United States Patent [19]

Taketo et al.

[11] **3,836,744**

[45] **Sept. 17, 1974**

[54] **INDUCTION HEATING APPARATUS HAVING A COVER PLATE FOR MINIMIZING THERMAL EXPANSION EFFECTS**

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[22] Filed: **May 4, 1973**

[21] Appl. No.: **357,171**

[30] **Foreign Application Priority Data**

May 17, 1972 Japan 47-48970
Oct. 5, 1972 Japan 47-100100
Nov. 21, 1972 Japan 47-134146

[52] **U.S. Cl.** **219/10.49**, 219/10.67
[51] **Int. Cl.** **H05b 5/04**
[58] **Field of Search** 219/10.49, 459, 464, 10.67, 219/10.79

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Primary Examiner—Bruce A. Reynolds
Attorney, Agent, or Firm—Oblon, Fisher, Spivak, McClelland & Maier

[57] **ABSTRACT**

An induction heating apparatus for induction-heating a heated apparatus by an exciter excited by the standard line frequency for generating an alternating magnetic field. The apparatus comprises a high resistant non-magnetic metal plate, preferably of stainless steel, placed at the surface between the heated apparatus and the exciter. Various configurations of grooves can be provided in the plate to minimize the effects of thermal expansion.

1 Claim, 18 Drawing Figures

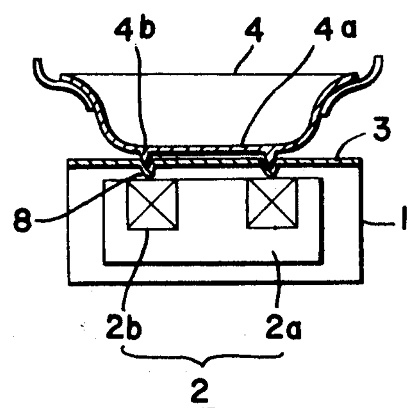


FIG. 1

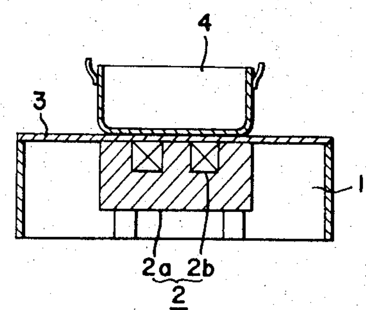


FIG. 2

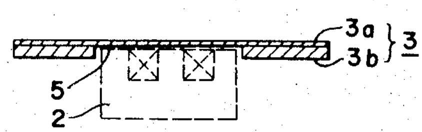


FIG. 3

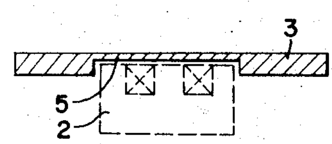


FIG. 4

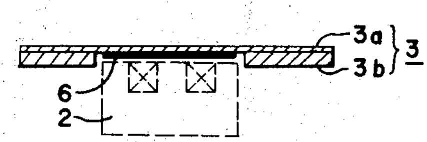


FIG. 5

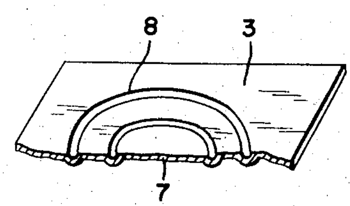


FIG. 6

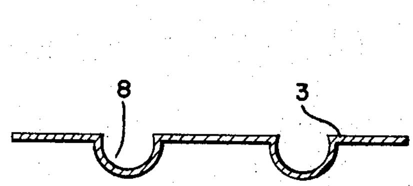


FIG. 7

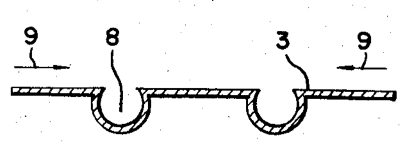


FIG. 8

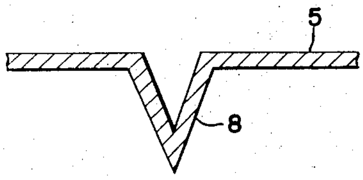


FIG. 9

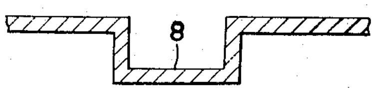


FIG. 10

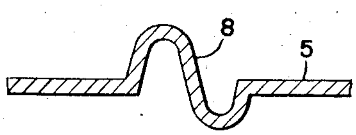


FIG. 11

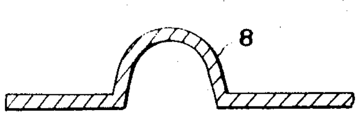


FIG. 12

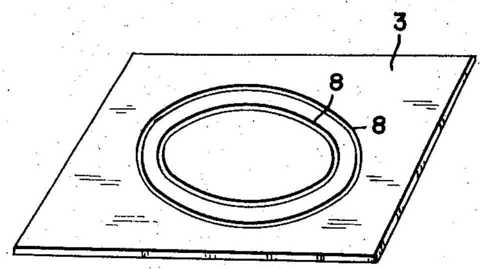


FIG. 13

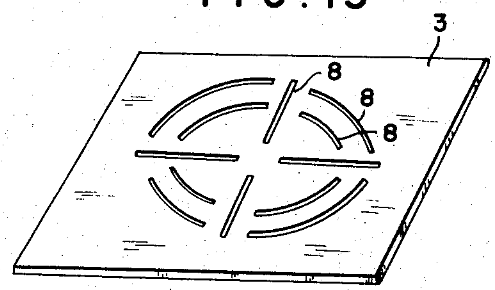


FIG. 14

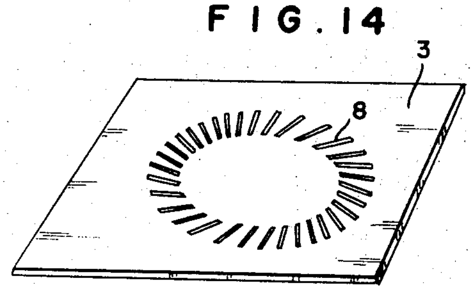


FIG. 15

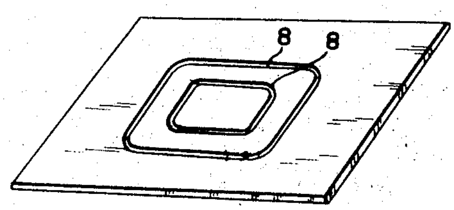


FIG. 16

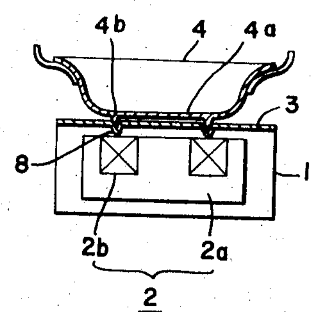


FIG. 17

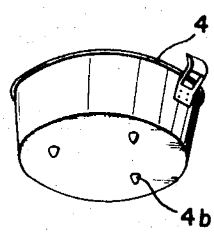
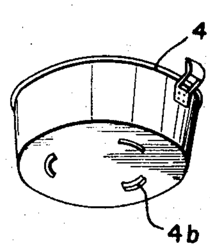


FIG. 18



INDUCTION HEATING APPARATUS HAVING A COVER PLATE FOR MINIMIZING THERMAL EXPANSION EFFECTS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an induction heating apparatus and more particularly to apparatus which utilizes heating by electromagnetic induction. Even more particularly, this invention relates to an induction heating cooking apparatus.

2. Description of the Prior Art

An induction heating apparatus for induction heating a cooking pot generally comprises an exciter for generating an alternating magnetic flux. The alternating magnetic flux is applied to the metal apparatus to be heated such as a cooking pot. The heating results from applying power, such as of the standard commercial line frequency, to an exciter in the body of the apparatus and inducing an eddy current at the bottom of a resistive cooking pot placed on the exciter by generating an alternating magnetic field. In such apparatus, sometimes the exciter is exposed and the cooking pot directly contacts the iron core thereof. Such apparatus is generally not suitable for household use, in that it has an inferior appearance and is dangerous when water or other contents of the cooking pot overflows.

Thus, a need exists for providing an induction heated cooking apparatus for household use that effectively overcomes the above mentioned infirmities.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an induction heating apparatus which is advantageous for use as a household cooker.

Another object of the present invention is to provide an induction heated cooking apparatus which enables a greater degree of safety and efficiency than heretofore obtainable.

A further object is to provide an induction heated cooking apparatus that comprises a coverplate for the exciter in which the effects of thermal expansion are minimized.

The foregoing and other objects are attained in accordance with one aspect of the present invention through the provision of an induction heating apparatus for induction-heating a cooking pot, which comprises an exciter for generating an alternating magnetic field and a cover plate made of a high resistant non-magnetic metal placed at the surface facing said exciter.

Preferably, the high resistant non-magnetic metal plate comprises stainless steel so as to provide high heat resistance and structural strength without interfering with the magnetic path consisting of the exciter and the cooking pot. The exciter is protected by forming the cover plate to keep the exciter clean to prevent dangerous operation thereof. The cover plate is preferably flat, to provide easy cleaning and a good appearance for the cooker.

In one embodiment of this invention, a groove for absorbing thermal expansion is formed in the plate between the high temperature part (a central part in contact with the cooking pot) and the room temperature part (a peripheral part not contacting the cooking pot). In another embodiment, a gap is provided for preventing thermal conductivity between the stainless steel cover plate and the exciter. In still another embodiment, an insulator is formed between the stainless steel cover plate and the exciter.

BRIEF DESCRIPTION OF THE DRAWINGS

Various objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description of the present invention when considered in connection with the accompanying drawings, in which:

FIG. **1** is a sectional front view of one embodiment of an induction heating apparatus according to the present invention;

FIGS. **2** to **4** are sectional views illustrating the structure of a stainless steel flat cover plate according to this invention;

FIG. **5** is a partially broken schematic view of a cover plate according to the present invention having grooves for absorbing thermal expansion;

FIGS. **6** and **7** are partial sectional views showing the condition of the cover plate of FIG. **5** during a non-cooking period (at room temperature) and during a cooking period (heating), respectively;

FIGS. **8** to **11** are partial sectional views illustrating various shaped grooves for absorbing thermal expansion which are formed on the cover plate;

FIGS. **12** to **15** are schematic views showing possible arrangements of the grooves for absorbing thermal expansion which are formed on the cover plate of the invention;

FIG. **16** is a sectional view of one embodiment of the present invention during its operation; and

FIGS. **17** and **18** are schematic views of possible configurations of the bottom of the cooking pot of FIG. **16.**

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, and more particularly to FIG. **1** thereof, there is illustrated a sectional view showing the structure of the induction heating apparatus according to this invention, wherein a body **1** of the apparatus comprises an exciter **2** and a cover plate **3.** Exciter **2** comprises an iron core **2**a and a winding **2***b*. The cover plate **3** is made of a high resistant nonmagnetic metal, preferably, for example, a stainless steel plate. The apparatus **4** comprises a cooking pot or similar utensil to be heated by the body **1.** The apparatus **4** is preferably made of a metal having a high calorific value due to induction heating, such as, for example, copper, iron, or the like. When the excitation of the apparatus is achieved by utilizing the standard line frequency or the like, it is preferable to utilize a copper-iron plate, which may comprise a copper plate having a thickness of about 0.2 – 1.7 mm layered on the outer surface of an iron plate having a thickness of about 0.1 – 2.0 mm.

FIG. 2 shows one embodiment of a cover plate **3** which may be constructed by welding two pieces of stainless steel plates **3***a* and **3***b*, each having a different thickness. Plate **3***a* preferably has a thickness of 3 mm or less, and plate **3***b*, suitable for supporting plate **3***a*, has a hollow near its center in which the exciter **2** may be inserted. The reference numeral **5** designates a gap between the cover plate **3** and the exciter **2.**

In FIG. **3,** the cover plate **3** comprises a unitary piece of stainless steel and the central hollow, similar to that shown in FIG. **2,** is provided for easy passage of the magnetic flux. Thus, in FIGS. **2** and **3,** there are shown structures for insulating thermal transmission wherein the gap **5** between the cover plate **3** and the exciter **2** comprises an air layer.

In FIG. **4,** between the cover plate **3** and the excitation device **2** is inserted a thermal insulation material **6** which has poor thermal conductivity as well as heat-resistance, and may comprise, for example, a polytetrafluoroethylene or glass-wool material or asbestos so as to insulate thermal transmission between the exciter **2** and the cover plate **3.**

In this invention, a stainless steel plate is preferably used for the cover plate **3.** It will be apparent from the following explanation that such a stainless steel plate is probably the best and almost the sole material suitable as a high-resistant non-magnetic metal.

The necessary pre-requisites for selection of the cover plate **3** are that:

1. It be a high resistant non-magnetic material;
2. the distance between the apparatus **4** and the exciter **2** be maintainable at less than a few millimeters;
3. it can withstand heat up to 500°C;
4. its structural strength be sufficiently great; and
5. the temperature in the cover plate **3** be less than 60°C except the portion in contact with the apparatus **4.**

The first condition ensures sufficient permeation of the alternating field generated by the exciter **2** to the bottom of the apparatus **4.** When a stainless steel plate is used, the permeating depth of the alternating field of a standard commercial frequency is very large, that is, a few tens of millimeters, so that in the case of a plate having a thickness less than 1 mm, the magnetic path formed by the exciter **2** and the apparatus **4** will not be interrupted (for example, utilizing the copper-iron plate including the copper plate of 0.2 mm – 1.7 mm thickness). Therefore, it is possible to obtain calorific values the same as in induction heating apparatus in which a cover plate of non-metallic material, e.g., glass, is used.

Further, it is necessary that the resistance of the cover plate **3** be as large as possible when compared with the resistance of the apparatus **4** in order to reduce the calorific values due to eddy-currents in the cover plate **3.** Stainless steel has a high specific resistance which is several times larger than that of the heated material (for example copper), and the calorific value formed by eddy-currents flowing into stainless steel is rather small, that is, only 2–3 percent of the calorific value of the heated apparatus. Therefore, the efficiency of the induction heating apparatus is not reduced.

The second condition enumerated above ensures that a large amount of magnetic flux is transferred into the bottom of the heated apparatus **4** by leaving a small distance between the exciter **2** and the heated apparatus **4.** It is known that it is difficult to obtain high electric efficiency unless said distance is theoretically less than few millimeters.

The third condition is necessary for ensuring high durability against the heat, which varies instantly. If this condition simply protects against melting at high temperatures, it is possible to use glass materials. However, glass is not preferable from the viewpoint of breakage which may result if a glass heated apparatus **4** were to accidentally fall onto the cover plate **3.** Obviously, a metallic material provides greater durability than glass.

The fourth condition is self-evidently for providing a material and construction which should not be damaged by accidents or the like.

The fifth condition is necessary for safety reasons, to ensure that the temperature of the parts, other than the heated apparatus, are kept low so that one will not be injured by coming in contact with the cover plate **3.** For this purpose, it is necessary in certain cases to prevent the heat from the exciter **2** from directly reaching the cover plate **3,** and also it may be necessary to lower the transmission of the heat of the heated apparatus **4** onto the cover plate **3.** As for the former, it is necessary to provide thermal insulation between the cover plate **3** and the exciter **2.** For this purpose there are two means, the first of which ensures a distance of less than few millimeters is maintained between the exciter **2** and the cover plate **3** so that they will not contact each other. The other means provides that thermal insulating materials, such as glass-wool, polytetrafluoroethylenes, or asbestos, are inserted into the gap in a flat shape or in a concentric annular shape, or in a dotted shape as seen in the drawings.

On the other hand, as for the latter requirement, from a thermal point of view, it is desirable to make the thickness of the cover plate at the contact portion of the heated apparatus and the cover plate as small as possible, while it is also necessary to support the weight of the heated apparatus **4** and materials contained in said apparatus (materials to be cooked). Accordingly, a thickness of 1 mm – 0.3 mm of the plate comprising an even metallic material is required.

A material which satisfies the above five conditions is, practically speaking, a stainless steel plate having less than **1** mm thickness. However, even if the thickness of the stainless steel plate is more than 1 mm, it may suffice in practical use.

As explained above, in accordance with this invention, by using a high resistant non-magnetic metal plate, especially a stainless steel plate, as an insulating material between the exciter and the heated apparatus, it is possible to obtain an insulating material which has high thermal resistance and high strength of structure and thus to obtain an induction heating apparatus which is of high practical value.

The flat cover plate as described above has great advantage as a cooking apparatus from the viewpoint of having a beautiful appearance and cleanliness. However, in the case of partially overheating a thin cover plate, there is a risk of causing a camber-deformation due to heat strain. Such camber-deformation from heat strain is due to the fact that during the inductive heating of the cooking pot **4** through the exciter **2,** a part of the heat generated on the bottom of said cooking pot is transmitted through the cooking pot to the cover plate **3,** so that the temperature of the portion making contact with the cooking pot **4** may become higher than that of the part not making contact therewith. In other words, because of the temperature gradient in the cover plate **3,** only the part thereof making contact with the cooking pot **4** expands in comparison with the other peripheral parts thereof. Since the coefficient of linear expansion of stainless steel is $16.4 \times 10^{-6}/°C$, when a temperature difference of 100°C exists, a strain of 1.64×10^3 will be imparted to the cover plate **3.** As a result, the cover plate **3** expands upwardly or downwardly in a convex shape at its central portion that contacts the cooking pot, so that it may be deformed. Due to such a deformation, the cooking pot **4** separates from the exciter **2,** thereby causing a lower efficiency of the induction heating cooking apparatus or an increase its vibration and noise, or both.

Referring now to FIG. **5,** one embodiment of a cover plate according to this invention, in which thermal deformation produced in the flat stainless steel plate can be prevented, is illustrated. The cover plate **3,** the general surface of which is flat in shape, comprises a concave groove **8** which is of concentric annular shape with its center position located where the cooking pot contacts therewith. One or more such concave-grooves **8** are provided for absorbing the thermal expansion of cover plate **3.** The shape, size, number and arrangement of such thermal expansion absorbing grooves are determined by considering such factors as the temperature gradient generated on the cover plate **3,** the coefficient of linear expansion of the cover plate, the attaching state of the cover plate, and the like.

FIG. **6** shows the condition of the thermal expansion absorbing concave groove **8** of the cover plate of the induction heating cooking apparatus according to this invention under normal conditions (no expansion), while FIG. **7** shows the condition of the groove **8** under thermal expansion. As shown in FIG. **7,** when elongation is produced, as represented by arrows **9,** due to thermal expansion of the cover plate **3,** the thermal expansion absorbing concave groove **8** absorbs said elongation by deforming as can be seen by comparing FIG. **6** and FIG. **7.**

FIGS. **8 – 11** show other embodiments of various shapes of a thermal expansion absorbing groove according to the present invention, all being provided with a cover plate **5.** Illustrated in cross-section is a V-shaped groove in FIG. **8,** a concave shaped groove in FIG. **9,** an S-shaped groove in FIG. **10,** and an upward convex-shaped groove in FIG. **11.**

FIGS. **12 – 15** illustrate examples of various arrangements of the thermal expansion absorbing grooves in a cover plate **3** which may be utilized according to this invention. FIG. **12** shows a cover plate **3** having the grooves **8** arranged concentrically. FIG. **13** shows a cover plate **3,** having the grooves arranged concentrically and radially. FIG. **14** shows a cover plate **3** having a twisted radial groove arrangement, while FIG. **15** illustrates a cover plate having a rectangular groove arrangement.

As described above in accordance with the embodiments depicted in FIGS. **5–15,** the present invention provides an induction heating cooking apparatus which is stabilized in heat efficiency and has very little noise since, even though heat strain is caused by the heat of the cooking pot being transmitted to the cover plate, the deformation caused thereby does not affect the cover plate, but is absorbed by the thermal expansion absorbing groove.

The use of such a cover plate provides further advan-

tages in that is it possible to place the cooking pot **4** on a predetermined position of the apparatus **1** without having to pay special attention to the apparatus during operation and also for maintaining its position during heating for optimized cooking. FIG. **16** shows the construction of one embodiment in such a case, wherein the reference numeral **4*b*** designates a projection provided at the bottom of the cooking pot **4*a*,** and **8** designates a circumferential groove provided on the cover plate **3.** In this embodiment, at the outside of the bottom portion of the cooking pot **4**a, a projection **4*b*** is located in three positions so as to fit into the circumferential groove **8** provided on the cover plate **3.** When the cooking pot is to be placed on the apparatus for initiating the cooking operation, the cook may simply slide the pot towards the center of plate **3** so that the projections **4**b at the bottom of the cookpot will engage the circumferential groove **8** of the cover plate **3.** Thus, it is possible to effect easy positioning. If the cooking pot **4** has revolutional symmetry, it is not necessary to position it with regards to its revolution.

Various shapes of projections may be provided, such as the projections of hemispherical shape **4**b as shown in FIG. **17,** the projections of circular arc-stick shape as shown in FIG. **18,** and so on. The size thereof is preferably selected to fit completely into the circumferential groove. In practical use, the projections of hemispherical shape or circular arc-stick shape have a radius of about 1 mm – 5 mm. Thus, as in the case of providing projections at three points, the cooking pot can be positioned on the table with very good stability.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by letters Patent of the United States is:

1. An induction heating apparatus, which comprises:

an exciter for generating an alternating magnetic field for induction heating apparatus by electromagnetic induction of said alternating magnetic field;

a high resistant non-magnetic substantially flat metal plate placed between said exciter and said heated apparatus;

thermal insulating means placed between said exciter and said non-magnetic metal plate for insulating thermal transmission therebetween; and

at least one concave grooved means of substantially circular configuration formed in said non-magnetic metal plate for substantially defining therewithin the zone of said non-magnetic metal plate which is in contact with said heated apparatus and for separating said zone from the portion of said non-magnetic metal plate which is not in contact with said heated apparatus, the temperature gradient existing between said zone and said portion of said plate creating a thermal strain within said plate which may consequently be absorbed by said grooved means.

* * * * *