Preferably, thermal insulation (not shown in FIG. 1) is inserted in the space between each of the induction heating coils and its associated wall of inner housing **12.** Such a construction allows the induction heating coils to be operated at or near ambient temperature or at least at a much lower temperature than the temperature at which the oven cavity is heated. Such thermal insulation can be made very effective so that a minimum of electric power is required to excite the induction heating coils **14** *a*–**14***e*, and a minimum of heat is lost to the surrounding atmosphere. In addition, the rate at which the oven can be brought up to a desired temperature can be very rapid. By thus rapidly heating all of the walls of the oven cavity (except for perhaps the door), thermal stability of the oven space is achieved and the hot convection currents normally produced in an oven cavity using radiant heating elements at start-up, is eliminated. Rapid initial heating of the oven cavity can be accomplished, and the power supplied to the induction heating coil thereafter reduced to a desired holding level which depends upon the food load in the oven cavity and heat loss.

FIG. 1A of the drawings illustrates a complete smooth-top cooking range employing a new and improved induction heated bake oven according to the invention as shown generally at **11.** The induction heated bake oven comprises an integral part of an overall kitchen range that further includes a plurality of surface induction heating units shown at **18***a* to **18***d* embedded under a thermal insulating smooth-top for the overall range. The surface units **18***a*–**18***d* are controlled by the control panel knobs shown at **19***a*–**19***d* that in turn control the excitation circuitry for each surface induction heating units. The units are contained within the range housing, and are constructed in the manner described in greater detail in the above-noted U.S. Pat. No. 3,710,062. If desired, the kitchen range also can be provided with storage drawers indicated at **21** and cabinet space closed by the door **22,** which are formed in the range housing in a well known manner.

FIG. **2** of the drawings is a cross-sectional view taken through the center of the bake oven illustrated in FIG. **1** of the drawing, and better illustrates certain of the constructional features of the new and improved inductively heated bake oven not shown in FIG. **1.** In FIG. **2,** it will be seen that the inner housing **12** of lossy metal material such as porcelainized stainless steel, titanium, etc., is physically supported within the outer housing **11** by a plurality of ceramic or other comparable, mechanically strong and thermally insulating, mounting studs shown generally at **25.** Studs **25** are braized, riveted, screwed, or otherwise bonded between the outer corners of the inner housing **12** and the corresponding inner corners of the outer housing **11** for mechanically supporting the inner housing within the outer housing in a structurally sound manner. By fabricating these posts from ceramic or other comparable material, good thermal insulation between the inner and outer housings is provided thereby further minimizing heat loss from the inner oven cavity.

The induction heating coils **14**a-**14**d comprise flat, spirally wound coils of insulated Litz-type wire which may be spirally wound to form a planar, pancake-shape coil as described more fully in the above-noted U.S. Pat. No. 3,710,062. For convenience, the manner of physically supporting the induction heating coils **14***a*–**14***d* within the space intermediate the respective sides of the inner and outer housings **11** and **12,** has not been illustrated since such construction is deemed to be obvious to one skilled in the art. The coils are excited by appropriate electrical connections to the center and to a point on the outer periphery of the coil as described more fully in the above-noted co-pending U.S. patent application. As noted earlier, layers of insulation, such as sheets of glass-wool mat or other similar high temperature insulating material shown at **26** and which are tranparent to magnetic lines of flux, are secured between each of the induction heating coils **14***b*–**14***d* and the respective adjacent sides of the inner housing **12** for thermally insulating the inner oven cavity from the induction heating coils and thereby improving their efficiency of operation. Further improvement in efficiency of operation of induction heating coils can be obtained by providing louvers or vents shown at **27**, to permit cooling air circulation around the induction heating coils in order to maintain the temperature of operation of the induction heating coils at or near ambient temperature levels of the kitchen or other cooking space in which the inductively heated bake oven is employed. By maintaining the induction heating coils **14***a*–**14***d* in a cool condition, improved operating efficiency can be obtained. In this manner, the outer housing **11** would not be heated significantly either by thermal conduction or by induction since as noted above, it is made of a low loss metal such as aluminum, copper or a sheet member made of composite steel clad on the inside with a thin layer of aluminum or copper which surrounds the inductive heating coils and inner oven cavity. Thus, the outer housing **11** protects and shields the inductive heating coils so as to prevent stray electromagnetic radiation of the magnetic induction field and reduces radio interference effects known as RFI.

In addition to the louvers or vents **27** formed in the outer housing **11,** the top **12**a of the inner housing **12** forming the oven cavity may have a series of louvers or vents shown at **28** formed therein to allow for the removal of moisture from the inner, heated oven cavity. The rate at which moisture is removed from the cavity can be controlled by the use of a small fan mounted within the space intermediate the inner and outer housings, and which causes air to move slowly out the small openings **28** in the oven wall. FIG. **3** of the drawing is a top plan view of a preferred construction for the top side **12**a of the inner housing **12** showing the vents or louvers **28** as comprising circular slots formed in the top **12***a*. The provision of such openings in the walls of the inner housing **12** increases the electrical resistance of the wall surfaces and makes these surfaces easier to heat with lower levels of induced current. Thus, it will be appreciated that the vented or louvered wall structures such as shown in FIG. **3** are compatible both with moisture removal from the oven cavity and improved heat generation. Where the vents or louvers **28** are formed in the top of the inner housing **11**, the layer of insulating material between the top and outer housing may be omitted to prevent clogging of the insulating material, depending on its nature. If it is solid insulating material, it too, may be provided with vent openings. Alternatively, the vents may be formed in the top and bottom of the oven front door. As stated earlier, the walls of the inner housing **12** may be made from sheet metal members of ferrous alloys such as porcelainized steel, stainless steel, titanium in thin **30** millimeter thickness sheets and the like. Titanium is exceptionally strong and easily heated by magnetic induction fields, and in addition is highly corrosion resistant and of relatively low density so as to keep the weight of the induction heated bake oven at a minimum.

It is believed evident that by supplying sufficient power to the magnetic induction heating coils **14***a*–**14***e*, rapid heating of the inner oven cavity can be readily accomplished. For this purpose, it is preferred that each induction heating coil be separately excited from its own power supply and control circuitry **15** (shown in FIG. **1** in block form only). This power supply and control circuitry would be substantially the same as described more fully in the above-noted U. S. Pat. No. 3,710,062. However, it should be noted that since the magnetic induction field produced by the induction heating coils is contained in a box shield, square wave or other sharp voltage wave form for the induction heating coils, can be tolerated, and simpler type designs for the inverter power supply circuits which are less expensive and complex, can be employed to excite the inductive heating coils **14***a*–**14***d*. More importantly, it should be noted that since the load on the induction heating coils is uniform, certain features such as the need for feedback diodes or filter components in the power supply circuitry are not so essential, if required at all, thus further lowering the cost of the electrical excitation circuitry for the inductive heating coils. Where individual electrical excitation control and power circuits are provided for each of the individual inductive heating coils, it, of course, becomes possible to control the level of heating by exciting fewer than the total number of induction heating coils, where the item being cooked in the oven is not sufficiently large to require that all heating coils be excited. Alternatively, the control could be set by the operator to quickly bring the oven cavity up to a desired temperature through excitation of all induction heating coils thereby uniformly heating the oven to a desired temperature in a rapid manner, and thereafter reducing the input power, or alternatively reducing the number of induction heating coils being excited, to maintain or hold the oven cavity at the desired temperature level. It is also believed evident that the new and improved induction heated bake oven can be made self-cleaning by heating it sufficiently to vaporize all spattered foodstuffs in a manner similar to that employed in known self-cleaning ovens. The fact that all of the walls of the oven cavity are heated directly could effectively lessen the total energy required to achieve self-cleaning. Certainly all of the surfaces of the inner oven cavity **12** can readily be kept free of condensible materials, perhaps on a continuous basis, in which a self-cleaning cycle automatically would occur after each use of the oven. By appropriate treatment of the inner surfaces of the inner housing **12** through procelainizing the surfaces, etc., ease of cleaning either manually or through the self-cleaning feature, can be enhanced.

As described more fully in the above-noted U.S. Pat. No. 3,710,062 the induction heating coil control and power circuitry can also be designed to include an infrared temperature sensor for controlling the heating effect of the induction heating coils. In FIG. **2**, infrared temperature sensors are shown at **31***a*–**31***d*, mounted within the relatively cool space between the induction heating coils and the walls of the outer housing **11** and are provided with ports or windows through the center of the induction heating coils, the insulating layer **26** and the walls of the inner housing **12** so that they can directly view the foodstuffs or cookware containing foodstuff disposed in the inner oven cavity. The infrared temperature sensors look into the oven cavity through a small port or window at the food being cooked. The infrared temperature sensors include a light chopping device which chops the infrared beam impinging upon the sensor so as to provide a contrast between the infrared radiation coming from the metal surfaces of the interior of the oven cavity, and the infrared radiation coming through the small window or port from the food being cooked. If the food is at a low temperature, as when it is initially placed in the oven, this contrast will be large, and is used to develop a control signal for maintaining the supply of power to the induction heating coils. If the food is at or near the oven cavity wall temperature, the contrast becomes smaller, and the control system logic is arranged to remove heating power when the radiation differential is at the desired low level. The differential in infrared radiation between the interior of the oven cavity and the food being cooked also can be compared against the temperature of the oven wall as measured directly by a contacting temperature sensor such as a thermostat or thermistor, in order to derive a desired contrasting temperature level for power supply control purposes. While a plurality of temperature sensors **31***a*–**31***d* have been shown, it is believed obvious to one skilled in the art that the unit readily could be modified to use only a single sensor, two or any desired number for temperature controlling purposes.

As stated above, the preferred electrical arrangement is for each induction heating coil **14***a*–**14***e* to be separately excited by its respective power supply and control circuitry including temperature sensor and control. It is also possible to use a single temperature sensor for controlling all or part of the induction heating coils with an arrangement such as is depicted in FIG. **4** of the drawings. In FIG. **4**, the induction heating coils have been illustrated schematically as being electrically connected between the inner and outer housings **11** and **12** with each of the housings serving the function of an electrical input or output terminal. The equivalent electrical circuit diagram as shown in FIG. 4A wherein it is seen that all four induction heating coils **14***a*–**14***d* are connected in parallel circuit relationship to a single source of electrical excitation signals. With such an arrangement a relatively large high frequency power source would be required to adequately power all four coils in parallel, and would be supplied from a 230 volt alternating current source, for example. FIGS. **5** and **5**A of the drawings show still another alternative arrangement wherein FIG. **5**A shows **3** induction heating coils **14***a*, **14***c*, and **14***d* which may be similar in construction to the coil shown in FIG. **5**, are connected in series circuit relationship across a single source of electrical excitation signals to provide increased inductance and a higher coupled field. It is believed obvious that two such coils, four such coils, or all five coils could be connected in similar series, parallel or combination series-parallel electrical circuit configurations and would function in essentially the same manner as described above with respect to their induction heating effect. In such arrangements where multiple coils are being excited from a single source of electrical excitation signals, it is anticipated that the single source would have a larger power rating than would be required where only a single coil was being driven. Thus, it is seen that there are many ways to interconnect the 4 or 5 inductive heating coils in order to assure a desired amount of electrical inductive reactance.

FIGS. **6** and **6**A of the drawings show an alternative configuration for the shape of say one of the induction heating coils **14***a*. In FIG. **6** it is seen that the induction heating coil **14***a*, for example, is formed by a parallel pair of insulated Litz wire conductors that are snaked up and down in a torturous path configuration suitable for creating concentrated lines of magnetic flux in the adjacent side of the inner housing member **12** associated with the snake-like heating coil. FIG. **6**A of the drawings illustrates the equivalent circuit diagram of the heating coil configuration of FIG. **6**. The inductance of this arrangement increases as the wires are separated and the field extending to the inner housing walls also increases.

An alternative and related coil geometry is shown in FIG. **6**B, wherein a conductor is shaped to form a series of loops that are interconnected. All conductors are insulated from each other in the regions where they cross. The circular heating circuits are insulated from the adjacent wall of inner housing **12**.

FIG. **7** of the drawing illustrates still another alternative form for fabricating a new and improved inductively heated bake oven according to the invention. In FIG. **7**, the lossy, magnetically susceptible inner housing member **12** of stainless steel, etc. is surrounded by a helically wound solenoid-type coil formed by an insulated conductor **14** that may be Litz wire or some other suitable insulated conductor. With such an arrangement, it will be appreciated that the helical windings of the solenoid coil will produce concentrated magnetic lines of flux that intercept and magnetically excite surface currents in the inner housing member **12**. The remainder of the structure would be quite similar to that illustrated in FIGS. **1**-**2** wherein insulation is interposed between the turns of the induction heating coil **14** and the exterior shielding outer housing member **11**. Thus, it will be appreciated that in all other respects, the arrangement of FIG. **7** would be comparable to that described with respect to FIGS. **1** and **2**. However, the flat spiral coil construction described with respect to FIGS. **1** and **2** provides more uniform heating and also allows easier tailoring of the electrical inductive characteristics by parallel connections, etc., and hence is preferred.

FIGS. **8** and **8**A of the drawings show still another alternative construction for the induction heating coils for use in fabricating the new and improved inductively heated bake oven. For that matter, the induction heating coil construction illustrated in FIGS. **8** and **8**A can be employed in fabricating surface cooking units such as those depicted at **18***a*–**18***b* in FIG. **1**A, and can be used in conjunction with power supply and control circuitry of the type described in the above-noted U.S. Pat. No. 3,710,062 either as surface cooking units or as bake oven heating coils as described hereinafter in connection with FIG. **9**. The induction heating coil illustrated in FIGS. **8** and **8**A is fabricated from a relatively thin sheet of aluminum, copper or similar highly conductive metal material having a thickness of the order of one-sixteenth inch and a length L of the order of **24** inches and a width W equal to about 30 inches. It should be noted that these dimensions are exemplary only, and readily may be altered to meet the requirements of a particular design. As shown in FIG. **8** the thin sheet **34** of highly conductive metal has spirally formed conductive turns formed therein by a spiral opening cut, stamped, molded, or otherwise formed in the sheet metal member so as to provide the resultant, spiral inductive heating coil turns having the dimensions depicted in FIG. **8**A. Each spiral turn is separated from the next adjacent turn by an opening or gap of the order of one-sixteenth inch (equivalent to the thickness of the sheet metal member) and has upper and lower, flat current conducting surfaces of the order of three-sixteenth of an inch. It is the larger dimension (three-sixteenths of an inch) top and bottom flat surfaces of the turns **35** which provide the current path since the current is excluded from the surfaces of the turns in the space between the gaps as depicted by the dotted line arrows shown in FIG. **8**A. These dotted line arrows depict the magnetic lines of flux produced by current flowing in the spirally wound turns **35** of the induction heating coil of FIG. **8**. It will be seen that in the gaps between the turns **35**, the opposing magnetic fields will cancel each other out so that essentially no or little current flows on the sides of the turns. To compensate for this effect, the top and bottom surfaces of the turns are made sufficiently large to support all of the current needed to produce a desired strength magnetic induction field required to produce a rated heating effect. The inductance of such a spiral heating coil formed in a sheel metal member in this manner will vary as the number of turns squared, assuming fixed spacing between the turns, or will vary as the radius squared. Flat, spiral coils may be insulated from one another, stacked axially, and series connected to obtain inductive reactance values larger than are obtainable from a single coil. Further, the sheet metal spiral coil is easily machined, although it may heat more than a comparable Litz wire wound pancake-type coil, particularly at the center. Such heating is not too severe, however, and could be used to advantage by conveying the heat inward toward the oven space.

It is also possible to fabricate more than one coil on each sheet metal member so as to increase the number of induction heating coils acting on any given side of the lossy inner oven cavity. FIG. **10** of the drawings illustrates such a dual heating coil sheet metal member **36** having two different inductive heating coils **37** and **38** formed in the member by spirally shaped cuts similar to those described more fully in connection with FIG. **8A** above. With such an arrangement, a single common terminal, shown at **39**, connected to the sheet metal member **36** serves as a common input terminal and connections **41** and **42** to the inner end or terminus of the spirally formed turns **37, 38** serve as separate output terminals. FIG. **10B** of the drawings illustrates the connections that would be required where it is desired to operate such induction heating coils either in parallel or in series circuit relationship, respectively. Where operated in series, it will be seen that no connection is made to the common terminal **39** corresponding to the body of the sheet metal member but instead is made only to the two inner terminal points of the spirally formed turns **37, 38.** FIG. **10A** of the drawings illustrates the manner in which such a dual induction heating coil would be physically mounted adjacent one of the lossy metal sides **12** of the inner housing of an oven such as shown in FIGS. **1** and **2** and preferably includes a layer of insulating material **43** in the space between the side of housing **12** and the planar sheet metal member **36** in which the spirally shaped heating coils are formed. The spacing "*d*" between the coil and the side **12** of the inner housing can be adjusted to control the degree of mutual coupling and hence the degree of heating.

FIG. **9** of the drawings is a cross-sectional view of an overall, new and improved, inductively heated bake oven constructed in accordance with the invention and which employs induction heating coils formed by cutting spirally wound openings in sheet metal members in the manner shown in FIG. **8.** For convenience of illustration, the insulation between the spirally cut sheet metal heating coils **35** and the lossy metal sides of the inner oven cavity housing **12** has not been illustrated in order to simplify the Figure, however, where such insulation is used, it would be used in the manner depicted in FIG. **10**A.

There are a number of different ways in which to interconnect the **4** or **5** spirally slotted sheet metal members **36** in which the induction heating coils **35** are formed. The sheet metal members may be supported at their centers by suitable insulating posts **45** which also can serve as terminal supports for making connections to the central terminal point of each spirally wound coil formed by turns **35.** The intersecting corners of the sheet metal members **36** may be clamped, screwed, welded, soldered, or otherwise secured together around the inner housing **12** forming the oven cavity. Where such intersecting corners are to be open circuited electrically, insulating spacers that also serve to join the corners together mechanically would be used. If desired, vent holes **28** may be placed in the top **12*a*** of the inner housing **12** for venting the oven cavity space and similarly vent holes **27** may be formed in the top as well as the bottom of the outer shielding housing **11** which is fabricated from highly conductive metal materials. The provision of such vent holes and perhaps also the inclusion of a cooling circulating fan in the space between the inductive heating coil sheet metal member **36** and the sides of the outer housing **11,** maintains the induction heating coils in a cool condition and thereby improves the operating efficiency of the inductively heated bake oven. In the resulting structure, it is desirable to provide optimum mechanical support for the various parts of the oven while at the same time providing for thermal tolerances (expansion and contraction) and assuring proper electrical operation. If desired, the vent holes **27** for venting the space between the outer housing and induction heating coils could conceivably be put in the top of the front door of the oven and still effect sufficient cooling to maintain efficient operation of the bake oven.

FIGS. **11** and **12** of the drawings illustrate different physical and electrical connections for the different sheet metal induction heating coils **35*a*–35*d*,** and FIGS. **11A** and **12A** illustrate their equivalent electrical circuit digrams. By thus interconnecting different ones of the sheet metal member, spirally formed, induction heating coils **35*a*–35*d*** as well as a rear coil (not shown) if one is provided, it is possible to design into the structure desired electrical characteristics, particularly adequate inductance. Such design is believed obvious to one skilled in the art in the light of the diagrams shown in FIGS. **11** and **12** and their equivalent circuit diagrams **11A** and **12A**, respectively. It should be particularly noted in FIGS. **11** and **12** that in order to obtain certain desired electrical circuit configurations, it may be necessary to open circuit different corner connections of the sheet metal induction heating coil members **35*a*–35*d*.** To do this suitable insulating mechanical connectors can be employed at those interconnections where open circuit electrical characteristics are desired.

FIG. **13** of the drawing is a cross-sectional view of a somewhat different form of the inductively heated bake oven wherein there is no inner, lossy metal housing or oven cavity. In its place, an inner, insulating housing shown at **51** is formed from ceramic, high temperature glass, high temperature polyimid plastic, or other suitable thermal insulating material that is transparent to magnetic induction fields and capable of withstanding high temperatures. The inner insulating housing **51** may include an insulating, non-metallic supporting rack **52** on which metal base cookware shown at **53** is supported. Foodstuff to be cooked must be placed in such metal base cookware **53** in order to achieve heating by the effect of the magnetic induction field produced by the spirally cut, sheet metal inductive heating coils **35*a*–35*d*.** If desired, vent holes shown at **54** may be formed in the top of the inner insulating housing **51** to provide for moisture removal from the oven cavity space. For this purpose, the metal base cookware **53** likewise should have a vent or port in its top to allow for moisture removal from inside this vessel.

If desired, a toasting nichrome or other similar radiant heater element such as shown at **55** can be mounted in the top of the insulating inner housing **51** and suitably energized from appropriate electrical connections to a conventional source of alternating current or otherwise. By the inclusion of such a toasting nichrome heating element, after baking foodstuff, the top can be taken off of the metal base cookware **53** and the toasting nichrome heating element **55** can be energized in order to brown the top of a roast, or other foodstuff contained in the metal base cookware. During such a browning or toasting operation, it would not be necessary to also operate the induction heating coil; however, simultaneous operation of both elements is possible. If desired, such a toasting nichrome heating element or other similar radiant heating element could be included in any other of the embodiments of the inductively heated bake ovens described hereinbefore in connection with FIG. 1 through 12.

A particular advantage of the embodiment of the invention shown in FIG. 13 is that it does not require the additional weight of the inner, lossy metal housing 12 that forms the oven cavity. It does however, require that foodstuff to be cooked in the oven be enclosed within metal base cookware that is susceptible to being heated by magnetic induction fields. This is not true of the previously described embodiments of the invention which provide a lossy metal inner housing 12 that forms a high temperature oven cavity wherein foodstuff can be baked in any known form of cookware such as Pyrex, ceramic bowls, etc. For the best results with the oven of FIG. 13, thermally insulated metal base cookware of the type described in U.S. Pat. application Ser. No. 179,010, should be used.

From the foregoing description, it can be appreciated that the invention provides a new and improved induction heated bake oven that can be heated rapidly and uniformly from all sides or walls of the oven cavity in a minimum time period. By thus heating all of the walls of the oven cavity in a uniform fashion, hot convection currents at start up are minimized, and by following the rapid initial heating with a smooth reduction in the input power to only holding levels of heating, maximum efficiency in cooking can be achieved with a minimum loss of heat to the outside environment. Such induction heating is achieved within a completely shielded housing which prevents stray electromagnetic radiation from the magnetic induction fields from producing undesired radio interference effects.

Having described several embodiments of a new and improved, inductively heated bake oven constructed in accordance with the invention, it is believed obvious that other modifications and variations of the invention are possible in the light of the above teachings. It is therefore to be understood that changes may be made in a particular embodiments of the invention described which are within the full intended scope of the invention as defined by the appended claims.

What is claimed is:

1. An inductively heated bake oven for heating and warming cookware disposed in the oven comprising an outer housing fabricated to a substantial extent from a highly conductive, magnetic field shielding material at high frequencies of the order of 20 kilohertz and having a plurality of different sides joined together to form an enclosed space with at least one of the sides forming a door to provide access to the enclosed space, an inner housing fabricated from magnetically susceptible metal material and having a plurality of different sides joined together to form an enclosed oven space-spaced from and supported within the sides of the outer housing and having at least one side thereof facing the door of the outer housing providing access to the interior of the enclosed oven space, a plurality of helically wound, pancake-shaped induction heating coils each supported within the space intermediate respective confronting sides of the inner and outer housings and arranged in a plane that is spaced from and generally parallel to a respective side of the inner housing to maximize the inductive coupling to the magnetically susceptible inner housing, and means for electrically exciting the induction heating coils at a relatively high frequency of the order of 20 kilohertz to thereby magnetically induce the generation of skin-effect heating in the inner housing defining the enclosed oven space.

2. An inductively heated bake oven according to claim 1, further including thermal insulating material disposed in the space intermediate the sides of the inner housing and the respective induction heating coils for thermally insulating the induction heating coils from the inductively heated inner housing.

3. An inductively heated bake oven according to claim 1, wherein the outer housing is fabricated from aluminum, copper or other similar highly conductive metal material for magnetically shielding the lines of flux from the induction heating coils and minimizing stray electro-magnetic radiation from the inductive heating coils.

4. An inductively heated bake oven according to claim 1, wherein the sides of the inner housing are fabricated from sheet metal members of iron, stainless steel, titanium, or the like of relatively thin dimension and shaped to form an oven enclosure of desired configuration.

5. An inductively heated bake oven according to claim 4, wherein the interior surface of the inner housing member is porcelainized to provide an attractive and easily cleaned interior surface.

6. An inductively heated bake oven according to claim 1, wherein each of the inductive heating coils is provided with a respective excitation power supply and control circuit that can be individually controlled.

7. An inductively heated bake oven according to claim 1, wherein at least the outer housing is provided with cooling vents for providing a flow of cooling air in the space between the inner and outer housing and thereby maintain the induction heating coils in a relatively cool condition for improved efficiency of operation.

8. An inductively heated bake oven according to claim 7, wherein at least one of the sides of the inner housing is provided with cooling vents to provide for removal of moisture from the enclosed oven space.

9. An inductively heated bake oven according to claim 7, wherein at least one of the sides of the inner housing is provided with cooling vents to allow for removal of moisture from the enclosed oven space and further including thermal insulating material disposed in the space intermediate the outer housing and the inductively heated inner housing, the outer housing is provided with cooling vents and is fabricated from aluminum, copper, or other similar highly conductive metal material for shielding the induction heating coils and preventing stray electro-magnetic radiation, the inner housing is fabricated from iron, stainless steel, titanium or the like sheet metal members of relatively thin dimension shaped to form the desired oven enclosure, the interior surface of the inner housing member is porcelainized to provide an attractive and easily cleaned interior surface, each of the induction heating coils is provided with a respective excitation circuit that can be individually controlled, and temperature sensitive and control means are provided for viewing the interior of the inner housing and controlling the excitation of the induction heating coils in a manner to maintain the temperature of the enclosed oven space at a desired set value.

10. An inductively heated bake oven according to claim 9, wherein at least two of the induction heating

coils are interconnected in common circuit relationship, and are excited simultaneously by a single electric excitation circuit means for electrically exciting the induction heating coils.

11. An inductively heated bake oven according to claim **1**, further including temperature sensitive and control means for viewing the interior of the inner housing and controlling the inductive heating coils in a manner to maintain the temperature of the enclosed oven space at a desired set value.

12. An inductively heated bake oven according to claim **1** wherein at least two of the induction heating coils are electrically connected in series, parallel or combination series-parallel circuit relationship and are excited simultaneously by a single electric excitation circuit means for electrically exciting the inductive heating coils.

13. An inductively heated bake oven according to claim **1**, wherein the induction heating coils are formed from relatively thin sheet metal members of highly conductive metal such as aluminum or copper and having a spiral opening or slot cut therein to form flat spirally wound conductive surfaces that act as induction heating coils.

14. An inductively heated bake oven according to claim **13**, wherein at least one of the sides of the inner housing is provided with cooling vents to allow for removal of moisture from the enclosed oven space, thermal insulating material is disposed in the space intermediate the inner housing and the induction heating coils from the inductively heated inner housing, the outer housing is fabricated from aluminum, copper or other similar highly conductive metal material for shielding the induction heating coils and preventing stray electro-magnetic radiation, the inner housing is fabricated from iron, stainless steel, titanium or the like sheet metal members of relatively thin dimension shaped to form the desired oven enclosure and the interior surface of the inner housing member is porcelainized to provide an attractive and easily cleaned interior surface, each of the induction heating coils is provided with a respective excitation circuit that can be individually controlled, and temperature sensitive and control means are provided for viewing the interior of the enclosed oven space defined by the inner housing and controlling the induction heating coils in a manner to maintain the temperature of the enclosed oven space at a desired set value.

15. An inductively heated bake oven according to claim **14**, wherein at least two of the induction heating coils are interconnected in circuit relationship and excited simultaneously by a single excitation circuit means for electrically exciting the inductive heating coils, and are electrically connected in series, parallel or combination series-parallel circuit relationship.

16. An inductively heated bake oven for heating and warming cookware disposed in the oven comprising an outer housing fabricated to a substantial extent from a highly conductive magnetic field shielding material at high frequencies of the order of 20 kilohertz and having a plurality of different sides joined together to form an enclosed space and with one of the sides comprising a door to provide access to the enclosed space, an inner housing having a plurality of different sides joined together to form an oven space-spaced from and supported within thesides of the outer housing, at least one of the sides of said inner housing coacting with said one side of said outer housing to form a door to provide access to the interior of the enclosed oven space, and induction heating coil means supported within the space intermediate respective confronting sides of the inner and outer housings and arranged to maximize inductive coupling to the magnetically susceptible members supported within or forming the inner housing, and means for electrically exciting the induction heating coil means at a relatively high frequency of the order of **20** kilohertz to thereby magnetically induce the generation of skin-effect heating within the enclosed oven space.

17. An inductively heated bake oven according to claim **16**, wherein the inner housing is fabricated from lossy magnetically susceptible material such as iron, stainless steel, titanium, etc., and the induction heating coil means is formed by a multiplicity of conductive turns wound around the inner housing.

18. An inductively heated bake oven according to claim **16**, wherein at least one of the sides of the inner housing is provided with cooling vents to allow for removal of moisture from the enclosed oven space, the inner housing is fabricated from iron, stainless steel, titanium or the like sheet metal members of relatively thin dimension shaped to form the desired oven enclosure and the interior surface of the inner housing member is porcelainized to provide an attractive and easily cleaned interior surface, thermal insulating material disposed in the space intermediate the inner housing and the induction heating coil means for thermally insulating the induction heating coil means from the inductively heated inner housing, the outer housing is vented and is fabricated from aluminum, copper or other similar highly conductive metal material for shielding the induction heating coils, and preventing stray radiation, the induction heating coil means is provided with excitation circuit means that can be individually controlled, and temperature sensitive and control means for viewing at least one of the sides of the inner housing and controlling the induction heating coil means in a manner to maintain the temperature of the enclosed oven space at a desired set value.

19. An inductively heated bake oven according to claim **18**, wherein the inner housing is fabricated from lossy magnetically susceptible material such as iron, stainless steel, titanium, etc., and the induction heating coil means is formed by a multiplicity of conductive turns wound around the inner housing.

20. An inductively heated bake oven according to claim **16**, wherein the induction heating coil means comprise a plurality of planar, helically wound, pancake-shaped induction heating coils, there being one coil for each side of the inner housing with the pancake-shaped, planar, induction heating coils being placed closely adjacent to the respective inner housing sides to maximize magnetic induction coupling to the inner housing whereby comparatively even heating of the oven space can be achieved by inductively heating from all of the sides of the inner housing forming the oven space.

21. An inductively heated bake oven according to claim **20**, wherein the induction heating coils are formed from relatively thin sheet metal members of highly conductive metal such as aluminum or copper and having a spiral opening or slot cut therein to form flat spirally wound conductive surfaces that act as inductive heating coils.

22. An inductively heated bake oven according to claim **21**, wherein at least one of the sides of the inner housing is provided with cooling vents to allow for removal of moisture from the enclosed oven space, the inner housing is fabricated from iron, stainless steel, titanium or the like sheet metal members of relatively thin dimension shaped to form the desired enclosure and the interior surface of the inner housing member is porcelainized to provide an attractive and easily cleaned interior surface, thermal insulating material disposed in the space intermediate the inner housing and the induction heating coils for thermally insulating the induction heating coils from the inductively heated inner housing, the outer housing is vented and is fabricated from aluminum, copper or other similar highly conductive metal material for shielding the induction heating coils and preventing stray electro-magnetic radiation, each of the induction heating coils is provided with a respective excitation circuit that can be individually controlled; and temperature sensing and control means for viewing the inner housing and controlling the induction heating coils in a manner to maintain the temperature of the enclosed oven space at a desired set value.

23. An inductively heated bake oven according to claim **16** wherein the inner housing comprises a relatively thin, lightweight, sturdy shell of insulating material that is penetrable by high frequency magnetic fields of the order of 20 kilohertz.

24. An inductively heated bake oven according to claim **23** wherein the inner housing is provided with a hard, attractive, easily cleaned and resistant to high temperatures inner surface.

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