

- [54] **ELECTRIC HEATING UNIT**
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- [73] Assignee: **Corning Glass Works**, Corning, N.Y.
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- [58] Field of Search ..... **219/216, 385, 432, 464, 219/522, 528, 543, 541; 338/212, 308, 309; 106/39, 52**

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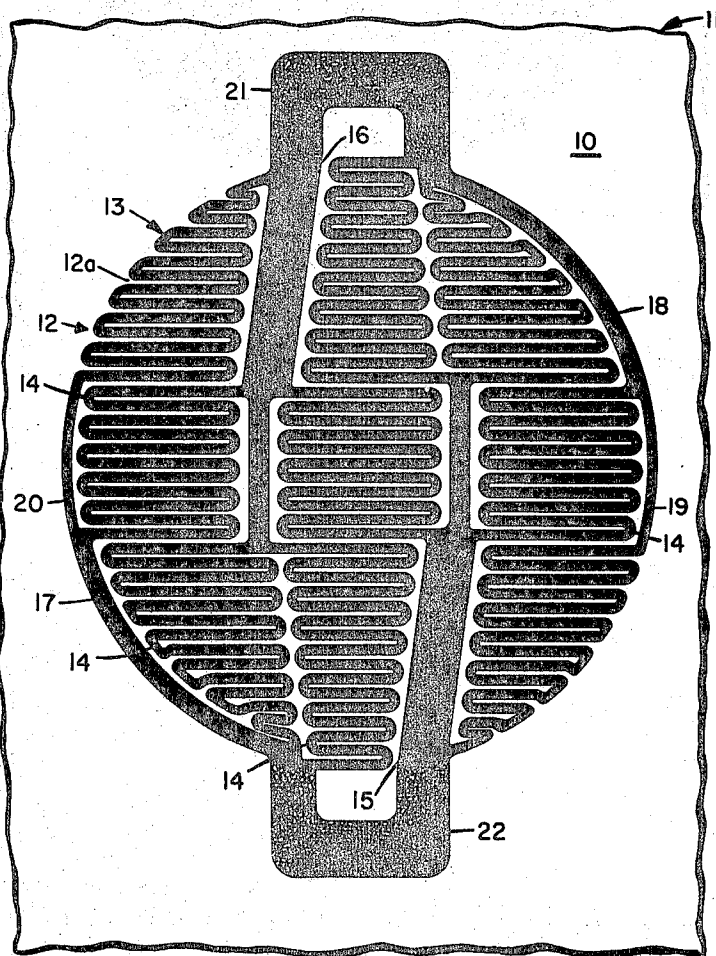
[57] **ABSTRACT**

An electric heating unit including a flat, smooth sheet or plate of a glassy material on the upper surface of which vessels are to be placed for heating or cooking purposes. A portion of the plate is selected as a heating portion and the lower surface of the selected portion is divided into a plurality of selected areas of generally equal areal expanse. There is bonded to or deposited on the surface of each selected area a sinuous or undulate pattern or strip of a thin film electrical resistance heating material having a linear positive temperature coefficient of electrical resistance, such strips being generally equal to each other in width and length to provide the strips with generally equal electrical resistances. A plurality of additional strips of the resistance material are also deposited on or bonded to the lower surface of the burner or burner portion and selectively connect with each other and with the sinuous strips to provide electrical bus bars which electrically connect the sinuous strips in parallel or multiple with each other, such additional strips being graded in width to maintain electrical power to all of the sinuous strips the same under normal cooking or heating conditions.

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4 Claims, 2 Drawing Figures



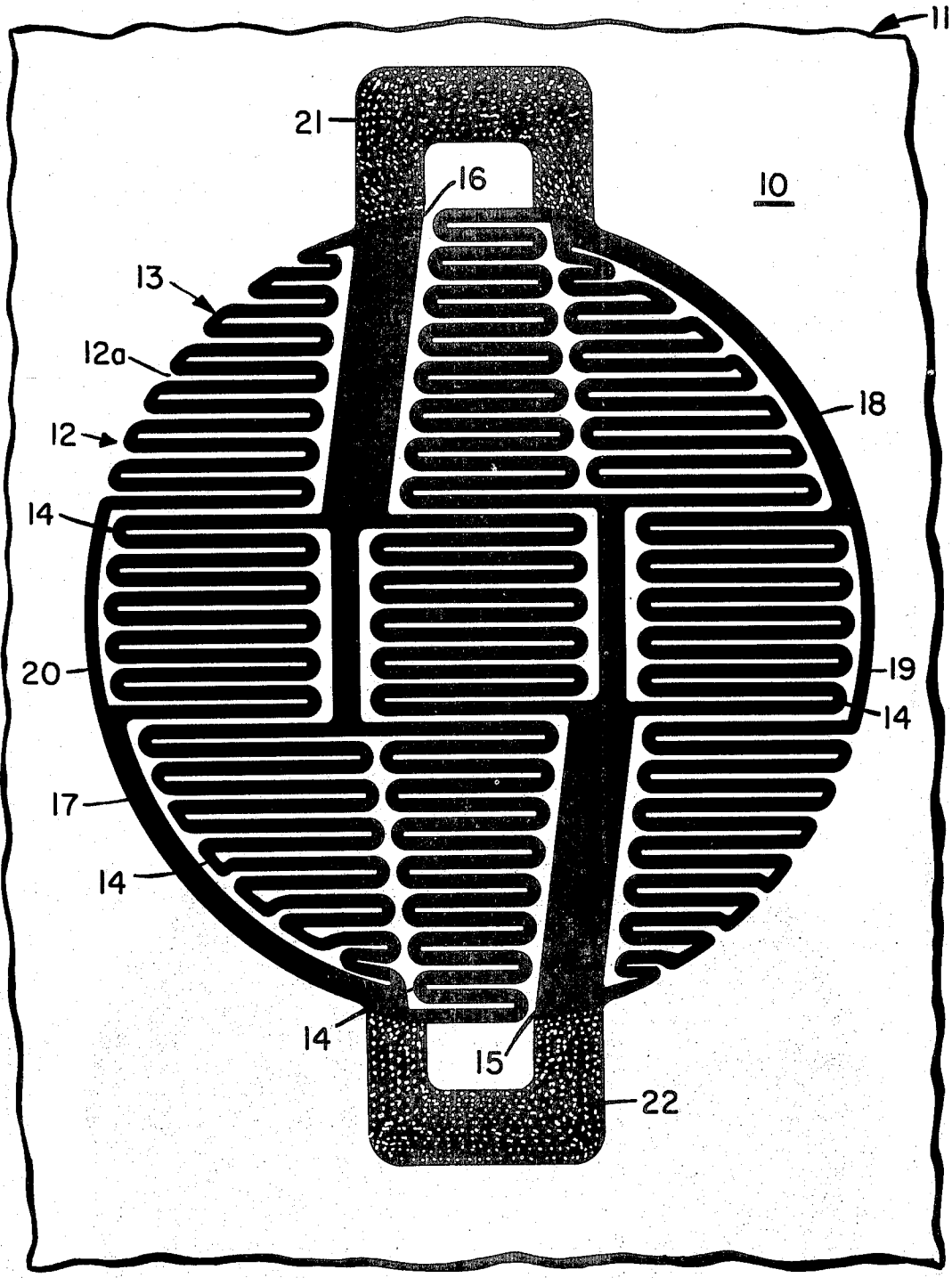


Fig. 1

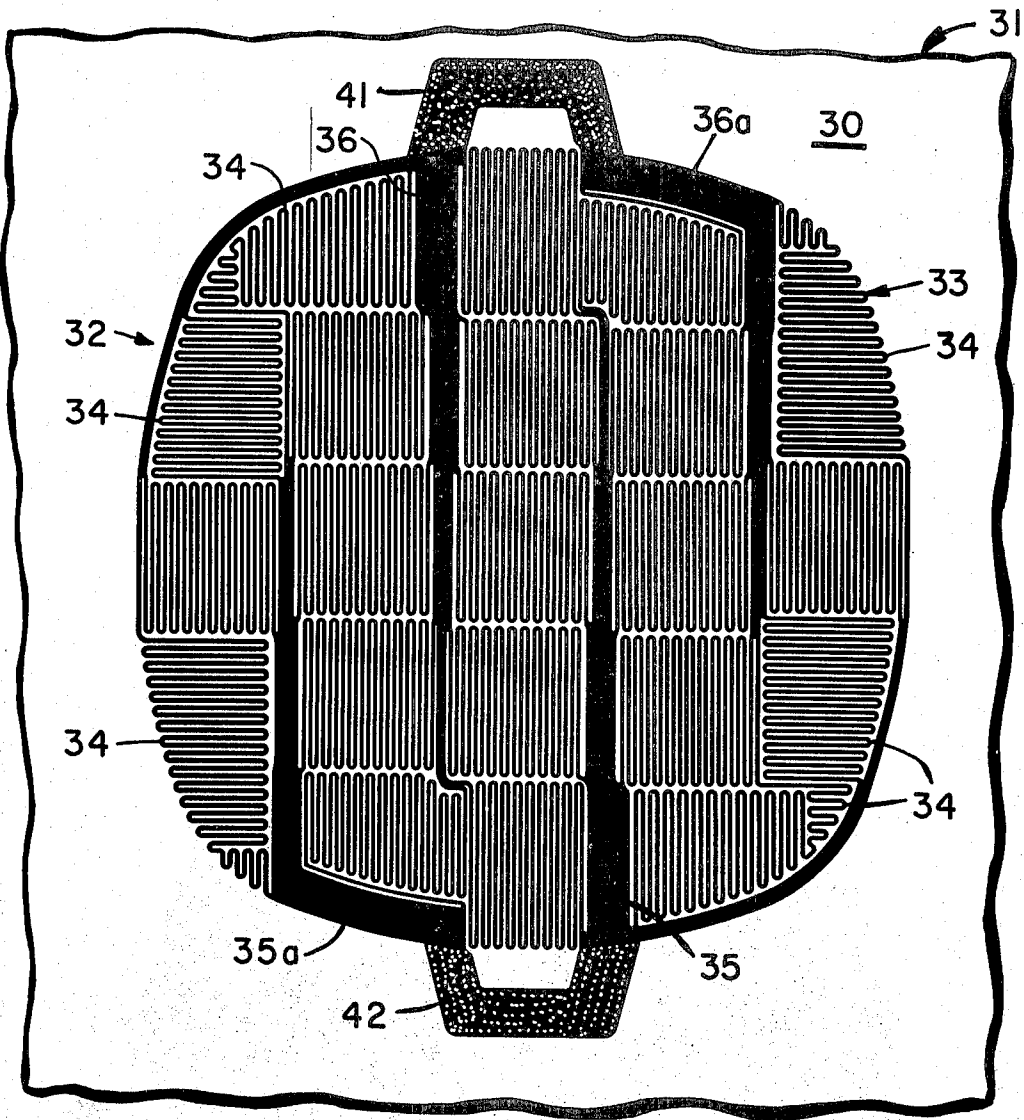


Fig. 2

## ELECTRIC HEATING UNIT

## BACKGROUND OF THE INVENTION

There is shown in FIG. 1 of U.S. Pat. No. 3,067,315, issued Dec. 4, 1962 to Bohdan Hurko, a serpentine shape heating element 12 which is deposited on and/or bonded to the underside of a base plate 11 of a glassy material to provide a heating portion of such material. If, for example, a heating element having a configuration such as said element 12 comprises a single uniform width conductor and is formed of a material having a linear positive temperature coefficient of electrical resistance so that the element may be used as its own temperature sensor as disclosed in my copending application, Ser. No. 345,719, filed Mar. 28, 1973 for Temperature Control Systems and assigned to the same assignee as the present application, electrical current supplied to the heating element or conductor such as 12, as from a 120V alternating current source such as shown in FIG. 1 of said copending application, would be the same in all sections of the current path of the heating element. The power density per unit of area  $A$  ( $I^2R/A$ ) of the heating element would be uniform only when the resistance is the same for all equal length increments of said current path. The outer regions of a heating element, because of lateral heat flow outward from such regions, generally run cooler than the central region of the heating element and, with a heating element having a positive temperature coefficient of electrical resistance, an increase in the resistance in the central region of the heating element results. This, in turn, results in an increase in power density in the area of the central region of the current path of the heating element which is well above the average for the whole area of the heating element. (Average power density =  $E^2/R_T A_T$  wherein  $R_T$  = total resistance  $A_T$  = total area.) Such increase in power density is somewhat self-limiting due to an increase in heat transfer by infrared radiation from the heating area of the plate 11, referring in this instance to the aforesaid patent to Hurko. However, without a complex grading or changes of the heater element width from central to outer areas thereof, it is not known how to attain both uniform temperature and power density with a single uniform width heating element. Furthermore, although heating elements with such grading thereof have been made, the power density therein can change with flat bottom cooking vessels used on a heating portion of a heating unit such as discussed above in conjunction with the aforesaid Hurko patent, if and when such flat bottom cooking vessels are not centered over said heating portion, or if or when reflective aluminum vessels or other similar vessels having dented or domed bottoms, or other similar vessels are used on heating portions of the class discussed.

As a first specific example, a water-filled flat bottom vessel covering all of the heating area of a heating unit such as discussed above may hold a heating element temperature down to a region of 450°C at a power density of 38 to 40 watts per square inch when a temperature control system such as that disclosed in the aforesaid copending patent application is used for temperature control of said heating element. Such temperature is well below that at which control action by said temperature control system will take place. However, now assuming said vessel is positioned off center so as to

cover only about 70 percent of the heating area, the temperature of the uncovered portion of such area will rise due to the increase in resistance to thermal transfer from said uncovered portion of the heating area. The increase in element temperature will lead to an increase in electrical resistance in the uncovered area and in turn to a shift of power toward such uncovered area and an even further increase in temperature to unsafe levels, that is, to levels which may cause damage to the heating element per se or to its supporting base or plate, or to both. Assuming now that a domed-bottom aluminum vessel, for example, is used on said heating area, there is reasonably good transfer of heat by conduction from the heating area to the vessel in a peripheral ring section of the vessel bottom. However, in the central area of the vessel bottom there is no contact with the heating area hence heat transfer to the vessel occurs rather poorly by infrared radiation. Consequently, the temperature of the element in that area which is under the central area of the vessel increases thereby leading to a power shift toward that area and a consequent further increase in element temperature. The increase in power density amounts to 10 to 20 percent in typical cases and leads to temperatures far exceeding recommended safe limits and such as may cause damage as mentioned above. It is, accordingly, an object of the present invention to provide an electric heating unit of the class described and which is provided with a heating element which will reduce the above discussed unsafe conditions to the maximum extent possible.

It is another object of the present invention to provide a heating unit which provides for the highest practicable efficiency of heat transfer from a heating element to a cooking or heating surface of a plate of a glassy material and, therefore, economy of operation of the unit to the greatest extent practicable.

Other objects and characteristic features of the invention will become apparent as the description proceeds.

## SUMMARY OF THE INVENTION

An adequate brief summary of the invention is believed to be set forth in the foregoing abstract of the disclosure and, therefore, for the sake of brevity and in order to prevent repetition or redundancy, no further summary of the invention is considered necessary nor is any given.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a plan view of the lower surface of a first embodiment of a heating unit employing the invention disclosed, and

FIG. 2 is a view similar to FIG. 1 and illustrating a second embodiment of a heating unit employing the invention disclosed.

## PREFERRED EMBODIMENTS OF THE INVENTION

Referring to FIG. 1 of the drawings, there is shown the lower surface 10 of a plate 11 of a relatively thin, heat resistant, high dielectric glass-ceramic or glassy material having high mechanical strength, good abrasion and thermal shock resistance, and flat and smooth upper and lower surfaces, plates of such characteristics being now well known in the art. A portion 12 of said

plate is selected as a heating portion for one embodiment of the heating unit disclosed and the lower surface 12a of such portion 12 is provided with an electric heating element 13 having characteristics and configurations such as discussed below. Said portion 12 is shown as being circular but such portion may have other shapes if desired.

There is deposited on or bonded to the lower surface 12a of portion 12 of lower surface 10 of plate 11 a plurality of sinuous or undulate thin film strips such as 14 of an electrical resistance material having a linear positive temperature coefficient of electrical resistance with each said strip, such as 14, being deposited on or bonded to an associated area of said lower surface 12a of portion 12, and with each such area being of an areal expanse generally equal to each of the others of such areas, each of said strips being generally equal to each other in length and width with the undulations thereof spaced equally apart. Nine of said strips such as 14 are shown in FIG. 1 but the number of such strips can be slightly reduced or substantially increased if found expedient or desirable to do so. Said portion 12 may, for example, be about 6 inches in diameter, and the width of each of said strips such as 14 may, for example, be nominally 0.110 inch.

There is also deposited on or bonded to the lower surface 12a of said portion 12 a plurality of thin film electrical buses or bus bars such as 15 through 20 which are of the same material as the strips such as 14. It will be noted that the buses or bus bars are graded in width in a stepwise manner, that is, bus bars 15 and 16 are the widest of the bus bars and bus bars 19 and 20 are the narrowest, with bus bars 17 and 18 being intermediate in width. Such buses or bus bars will be discussed further hereinafter. However, it is believed expedient to point out at this point that the strips such as 14 and the bus bars such as 15 through 20 are preferably applied to lower surface 12a of heating portion 12 by the well-known silk-screen process and are subsequently subjected to a heat treatment to make the strips and bus bars an integrant part of plate 11. However, other well-known methods of deposition of the strips and bus bars to lower surface 12a of a heating portion such as 12 can be employed if found expedient or desirable.

There is also shown in FIG. 1 a pair of electrical terminals 21 and 22 which are intended to be connected to first and second terminals, respectively, of a source of current suitable for energizing the heating element 13 and which may, for example, be the 120V alternating current source shown in FIG. 1 of the drawings of my aforementioned copending application Ser. No. 345,719. A heating element such as 13 can, of course, be connected to the first and second terminals of a 240V alternating current source or any other suitable source of electrical power by changing the parameters of the strips such as 14 and the bus bars such as 15 through 20, and/or the composition of the material of such components, as is believed will be readily apparent to those skilled in the art. The terminals 21 and 22 may, for example, also be applied to the lower surface of plate 10 by the silk-screen process such as mentioned above.

Returning to the electrical buses or bus bars 15 through 20, it will be noted that aforesaid terminal 21 connects with a first end of medium width bus bar 18 and with a first or one of the ends of wide bus bar 16.

The second end of bus bar 18 connects selectively with first ends of two of the strips such as 14 and the second end of bus bar 16 connects with first ends of two of the strips such as 14 and with a first or one end of another bus bar of intermediate width and whose second end connects selectively with first ends of two others of the strips such as 14. The second end of bus bar 18 connects selectively with first ends of two of the strips such as 14. Similarly, the aforesaid terminal 22 connects with a first end of medium width bus bar 17 and with one or a first end of wide bus bar 15. The second end of bus bar 17 connects selectively with second ends of two of the strips such as 14, and the second end of bus bar 15 connects with second ends of two of the strips such as 14 and with a first or one end of still another bus bar of intermediate width and whose second end connects selectively with first ends of another two of the strips such as 14. The second end of bus bar 17 connects selectively with second ends of two of the strips such as 14. Bus bars 19 and 20 connect selectively with bus bars 18 and 17, respectively, and to a first end of each of the strips such as 14 as mentioned above. The second ends of these latter strips connect selectively with the first ends of bus bars 16 and 15 at points adjacent terminals 21 and 22, respectively.

By the electrical connections described above it will be apparent that heating element 13 and terminals 21 and 22 are disposed on plate 10 so that such components are reversibly or reversely bisymmetrical on opposite sides of any median line extending through the center of heating portion 12. That is to say, taking any median line extending through the center point of portion 12 (or surface 12a) the half of portion 12 on one side of the taken median line (including those parts of the strips such as 14, the bus bars 15 through 20 and the terminals 21 and 22 on such side of the taken median line) will be seen to be geometrically congruent with the half of portion 12 on the other side of the taken median line if or when either one of the halves is rotated 180° relative to the other half in the plane of the area of portion 12. It is, however, pointed out that said portion 12 and its associated thin film components need not necessarily be bisymmetrical, as discussed, but it is expedient to make it so for the purpose of attaining equal electrical resistance in each of the circuit paths of heating element 13.

The buses 17, 18, 19, and 20 in the peripheral areas of the burner are designed to have essentially the same power density as each of the said strips such as 14. The buses 15 and 16, as well as the intermediate width strips connecting with second ends of such buses 15 and 16 in the central region, are designed to operate at a lower power density such as, for example, 85 percent of that for each of said strips such as 14. The lower power density for buses 15 and 16 is for the purpose of allowing for power density increases in these buses such as previously mentioned, that is, for example, for conditions of off-center placement of a flat bottom water-filled vessel. As an example, at such a time, the greatest temperature rise in bus 16 would occur when said vessel is positioned to cover all or a substantial part of the areas of surface 12a of portion 12 which are heated by the strips such as 14 which are connected to bus 16 while, at the same time, the areas occupied by and/or surrounding bus 16 are not covered by said vessel. Such an aforesaid 85 percent power density factor for the central bus such as 16 is applicable when using an ele-

ment material which has, for example, a resistance at 450°C which is nominally 1.5 times the resistance of said element material at 20°C and thereby, results in a bus temperature, during the off-center vessel condition, that is nearly identical to the temperature of the strips such as 14. Of course, heating element materials which have higher or lower positive temperature coefficients of electrical resistance would require the employment of power density factors lower and higher, respectively, than 85 percent.

Before briefly describing the embodiment of the invention of FIG. 2 of the drawings, the following further discussion in relation to FIG. 1 is considered expedient.

The strips such as 14 are arranged to be electrically connected in multiple, that is, in parallel across an electrical power source, and the major portion of the conductor path of each individual ones of said strips is confined to a selected small area of the total area covered by the heating element (excluding the area covered by terminals 21 and 22) with each such selected area being of an areal expanse substantially equal to each of the others of such selected areas. The current in each strip such as 14 is common to current in each of the other of such strips only in the relatively short lengths of common supply buses. Consequently, the current in each strip such as 14 is, normally, generally independent of the current in each of the other of such strips. Thus, when the temperature of an individual strip tends to rise, because of poor heat transfer to a vessel or to ambient for reasons such as previously discussed, the resistance,  $R_x$ , of that strip increases and the power density of such strip decreases according to the applicable relationship  $P = E^2/R_x$ . Therefore, rather than a power density increase of 10 to 20 percent which would result in a single conductor heating element as previously discussed, a decrease of 10 to 20 percent will result.

Referring now to FIG. 2 of the drawings, there is shown a 21 section heating element, that is, a heating element 33 having 21 electrical resistance heating strips such as 34 and a plurality of electrical buses or bus bars which are graded in width in a manner similar to that in which the buses or bus bars 15 through 20 of FIG. 1 are graded, that is, in a stepwise manner. The width of each of the strips such as 34 may, for example, be 0.046 inch and the total area covered by such strips on the order of 66 square inches. Heating element 33 may, for example, have an electrical resistance of 0.35 ohms per square and be energized from a 240V source of alternating current. However, as with heating element 13 of FIG. 1, the parameters of element 33 may be changed so as to be energized from any suitable source of current as will be readily apparent to those skilled in the art.

The foregoing discussion of the embodiment of the invention of FIG. 1 of the drawings is similarly applicable to the embodiment of FIG. 2 of the drawings and it is additionally pointed out that parts and/or components 30 through 42 of FIG. 2 respectively correspond to the parts and/or components 10 through 22 of FIG. 1. However, FIG. 2 includes a pair of electrical buses or bus bars 35a and 36a of which corresponding ones do not appear in FIG. 1 of the drawings but which are stepwise graded in width similarly to bus bars 35 and 36. A detailed discussion of the operation of the embodiment of the invention shown in FIG. 2 is believed

not to be necessary in view of the previous description and, therefore, in order to keep the disclosure as brief as practicable, no additional discussion will be given.

Although there is herein shown and described only two embodiments of the invention disclosed, it will be understood that various changes and modifications may be made therein within the scope of the appending claims without departing from the spirit and scope thereof.

I claim:

1. An electrical cooking unit comprising:

I. a thin plate of a glassy material and having flat and smooth upper and lower surfaces with a portion of said plate selected as a heating portion upon whose upper surface vessels are to be placed for cooking purposes;

II. a plurality of areas of the lower surface of said heating portion selected to have generally equal areal expanses and having deposited thereon undulate and relatively narrow continuous strips of metallic thin film of an electrical resistance material of a linear positive temperature coefficient of electrical resistance, all of said strips being generally equal to each other in length and width and in spacing between the undulations of each respective strip to normally provide equal electrical resistance to each said strip;

III. a plurality of metallic thin film conductors of the same material as said strips and deposited on said lower surface of said heating portion, first ends of such conductors selectively connecting with each other and with the ends of said strips to provide electrical bus bars for a selected number of the strips and such bus bars being graded in width accordingly as the number of the strips with which each respective bus bar connects increases and decreases to thereby, provide equivalent electrical resistance feeds to each of said strips; and

IV. a pair of metallic thin film terminals of a low electrical resistance material deposited on the lower surface of said plate, first and second ones of such pair of terminals electrically connected to selected first and second ones, respectively, of the second ends of the wider ones of said bus bars.

2. An electrical cooking unit as in claim 1 and in which said heating portion of said plate is circular and such portion, including said strips and conductors, is reversibly bilaterally symmetrical on opposite sides of any median line passing through the center of the heating portion.

3. In combination with a flat and smooth thin glass-ceramic plate for a cooking unit having a portion thereof selected to provide a heating portion having an upper surface for supporting vessels for cooking purposes, a heating element bonded to the lower surface of said selected portion of said plate, such element comprising:

I. a plurality of sinuous strips of an electrical resistance heating material having a linear positive temperature coefficient of electrical resistance, each said strip being bonded to an associated area of said lower surface of said portion with each such area being of an areal expanse generally equal to each of the others of such areas and each of said strips being generally equal to each other in length and width with the undulations thereof generally spaced equally apart;

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II. a plurality of electric bus bars formed of the same material as said strips and bonded to areas of said lower surface of said portion, said bus bars having first ends selectively connected with each other and to selected first ends of said strips to connect the strips in an electrical parallel relationship with each other and the bus bars being graded in width to provide electrical feed paths of equal electrical resistance for each of said strips; and

III. first and second low resistance electrical terminals connected to the second ends of the wider

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ones of said electrical bus bars for supplying electrical power equally to each of said strips.

4. A plate and heating element in accordance with claim 3 and in which the total area of said heating portion is generally circular in configuration and in which said strips, electrical bus bars, and terminals are reversely bisymmetrical on opposite sides of any median line extending through the center of the total portion area.

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