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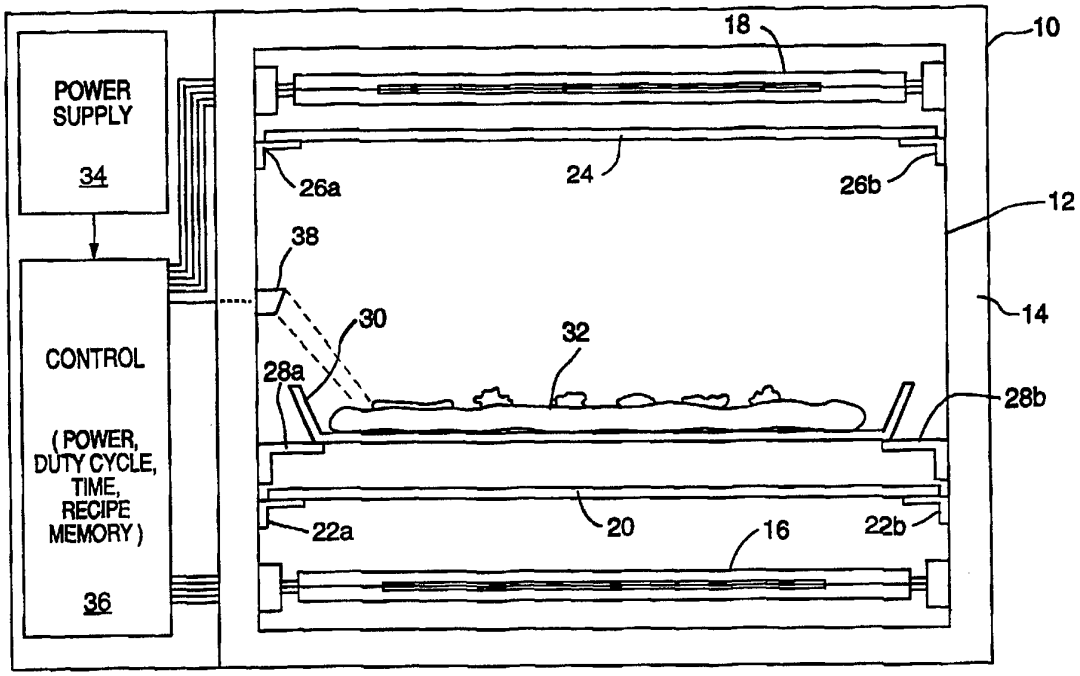
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(54) Title: METHOD AND APPARATUS OF COOKING FOOD IN A LIGHTWAVE OVEN



(57) Abstract

A lightwave oven (10) cooking method and apparatus using pulsed power to a plurality of high power lamps (18a-18e, 16a-16e) provides visible and near-visible wavelength radiant energy wherein power is applied to the lamps (18a-18e, 16a-16e) for a time period without vaporizing all suface water on the food, then reducing irradiation to complete the cooking cycle avoiding significant surface browning which inhibits deep penetration in the food in the near-visible and visible ranges. Reduction in power is achieved by reducing the duty cycle in steps or continuously.

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METHOD AND APPARATUS OF COOKING FOOD IN A LIGHTWAVE OVEN

Cross References to Related Applications

This application is a continuation-in-part of U.S. Patent application serial No. 738,207 filed on July 30, 1991, which was a continuation-in-part of U.S. Patent application serial No. 350,024 filed on May 28, 1989, now U.S. Letters Patent No. 5,036,179 issued July 30, 1991, and a continuation-in-part of U.S. patent application serial No. 769,370, filed October 1, 1991, which was a continuation of U.S. patent application serial No. 664,494, filed March 5, 1991 (now abandoned), which was a continuation of U.S. patent application serial No. 195,967, filed May 19, 1988 (now abandoned).

Field of the Invention

This invention relates to the field of cooking method and apparatus. More particularly, this invention relates to the use of power and pulsed power applied to high-power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges.

Background of the Invention

Ovens for cooking and baking food have been known and used for thousands of years. Basically, oven types can be categorized in four cooking forms; conduction cooking, convection cooking, infra-red radiation cooking and microwave radiation cooking.

There are subtle differences between cooking and baking. Cooking just requires the heating of the food. Baking of a product from a dough, such as bread, cake, crust, or pastry, requires not only heating of the product throughout but also a chemical

reaction coupled with driving the water from the dough in a predetermined fashion to achieve the correct consistency of the final product and finally browning the outside. Following a recipe when baking is very important. An attempt to decrease the baking time in a conventional oven by increasing the temperature results in a damaged or destroyed product.

In general, there are problems when one wants to cook or bake foodstuffs with high-quality results in the shortest times. Conduction and convection provide the necessary quality, but both are inherently slow energy transfer methods. Long-wave infra-red radiation can provide faster heating rates, but it only heats the surface area of most foodstuffs, leaving the internal heat energy to be transferred by much slower conduction. Microwave radiation heats the foodstuff very quickly in depth, but during baking the loss of water near the surface stops the heating process before any satisfactory browning occurs. Consequently, microwave ovens cannot produce quality baked foodstuffs, such as bread.

Radiant cooking methods can be classified by the manner in which the radiation interacts with the foodstuff molecules. For example, starting with the longest wavelengths for cooking, the microwave region, most of the heating occurs because of the coupling of radiant energy into the bipolar water molecule causing it to rotate and thereby absorb energy to produce heat. Decreasing the wavelength to the long-wave infra-red regime, we find that the molecules and their component atoms resonantly absorb the energy in well-defined excitation bands. This is mainly a vibrational energy absorption process. In the near-visible and visible regions of the spectrum, the principal absorption mechanism is excitation of

the electrons that couple the atoms to form the molecules. These interactions are easily discerned in the visible band of the spectra, where we identify them as "color" absorptions. Finally, in the ultraviolet, the wavelength is short enough, and the energy of the radiation is sufficient to actually remove the electrons from their component atoms, thereby creating ionized states. This short wavelength ultraviolet, while it finds uses in sterilization techniques, probably has little use in foodstuff heating, because it promotes chemical reactions and destroys food molecules.

Summary of the Invention

Broadly stated, the present invention is directed to method and apparatus for cooking food in a lightwave oven having a plurality of high-power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges wherein irradiation is applied to the food by applying power to the lamps for a period of time and without vaporizing all of the surface water on the food and then applying reduced irradiation to the food. In accordance with this invention, thick foods can be cooked with deep penetrating visible and near-visible light radiation without producing an overly browned surface which will absorb the radiation at the surface and will reduce the amount of visible and near-visible light radiation which can penetrate deeply into the food.

In accordance with the preferred embodiment of the present invention, the reduced irradiation is produced by applying power to the lamps at a reduced duty cycle which can either be done in a sequence of one or more reducing steps in the duty cycle or a continuous reduction of the duty cycle of the power applied to the lamps.

A feature and advantage of this invention is that water from deep within the food can migrate to the surface and prevent the surface from being heavily browned by infra-red radiation that would then inhibit deep penetration of radiation in the near-visible and visible ranges.

In accordance with another aspect of the present invention, full power is first applied to the lamps for irradiating the food without vaporizing all of the surface water from the food and thereafter power is applied to the lamps at a reduced duty cycle as the flow of water to the surface of the food decreases.

In accordance with another aspect of the preferred embodiment of the present invention, the lamps are turned off or radiation to the food eliminated periodically, preferably in between application of power to the lamps at different duty cycles whereby water is replenished from within the food onto the surface of the food.

In accordance with still another aspect of the present invention, a change in the color or the surface of the food of a given degree is sensed and irradiation of the food then terminated to allow water from within the food to reach the surface of the food.

In accordance with still another aspect of the present invention and as a final step for cooking the food, the duty cycle of the power to the lamps is increased from an operating duty cycle level for browning the food when the desired level of cooking has been accomplished deep within the food or the duty cycle can be established that allows a slow browning reaction throughout the latter portion of the cycle so that final heating and browning occur simultaneously.

By providing a sufficiently intense source of visible and near-visible radiation in conjunction with the longer infra-red radiation over an extended period of time while the duty cycle of the power to the lamps is reduced, a novel and very effective cooking method and apparatus results, especially for cooking thicker foods.

The low absorption of visible and near-visible radiation allows the energy to penetrate the foodstuff and heat it deeply like microwave energy. By contrast the longer infra-red radiation does not penetrate very deeply and acts as a very effective browning agent. By combining these sources of radiation into a single cooking process it is possible to produce a very rapid and highly efficient method of cooking and baking a wide variety of foodstuffs.

Using intense visible, near-visible, and infra-red radiation to cook food has a number of significant advantages. First of all, the cooking process is very fast. Bakery products, like pizza crust for example, can be baked five to ten times faster than ovens that rely on conventional convection and conduction processes only. Large, thick meat and poultry products, such as roasts and whole chickens and turkeys, can be cooked three to five times faster than by convection and conduction processes alone. Second, the quality of the cooking process is enhanced for many foodstuffs. For example, crusts become fully cooked with crispy exteriors and moist, chewy interiors. Vegetables are cooked so fast that they are virtually steamed in their own water vapor, leaving them hot, but with very little loss of any of their nutritive values. Third, the process is very energy efficient. Because the oven has reflective inner walls, a large fraction of the energy produced by the sources is used to cook

the food rather than heat the oven. A pizza can be fully baked for about $.01 of electrical energy.

Additionally, the present invention enables the fast cooking times available with microwave energy but with a more flavorful taste and a more traditional texture and surface coloring as in convection and infra-red cooking.

These and other aspects, features and advantages of the present invention will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein similar characters of reference refer to similar items in each of the several views.

Brief Description of the Drawings

Figure 1 shows a front cross section of a preferred embodiment of the present invention.

Figure 2 shows a side cross section of the preferred embodiment of the present invention.

Figure 3 is a graph showing the approximately inverse linear relationship between cooking power and cooking time.

Figure 4 is a graph showing the constant power-time product for baking a pizza in the oven of the preferred embodiment.

Figure 5 is a graph showing a power-time illustration for applying power at different duty cycles to lamps for radiating a food product with this invention.

Figures 6, 7 and 8 are graphs similar to Fig. 5 showing alternative embodiments of this invention.

Detailed Description of the Preferred Embodiment

Figs. 1 and 2 are front and side cross sectional views of the apparatus of a preferred embodiment of the present invention. The oven in Fig. 1 includes an outer enclosure 10. The enclosure has an inner

wall 12 coupled to the outer wall 10. Ordinarily, an insulating layer 14 is formed between the outer enclosure 10 and the inner wall 12. Because of the inherent speed of the cooking cycle, the insulating layer 14 may be a layer of air.

The present invention has been used to cook pizzas reasonably continuously for an hour in an oven with only air as an insulator. While the exterior of the oven did warm up, it never became too warm to touch comfortably. This is true because the interior walls of the oven are reflective so that a large fraction of the energy is used to cook the food, not heat the oven. Second, a fan is used to pull hot air out of the oven. Though some air is heated directly by the radiation, most of the air is heated by convection from the cooked food. Because the cooking times are so short with the present invention, the hot air is removed to prevent further cooking after the radiation source is turned off.

The energy for cooking is supplied by the lower radiation heating lamps 16 and the upper radiation heating lamps 18. These lamps are generally any of the quartz body, tungsten-halogen or quartz arc lamps commercially available, e.g., 1.5KW 208V quartz-halogen lamps. The oven according to the preferred embodiment utilizes ten such lamps and cooks with approximately forty percent (40%) to fifty percent (50%) of the energy in the visible and near-visible light portion of the spectrum, which is significant. Quartz xenon-krypton arc lamps have been used as an alternate source in which ninety-five percent (95%) of the radiation is below 1 μm and good cooking results have been achieved with their shorter wavelengths.

There is no precise definition for the range of wavelengths for visible light because the perceptive ranges of each human eye is different. Scientific

definitions typically encompass the range of 0.39 μm to 0.77 μm. An engineering shorthand for visible light specifies the range of 0.4 μm to 0.7 μm. The term "near-visible" has been coined for radiation that has wavelengths longer than the visible range, but less than the water absorption cut-off at 1.35 μm. The term "long-wave infra-red" refers to wavelengths greater than 1.35μm.

The inner surface of the inner wall 12 is preferably a highly polished, poorly absorptive surface, so that it appears to be very reflective to the wide spectrum of wavelengths from the radiant lamps. Polished aluminum and stainless steel have been successfully used for the inner wall 12. Plating the inner wall 12, such as with gold, increased the efficiency of the reflector for visible light by about ten percent (10%) over the polished aluminum walls. Two radiation transparent plates 20 and 24 are used to isolate the cooking chamber from the radiant sources making the oven easier to clean as shown in Fig. 3. These plates can be formed from such materials as quartz, glass or pyroceramic that transmit visible, non-visible and infra-red radiations. The lower transparent plate 20 is supported by brackets 22a and 22b and is positioned above the lower lamps 16. The upper transparent plate 24 is supported by brackets 26a and 26b and is positioned below upper lamps 18.

Brackets 28a and 28b support a platter 30 which is positioned above the lower transparent plate 20 and below the upper glass plate 24. A food item 32 is positioned on platter 30 to be cooked.

The platter 30 may formed of a material similar to the transparent plates 20 and 24 to allow even cooking over the surface of the food item 32. However, in some circumstances it may be desirable to crisp the bottom of the food item 32. As a

particular example, when cooking a pizza, it is desirable that the crust be light and crispy, rather soggy and doughy. In such an application, the cooking platter 30 can be formed of a radiation absorbing, heat conducting material, such as black anodized aluminum. In this way, the lower lights 16 would rapidly heat the platter 30 to a high temperature in order to crisp and brown the bottom of the pizza. It may also be desirable to perforate the platter 30 in order to allow steam to escape from the cooking pizza dough. Alternatively, the platter could also be a grill structure. Platter 30 should touch the support brackets 28a and 28b over very limited areas, so that the heat delivered to platter 30 is not lost by conduction.

The lamps 16 and 18 produce very high intensity visible and infra-red radiation. Prior art uses of radiant energy heat sources teach cooking using radiation in the infra-red portion of the electromagnetic spectrum. For example, see Malick U.S. Patent 4,481,405 and Bassett U.S. Patent 4,486,639. Burkhart, in U.S. Patent 4,516,486, discloses a radiant energy cooker for the exclusive purpose of charring the surface of foods, particularly meats.

The use of high intensity visible radiation provides a very rapid method of high quality cooking and baking both alone or in combination with infra-red radiation. The radiant energy from the lamps 16 and 18 radiates from each bulb in all directions. A portion of the energy radiates directly onto the food item 32. The remainder of the energy will be reflected off the surface of the preferably metal inner wall 12 and then strike the food item 32 for more efficient cooking.

A power supply 34 provides the power for the lamps 16 and 18, the operation of which is controlled by a control circuit 36, shown as a circuit block.

It is possible to control the power level and/or duty cycle of each of the lights 16 and 18 independently with the control circuit 36. The control circuit 36, shown as a circuit block in Fig. 3, may include a microprocessor or a microcontroller and associated memory to store individual cooking recipes to control proper heating of the food product.

For example, in cooking a pizza, it may be desirable to run the upper lamps 18 at a reduced power level for a time. For a pizza having fresh vegetables, this would prevent the overcooking of the vegetables making them mushy. The lower lamps 16 might be operated at a higher power level to make the pizza crust light and crispy.

In the preferred embodiment as shown in Fig. 2, there are five lower lamps 16a through 16e and five upper lamps 18a though 18e. By appropriately selecting the lateral spacing between the lamps relative to the food, even cooking can be achieved over the entire surface. A door 40 is also shown.

Experimental results show that cooking with one 1.5KW lamp above and one below, i.e. impinging a maximum of 3KW of radiant energy onto a pizza, does not achieve the dramatic improvement in speed that is possible according to the present invention. The oven in the preferred embodiment includes five lamps above and five lamps below. This number provides for a maximum of 15KW of cooking energy.

Pizza has been successfully cooked using a modification of the present invention with more powerful bulbs using total power in the range in excess of 4KW to approximately 24KW. There appears to be no reason preventing the power ranges in excess

of 20KW. This is a significant advantage of the present invention. Cooking times can be reduced by increasing power. The only way to increase power in a conventional oven is to increase temperature which damages the food.

While cooking a pizza using total power in excess of about 4KW an approximately inverse linear relationship develops between time and cooking power. In other words, as the power delivered to the pizza is doubled, the time to cook a pizza is cut in half. This result is totally unexpected in view of conventional oven baking where increasing oven temperature to achieve a higher energy transfer rate results in a burnt product which may have an uncooked interior.

Fig. 3 is a graph showing the power-time product versus power for baking a pizza in the oven of the preferred embodiment. Note that in the preferred oven the power-time product is constant and has a value of about 470KW-sec.

This cooking in the linear range of the power-time product appears to be a function of both the wavelength of radiation and the amount of power applied. Thus, the specific mechanical configuration of the oven in the preferred embodiment is not critical to the invention. Rather, it is the combination of the lamps that provides at least a significant portion of radiation in the visible and near-visible light range with total radiant power in excess of 4KW and impinging the radiation directly onto the food item of energy which provides the dramatic speed increase of the present invention.

For example, an oven having a reflective inner surface could operate according to the present invention with a single arc lamp capable of producing sufficient power in the desired frequency ranges. In certain circumstances it may be desirable in such a

single source oven to place the food product, such as a pizza, on a highly thermally conductive platter with the lamp positioned above the food item. The amount of heating to the bottom of the pizza can be regulated by heating the platter and by adjusting the ratio of the size of the pizza to the size of the pan. In other words, the amount of exposed area of the pan would control the amount of energy absorbed by the pan used to heat the bottom of the pizza.

Microwave ovens cannot be used in cooking high quality freshly prepared pizza. The commercially available frozen pizzas for microwave ovens are precooked and then frozen. The pizza is merely heated to the proper serving temperature in the microwave oven, but the result is usually unsatisfactory. A higher quality pizza can be baked in a commercial grade conduction/convection oven. There, the pizza is placed directly on the hot floor of the oven to properly crisp the bottom of the crust (up to 900°F in a brick oven). Unfortunately, the ovens have various "hot" spots and require constant operator attention to avoid over or under cooking the pizza, i.e., consistency is a major problem. Such ovens cook a pizza in 5 to 20 minutes. Conveyorized infra-red and hot air convection ovens can cook a pizza in 5 to 15 minutes, but have great difficulty in properly crisping the bottom of the pizza. A pizza can be cooked using the present invention in as little as 30 to 45 seconds. This speed is very important in the commercial pizza market because it enables pizza to be produced in a manner that would qualify it as a true fast-food.

The energy efficiency of the present invention is illustrated by the fact that the energy cost to cook such a pizza is about $0.01. The majority of the radiant energy produced by the oven is utilized in cooking the pizza and after the cooking process is

completed the energy is turned off. In contrast, conventional commercial pizza ovens must be preheated to desired cooking temperatures. Ordinarily, the oven in a pizza restaurant is left on all day, whether cooking a pizza or not, making the energy consumption significant.

In accordance with the present invention, not only thick pizza, but most importantly, thicker and more dense foods such as steaks, roasts, chicken, turkey, etc. are advantageously cooked by time varied pulsing the amount of radiation directed onto the food substance.

With reference to Fig. 5, the power directed to the lamps being used to cook the food in the preferred embodiment is initiated at a maximum or given level 40 for a period of time T_1. At this intensity radiation in the near-visible and visible light range penetrates deeply into the food. The radiation in the infra-red range which does not penetrate deeply into the food is principally responsible for browning the surface of the food which happens typically when you get to 300-400°F. Steam goes off the surface at 212°F so as long as surface water or moisture is present browning will not occur. Browning of the surface inhibits transmission of the visible light therethrough. Therefore, for deep cooking with a lightwave oven in accordance with the present invention it is desired to keep water on the surface the temperature of the surface at or below 212°F as long as possible.

In the initial cooking stage during time period T_1 the combination of radiation in the infra-red, near-visible and visible ranges does not vaporize all of the surface water on the food which includes water migrating to the surface of the food due to the cooking process both at the surface and deep within the food. Thus, the length of time period T_1 is

established by experimentation or otherwise such as by sensing the temperature of the surface and/or the presence of steam and/or a color change in the surface indicative of initiation of the browning process with a sensor 38 to terminate period of time T_1 before all the surface water is removed from the food. Thus, the cooking process is designed so that browning on the outside is well controlled in such a way that browning of the outside surface does not occur before the inside of the food has been cooked. After time T_1, radiation directed to the food is eliminated for a period of time T_2 during which water is replenished from within the food onto the surface of the food. The elimination of radiation is preferably accomplished by turning off the power to the lamps but can also be accomplished by shielding the food from radiation from the lamps.

After the time period T_2 reduced radiation is applied to the food typically by reducing the duty cycle of the power to the lamps (e.g., to fifty percent (50%) duty cycle) for a period of time designated T_3 in Fig. 5. In the preferred embodiment of the invention the power pulses during the reduced duty cycle T_3 are maintained at the same maximum or preset power level 40 for applying the near-visible and visible light to the maximum depth within the food. Since during energization of the typical high-power lamps the percentage of infra-red radiation is the highest, periodically shielding the food from the radiation of the lamps may be preferable under certain circumstances to actually turning off the power to the lamps.

After irradiating the food at a reduced duty cycle during time period T_3, radiation can be eliminated from the food for a another period of time T_4 followed by the application of additional radiation at a second and still lower duty cycle (e.g., for a

ten percent (10%) duty cycle) for a time period T_5. The time periods T_1-T_5 are selected so that the maximum amount of near-visible and visible radiation can pass deeply into the food without being obstructed by the effect of browning of the surface resulting from infra-red radiation applied to a surface with no surface water. The individual time periods can be determined by experimentation in the manner described below, or the time periods can be arbitrarily set based on experimentation with other foods and then used on the given food and kept or adjusted depending on the results.

Depending upon the particular food, the power level and the duty cycle, the elimination of radiation in time periods T_2 and T_4 can be dispensed with so that the time periods T_1, T_3 and T_5 can occur sequentially without intervening time periods T_2 and T_4.

Sensor 38 can be used to monitor the surface of the food and to signal a change in the color of the surface of the food of a given degree so as to then trigger termination of one of the time periods T_1, T_3 or T_5, thereby allowing replenishment of surface water from within the food.

For providing a desired aesthetic brown surface and/or harder surface texture, a final period can be provided with increased radiation to the food surface for time T_6. During time period T_6, the lamps may be restored to full power as indicated in Fig. 5 or the duty cycle from time period T_5 can be increased to the duty cycle of time period T_3 or some other duty cycle 6.

By way of example, experimentation for cooking with the present invention to establish a preferred cooking recipe for a given food can proceed as follows. You take an example of the food made up of the specified ingredients, such as for a muffin, and

you place that food in the oven and turn on the lamps at full power for a first very long time period T_1 which is much longer than it typically will take and watch the cooking process to observe when the surface begins to brown. In the case of a muffin cooked with a lightwave oven of this invention, usually by 30 seconds you see that the surface is starting to brown. You then provide a safety factor by subtracting a number of seconds, for example five seconds, from the time at which browning was first noticed to establish the first time period T_1 for the muffin cooking recipe. You then put another muffin in the oven and follow the cooking cycle with T_1 equal to 25 seconds and then a prolonged reduced duty cycle (i.e., fifty percent (50%)) for a prolonged time period T_3. When you observe the muffin starting to brown during time period T_3, you stop the cooking cycle and subtract a number of seconds, for example five, from the shortened time period T_3 and then proceed with a third muffin to determine the time period T_5 until a muffin properly cooked and properly browned is achieved. Then this final cooking recipe of selected times T_1, T_3 and T_5 is utilized and can be adjusted if needed. As set forth above, the termination of each of the time periods T_1, T_3 and T_5 in the foregoing experiment can be selected using an optical sensor to sense a given change in the color of the surface of the food or other parameters such as the temperature of the muffin surface and/or the decrease or an absence of steam in the oven.

As an alternative to the step-wise reduction of the duty cycle from full duty cycle during T_1 to a first reduced level of duty cycle during T_3 and to a second further reduced duty cycle during T_5, the duty cycle can be continuously reduced over a given period of time as shown in Fig. 6 wherein the duty cycle is shown as decreased from one hundred percent (100%) to

seventy percent (70%) to fifty percent (50%) to forty percent (40%) to thirty percent (30%) to twenty percent (20%) to ten percent (10%). Typically, the decreases in the duty cycle will be in smaller increments.

The present invention allows the chef to set up recipes or the manufacturer to program recipes in which the intensity is independently set with different duty cycles and the spectrum of irradiation from the lamps independently set by selecting different power levels and those different settings can be changed periodically through the cooking cycle to achieve unique recipes for cooking special foods.

Figs. 5-8 can be considered as either a graph of the power versus time for all of the lamps or the power versus time for a single lamp, and since the lamps can be controlled independently different lamps can be on at different times and following different power levels to control the spectrum and different duty cycles to control the intensity at different times during the cooking process.

In a preferred embodiment of the present invention, applicable to cooking many different types of food such as thin and thick steaks, roasts, chickens, turkeys and other poultry, bread products, cakes, cookies and even frozen products, a fifty percent (50%) duty cycle is utilized during time period T_3, such as the lamps being on for three seconds and off for three seconds, and then the duty cycle reduced to 10:1 for the second lower reduced duty cycle during time T_5 such as with the lamps on for one second and off for ten seconds.

The following examples show the timing for cooking various different types of foods with maximum power indicated as one hundred percent (100%) intensity in each case:

1. Carrot Cake - 100% Intensity

Period	Time	Duty Cycle
T_1	11 sec.	on full
T_2	3 sec.	
T_3	16 sec.	3 sec. on/3 sec. off
T_4	5 sec.	
T_5	220 sec.	1 sec. on/10 sec. off
T_6	0 sec.	

2. Cinnamon Rolls - 100% Intensity

Period	Time	Duty Cycle
T_1	20 sec.	on full
T_2	0 sec.	
T_3	30 sec.	3 sec. on/3 sec. off
T_4	0 sec.	
T_5	190 sec.	1 sec. on/6 sec. off
T_6	0 sec.	

3. Turkey (9 pounds) - 100% Intensity

Period	Time	Duty Cycle
T_1	165 sec.	on full
T_2	0 sec.	
T_3	160 sec.	3 sec. on/3 sec. off
T_4	0 sec.	
T_5	960 sec.	1 sec. on/3 sec. off
T_6	0 sec.	
T_7	480 sec.	1 sec. on/6 sec. off
T_8	0 sec.	

While for maximum penetration into thick foods, full power is preferably applied to the lamps during the initial continuous power period T_1 and during the reduced duty cycles, T_3 and T_5, there may be certain types of foods where the desired cooking of the food itself or specifically one surface thereof is cooked using less than full power to certain or all of the lamps. Thus, the amount of radiation directed onto the food can be reduced during a given period or a lower power level can be applied to the lamps during a reduced duty cycle.

For example, Fig. 7 illustrates a continuously reduced power at a fifty percent (50%) duty cycle from an initial time period T_1 of full power.

Fig. 8 illustrates a cooking recipe where both the power and the duty cycle are reduced following an initial

cooking period T_1 of full power at one hundred percent (100%) duty cycle.

The oven of the present invention may also be used cooperatively with other cooking sources. For example, the oven of the present invention may include a microwave radiation source. Such an oven would be ideal for cooking a thick highly absorbing food item such as a roast beef. The microwave radiation would be used to cook the interior portions of the meat and the infra-red and visible light radiation of the present invention would cook the outer portions. Further, the oven according to the present invention could be used with a convection oven or with both convection oven and microwave oven cooking sources.

The present invention was described in relation to a preferred embodiment. However, it will be apparent to one skilled in the art that one can change the parameters and still practice an invention within the spirit and scope of the present invention.

C L A I M S

What is claimed is:

1. The method of cooking food in a lightwave oven having a plurality of high power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges comprising the steps of:

irradiating the food by applying power to at least one of said lamps without vaporizing all the surface water on the food for avoiding browning of the surface thereby enabling deep penetration of the food by radiation in the near-visible and visible ranges and

then applying reduced radiation to the food.

2. The method of claim 1 including the step of controlling the level of the power applied to said lamps to control the spectrum of the radiation applied to the food.

3. The method of claim 1 wherein the step of applying reduced radiation to the food includes applying power to said at least one lamp at a reduced duty cycle.

4. The method of claim 3 including the step of controlling the duty cycle of the power to said at least one lamp to control the average intensity of the radiation applied to the food.

5. The method of claim 1 wherein the step of applying reduced radiation to the food includes continuously reducing the duty cycle of the power applied to said at least one lamp.

6. The method of cooking food in a lightwave oven having a plurality of high power lamps providing radiant

energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges comprising the steps of:

irradiating the food by applying power to at least one of said lamps without vaporizing all the surface water on the food and

then applying reduced radiation to the food by said at least one lamp including applying power to said at least one lamp at a reduced duty cycle and at less power than during the first step of irradiating the food.

7. The method of claim 1 including the step of irradiating the food to brown the surface of the food.

8. In the method of claim 1 sensing a change in the color of the surface of the food of a given degree and terminating irradiation of the food.

9. In the method of claim 1 sensing a change in the water vapor concentration emitted from the surface of the food to a pre-determined degree and then terminating irradiation of the food.

10. In the method of claim 1 sensing the temperature of the food to a pre-determined degree and then terminating irradiation of the food.

11. In the method of claim 1 sensing the generation of steam and then the reduction of steam below a pre-determined level and then terminating irradiation of the food.

12. The method of cooking food in a lightwave oven having a plurality of high power lamps providing radiant energy in the electromagnetic spectrum including a

significant portion in the near-visible and visible ranges comprising the steps of:

applying continuous power to at least one of said lamps for a first given period of time for deep penetration cooking with energy in the near-visible and visible ranges without vaporizing all of the surface water on the food for prevention of significant browning and

then applying power to said at least one lamp at a first lower duty cycle for a second given period of time to continue cooking the food.

13. The method of claim 12 including the step of controlling the level of the power applied to said lamps to control the spectrum of the radiation applied to the food.

14. The method of claim 12 including the step of controlling the duty cycle of the power to said at least one lamp to control the intensity of the radiation applied to the food.

15. In the method of claim 12 turning off said at least one lamp for a third given period of time between said first step of applying continuous power and said step of applying power at a first lower duty cycle.

16. The method of claim 12 wherein the step of applying power at a first lower duty cycle includes continuously reducing the duty cycle of the power applied to said at least one lamp.

17. The method of claim 12 wherein the step of applying power at a first lower duty cycle includes applying less power at said first lower duty cycle.

18. The method of claim 12 including after said power applying step at a first lower duty cycle applying power to said at least one lamp at a duty cycle higher than said first lower duty cycle for a fourth given period of time to brown the surface of the food.

19. The method of claim 12 including after said power applying step at a first lower duty cycle applying power to said at least one lamp at a second reduced level and at a second lower duty cycle lower than said first lower duty cycle for a fourth given period of time.

20. The method of claim 12 including the step of irradiating the food to brown the surface of the food.

21. The method of cooking food in a lightwave oven having a plurality of high power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges comprising the steps of:

irradiating the food with full power to said lamps continuously at a full duty cycle without vaporizing all the surface water on the food,

eliminating radiation from said lamps until water is replenished from within the food onto the surface of the food, and

then irradiating the food with reduced power to said lamps at a lower duty cycle.

22. The method of claim 21 including the step of controlling the level of the power applied to said lamps to control the spectrum of the radiation applied to the food.

23. The method of claim 21 including the step of controlling the duty cycle of the power to said lamps to

control the average intensity of the radiation applied to the food.

24. In the method of claim 21 sensing a change in the color of the surface of the food of a given degree and terminating irradiation of the food.

25. In the method of claim 21 after the step of irradiating with reduced power the step of subsequently irradiating the food with still further reduced power to said lamps at a reduced duty cycle below said lower duty cycle for continued cooking of the food.

26. The method of cooking food in a lightwave oven having a plurality of high power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges comprising the steps of:

applying substantially full power substantially continuously to at least one of said lamps for a first given period of time for deep penetration cooking without significant browning,

turning off said at least one lamp for a second given period of time, and

then applying power to said at least one lamp at a reduced level and at a first lower duty cycle for a third given period of time to continue cooking the food.

27. The method of claim 26 including the step of controlling the level of the power applied to said at least one lamp to control the spectrum of the radiation applied to the food.

28. The method of claim 26 including the step of controlling the duty cycle of the power to said at least

one lamp to control the intensity of the radiation applied to the food.

29. The method of claim 26 including after said power applying step at a first lower duty cycle applying power to said at least one lamp for a fourth given period of time to brown the surface of the food.

30. The method of claim 26 including after said power applying step at a first lower duty cycle applying power to said at least one lamp at a second reduced level and at a second lower duty cycle lower than said first lower duty cycle for a fourth given period of time.

31. The method of claim 26 including the step of irradiating the food to brown the surface of the food.

32. The method of cooking food in a lightwave oven having a plurality of high power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges comprising the steps of:

irradiating the food with full power of at least certain of said lamps substantially continuously at a full duty cycle only until substantially all the surface water on the food has been vaporized,

delaying further application of radiation from said at least one lamp until water is replenished from within the food onto the surface of the food, and

then irradiating the food with first reduced power to said at least one lamp at a first lower duty cycle.

33. The method of claim 32 including the step of controlling the level of the power applied to said at least one lamp to control the spectrum of the radiation applied to the food.

34. The method of claim 32 including the step of controlling the duty cycle of the power to said at least one lamp to control the intensity of the radiation applied to the food.

35. In the method of claim 32 sensing a change in the color of the surface of the food of a given degree and terminating irradiation of the food.

36. The method of claim 32 including the step of irradiating the food with second reduced power of said at least one lamp lower than said first reduced power at a second lower duty cycle lower than said first lower duty cycle for continued cooking of the food.

37. Cooking apparatus comprising:

a cooking chamber,

a plurality of high power lamps providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges and mounted in said chamber,

means for applying power to at said lamps for irradiating the food,

means for reducing the power to said lamps to a lower duty cycle,

means for controlling the level of the power applied to said lamps to control the spectrum of the radiation applied to the food, and

means for controlling the duty cycle of the power to said lamps to control the intensity of the radiation applied to the food.

38. In the apparatus of claim 37 means for sensing a change in the color of the surface of the food of a given degree and means for terminating irradiation of the food upon said sensing means sensing said given degree of change in color.

39. Cooking apparatus comprising:

a cooking chamber,

a plurality of high power lamps mounted in said chamber for providing radiant energy in the electromagnetic spectrum including a significant portion in the near-visible and visible ranges to food at a cooking location in said chamber,

means for applying power to at least certain of said lamps continuously or at a reduced duty cycle,

means for controlling the level of the power applied to said lamps to control the spectrum of the radiation applied to the food, and

means for controlling the duty cycle of the power to said lamps to control the intensity of the radiation applied to the food.

40. The cooking apparatus of claim 39 including means for sensing a change in the color of the surface of the food of a given degree and means for terminating irradiation of the food upon said sensing means sensing said given degree of change in color.

41. The apparatus of claim 39 including means for continuously reducing the duty cycle of the power applied to said lamps.

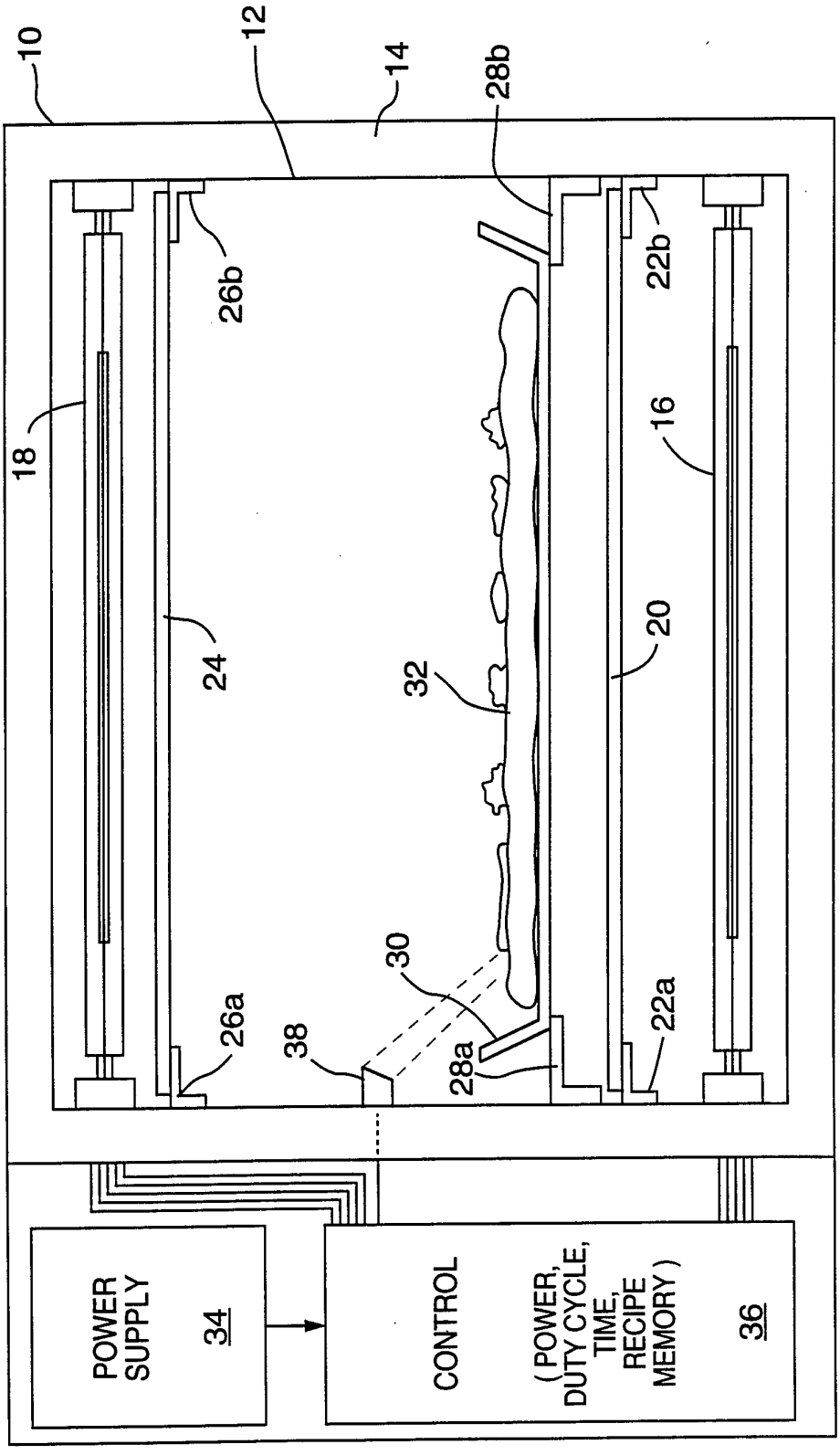

10
12
14
28b
26b
22b
18
16
24
20
32
30
26a
38
28a
22a
POWER SUPPLY
34
CONTROL
(POWER, DUTY CYCLE, TIME, RECIPE MEMORY)
36

FIG. 1

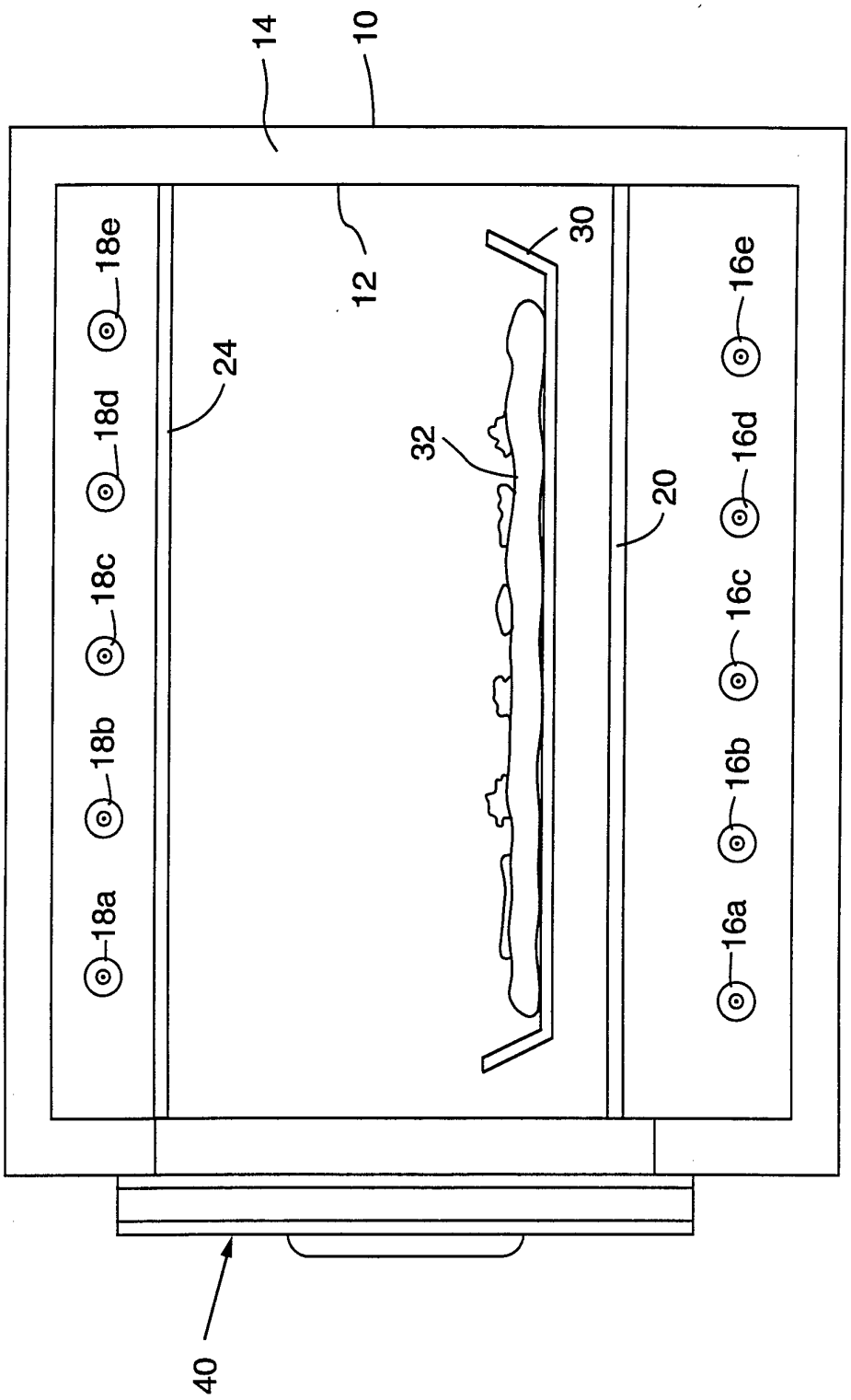


FIG. 2

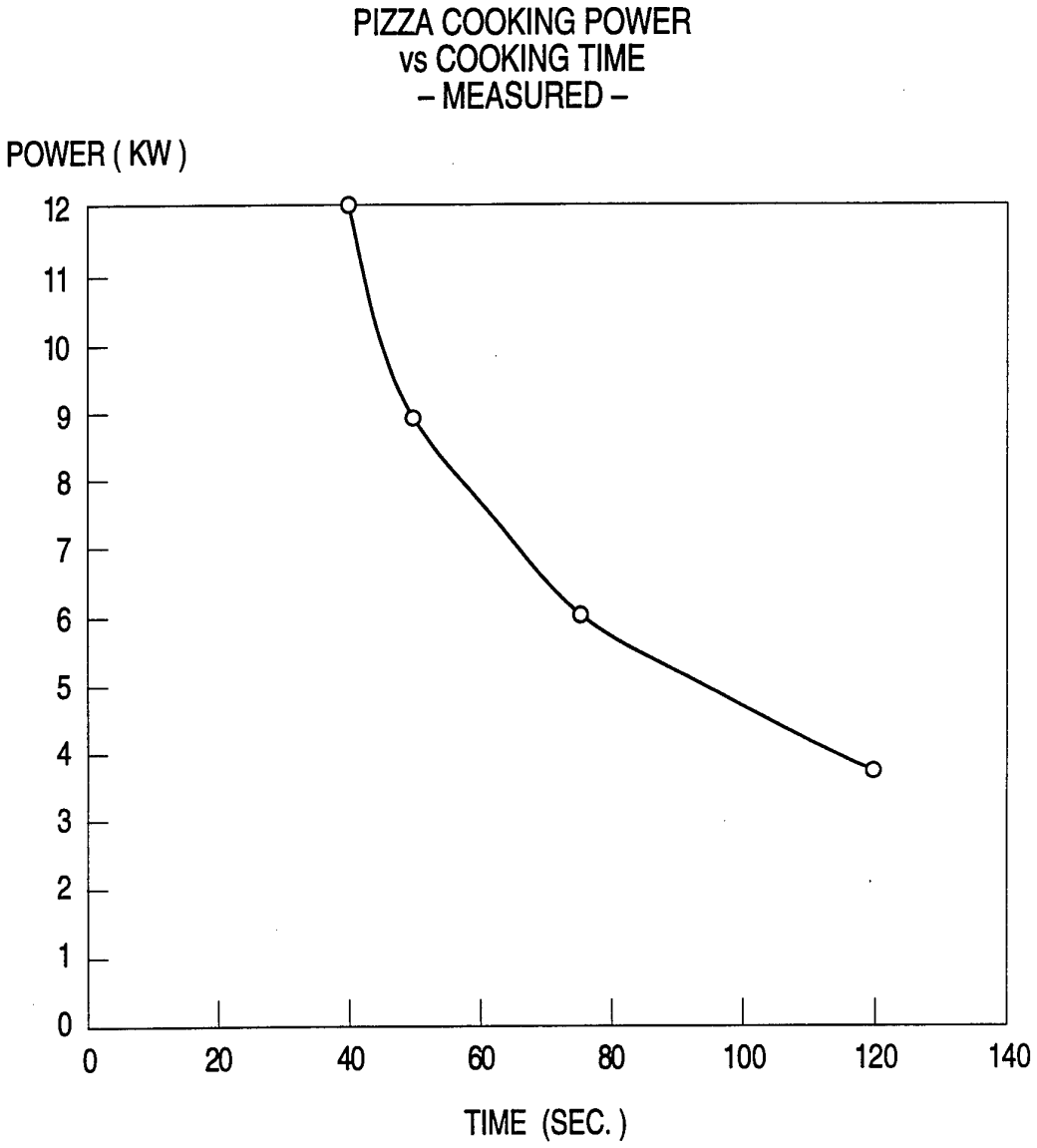

PIZZA COOKING POWER
vs COOKING TIME
– MEASURED –
POWER (KW)
12
11
10
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
140
TIME (SEC.)

FIG. 3

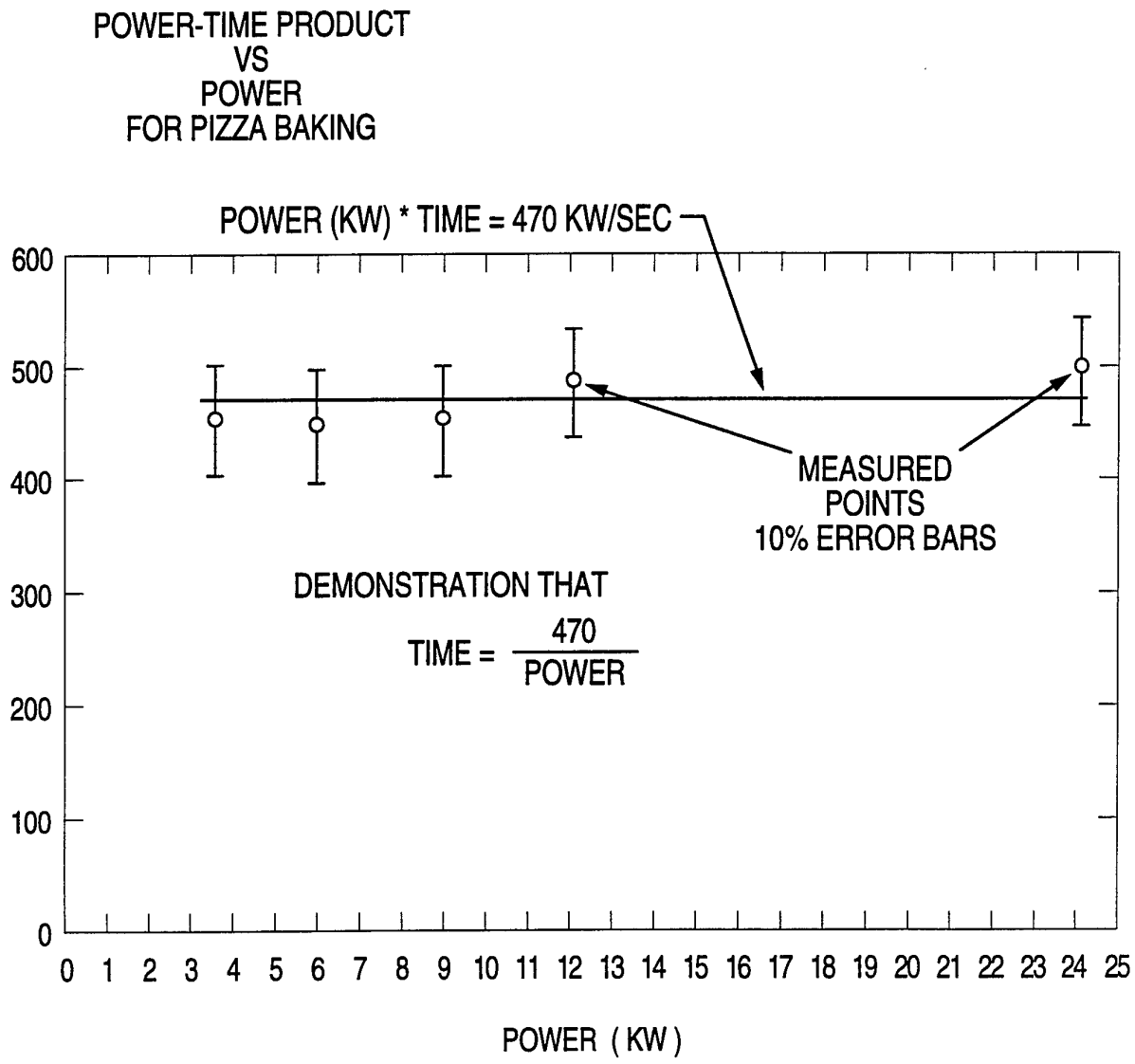

POWER-TIME PRODUCT
VS
POWER
FOR PIZZA BAKING
POWER (KW) * TIME = 470 KW/SEC
MEASURED
POINTS
10% ERROR BARS
DEMONSTRATION THAT
TIME = 470 / POWER
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
POWER (KW)

FIG. 4

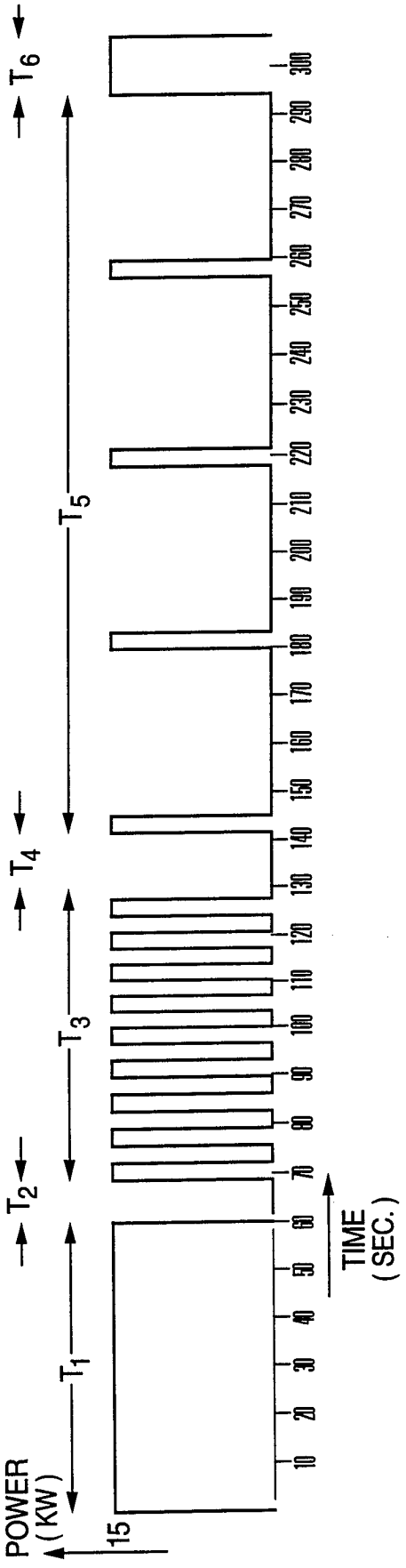

POWER (KW)
15
TIME (SEC.)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
T1
T2
T3
T4
T5
T6

FIG. 5

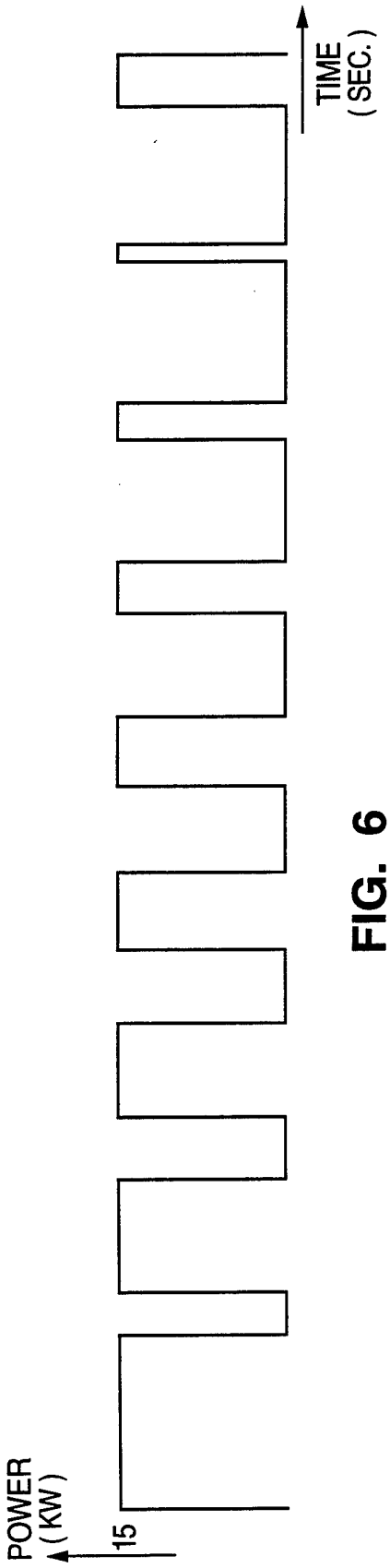

POWER (KW)
15
TIME (SEC.)

FIG. 6

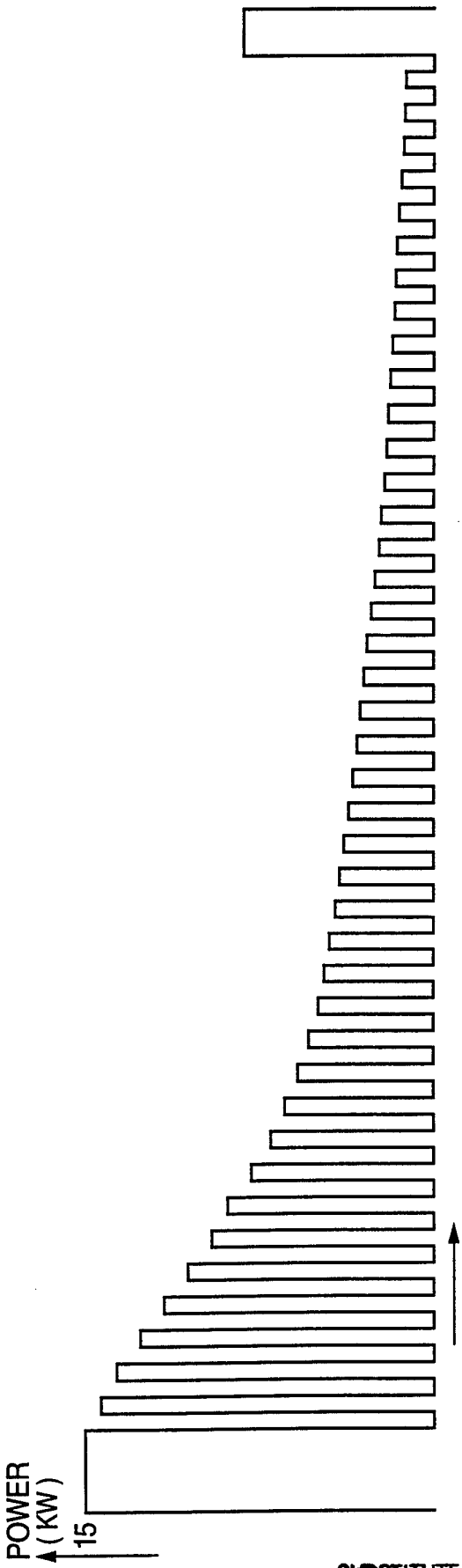


FIG. 7

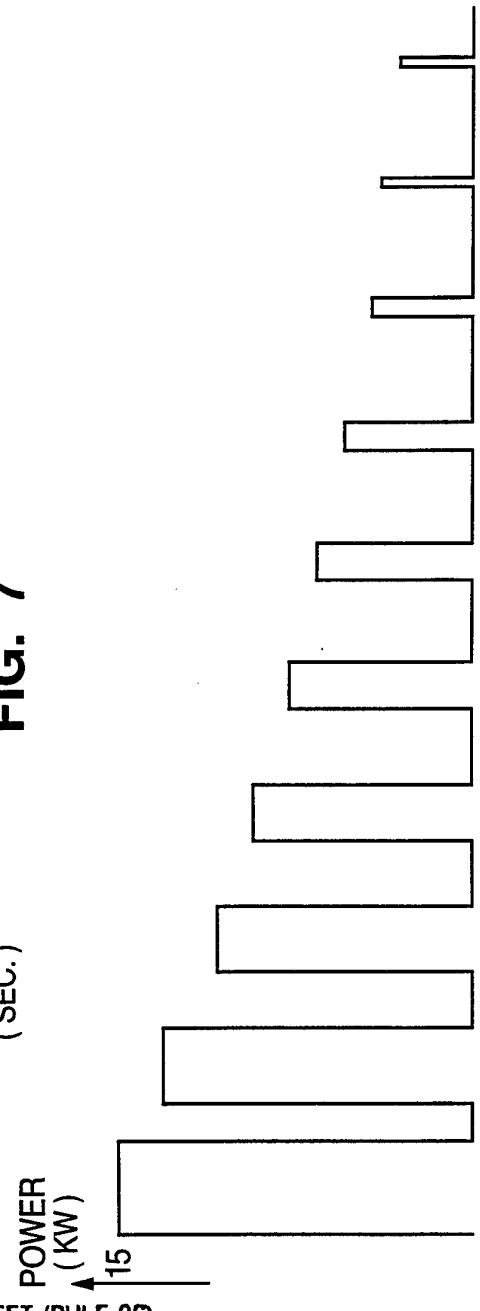


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/12396

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H05B 3/00
US CL : 219/411
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/411,405,485,412-414,492,509; 392/416,418; 426/523,241,243,248; 99/326,325,331

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,870,806 (CAPOSSELA ET AL), 11 MARCH 1975, COL. 3, LINE 57-COL. 4, LINE 3.	1-5, 7, 8, 12-14, 16, 18, 20, AND 21
Y	US, A, 5,039,535 (LANG ET AL), 13 AUGUST 1991, COL. 11, LINE 35 THROUGH COL. 12, LINE 65	3-5, 12-14, 16, 18, 21, 37, 39, AND 41
Y	US, A, 4,245,148 (GISSKE ET AL), 13 JANUARY 1981, ENTIRE DOC.	8, 38, AND 40
Y	GB, A, 839,551 (PANISSET), 29 JUNE 1960, SEE FIG. 3	5 AND 16
A	US, A, 3,470,942 (FUKADA ET AL), 07 OCTOBER 1969, FIGS. 3-5	17

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 DECEMBER 1994	JAN 27 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 308-2829	Authorized officer JOHN JEFFERY Telephone No. (703) 308-1989

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/12396

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SU, A, 1,215,651 (ILYASOV ET AL), 07 MARCH 1986, ENTIRE DOC.	1-41