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PETER H. SMITH, ANCHORAGE, KY.

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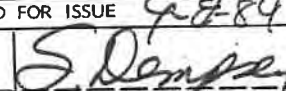
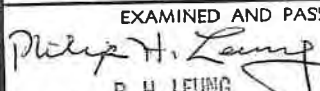
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AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

U.S. DEPT. of COMM.-Pat. & TM Office -- PTO-436L (rev. 10-78)

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 PATENT OPERATION
 June 21, 1983

 Honorable Commissioner of Patents and Trademarks
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Re: Docket No. 9D-RG-16129

Sir:

 Herewith I hand you specification and drawing, 4 sheet(s),
 for an application for Letters Patent upon an improvement in:

AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

the invention of: Peter Harold Smith

Basic Fee \$300.00

Additional Fees:

 Multiple dependent claims _____ 0
 (\$100)

 Total number of claims in
 excess of 20, times \$10 _____ 0

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 claims minus 3, times \$30 \$90.00

 Total Filing Fee \$390.00

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Respectfully,

 H. Neil Houser
 Patent Counsel
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BACKGROUND OF THE INVENTION

The present invention relates generally to improvements in a microwave oven and more particularly to an arrangement for anticipating the occurrence of combustion in the cooking cavity of a microwave oven.

5 When heating a food load in a microwave oven, if the food load is allowed to heat substantially longer than required for proper cooking, the food itself or the container for the food may become heated to the combustion point, resulting in a fire in the oven cavity. The overcook-
10 ing of whole potatoes, fats raised to the combustion temperature due to excessive overcooking of meats, and oven shelf hot spots due to imper- fections in the pyroceramic shelf when heated over a prolonged period, are three primary sources of such cavity fires. The potato is particularly
15 vulnerable to fire since it dries out non-linearly with the core of the potato getting hot before the outer portions. The heat from the core is not readily dissipated. As a result the core of the potato can be heated to its ignition point relatively quickly.

One commonly used approach to the cavity fire detection problem is to provide a thermal cutout switch on the oven cavity ceiling which cuts off the magnetron when the oven cavity ceiling temperature exceeds
20 a predetermined level. This arrangement works satisfactorily but is relatively costly and has a relatively slow response time. An alternative approach is disclosed in U.S. Patent 4,133,995 to Buck. In the Buck arrangement a humidity sensor and a temperature sensor are employed to
25 monitor the relative humidity and temperature in the cavity. A micropro- cessor is programmed to detect a fire condition when both the temperature rises and the humidity falls by predetermined amounts within a prescribed time period, on the order of 10-30 seconds, and to de-energize the oven upon detecting such a condition.

The present invention improves over both of the foregoing
30 approaches to fire detection in the microwave oven by providing an

arrangement which anticipates fire conditions developing in the cooking cavity before actual ignition employing a single sensor normally used for cooking control which is responsive to the concentration of gases in the circulating air exiting the cooking cavity. In addition to providing an anticipatory warning of an imminent fire condition, this arrangement eliminates the need for the relatively costly thermal cutout switch and also eliminates the need for the "in situ" temperature sensor of the Buck method.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for anticipating the occurrence of a fire in the cooking cavity of a microwave oven. The oven is provided with means for continuously circulating outside air through the cooking cavity to carry away gases emitted by food loads being heated therein. A sensor responsive to the concentration of gases in the circulating air monitors the gas concentration level and generates an output signal representative thereof. Sensor monitoring means responsive to the sensor output signal is operative to determine the rate of change of the gas concentration level, and detect a characteristic rate of change indicative of the load being heated closely approaching its combustion point. Upon detection of the characteristic rate of change, means responsive to the sensor monitoring means de-energizes the oven and provides an indication to the user that a combustion condition in the oven cavity is imminent.

In accordance with one form of the invention, the sensor monitoring means detects the characteristic rate of change by first detecting a relatively slow rate of change indicative of the food load drying out and thereafter detecting a relatively rapid rate of change indicative of the load being heated to a temperature closely approaching its combustion temperature.

Brief Description of the Drawings

While the novel features of the invention are set forth with particularity in the appended claims, the invention both as to organization and content will be better understood and appreciated from the following detailed description taken in conjunction with the drawings, in which:

FIG. 1 is a perspective view of a microwave oven embodying the present invention;

FIG. 2 is a schematic sectional view of the oven of FIG. 1 taken along lines 2-2;

FIG. 3 depicts a curve representative of the gas emission characteristics of a baked potato heated in the microwave oven of FIG. 1;

FIG. 4 is a simplified schematic circuit diagram of that portion of the microprocessor-based control system of the oven of FIG. 1 illustratively embodying the present invention; and

FIG. 5 is a flow diagram illustratively embodying a fire detection control algorithm implemented by the microprocessor in the circuit of FIG. 4 in accordance with the present invention.

DETAILED DESCRIPTION

Referring now to FIGS. 1 and 2, there is shown a microwave oven designated generally 10. The outer cabinet comprises six cabinet walls including upper and lower walls 12 and 14, a rear wall (not shown), two side walls 18 and 20, and a front wall partly formed by a hingedly supported door 22 and partly by control panel 23. The space inside the outer cabinet is divided generally into a cooking cavity 24 and a controls compartment 26. Cooking cavity 24 is formed by a top wall 28, a bottom wall 30, side walls 32 and 34, the rear cavity wall being a cabinet wall and the front cavity wall being defined by the inner face 36 of door 22. A shelf 38 of pyroceramic material or other suitable material pervious to microwave energy is provided in the lower region of cavity 24 to support food loads to be heated in cavity 24.

5 A magnetron 40 adapted to produce microwave energy is mounted
in controls compartment 26. Means for circulating air through the
cavity 24 includes a blower designated generally 42 which draws cooling
air into the controls compartment 26 through louvered openings (not
shown) formed in the back cabinet wall. This air passes over cooling
fins 44 of magnetron 40. A portion of the air drawn in by blower 42
enters cavity 24 via perforations 46 formed in cavity side wall 32.
This air circulates past the food load (not shown) being heated in
cavity 24 and exits cavity 24 through perforations 48 formed in upper
cavity wall 28 near the upper left corner of cavity 24. Vent holes 50
formed in side cabinet wall 20 near the upper left corner of the oven
cabinet permit air exiting cavity 24 via perforations 48 to exit the
oven cabinet to the exterior.

15 Foods heated in the microwave oven tend to emit water vapor
and other gases as the food heats. Such gases mix with the air circulating
in the cavity and are removed from the cavity by the circulating air.
Means for sensing the concentration level of such gases in the air
leaving the cavity is provided in the form of a gas sensor 52 disposed
in the air flow path between perforations 48 in cavity wall 28 and vent
openings 50 in cabinet wall 20. Sensor 52 is supported proximate perfora-
tions 48 by mounting bracket 54 which is suitably secured to cavity wall
28. Sensor 52 in the illustrative embodiment of FIG. 2 is a gas sensor
readily commercially available from Figaro Engineering, Inc., identifiable
as Model TGS No. 186. This sensor is responsive to the cumulative
concentration of water vapor and various organic gases. Use of such a
sensor in a microwave oven for automatic cooking control is known in the
art. One example of such a control arrangement is described in U.S.
Patent 4,311,895.

30 In accordance with the present invention, information regarding
the concentration level of gases in the circulating air exiting cavity

24 provided by sensor 52 is used to anticipate the occurrence of combustion conditions in the cavity.

It has been empirically determined that for foods likely to ignite in the oven cavity when overcooked, the concentration of gases emitted by the food load into the air circulating through the cavity changes during heating in a predictable fashion. At the beginning of the cooking cycle, the food load is normally not sufficiently heated to cause significant gaseous emissions from the food. Consequently, the sensed gas concentration level remains relatively low and constant. As the food continues to heat, it reaches sufficient temperature to begin emitting water vapor and organic gases. There ensues a period of relatively rapidly increasing gas concentration level which continues until the food load is heated to a point of near maximum gaseous emissions. The recommended cooking time for most foods is such that the cooking cycle is normally terminated prior to reaching this point. However, if the food continues to be heated beyond this point such as may inadvertently occur due to the miscalculation of appropriate cooking time or simply forgetfulness, the temperature of the food continues to rise but the gas concentration level increases relatively slowly during what can be a relatively long period, hereinafter referred to as the "drying out" period. Eventually, the temperature of the food closely approaches its combustion temperature. However, before actually reaching the ignition point, the food begins to char, smoke or smolder, resulting in a second period of relatively rapidly increasing gas concentration in the circulating air, comparable to that rate of increase which characterizes the normal cooking period. This second period of rapidly increasing concentration level, referred to hereinafter as the "pre-combustion" period, typically begins a matter of minutes before actual combustion in the cavity. Thus, detection of the transition from the drying out phase to the pre-combustion phase provides an advance warning that a combustion condition in the cavity is

imminent. Hence, according to the present invention, a fire condition in the cavity of a microwave oven may be anticipated by monitoring the gas concentration level of the air circulated through the cavity during the cooking cycle, periodically determining the rate of change of the sensed concentration level during heating, and detecting a rate of change characteristic of the food load closely approaching its combustion temperature.

The sensor resistance versus time curve of FIG. 3 shows the change in resistance of the sensing element of sensor 52 during the cooking cycle for a whole potato heated in cooking cavity 24 of oven 10 in response to the changing gas concentration level in the air exiting the cooking cavity as the potato is heated to its combustion point. The potato was chosen for purposes of illustration because, as described briefly in the Background discussion, it is one of the foods most easily overcooked to the point of combustion. Also, the basic shape of the response curve is fairly representative of all food loads of the type conducive to ignition when overcooked.

The resistance R_s of the TGS 186 sensor varies with gas concentration level in the air to which it is exposed in accordance with the formula

$$R_s = A \times C^{\alpha} \quad \text{where } A \text{ and } \alpha \text{ are constants and } C \text{ is the gas concentration.}$$

Hence, the changing resistance as the potato cooks reflects the aforementioned predictable variation in concentration level.

Referring particularly to FIG. 3, as the cooking cycle begins, the resistance is relatively high and constant indicative of the relatively low and essentially constant concentration level at this point. There next ensues a period in which the resistance decreases relatively rapidly indicative of the concentration level increase, characteristic of the normal cooking phase for the potato. The change from a relatively rapidly decreasing resistance to a relatively slowly decreasing resistance

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is indicative of the change from a relatively rapidly increasing concentration level to a period of relatively slowly increasing concentration level which marks the transition from the normal cooking phase to the drying out phase for the potato. Continued heating of the potato continues to raise its temperature but the resistance continues to decrease at a relatively slow rate indicating that during the relatively long drying out phase for the potato, which is roughly twice the duration of the normal cooking period, the gas concentration level is increasing at a relatively slow rate. As the temperature of the potato sufficiently closely approaches its combustion point, the resistance begins to decrease at a relatively rapid rate indicative of a relatively rapidly increasing gas concentration level. The transition from relatively slow to relatively rapid increase in concentration level marks the transition from the drying out phase to the pre-combustion phase. For a potato cooked in oven 10, this transition typically occurs at least 2-3 minutes prior to reaching the combustion temperature of the potato. Thus, by detecting the rate of change of the gas concentration level characteristic of the pre-combustion phase early in this phase, it is possible to anticipate a combustion condition in the cavity at least 2 to 3 minutes in advance. By turning off the power to the magnetron and blower at this point, fire in the cavity may be prevented.

Referring now to the simplified schematic circuit diagram of FIG. 4, gas sensor 52 is incorporated in a microprocessor based control arrangement which illustratively embodies the apparatus and performs the method of the present invention. The circuit of FIG. 4 includes a gas sensing circuit 60 for sensing the concentration level of gases in the circulating air as it exits cooking cavity 24, and generating a voltage signal having a magnitude representative of the sensed gas concentration level; a sensor heater circuit 62 for maintaining the sensing element of gas sensor 52 at its proper operating temperature; a microprocessor 64

for monitoring the voltage signal from sensing circuit 60; a power circuit 65 for oven 10 including a magnetron power circuit 66, an air circulating blower motor 67 and a power control relay 68 for controlling energization of magnetron power circuit 66 and air circulating blower 67 in response to a control signal from microprocessor 64; and an alarm circuit 69 responsive to a control signal from microprocessor 64 for providing an audible signal to the user of an imminent fire condition in the cooking cavity. Power for the circuit of FIG. 4 is provided by a conventional DC power supply circuit 70 which converts a standard 120 volt, 60 Hz AC signal input on lines L1 and N to dc output power signals of -9 volts, -9 volts and -16 volts on lines 72, 74, and 76, respectively.

Gas sensor circuit 60 includes a gas sensing element 80. Element 80 is the gas sensing element of sensor 52 (FIG. 2), which is exposed to the circulating air exiting cooking cavity 24. The resistance R_s of sensor element 80 varies with gas concentration level in the circulating air exiting cavity 24 (FIG. 2) as hereinbefore described with reference to FIG. 3. Sensing element 80 is connected between the output terminal 82 and the inverting input terminal 84 of conventional operational amplifier 86. Capacitor 88 connected in parallel with sensor element 80 serves as a high pass filter for noise reduction. Input resistor 90 connects inverting input terminal 84 of amplifier 86 to DC supply line 74. Reference voltage divider 92 comprising resistors 94 and 96, serially connected between dc input line 74 and said system ground, provides the reference input signal for amplifier 86 at terminal 98. This signal is coupled to amplifier 80 by reference input resistor 100 connected between divider terminal 98 and the non-inverting input terminal 102 of amplifier 86.

The output voltage V_o appearing at amplifier output terminal 82 is proportional to the ratio of the resistance of sensor element 80 to the resistance of input resistor 90. Hence, voltage V_o varies linearly with the resistance of sensor element 80. Output terminal 82 of amplifier 86 is connected to input port J1/A1 of microprocessor 64 to couple the

sensor output voltage V_o to the microprocessor. As shown in FIG. 3, the approximate dynamic range for sensor element resistance R_s of the illustrative embodiment during the cooking cycle is from 75K ohms at the beginning of the cooking cycle to less than 5K ohms at the combustion point. The magnitude of input resistor 90 and the magnitude of reference voltage from divider 92 are selected to scale and position the output voltage V_o to fall within the desired input range for the internal analog to digital convertor of microprocessor 64 over the dynamic range of sensor element 80.

TGS 186 gas sensor 52 includes heater element 104 as an integral component of the sensor package to maintain sensing element 80 at an appropriate temperature for satisfactory operation. For stable sensor operation, the voltage applied to sensor heater element 104 should be closely regulated. To this end, heater circuit 62 includes, in addition to sensor heater element 104, a voltage regulator integrated circuit 106. Heater element 104 is serially connected between the output of voltage regulator 106 and system ground. Voltage regulator 106 regulates the -9 volt dc signal from line 72 of power supply 70 to provide a regulated -5 volt signal to heater 104. Regulator circuit 106 in the circuit is a standard 7905 integrated circuit readily commercially available from National Semiconductor. Bypass resistor 108 connected in parallel with integrated circuit 106 and capacitor 109 in parallel with heater 98 reduce power dissipation in voltage regulator 106.

Sensor monitoring means responsive to the voltage signal V_o generated by the sensor circuit 60 at terminal 82 is provided in the circuit of FIG. 4 by microprocessor 64 which is appropriately programmed to provide means for detecting a magnitude of V_o indicative of a gas concentration level greater than a reference level, means for determining the rate of change of the magnitude of V_o , and means for first detecting a relatively small rate of change of magnitude indicative of the drying out phase for the food being heated following detection of concentration

level greater than said reference level and thereafter detecting a relatively large rate of change of magnitude indicative of the transition to the pre-combustion phase. Microprocessor 64 is further programmed to generate a signal at output ports R11 and R12 upon detection of the large rate of change. The signal at R11 is operative to energize alarm oscillator circuit 69. Oscillator circuit 69 may comprise any one of a number of conventional multivibrator circuits known in the art to drive load speaker 110 at a frequency discernible by the user to indicate that a fire condition in cavity is imminent. The signal at R12 is operative to open power control relay 68, de-energizing power circuit 65, thereby de-energizing magnetron 40 and blower motor 67.

Microprocessor 64 is a standard TMS 2670 series 4K microprocessor of the type readily commercially available from Texas Instruments. The ROM of microprocessor 64 has been customized to perform the desired control functions for microwave oven 10.

Power circuit 65 is connected between power input lines L1 and N to provide power to magnetron 40 and blower motor 69 of blower 42 (FIG. 2). The power circuit 66 for magnetron 40 includes power transformer 112 having a high voltage secondary 114 connected to energize magnetron 40 through a half-wave voltage doubler comprising series capacitor 116 and rectifying diode 118 connected across the magnetron anode and cathode terminals 120 and 122, respectively, and oppositely poled with respect thereto. Secondary winding portion 124 of transformer 112 is connected as a filament winding to heat the cathode of magnetron 40. Power line L1 is coupled to terminal 126 of primary winding 128 of transformer 112 through a fuse 130 and main power relay switch 68. Main power relay 68 is controlled by a signal from microprocessor 64 coupled to the relay coil 134 of relay 68 from output port R12 via conventional relay driver circuit 136. The other terminal 138 of primary winding 128 is coupled to power line N via triac 140 having a gate terminal 142. Triac 140 is operated in a duty cycle control mode by suitable control signals from

output port R13 of microprocessor 64 which are coupled to triac gate terminal 142 via conventional opto-coupler circuit 143.

Energization of fan motor 67 is controlled by triac 144 serially connected to motor 67 across power lines L1 and N. Triac 144 is controlled by signals from output port R10 of microprocessor 64 connected to triac gate terminal 146 of triac 144 via conventional opto-coupler 145.

The following component values have been found suitable for use in the circuit of FIG. 4. These values are exemplary only and are not intended to limit the scope of the claimed invention.

FIXED RESISTORS

90	107K ohms
94	732 ohms
96	511 ohms
100	22K ohms
108	56 ohms

CAPACITORS

88	.01 μ f
108	10 μ f
116	.91 μ f

Operation of the circuit of FIG. 4 will now be described with reference to the flow diagram of FIG. 5. This flow diagram illustrates an algorithm which is implemented in the ROM of microprocessor 64. From this diagram, one of ordinary skill in the programming art can readily prepare a set of instructions for permanent storage in the ROM of microprocessor 64. It is of course to be understood that other portions of the microprocessor ROM may be utilized to implement additional oven control algorithms. Since the details of such additional algorithms add

nothing to the understanding of the present invention such details have been omitted for brevity and simplicity.

The method of anticipating a fire condition in the cooking cavity implemented by the algorithm illustrated in the flow diagram of FIG. 5 includes the following steps. First, in order to distinguish the initial period of relatively constant gas concentration which normally occurs at the beginning of the normal cooking phase (FIG. 3), from the later occurring "drying out" phase, the sensor output voltage V_0 is monitored to detect a voltage magnitude corresponding to a concentration level indicative of having progressed in the cooking cycle to a point beyond the initial plateau. Having detected a concentration level in excess of the reference level, the rate of change of V_0 corresponding to the rate of change of sensed concentration level is periodically determined. The rate of change of voltage magnitude is then monitored, first to detect a rate of change corresponding to a rate of change of concentration level less than a predetermined rate signifying transition from the normal cooking phase to the drying out phase. Having detected such a lesser rate, the rate of change of V_0 is thereafter monitored to detect a rate of change corresponding to a rate of change of concentration level greater than a predetermined rate, signifying the transition from the drying out phase to the pre-combustion phase. Upon detection of the greater rate, the magnetron and the blower motor are de-energized and an indication is provided to the user such as an audible signal signifying that a combustion condition in the cavity is imminent.

Referring now to FIG. 5, the FIRE DETECTION routine is periodically entered from the master or executive program for microprocessor 64 throughout the cooking cycle. Such periodic entry may be satisfactorily made with a time between entries on the order of 2-5 seconds. However, time between entries need not be limited to this range for satisfactory performance. Upon entering the routine, the sensor output voltage V_0 at

-12-
B

input port J1/A1 is sampled (Block 152). Inquiry 154 compares the sampled voltage V_o with a predetermined reference value V_R representative of the food being heated having reached that portion of the normal cooking phase characterized by a relatively rapidly increasing concentration level. In the illustrative example, a reference voltage level V_R corresponding to the sensor resistance at point A (FIG. 3) was somewhat arbitrarily selected as being about the midpoint of this portion of the normal cooking phase for a potato. The precise reference value is not critical provided it represents a point between the initial constant portion of the normal cooking phase and the transition into the drying out phase. A No response to Inquiry 154 results in a return (Block 156) to the master program. As the food continues to heat, at some point prior to the end of the normal cooking phase the sensor output voltage V_o will drop below the reference value V_R , resulting in a YES to Inquiry 154. On this and each subsequent pass through the FIRE DETECTION routine during the same cooking cycle, the response to Inquiry 154 will be Yes and Blocks 158-164 and Inquiry 166 will determine the rate of change of the magnitude of output voltage V_o . As shown by the resistance curve in FIG. 3, the change in resistance as the cooking cycle progresses is not a smooth curve but, rather, is characterized by irregular small oscillations. For proper operation the system must respond to the average rate of change computed over a sufficiently long period to smooth out the oscillations. The average rate of change is periodically determined as follows. First, the current incremental change ΔV in the output voltage V_o is computed by subtracting V_o from the previously sampled voltage signal stored as V_o' (Block 158). V_o is then placed in memory as V_o' (Block 160). The cumulative or total change ΔV_T in voltage over the averaging period T_p is updated by adding the just computed ΔV to the old ΔV_T (Block 162). Next, the timer T is incremented (Block 164). The duration of the averaging period is controlled by Inquiry 166 which detects

T greater than T_p where T_p is the desired duration of the averaging period. The duration of the averaging period is not critical and may fall in a wide range of values provided only that it be of sufficient duration for adequate smoothing and yet sufficiently short to provide a satisfactory response time for the system. A period on the order of 30 seconds duration is thought to provide satisfactory smoothing. Until completion of the period T_p , a NO to Inquiry 166 causes a return (Block 156) to the main program. At the completion of each averaging period signified by a YES to Inquiry 166, the timer is reset (Block 168). The average rate of change $\left(\frac{dv}{dt}\right)_A$ for the just completed averaging

10 period is set equal to the cumulative change for that period ΔV_T (Block 170).

This value is directly proportional to the true average since the time period

11 T_p is constant. ΔV_T is then reset for the next averaging period (Block 172). Having updated the average rate, Inquiry 174 checks the status of a Drying Out Flag, which is set upon detection of an average rate of change

15 characteristic of the cooking operation having progressed to the drying out phase. Thus, initially, this Flag is not set and the response to Inquiry 174 is No. Inquiry 176 then compares $\left(\frac{dv}{dt}\right)_A$ with a predetermined reference ΔS .

16 ΔS corresponds to an average rate of change sufficiently small as to be characteristic of the cooking cycle having entered the drying out phase.

20 Hence, Inquiry 176 detects the small rate of change characteristic of the drying out phase. During the balance of the normal cooking phase, the answer to Inquiry 176 is No and the program returns to the master program at this point (Block 156). As the food continues to be heated beyond the normal cooking phase, it enters its drying out phase. During this phase, as hereinbefore described, the rate of change of the concentration level drops off significantly. When a $\left(\frac{dv}{dt}\right)_A$ less than ΔS (Yes to Inquiry 176)

25 is first detected indicative that the transition into the drying out phase has occurred, the Drying Out Flag is set (Block 178) and the program returns (Block 156). Thereafter, for the balance of the cooking cycle, Inquiry 174

indicates that the Drying Out Flag is set and the program will proceed to Inquiry 180 to detect a rate of change greater than a predetermined reference rate of change ΔL characteristic of entering the pre-combustion phase. For the balance of the drying out phase, Inquiry 180 will be No and the program will return to the master program at this point (Block 156). Upon detection of a rate of change greater than reference ΔL , (Yes to Inquiry 180) a signal is provided at output port R12 causing power control relay 68 to open, thereby de-energizing magnetron 40 and the blower motor 67 (Block 182). It will be appreciated that fan motor 67 and magnetron 40 could alternatively be de-energized by inhibiting trigger signals to triac gate terminals 146 and 142, respectively, rather than by opening relay 68. The de-energizing of both the magnetron and the blower motor using either technique in effect turns off power to the oven. Also following a Yes to Inquiry 180, a signal is provided at R11 triggering the alarm oscillator circuit 69 into oscillation to provide an audible signal to the user that a fire condition in the cavity is imminent (Block 184).

By detecting the occurrence of a rapid increase in the rate of change of concentration level by the hereinbefore described method, magnetron 40 is de-energized prior to the load being heated in the oven reaching its actual combustion temperature, thereby anticipating a potential fire condition and preventing the load from reaching its combustion point.

While a specific embodiment of the method and apparatus of the present invention has been illustrated and described herein, it is realized that modifications and changes will occur to those skilled in the art to which the invention pertains. For example, to distinguish the drying out phase from the initial relatively constant portion of the normal cooking phase, rather than detecting a concentration level greater than a predetermined reference level to initiate looking for the relatively

small rate of change marking the transition into the drying out phase,
the reference level may be computed as a percentage of the initial value
for each cycle. Alternatively, the elapsed time since initiation of the
cooking cycle might be monitored to determine a starting point for
5 detecting the small rate of change. It is therefore to be understood
that the appended claims are intended to cover all such modifications
and changes as fall within the true spirit and scope of the invention.

On which...

What is claimed is:

1. A method of anticipating a fire condition in the cooking cavity of a microwave oven of the type having means for continuously circulating air through the cavity to remove gaseous emissions from the food being heated in the cavity and sensor means for sensing the concentration of such gases in the circulating air, said method comprising the steps of:

circulating air through the cavity to remove therefrom gases emitted from the food load being heated in the cavity;

sensing the concentration level of such gases in the circulating air;

periodically determining the rate of change of concentration level;

monitoring the rate of change to detect a rate of change characteristic of the temperature of the food load in the cavity closely approaching its combustion temperature; and

having detected the characteristic rate of change, turning off power to the oven.

2. The method of Claim 1 wherein the step of detecting the characteristic rate of change includes the steps of detecting a first relatively slow rate of change indicative of the load having been cooked to its drying out stage and thereafter detecting a second relatively rapid rate of change, detection of said second rate following said first rate being indicative of closely approaching the combustion temperature of the load.

3. A method of anticipating a fire condition in the cooking cavity of a microwave oven of the type having means for continuously circulating air through the cavity to remove gaseous emissions from the food being heated in the cavity and sensor means for sensing the concen-

5 tration of such gases in the circulating air, said method comprising the steps of:

PI continuously circulating air through the cooking cavity;

L sensing the concentration level of gases emitted by the food in the circulating air;

10 PI detecting a concentration level above a predetermined reference level indicative of having heated the food sufficiently to cause the food to emit gases into the circulating air;

PI having detected a concentration level greater than the reference level, thereafter periodically determining the rate of change of the concentration level as a function of time;

15 PI monitoring the rate of change of the concentration level to detect a relatively small rate of change characteristic of the drying out of the food load;

PI having detected the small rate of change, thereafter monitoring the rate of change to detect a relatively large rate of change; and

PI upon detection of the relatively large rate of change, turning off power to the oven and providing an indication to the user that a combustion condition in the oven is imminent.

4. A method of anticipating and preventing a fire condition in the cooking cavity of a microwave oven of the type having means for circulating air through the cavity and sensor means for sensing the concentration of gases in the circulating air emitted from food loads being heated in the cavity, said method comprising the steps of:

PI (a) continuously circulating air through the cooking cavity of the oven during the cooking cycle;

PI (b) periodically sensing the concentration level in the circulating air of gases emitted from the food during cooking and generating a voltage signal representative of the sensed concentration level;

10

P1 (c) monitoring the voltage signal to detect a voltage level indicative of having completed an initial portion of the normal cooking cycle;

P1 (d) having detected an indicative voltage, thereafter periodically computing the rate of change of voltage with time;

15 P1 (e) monitoring the rate of change of voltage to detect a small rate of change of voltage characteristic of the drying out of the food load;

20 P1 (f) having detected the small rate of change, thereafter monitoring the rate of change to detect a large rate of change characteristic of a relatively rapid increase in the concentration of gases in the circulating air; and

P1 (g) upon detection of the large rate turning off the power to the oven and providing an indication to the user that a combustion condition in the oven is imminent.

ψ
 A method for anticipating the occurrence of a fire in the cooking cavity of a microwave oven of the type having means for circulating air through the cavity during the cooking process and a sensor for determining the concentration of gases in the circulating air emitted by foods
 5 being cooked in the cavity, which concentration level as a function of time is divided into three phases: a normal cooking phase characterized by an initial brief period of relatively constant concentration level followed by a period of relatively rapidly increasing concentration level; a drying out phase characterized by a relatively slowly increasing concentration
 10 level, and a pre-combustion phase, characterized by a relatively rapidly increasing concentration level, said method comprising the steps of:

P1 circulating air through the cooking cavity of the oven;
 L detecting a concentration level of gases in the circulating air indicative of the cooking cycle having progressed beyond the initial
 15 period of the normal cooking phase for the food being heated;

thereafter periodically determining the rate of change of concentration level as a function of time;

detecting a first rate of change characteristic of the drying out phase;

having detected said first rate of change, thereafter detecting a second rate of change indicative of the pre-combustion phase; and

upon detection of said second rate of change, turning off power to the oven and providing an indication to the user that a fire condition in the cavity is imminent.

5. A control arrangement for a microwave oven comprising:
means for generating microwave energy for heating foods received in the cooking cavity;

means for continuously circulating air through the cooking cavity to remove therefrom gases emitted by the food load being heated in the cavity;

sensing means for sensing the concentration level of such gases in the circulating air and generating a first signal having a magnitude representative of the sensed concentration level;

sensor monitoring means responsive to said first signal and including means operative to periodically determine the rate of change of concentration level as a function of time, and means operative to detect a rate of change indicative of closely approaching the combustion point of the load being heated in the oven and generating a second signal upon such detection; and

means for terminating operation of said microwave energy generating means and said air circulating means in response to said second signal.

7. A control arrangement in accordance with Claim 6 wherein said means for detecting said characteristic rate includes means for detecting the occurrence of the second of two periods of relatively rapidly increasing concentration level separated by a period of relatively slowly increasing concentration level, and generating said second signal upon detection of said second period.

8. The control arrangement of Claim 6 wherein said sensor monitoring means comprises means for detecting a relatively slow rate of increase in concentration level indicative of the food load being heated to its drying out stage and thereafter detecting a relatively rapid increase in concentration level indicative of closely approaching the combustion point of the food load and wherein said second signal is generated upon detection of said relatively rapid increase.

9. A control arrangement for a microwave oven which anticipates a fire condition in the cooking cavity of the oven, said control arrangement comprising:

P1 means for generating microwave energy for heating foods received in the cooking cavity;

P1 means for continuously circulating air through the cooking cavity to remove therefrom gases emitted from the food load being heated in the cavity;

P1 sensing means for sensing the gas concentration level of the circulating air and generating a first signal having a magnitude representative of the sensed gas concentration level;

P1 sensor monitoring means responsive to said first signal including: means for detecting a signal magnitude indicative of a gas concentration level greater than a reference level; means for determining the rate of change of said signal magnitude; means for first detecting a

relatively slow rate of change following detection of said concentration level greater than said reference level and thereafter detecting a relatively rapid rate of change;

20 P1 means responsive to said sensor monitoring means operative to de-energize said microwave energy source and to terminate operation of said air circulating means following detection of said rapid rate of change; and

P1 means responsive to said sensor monitoring means operative to provide an indication to the user that a fire condition in the cavity
25 is imminent following detection of said rapid rate of change.

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AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

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ABSTRACT

A method and apparatus for anticipating the occurrence of a fire in the cooking cavity of a microwave oven. The oven is provided with a blower for continuously circulating outside air through the cooking cavity to carry away gases emitted by food loads being heated therein. A sensor responsive to the concentration of gases in the circulating air monitors the gas concentration level and generates an output signal representative thereof. Sensor monitoring circuitry responsive to the sensor output signal is operative to determine the rate of change of the gas concentration level, and detect a characteristic rate of change indicative of the load being heated closely approaching its combustion point. Upon detection of the characteristic rate of change, power to the oven is turned off and an indication is provided to the user that a combustion condition in the oven cavity is imminent.

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3 101
3 102

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COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

, the specification of which:

(check ☒ is attached hereto.

one) ☐ was filed on _____ as Application Serial No. _____ and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby appoint H. Neil Houser, Reg. No. 28,859; and Radford M. Reams, Reg. No. 22,006;

Range Engineering, Appliance Park, Building 1, Room 230, Louisville, KY 40225,

and Joseph B. Forman, Reg. No. 15795, Fred Jacob, Reg. No. 18111, and Ernest F. Chapman, Reg. No. 25961, Washington Patent Operation, General Electric Company, 2001 Jefferson Davis Highway, Arlington, Virginia 22202, jointly, and each of them severally, my attorneys and attorney, with full power of substitution, delegation and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent and to transact all business in the Patent and Trademark Office connected therewith. I hereby direct that all correspondence and telephone calls in connection with this application be addressed to the said H. Neil Houser, General Electric Co.,

at Appliance Park, Building 1, Room 230, Louisville, KY 40225
(mailing address)

Telephone No. (502) 452-4653

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor Peter Harold Smith

Inventor's signature Peter Harold Smith June 27 1983
(Date)

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Full name of second joint inventor, if any _____

Second Inventor's signature _____ (Date)

Residence _____

Citizenship _____

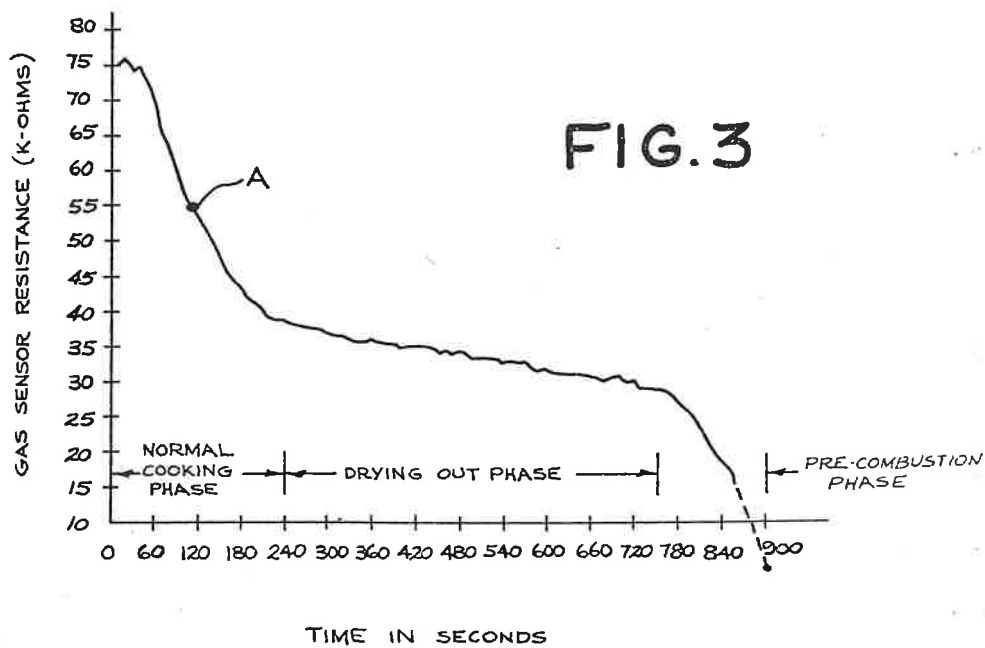
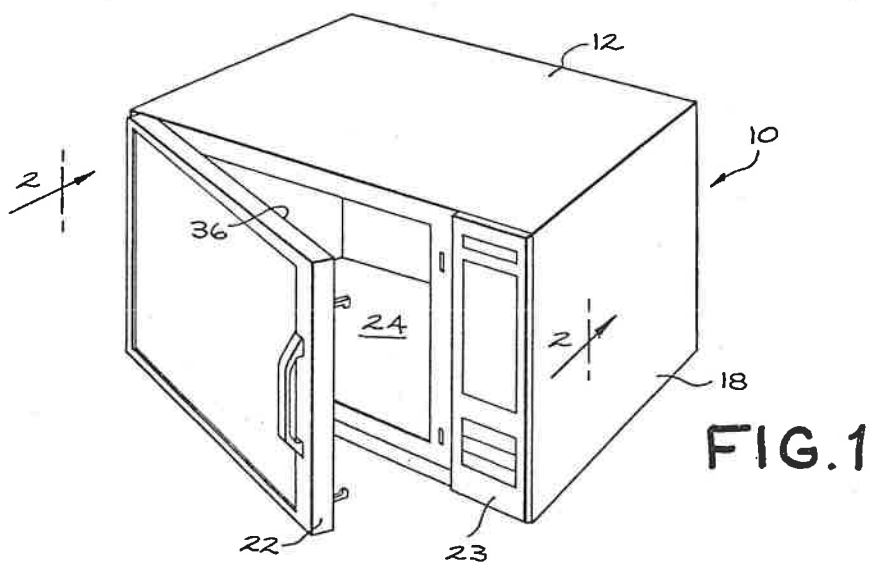
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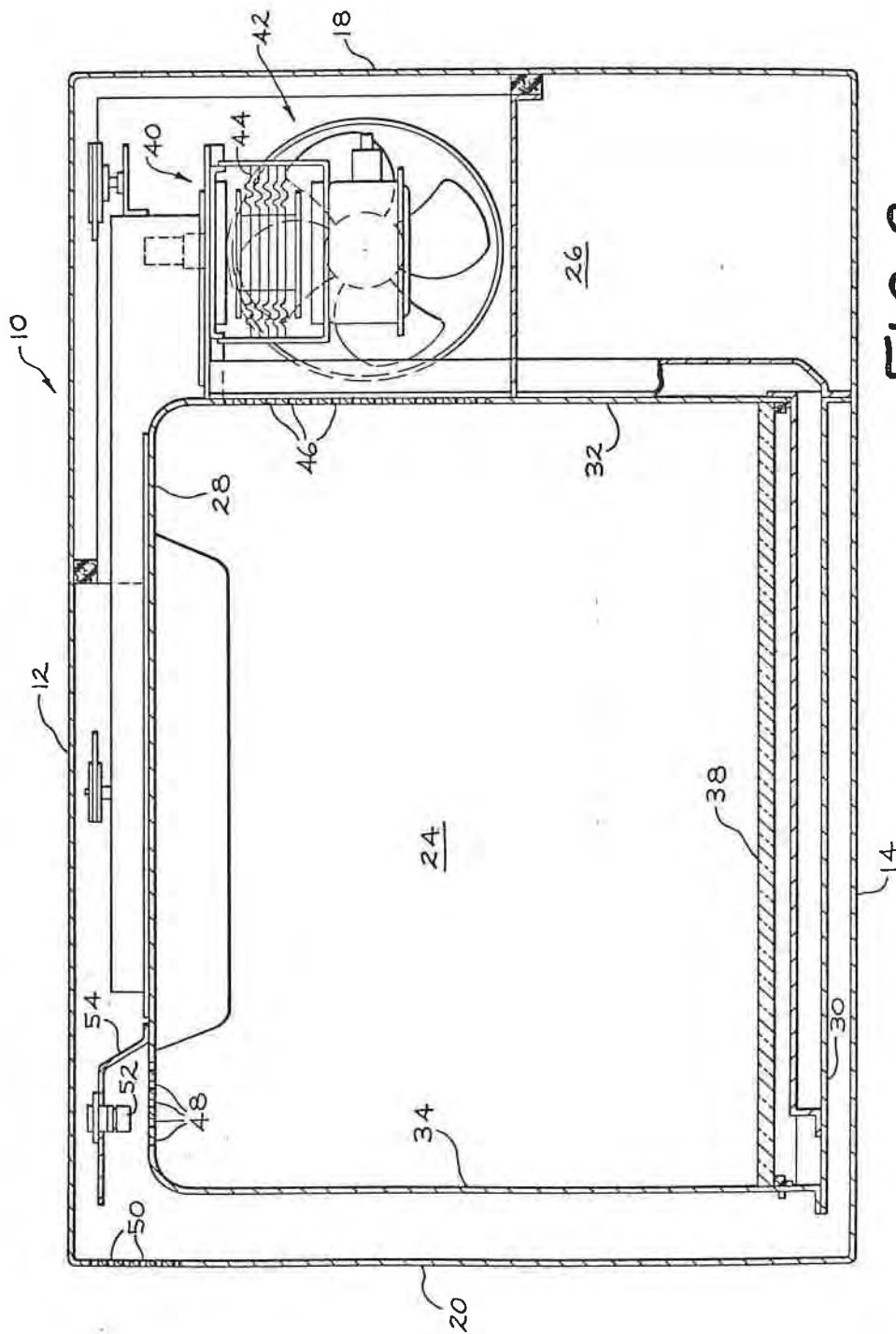
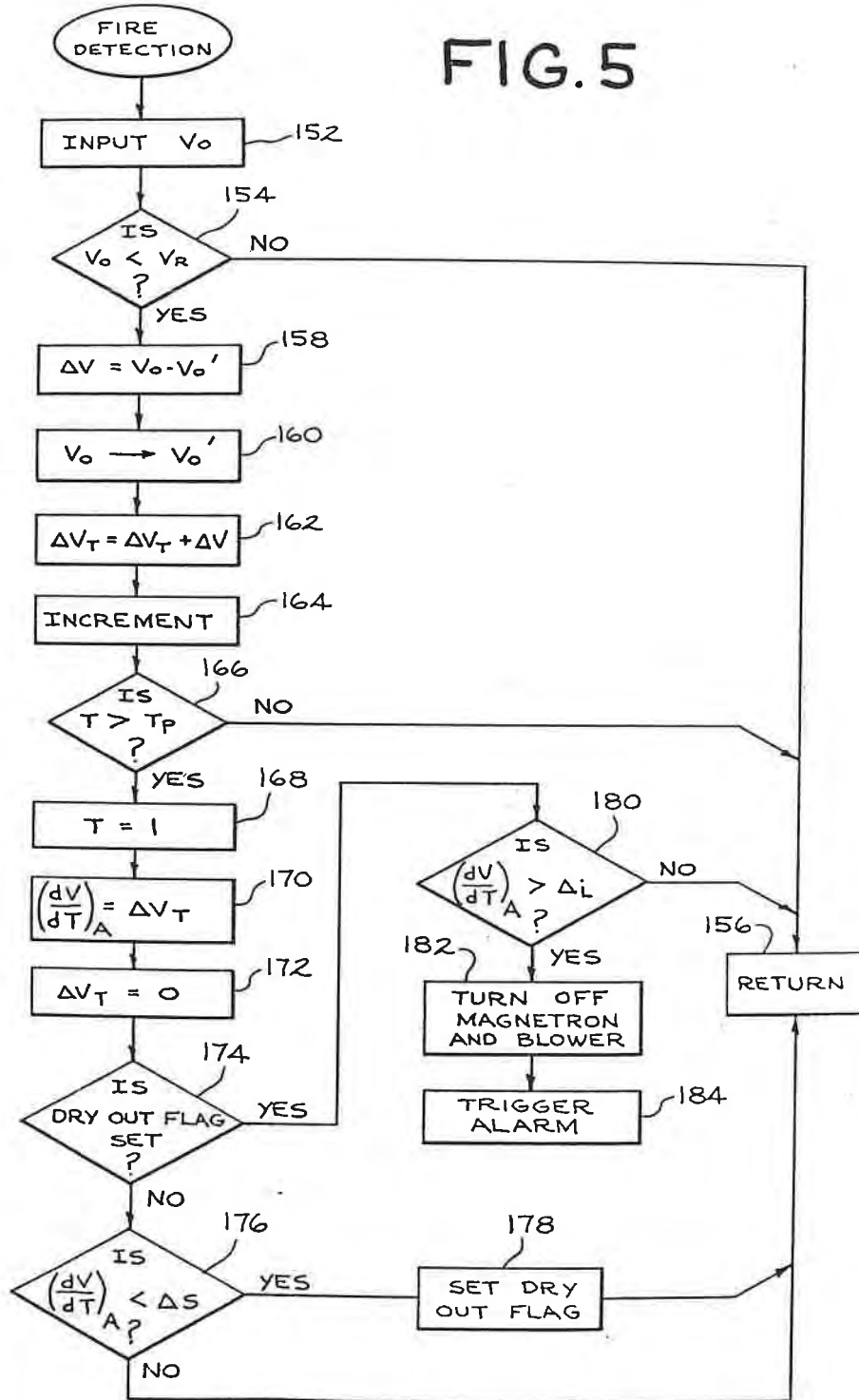


FIG. 2



FIG. 5





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Docket No. 9D-RG-16129

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AUG 16 1983

GROUP 210

*#2
Prior Art*

Applicant: PETER H. SMITH

Serial No. 511,556

Group Art Unit: 218

Filing Date: July 7, 1983

Examiner:

Title: AUTOMATIC FIRE DETECTION FOR A
MICROWAVE OVEN

STATEMENT OF RELEVANCE OF PRIOR ART CITED BY APPLICANT

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

SIR:

The following statement of relevance is submitted with the accompanying Form PTO-1449 (Rev. 7-80).

Document Designation	Relevance
Page 1	
AA	Discloses an arrangement for controlling the heating power applied to the object being heated in a microwave oven as a function of the humidity of the air exiting the cooking cavity.
AB	Discloses apparatus for controlling heating time in a microwave oven as a function of sensed humidity in the cooking cavity.
AC	Discloses a method of detecting a fire in the cooking cavity of a microwave oven by sensing the time dependent humidity and temperature conditions in the cavity; a fire is indicated when the humidity decreases and the temperature increases within a predetermined time interval. Upon detection, the oven is turned OFF.
AD	Discloses a method of controlling cooking in a microwave oven as a function of the sensed humidity and temperature in the cooking cavity.

<u>Document Designation</u>	<u>Relevance</u>
AE	Discloses a microwave oven sensing system which incorporates a temperature sensor and a humidity sensor for cooking control.
AF	Discloses a method of determining the optimum time to turn meats heated in a microwave oven as a function of the sensed temperature and humidity in the oven.
AG	Discloses a method of detecting the degree of doneness for meats heated in a microwave oven as a function of sensed humidity and temperature in the oven.
AH	Discloses an arrangement for detecting microwave oven cooking cavity temperatures approaching abnormal levels and suppressing microwave generation upon such detection, which employs a heat sensitive film to detect the abnormal condition.
AI	Discloses a method of cooking thin meats in a microwave oven as a function of sensed temperature and humidity in the oven.
AJ	Discloses the auxiliary use in a microwave oven of a Figaro gas sensor as an ambient leak detector when the oven is not in use for cooking.
AK	Discloses use of a Figaro gas sensor for food doneness sensing in a combination microwave and thermal oven.

Page 2

AA	Discloses use of a Figaro gas sensor and a temperature sensor for food doneness sensing in a combination microwave and thermal oven.
AB	Discloses a malfunction detection arrangement for a Figaro gas sensor employed in a microwave oven.
AC	Discloses a control arrangement for a combination microwave and thermal oven providing for user selection of the reference level against which the Figaro gas sensor output is to be compared for doneness sensing.

Docket No. 9D-RG-16129

Document
Designation

Relevance

AD

Discloses a building alarm system employing a gas sensor, which system is responsive to a predetermined concentration of gaseous hydrocarbon in an area.

AL

Discloses an arrangement for controlling doneness in a combination microwave and thermal or browner oven, which employs a gas sensor selectively operative in two modes, a humidity sensing mode for microwave control and soot sensing mode for "grille menus."

Full text copies of the art listed above are enclosed. It is respectfully requested that this art be considered by the examiner in the above-entitled application and made of record therein.

Respectfully submitted,



H. Neil Houser
Attorney
Reg. No. 28,859

August 9, 1983

LIST OF PRIOR ART CITED BY APPLICANT

(Use several sheets if necessary)

APPLICANT

PETER H. SMITH

FILING DATE

July 7, 1983

GROUP

213

GROUP 210

RECEIVED

AUG 16 1983

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
me	AA	3 8 3 9 6 1 6	10/1/74	Risman	219	10.55	
me	AB	4 0 9 7 7 0 7	6/27/78	Kobayashi et al (i)	219	10.55B	
me	AC	4 1 3 3 9 9 5	1/9/79	Buck	219	10.55M	
me	AD	4 1 5 4 8 5 5	5/15/79	Buck	426	243	
me	AE	4 1 6 2 3 8 1	7/24/79	Buck	219	10.55B	
me	AF	4 1 6 6 1 3 7	8/28/79	Buck	426	243	
me	AG	4 1 7 1 3 8 2	10/16/79	Buck	426	243	
me	AH	4 2 2 1 9 4 9	9/9/80	Minakawa	219	10.55C	
me	AI	4 2 8 1 0 2 2	7/28/81	Buck	426	233	
me	AJ	4 2 9 5 0 2 8	10/13/81	Tanabe	219	10.55B	
me	AK	4 3 1 1 8 9 5	1/19/82	Tanabe	219	10.55B	

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION	
							YES	NO
	AL							
	AM							
	AN							
	AO							
	AP							

OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, Etc.)

	AR	
	AS	
	AT	

EXAMINER

PHILIP H. LEUNG

DATE CONSIDERED

MAY 10, 1984

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Ex. 2003.0039

[54] METHOD AND DEVICE FOR PRODUCING
HEATING OF MOISTURE-CONTAINING
OBJECTS

[75] Inventor: Per Olov Risman, Tenhult, Sweden

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[22] Filed: Feb. 13, 1973

[21] Appl. No.: 332,144

[30] Foreign Application Priority Data
Feb. 14, 1972 Sweden..... 1752/72

[52] U.S. CL..... 219/10.55, 200/61.06, 338/34

[51] Int. Cl..... H05b 9/06, H01c 13/00

[58] Field of Search..... 219/10.55; 338/34;
200/61.06

[56] References Cited

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Primary Examiner—J. V. Truhe

Assistant Examiner—Hugh D. Jaeger

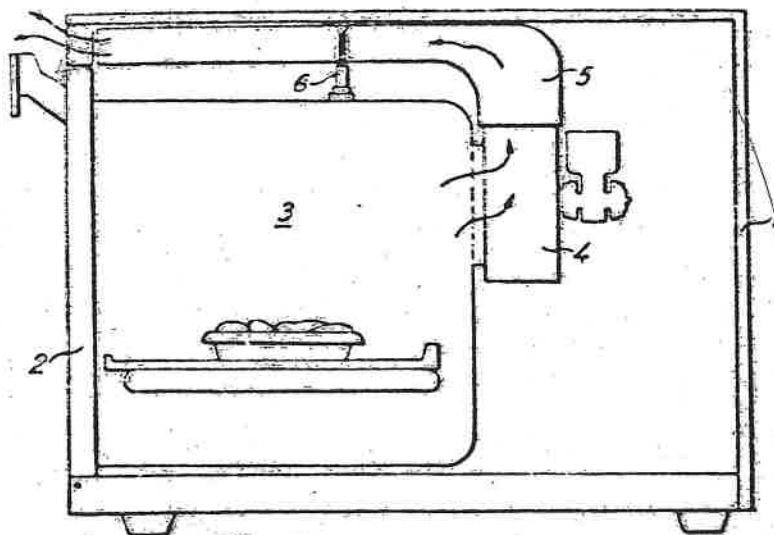
Attorney, Agent, or Firm—Holman & Stern

[57]

ABSTRACT

A method for the periodic heating of a moisture-containing object is disclosed whereby the change in humidity of the moisture, liberated when the object is heated, is measured by a measuring process and converted to a measuring quantity which controls the heating power fed to the object; a device is also disclosed for carrying out the method.

4 Claims, 3 Drawing Figures



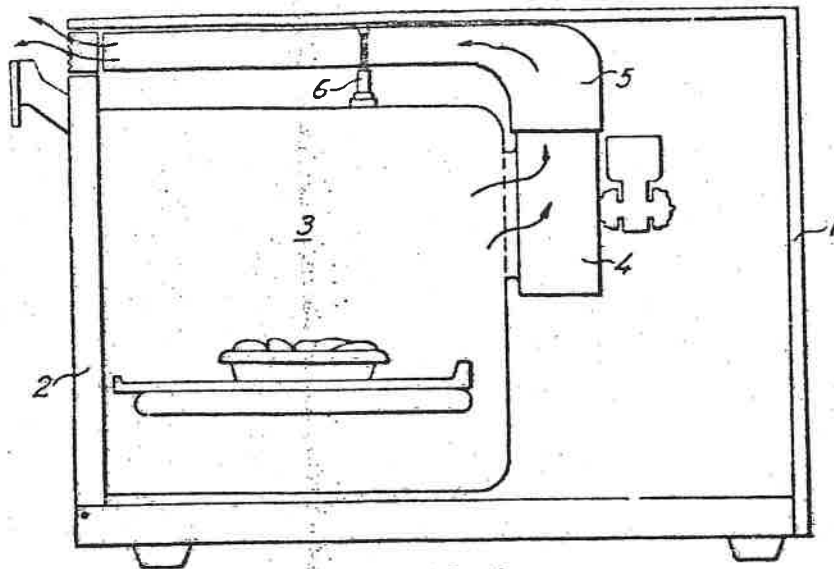


Fig. 1

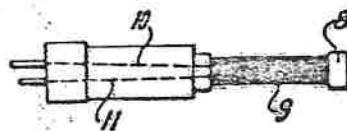


Fig. 2

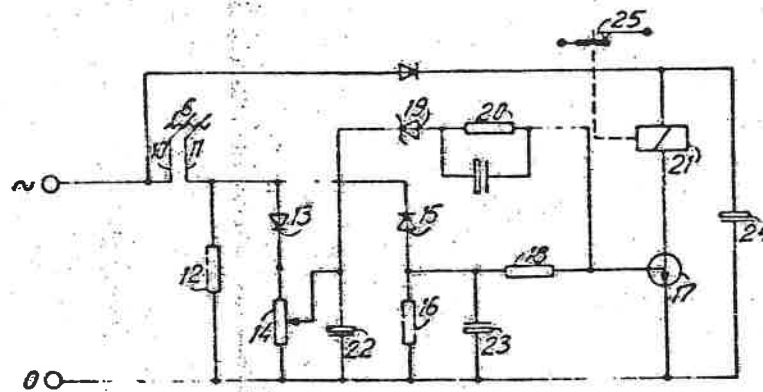


Fig. 3

METHOD AND DEVICE FOR PRODUCING HEATING OF MOISTURE-CONTAINING OBJECTS

BACKGROUND OF THE INVENTION

The present invention relates to a method for periodic heating of water-containing objects, in which the heat is added and the moisture removed. The method can be used to prevent boiling or overheating in certain parts of the object most exposed to the heating. The method has advantages, especially for heating in a micro-wave oven, which is equipped with a device for application of the method.

When heating sensitive substances, such as food-stuffs, the risk of overheating is obvious, and can result in certain parts of the object being burned or dried out. This risk was previously noted and partially eliminated by control of the addition of heat, for example the division of the heating time into periods with full power, separated by intervals with no power. Such a control can be produced with the aid of a timer with repeating unit. Such a division of the heating into certain time periods, however, has drawbacks, the period of time having to be adapted to the substance which is to be heated. It must therefore be considered that there is an urgent need for a heating method in which the substance itself provides an indication of how the periodicity in the heating is to be, in order to avoid overheating. Since the water-containing substance gives off steam as it is heated, and therefore the air flowing from the heating place is moist, a control of the addition of heat can be arranged in such a way that the humidity of the air flowing out is measured, and the quantity measured is used to influence contact devices which close and open the circuit as a function of the humidity of the air, and hence of the evaporation from the heated object. But the problem is not completely solved; it is inescapable that the moisture in the ambience around the object, and the heating place, is a slow "reagent" at the temperature of the object in question. Moreover, the measuring equipment must be well calibrated and free of contamination, which raises a number of practical obstacles to a solution of the problem, depending merely on the humidity of the air.

SUMMARY OF THE INVENTION

A better way of solving the reading of the temperature of the object is to measure changes in humidity, that is to say, the derivative of the humidity, in the air flowing around the heating place. Because the absolute humidity of the air rises in discrete jumps as the boiling begins, and the boiling starts at a certain temperature, it is possible, by measuring the humidity derivative, to obtain a quick and reliable jump at the time during the heating of the object when the boiling point is reached. Moreover, in such a method of measurement, the influence of the temperature of the air, and of impurities on the indicator are eliminated, which means that any errors in calibration of the measuring system will have little effect on the precision of measurement.

With the method, a known indicator for measurement of the humidity of the air can be used. Such indicators form part of previously known coupling systems for measuring absolute and relative humidity in the air. The moisture-sensitive substance in such an indicator is composed of a salt, for example lithium chloride, which has the property of increasing its electrical con-

ductivity as the water absorption in the substance is increased. The principle of using a lithium chloride cell's resistance as a gauge of the moisture in the air around the cell, and the measurement, and transformation of the measured values into a humidity figure is therefore known from such coupling systems.

BRIEF DESCRIPTION OF THE DRAWINGS

Further clarification of the method according to the invention will be found in the following description of a practical embodiment of the same in connection with the description of a device shown in the attached drawing for production of periodic heating according to the invention. The drawing shows:

In FIG. 1, an oven for heating objects, equipped with a device according to the invention;

In FIG. 2 a diagrammatic sketch of an indicator used in the device, and in

FIG. 3, a hookup in which the indicator forms a part of the device.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. 1 shows, schematically, a micro-wave oven in longitudinal section, equipped with a case 1, a lid 2 and an oven space 3 which is ventilated with the aid of a fan 4, placed on the back of the oven, which fan draws air from the oven chamber and blows the latter out as the arrows indicate, through a channel 5 under the top of the oven. In this channel there is an indicator element 6 mounted in the airflow from the fan.

The construction of element 6 is shown in FIG. 2. Over a cylindrical container 8 of temperature-resistant plastic, a piece of glass fiber hose 9 is fitted. The hose 9 is made of untreated, glass fiber heated to incandescence, which can absorb water by capillary force. The diameter of the container is about 6mm when the glass fiber hose is fitted. The length of the hose, when it fits tightly around the holder, is about 30mm. Bifilar silver wires 10, 11 are wound on the glass fiber hose. Each wire is wound for a total of 6-7 turns. The glass fiber hose is impregnated with a 20 percent LiCl solution which subsequently assumes hygroscopic equilibrium with the humidity of the air.

The indicator 6 is supplied with AC without DC components, otherwise electrolysis can arise. When the power is switched on, the indicator 6 first constitutes an almost perfect short-circuit. But it is quickly heated up by the current, and, in the present case, after about one minute, it assumes such a high temperature after the solution dries up, that the current drops to zero. If the indicator is exposed to an air current, however, the "swingover," that is to say the drying up, is of short duration. After another few minutes the indicator temperature stabilizes at a temperature which is a direct function of the partial pressure of the water vapor in the air. This temperature normally lies 20°-30° above the air temperature. In order to maintain this temperature difference, a certain indicator current is required, in normal cases, in a stationary state, 15-30 m.a., if the indicator voltage is about 24 volts AC.

The reason for this self-regulating property is the extraordinarily good hydrophilic properties of lithium chloride; this substance is probably the most hydrophilic of all substances, apart from those which change chemically as they absorb water. The salt can therefore never dry out as long as it is not heated, the tempera-

ture of equilibrium is precisely the drying-out temperature. On drying out, however, the electrical conductivity drops so that the current is reduced and the temperature begins to drop.

When the indicator 6 is exposed to an increase in air humidity at constant speed, in the ambient air, it is quickly saturated, and the indicator current consequently rises. But the indicator is heated thereby and the current gradually drops to approximately the same value as before. The indicator current consists, therefore, of two components, on the one hand a "basic component" corresponding to the stationary humidity and the air speed, and on the other hand a "dynamic" component which depends on the changes in humidity, that is, the derivative of the humidity with respect to time. The temperature also changes, very often at the same time as the humidity is changed, but because the indicator temperature is quite high even in the stationary state, this influence is dominated completely by the influence of changes in the humidity.

As an example, it can be stated that if water is heated with about 1 kw of electricity, the indicator current in a few seconds, as boiling begins, rises to more than 200 m.a., provided that the suction fan as shown in FIG. 1 is used. After about 20 minutes, the current has dropped to below 100 m.a.

As mentioned above, the indicator unit forms part of a circuit of electrical components according to the diagram in FIG. 3. The following is a description of this circuit. Indicator element 6, with feedleads 10, 11 is in series with a resistance 12 connected to a source of AC. In parallel with the resistance there is an amplifier circuit, which includes two branches containing rectifier 13, potentiometer 14 and rectifier 15, respectively, and resistance 16, with rectification in each direction. A current flows through resistance 16, during the negative half cycle of the voltage, and this negative voltage through the resistance is fed to the base of a transistor 17 via another resistance 18, hence the transistor is non-conductive. The base of the transistor is also connected to a branch of the circuit which contains a Zener diode 19 and a resistance 20, and is fed from potentiometer 14. The positive voltage through the latter is applied to the Zener diode 19. Because the resistance in resistance 20 is relatively low, the voltage at the base will rise when the indicator current and hence the voltage across the resistance 12 rises. Since a negative current is flowing through resistance 18, a stronger current through 20 will be required, so that the base current will be strong enough for relay 21 to draw. This compensation means that the working current through the Zener diode, when the relay operates, will be on the straight part of the Zener characteristic, and not the current "knee," hence a faster relay function is obtained. Potentiometer 14 is used for adjustment of the operation of the relay for a desired indicator current. Condenser 22-24 are smoothing condensers. Relay 21 has a contact 25 which forms part of the feed circuit to the oven and hence cuts off the power supply when the relay draws. When the indicator current drops, the relay falls back again, and contact 25 again closes the circuit.

Because indicator element 6 is mounted in the air-flow channel as shown in FIG. 1, a favorable control of the switching on and switching off of the oven is obtained. Two factors contribute to reducing the influence of impurities such as grease etc., in the evacuated

air. First of all, the indicator current has a "basic component" which need not necessarily come from the lithium chloride, but can result from impurities. In connection with this, we may point out that the quantity of lithium chloride in the indicator is not critical. Secondly, the indicator temperature is higher than the air temperature, which considerably reduces the deposition of impurities on the indicator. Electrolytically conductive impurities generally dry up so that their influence is eliminated.

In a microwave oven, the temperature of the evacuated air is low in comparison with the use of conventional sources of heat. Because the changes in the indicator current are dependent on changes in the temperature and humidity, an undesirable influence of air temperature changes, as boiling begins in the object, is limited. As boiling begins, the absolute humidity in the evacuation air is changed considerably, hence the rise of indicator current will be very substantial; the size of the object therefore plays a very small part, provided that the water content is sufficiently high. Even the fact that the microwave power, and hence the absolute boiling speed, is very little dependent on the size of the object, contributes toward making the adjustment of indicator current for disconnection, non-critical.

Even though the device described here is constituted as a form of regulator of the power to a microwave oven, other fields of application are not, of course, excluded. One field related to that described here would be temperature control of chemical processes. It is naturally possible to vary the device accordingly to the field of use in question. The indicator cell and hookup just described for obtaining control current to a contactor must therefore be considered as an example of execution of a device according to the invention. The method of construction of the device and the device as such are defined in the following claims.

What is claimed is:

1. A method for applying periodic microwave heating to a moisture-containing object comprising the steps of:

- heating the object to liberate moisture;
- measuring the changes in humidity caused by the liberated moisture;
- converting the measured changes to a first measuring quantity;
- cutting off the heat supplied to the object using said first measuring quantity whereby the object begins to cool;
- measuring the consequent changes in humidity liberated from the object;
- converting the measured consequent changes to a second measuring quantity;
- resupplying heat to the object utilizing said second measuring quantity to thereby increase the humidity liberated from the object; and
- continuously repeating steps (b) through (g) to thereby apply periodic heating to the moisture-containing object.

2. A device for producing periodic microwave heating of a moisture-containing object comprising:

- a heating chamber, microwave heating means having a power feed circuit and disposed in said chamber; fan means arranged to be in interworking relationship with said chamber; a moisture-sensitive resistance means disposed in close proximity to the object and arranged so as to be in the path of the air

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stream produced by said fan means, which air-stream contains the moisture liberated by the object when heated by said heating means, said moisture-sensitive resistance means being operatively responsive to the moisture in the air-stream for periodically controlling the power fed to said heating means.

3. A device as claimed in claim 2 wherein said moisture-responsive resistance means is composed of a lithium chloride cell with two electrodes.

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4. A device as claimed in claim 3 wherein said lithium chloride cell is connected to an amplifier coupling comprising a transistor controlling a relay in the power feed circuit to said heating means, said transistor being set into conduction by a control current produced by a circuit containing a Zener diode, said Zener diode being fed by a voltage through a resistance connected in series with said moisture-sensitive means.

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[54] APPARATUS FOR CONTROLLING HEATING TIME UTILIZING HUMIDITY SENSING

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[73] Assignee: Matsushita Electric Industrial Co., Ltd., Osaka, Japan

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[52] U.S. Cl. 219/10.55 B; 99/325

[58] Field of Search 219/10.55 R, 10.55 M,
219/10.55 B; 34/50; 99/325, 468, 486

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Primary Examiner—J. V. Truhe

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[57] ABSTRACT

Apparatus for controlling heating time for food placed in a cooking apparatus such as a microwave oven in which heating time required for the humidity of the food which varies with the heating of the food to reach a representative humidity value after abrupt change with a positive gradient is measured, and the product of the measured heating time multiplied by a predetermined heating time coefficient which is inherent in the particular food is added to the measured heating time so that the sum represents the total required heating time for the food.

5 Claims, 9 Drawing Figures

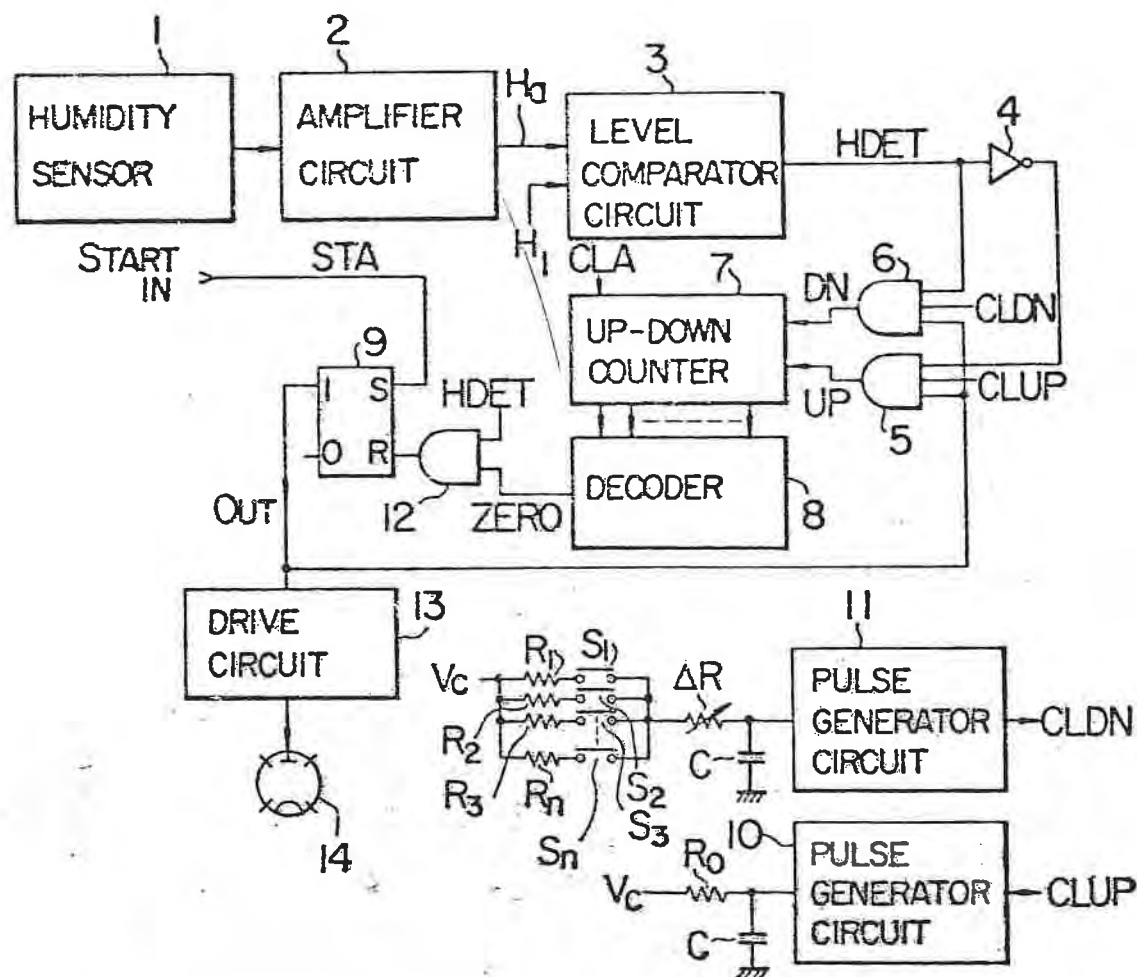


FIG. 1a

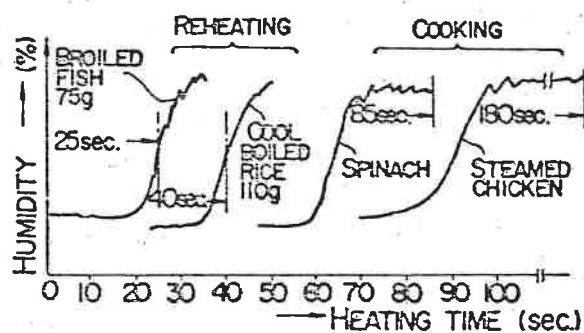


FIG. 1b

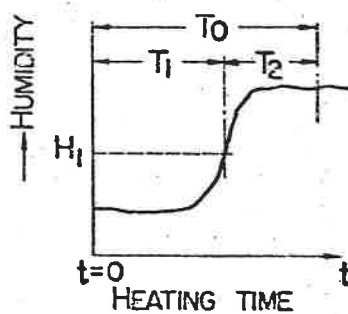


FIG. 2a

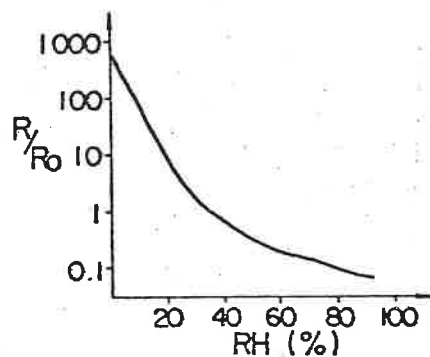


FIG. 2b

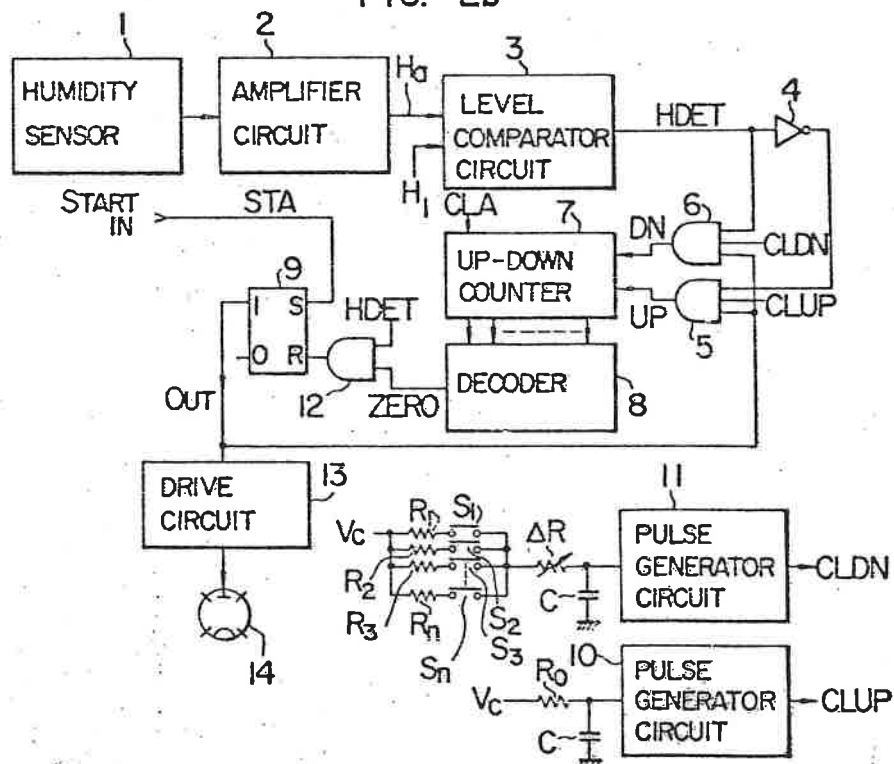


FIG. 3a

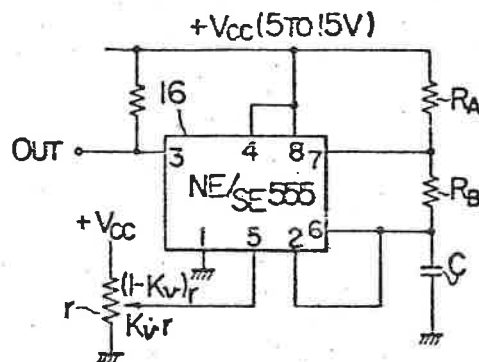


FIG. 3b

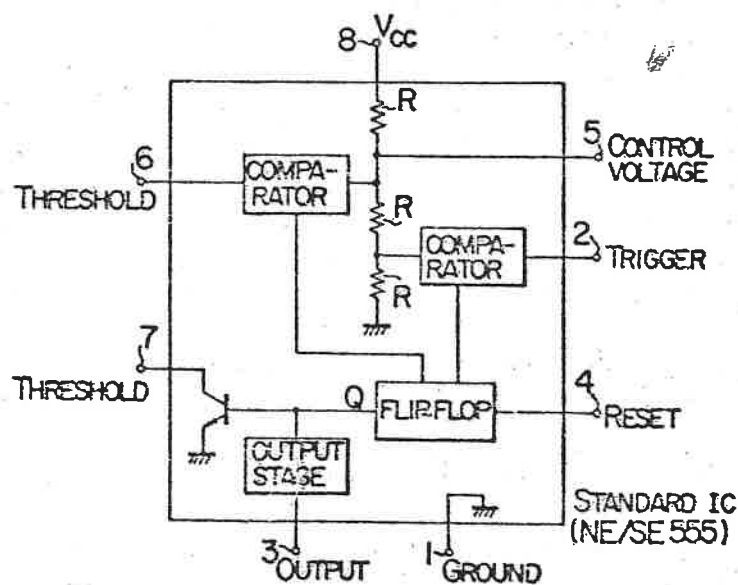


FIG. 4a

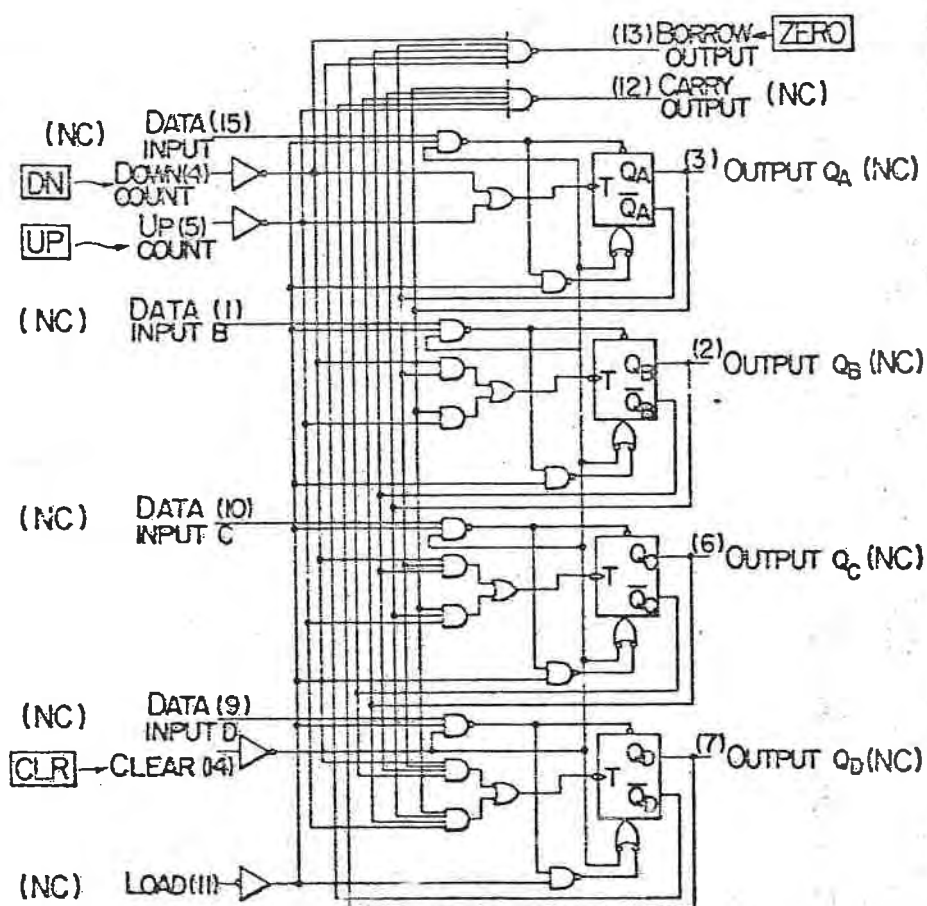
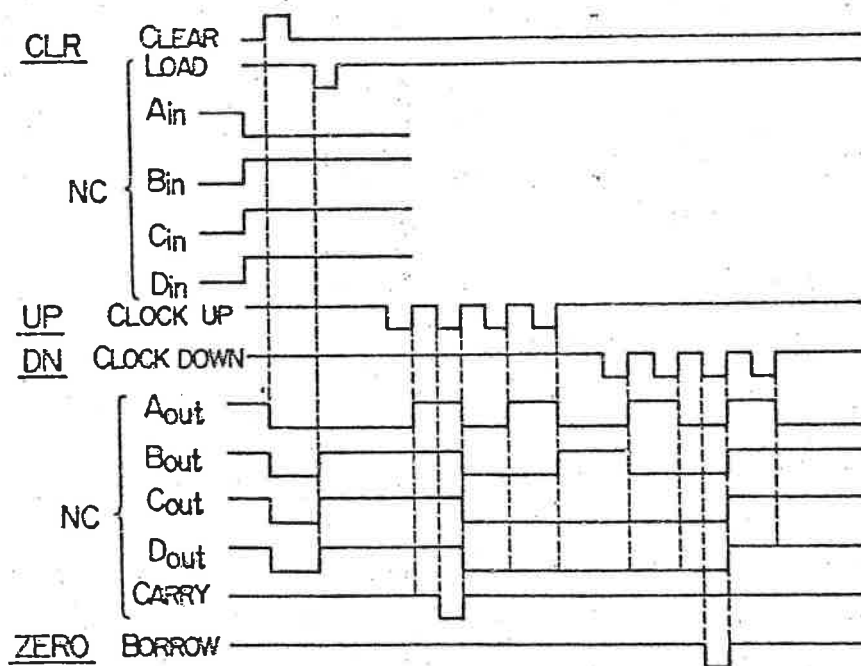


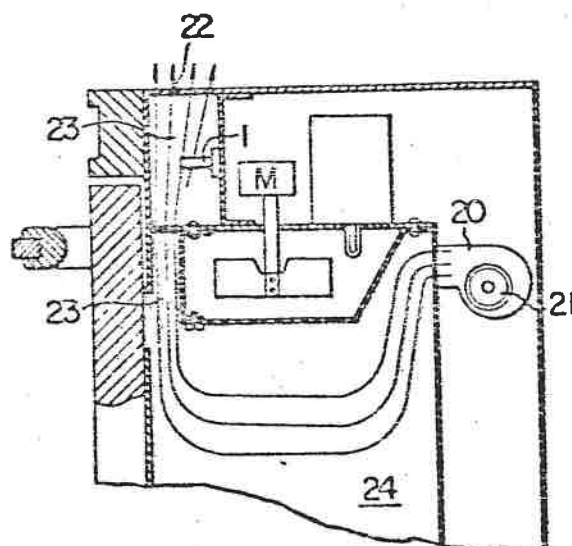
FIG. 4b



NOTES: 1. A, B, C, AND D INPUTS ARE FREE TO CHANGE AFTER LOAD INPUT IS DISABLED.

2. WHEN COUNTING "UP", THE "DOWN" CLOCK MUST BE IN THE LOGICAL 1 STATE, AND CONVERSELY.

FIG. 5



APPARATUS FOR CONTROLLING HEATING TIME UTILIZING HUMIDITY SENSING

The present invention relates to an apparatus for automatically controlling heating time for a food depending on the food to be heated in a cooking apparatus such as a microwave oven.

In microwave heating, the optimum heating time for a food to be heated is determined by various factors such as the initial temperature of the food to be heated, the volume of the food, the temperature to which the food is to be heated, the specific heat of the food and the microwave power to be supplied.

Heretofore, the heating time in the microwave oven has been determined by setting a standard heating time which was experimentally determined depending on the type and volume of the food.

Such a heating time setting method however involved the disadvantage that no special attention was paid to other factors for determining the heating time such as the initial temperature of the food, the specific heat of the food, the destination temperature and the microwave power, and hence proper heating or cooking of the food was not attained. This is because a main factor that determines the finished state of the food is not the heating time but the temperature rise of the food to be heated per se.

Thus, if the temperature rise of the food being heating can be detected by some means, an optimum heating and cooking of the food will be attained, the finished state of which will not be influenced by the initial temperature of the food, the volume and the specific heat of the food and the microwave power supplied.

As a method for sensing the temperature rise of the food, it has been proposed to insert a temperature sensor directly into the food and to sense the temperature rise of the food by a non-contact temperature sensor. However, applications thereof are limited because the former method requires the direct contact of the temperature sensor with the food and the latter method cannot always provide accurate sensing of the temperature. On the other hand, it has been known to sense the temperature of the food or degree of heating by measuring the change of humidity which takes place as the food is heated. For example, in most foods, water included therein abruptly evaporates when the temperature of the food reaches 100° C and a large amount of water vapor appears in the oven. By detecting such change of humidity by a humidity sensor, the time at which the humidity abruptly changes can be related to the time at which the food has reached 100° C.

The present invention makes use of such a relation between the food temperature and the humidity appearing thereat.

A method for detecting the humidity generated from the food to control the power of a magnetron is disclosed in U.S. Pat. No. 3,839,616 issued to Risman. This patent, however, uses a humidity sensor in order to periodically interrupt the heating of the food to prevent overheating of the food and does not provide automatic heating and cooking as in the present invention.

It is a first object of the present invention to eliminate the setting operation of heating time in an oven as represented by a microwave oven, which heating time is normally determined taking the volume of the food to be heated into consideration.

It is a second object of the present invention to eliminate the troublesome operation of taking a correction of the heating time into consideration, which correction is otherwise needed due to the variation of the initial temperature of the food.

It is a third object of the present invention to eliminate the troublesome operation of taking a correction of the heating time into consideration, which correction is otherwise needed due to the variation in the capacity of a thermal energy source such as a magnetron and the variation of the microwave absorption factor of the food.

It is a fourth object of the present invention to enable the detection of the temperature of the food under heating without requiring direct contact with the food.

It is a fifth object of the present invention to eliminate a timer setting operation for the reasons set forth in connection with the above objects.

It is a sixth object of the present invention to provide a function which enables external adjustment of the heating time so that a user can determine the heating time as he desires.

These and other objects, features and advantages of the present invention will become more apparent from the following description of the preferred embodiments of the invention when taken in conjunction with the accompanying drawings.

FIG. 1a illustrates examples of the change of humidity which occurs with the heating of the food in a microwave oven.

FIG. 1b is a generalized representation of FIG. 1a.

FIG. 2a shows a characteristic of a humidity sensor adapted to be used in the present invention.

FIG. 2b shows a particular embodiment of the present invention.

FIG. 3a shows an example of a circuit of a pulse generator capable of controlling a pulse period thereof, constructed in a standard integrated circuit.

FIG. 3b shows an internal configuration of the above integrated circuit NE/SE 555.

FIG. 4a shows a particular circuit diagram in which the functions of a counter 7 and a decoder 8 in the embodiment of FIG. 2b are combined.

FIG. 4b shows a timing chart for a standard MSL/74193.

FIG. 5 is a cross-sectional view of a microwave oven in which cooling air flow together with a humidity sensor are shown.

Referring to FIG. 1a, in microwave heating of the food, the change of humidity near the food being heating with the heating time generally rises abruptly, after the elapse of a certain period of time, with a different gradient than the previous one.

The time at which such abrupt change of gradient appears in reheating the food approximates the time at which the temperature of the food reaches an optimum temperature, and in many cases it approximates the reheating time which has been specified in a prior art microwave oven for the particular food according to experience.

It has been known from the experiment of heating and cooking of the food that a certain type of food must be further heated after the humidity has reached H₁, for a time period determined by the volume of the food to be heated and the particular cooking method therefor.

Since the time at which the humidity start to increase already includes the influence factors such as the amount of the food, the initial temperature of the food

and the microwave power, there is no need for further taking the initial temperature and the volume into consideration when such humidity change is related to the temperature of the food and it is thus possible to automatically control the heating time.

Referring now to FIG. 1b, the heating time T_0 for the food is generally given by the sum of a time T_1 required to reach a humidity value H_1 which represents an abrupt rise of the humidity and a time T_2 following T_1 , which is determined by the volume of food and the type of cooking. That is;

$$T_0 = T_1 + T_2 \quad (1)$$

Since the time T_2 is determined by T_1 and the volume of the food and the type of cooking, it can be represented by;

$$T_2 = kT_1 \quad (2)$$

where k is a coefficient inherent to the particular food. From the formulas (1) and (2),

$$T_0 = T_1 + kT_1 \quad (3)$$

It is thus possible to determine the total required heating time by measuring the time T_1 required for the humidity to reach the appropriate value H_1 on the steep gradient and obtaining the sum of the time T_1 and the product of T_1 multiplied by the factor k which is determined by the type of the food and the type of cooking.

A process for determining the total required heating time can be realized, in principle, by the combination of humidity sensing means, a counter for counting the time T_1 , a multiplier circuit for producing the product of $T_1 \times k$, a memory for the coefficient k for each type of cooking and a counter for counting the time T_2 , and according to the present invention it can be accomplished by the following simple construction.

Assuming that the period of a clock signal is τ (frequency $1/\tau$) and n clock signals are counted in T_1 seconds, then

$$T_1 = n\tau \text{ (sec.)} \quad (4)$$

By putting the formula (4) to the formula (2),

$$T_2 = kT_1 \text{ (sec.)} \quad (5)$$

When an up-down counter is used to count the number n wherein counting of T_1 is effected in count-up mode while counting of T_2 is effected in count-down mode and the circuit is arranged such that the content of the counter after the counting in the count-down mode reaches zero at the time $T_0 = T_1 + T_2$, then the heating time T_0 can be counted only with the up-down counter.

When such a counting system is used, the content in the count-up mode and the content in the count-down mode are equal to each other. Therefore, in order to satisfy the relation of $T_2 = kT_1$, the period of the clock signal in the count-down mode should be set to be k times as large as the period of the clock-signal in the count-up mode, as seen from the formulas (4) and (5).

The frequency of the clock signal may be changed by changing circuit constants which determine the frequency of a clock signal generating circuit, such as a capacitance C or resistor R . In other words, the coefficient k which is inherent to the particular food to be

heated can be related to the magnitude of the circuit constant C or R .

A particular circuit configuration based on the above principle is shown in FIG. 2b.

In FIG. 2b, a humidity sensor 1 has a characteristic which exhibits a decrease of resistance with an increase of humidity as shown in FIG. 2a. The humidity sensor 1 is mounted at a suitable location in an oven to detect the humidity in the heating cavity. For example, the sensor may be located in the path of exhaust air flow from the heating cavity. As a typical example, a titanium oxide (TiO_2) ceramic humidity sensor has an excellent response, stability and reliability. An amplifier circuit 2 converts the change in the resistance of the humidity sensor 1 to a voltage and amplifies the same. A level comparator circuit 3 compares the output magnitude H_a of the amplifier circuit 2 with a preset reference magnitude H_1 and produces a binary signal of either high level i.e. a "1" signal or low level i.e. a "0" signal depending on the relation $H_a \geq H_1$ or $H_a < H_1$. Reference numeral 4 designates an inverter circuit, and 5 and 6 designate three-input AND gates, the outputs of which are applied to an up-down counter 7 as counting input signals. The up-down counter 7 operates in the count-up mode when the output of the AND gate 5 is UP and in the count-down mode when the output of the AND gate 6 is DN (down). A CLA signal clears the contents of the counter.

The counter is a binary counter and the states of the respective bits are taken out. A decoder 8 receives the output signals for the respective bits of the counter 7 and the output ZERO thereof assumes the "1" state only when all of the bit output signals are "0".

A two-input AND gate 12 produces a "1" output only when both of the signals at HDET and ZERO outputs are in the "1" state.

Reference numeral 9 designates a flip-flop and the output signal OUT of which assumes the "1" state in response to a start signal STA and assumes the "0" state in response to the output signal from the AND gate 12.

The output signal OUT of the flip-flop 9 is applied to a drive circuit 13 for a magnetron 14. The CLA signal also clears the flip-flop 9 to render the output signal OUT to assume the "0" state.

Reference numerals 10 and 11 designate pulse generator circuits, the oscillation frequencies of which are varied with the magnitudes of resistors and capacitors. Typically they may be astable multivibrators.

Switches $S_1, S_2, S_3, \dots, S_n$ are food group selection switches which select a desired resistor which is one of the parameters to determine the pulse period, in order to relate the coefficient k determined by the particular food to the period of the clock pulse as described above. The operation of the circuit will now be described with reference to FIGS. 1 and 2.

The CLA signal clears the flip-flop 9 and the counter 7. This may be effected by a circuit arrangement which automatically produces the CLA signal upon the power being turned on, although such a circuit is not a part of the present invention.

The selection switches $S_1, S_2, S_3, \dots, S_n$ select one of the clock pulses CLDN having a period which is k times as large as the period T of the clock pulse CLUP produced by the pulse generator circuit 10. In other words, the selection switches select one item of food to be cooked. After the item of food has been selected, a heating start switch is depressed so that a start signal STA is developed to set the flip-flop 9. Thus, the output

signal OUT assumes the "1" state. When this occurs, the drive circuit 13 powers the magnetron 14 so that the food is subjected to the heating condition.

On the other hand, the output HDET of the level comparator remains "0" until H_a reaches H_1 and the output HDET of the inverter 4 remains "1". Since the OUT signal is "1", the AND gate 5 opens so that the clock pulses CLUP are applied to the up-down counter as the count-up input signal UP. Thus the pulses CLUP are serially counted up.

As heating proceeds, humidity increases. When the input signal H_a of the level comparator circuit 3 reaches H_1 , the HDET assumes the "1" state and the HDET assumes the "0" state. At the same time, the AND gate 5 is closed and the count-up input signal UP ceases, and the AND gate 6 is opened so that the clock pulses CLDN are applied to the counter 7 as the count-down input signal DN. Thus, the contents of the counter 7 are counted up until the time at which H_1 is reached and are thereafter counted down by the pulses CLDN. The period of the pulses CLDN is selected by the selection switches and it corresponds to k .

The contents of the counter 7 are applied to the decoder 8 which monitors the "0" content of the counter 7. As the contents of the counter are counted up until the time T_1 and are thereafter counted down, the contents of the counter 7 reach "0" when the time $kT_1 = T_2$, which is determined by the period of the clock pulses CLDN, has elapsed. At this time, the output ZERO of the decoder 8 is in the "1" state. On the other hand, after the time T_1 , the HDET is at the "1" state. Thus, the AND gate 12 is actuated and the flip-flop 9 is reset. That is, the output OUT is inverted to the "0" state so that the drive circuit 13 ceases to supply power to the magnetron resulting in a cessation of heating. Accordingly, by merely depressing one of the cook item selection switches, the user can heat the food automatically for an appropriate heating time ($T_1 + kT_1$) without using a timer.

However, the palate of human beings differs from person to person and the cooked state of the food heated in the above automatic heating system is an average. If the heating time can be externally controlled within an appropriate range in the above automatic heating system depending on the requirements of individuals, more satisfactory heating will be obtained. Thus, in the formula (3), T_1 is determined by the humidity. If k can be varied in the range of $\pm \Delta k$ around the center value k_0 , then the total heating time T_0 is represented by:

$$\begin{aligned} T_0 &= T_1 + kT_1 \\ &= T_1 + (k_0 \pm \Delta k)T_1 \\ &= T_1 + k_0T_1 \pm \Delta kT_1 \end{aligned} \quad (6)$$

where $k \approx k_0 \pm \Delta k$. Thus, the total heating time can be adjusted by the amount $\pm \Delta kT_1$. The coefficient k corresponds to the period of the clock pulses CLDN, which in turn corresponds to the magnitude of the resistance which is the parameter for the period. Therefore, by changing the resistance corresponding to the coefficient k to assume $R_0 \pm \Delta R$, the formula (6) can be satisfied. FIG. 3 shows an embodiment of such a clock pulse generator. In FIG. 3a, a period τ_p of the pulses generated is given by the following formula:

$$\tau_p = 0.7(R_A + 2R_B)k \quad (7)$$

where

$$k = k_r (0 \leq k_r \leq 1) \quad (8)$$

FIG. 3b shows the internal configuration of the element 16 in FIG. 3a, and it corresponds to a standard timer IC 555 (Integrated Circuit).

FIG. 4a shows a particular circuit wherein the functions of the counter 7 and the decoder 8 in the embodiment of FIG. 2b are combined. It is realized by a standard MSI (binary up/down counter) 74193. The decoder produces an output when the contact of the counter is all "0". NC in FIG. 4a designates non-connected terminal.

FIG. 4b shows a timing chart for the standard MSI/74193.

Referring to FIG. 5 which shows a cross-section of a microwave oven, a fan 20 driven by a motor 21 is used to supply cooling air flow forcibly and also to cause the air flow to be exhausted from an exhaust port 22 through a heating cavity 24 along an air-flow path 23. The humidity sensor 1 is located, for example, down stream of the air-flow path 23. Alternatively, cooling air flow which is also used to cool a magnetron and other electrical devices may be utilized.

What is claimed is:

1. A heating time control apparatus for use in a microwave oven having a heating cavity, heating means for heating food-stuff in said heating cavity, and air blowing means for blowing air into said heating cavity, said heating time control apparatus comprising:
 - humidity sensing means located in the path of air blown by said air blowing means,
 - comparison means connected to said humidity sensing means for comparing the sensed humidity with a predetermined humidity level and for generating a signal when the sensed humidity reaches said predetermined level,
 - heating time determining means for determining the total heating time consisting of first and second heating time periods for said food-stuff, said first time period being measured from the application of power to said heating means until the signal from said comparison means is received and said second time period corresponding to the product of a heating time coefficient and said first time period, said heating time coefficient being predetermined depending on the type of food-stuff, and
 - heating control means for controlling the supply of power to said heating means in response to a signal from said heating time determining means.
2. A heating time control apparatus according to claim 1, wherein said predetermined humidity level corresponds to the humidity at an abrupt humidity gradient.
3. A heating time control apparatus according to claim 1 wherein said humidity sensing means senses the humidity which varies with the heating of said food-stuff, and wherein said heating time determining means comprises
 - a first signal generator for generating a train of reference clock pulses having a first period,
 - a second signal generator for generating a train of clock pulses having a second period depending on the type of food-stuff,
 - a counter circuit for serially counting up the clock pulses generated by said first signal generator until the sensed humidity reaches said predetermined humidity level thereby measuring said first heating

time period and thereafter serially counting down the clock pulses generated by said second signal generator thereby measuring said second heating time period, and

- a decoder circuit for producing an output signal when the content of said counter circuit during the count-down operation reaches a predetermined value, the output signal of said decoder circuit being supplied to said heating control means to stop the supply of power to said heating means.
4. A heating time control apparatus according to claim 3, wherein said second signal generator includes a

pulse generator circuit and a plurality of parallel circuits each having a resistor and a switch associated therewith, the pulse period of said train of clock pulses generated by said pulse generator circuit being determined by selecting one of said plurality of parallel resistors by means of a switch corresponding to the type of food-stuff.

5. A heating time control apparatus according to claim 1 wherein said humidity sensing means is made of titanium oxide ceramic.
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[54] METHOD OF FIRE DETECTION IN A MICROWAVE OVEN**[75] Inventor:** Ronald G. Buck, Burnsville, Minn.**[73] Assignee:** Litton Systems, Inc., Beverly Hills, Calif.**[21] Appl. No.:** 829,879**[22] Filed:** Aug. 30, 1977**[51] Int. Cl.:** H05B 9/06**[52] U.S. Cl.:** 219/10.55 M; 219/10.55 B; 219/510**[58] Field of Search:** 219/10.55 B, 10.55 R, 219/10.55 C, 494, 499, 510; 340/227 R, 227 D, 228 R; 426/241, 242, 243; 236/44 C, DIG. 8**[56] References Cited****U.S. PATENT DOCUMENTS**

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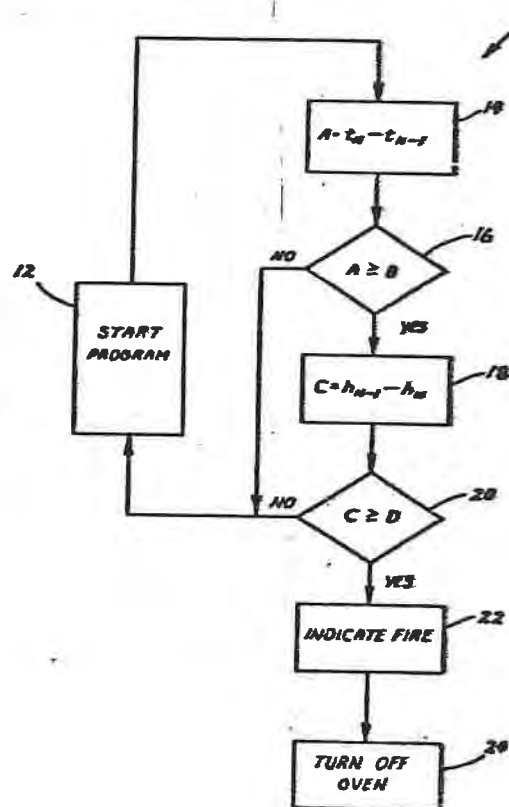
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Primary Examiner—Arthur T. Grimley
Attorney, Agent, or Firm—Robert E. Lowe

[57] ABSTRACT

A method for detecting a fire in a microwave oven heating cavity by sensing the time dependent "in-situ" humidity and the temperature environmental conditions of a microwave oven heating cavity in a microwave oven. The humidity sensor and the temperature sensor connect to a programmable controller in the microwave oven. When the sensed "in-situ" relative humidity decreases and the sensed temperature increases within a predetermined time interval, there is a fire in the cavity. The programmable controller processing the sampled humidity and temperature signal information turns off the microwave oven upon sensing the decreasing humidity and increasing temperature within the predetermined time interval indicating a fire.

8 Claims, 1 Drawing Figure



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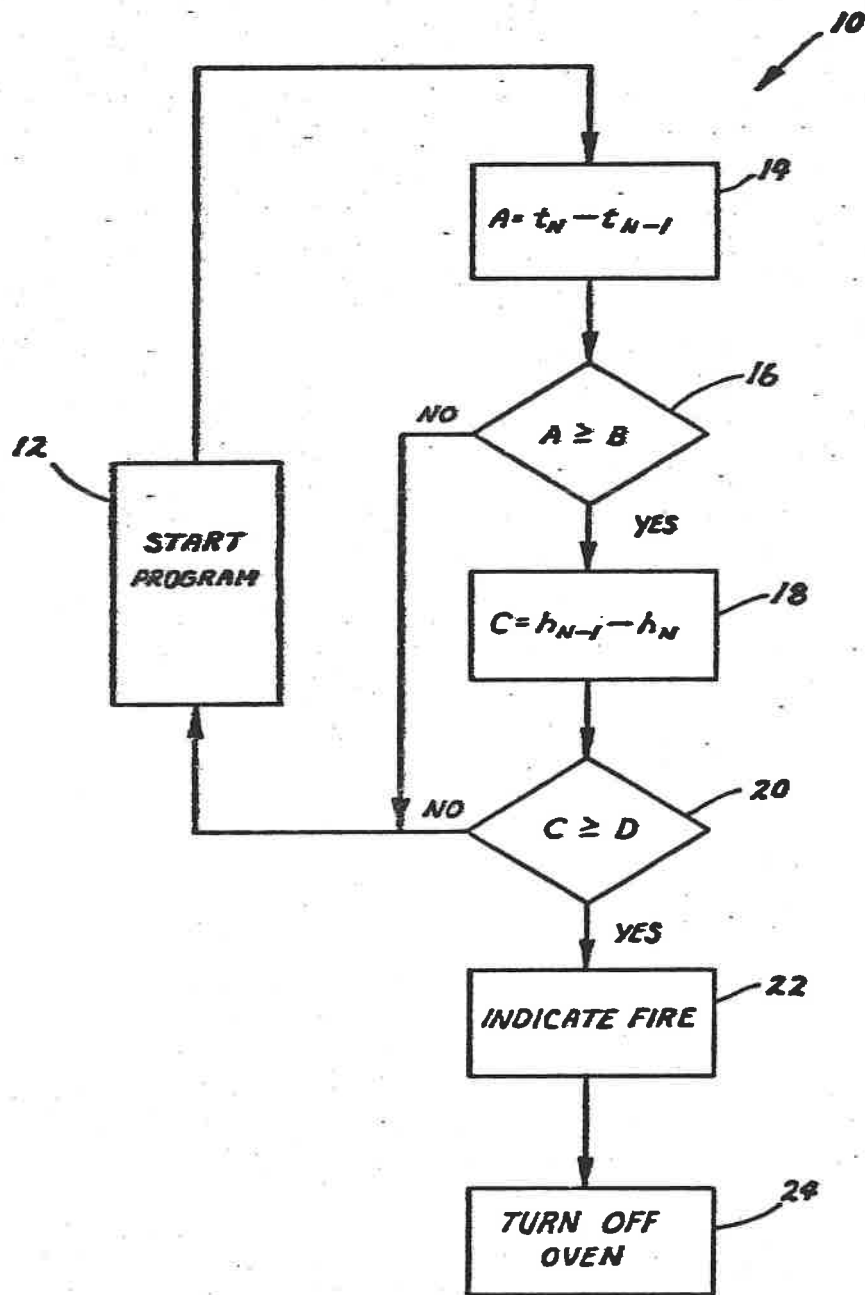


FIG. 1

METHOD OF FIRE DETECTION IN A MICROWAVE OVEN

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to improvements in a microwave oven, and more particularly, pertains to a new and improved method of fire detection in a microwave oven heating cavity.

2. Description of the Prior Art

Those concerned with the development of microwave ovens have long recognized the need for an accurate method of fire detection in a microwave oven heating cavity. The present invention fills this need.

Past devices have failed to accurately determine a fire condition in a microwave oven heating cavity. While microwave ovens cook with "cool" microwave energy, sometimes it occurs that a cook will let a particular food cook longer than required or fail to turn the microwave oven off, thereby causing the food to overheat and combust resulting in a fire condition in the microwave oven heating cavity.

Smoke sensors cannot be located in the duct connecting the microwave oven heating cavity to the outside environment, as such sensors would be unsatisfactory due to dynamic gas flow within the duct system and the time lag taking the smoke to travel from the microwave oven cavity through the duct system to the point at which the sensor senses the smoke. Also, it has been impossible to locate fire sensors directly in the microwave oven heating cavity to electromagnetic interference consideration.

This invention, method of fire detection in a microwave oven, overcomes these disadvantages by providing an accurate and responsive sensing system of the time dependent "in-situ" environmental conditions of the microwave oven heating cavity when a fire occurs.

SUMMARY OF THE INVENTION

The present invention obviates the foregoing disadvantages of the prior art by providing a method of fire detection in a microwave oven to sense the time dependent "in-situ" environmental conditions when a fire occurs in the microwave oven heating cavity. The time dependent "in-situ" environmental conditions are defined as the sensed humidity and temperature conditions of the microwave oven heating cavity by humidity and temperature sensors.

According to the preferred embodiment of the present invention, there is provided a method of fire detection in a microwave oven having the steps of sensing time dependent "in-situ" humidity and temperature environmental conditions of a microwave oven heating cavity in a microwave oven, monitoring the humidity for a substantial decrease in sensed value and monitoring the temperature for a substantial increase in sensed value over a predetermined time, and turning off the microwave oven if the humidity decrease and temperature increase conditions occur within the predetermined time interval indicating a fire.

A significant aspect and feature of the present invention is a method for fire detection in a microwave oven within a matter of seconds after a fire occurs in the microwave oven heating cavity. By monitoring the "in-situ" environmental conditions of the microwave heating cavity with a humidity sensor and a temperature sensor, a fire can be detected in minimal time due to

the change of the time dependent "in-situ" environmental conditions.

Having briefly described the preferred embodiment of the invention, it is a principal object to provide a new and improved method of fire detection in a microwave oven heating cavity.

An object of the present invention is to provide an accurate method for detecting a fire in a microwave oven heating cavity.

Another object of the present invention is to sense the "in-situ" environmental conditions of the microwave oven heating cavity by positioning sensors at an exit ventilation port which input the sensed "in-situ" environmental conditions to a programmable controller which determines when a fire exists within the microwave oven heating cavity. The term "in-situ" as used in this application is defined as the actual time dependent environmental conditions which exist in the environment surrounding the food product which is located in and cooked in the microwave oven heating cavity. Although in the present invention, a humidity sensor and a temperature sensor may be positioned outside of the microwave oven heating cavity, the sensors are configured to sense the "in-situ" environmental conditions of the microwave oven heating cavity and provide "in-situ" signal information of the environmental conditions of the microwave oven heating cavity to a programmable controller controlling the microwave oven.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing in which like reference numerals designate like elements throughout the figure thereof and wherein:

FIG. 1 illustrates a flow chart of the steps for the method of fire detection in a microwave oven cavity in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a flow chart 10 of the steps of a method of fire detection in a microwave oven cavity in accordance with the present invention. The method is commenced by starting the program at 12. First, a previously sensed temperature at time t_{n-1} is subtracted from the sensed temperature 14 at time t_n to determine if the difference A is greater than or equal to a predetermined value B 16. If a NO condition exists, the program restarts itself at 12. If a YES condition exists, then the sensed humidity at time t_n is subtracted from the previous sensed humidity 18 at time t_{n-1} to determine if the difference C is greater than or equal to a predetermined value D 20. If a NO condition exists with the difference C of humidity 18 being less than or equal to a predetermined value D 20, the program restarts itself at 12. If a YES condition exists where C is greater than or equal to the predetermined value D, then an indicate fire 22 followed by a turn-off oven 24 results.

Preferred Mode of Operation

The method for fire detection in a microwave oven can be implemented in accordance with the flow chart 10 of the figure as an algorithm stored in a programmable controller such as an Intel 8080 Microprocessor of the microwave oven. This algorithm detects the point in

time at which a fire occurs in the microwave oven heating cavity. In implementation, the difference in temperature rise would be between 30 to 20° C. while the difference in the humidity would be between 10 to 20% of the sensed relative humidity over a predetermined time interval of ten to thirty seconds.

An aluminum oxide humidity sensor, such as a Thunders Scientific TC-2000 Humidity Measurement Module, and a temperature sensor such as a National Semiconductor Corporation LX 5709 temperature transducer are positioned adjacent to and by the exit ventilation port for way of example and purposes of illustration only on the exterior side of the microwave oven heating cavity and connect to the programmable controller to input the sensed and sampled values of humidity and temperature respectively. The sensors are positioned to sense the time dependent "in-situ" environmental conditions of the microwave oven heating cavity and are electromagnetically protected from the microwave oven heating cavity. The programmable controller connects to the microwave power source power supply and to the air exchange control circuit to indicate a fire and turn off the oven when a fire is detected.

The basic premise of the method as shown in the figure is to detect a point in time where the sampled and sensed "in-situ" temperature is increasing at a rapid rate for a predetermined value and a sampled and sensed "in-situ" humidity is decreasing at a rapid rate for a predetermined time value. Over the time interval these two conditions occur, there is an indication that a fire exists and the oven is turned off. In turning off the oven, the microwave power source control circuit and the air exchange control circuit are disabled when the oven is turned off at condition 24.

The first step of the method of the algorithm of FIG. 1 is to subtract the previous sampled and sensed "in-situ" temperature from the present sampled and sensed "in-situ" temperature to determine if the difference A is greater than or equal to some predetermined value B at 16 in the flow chart. This predetermined value for increasing temperature is the range of 10° to 20° C. If the temperature condition 16 is satisfied, then the sampled and sensed "in-situ" humidity is subtracted from the previous sampled and sensed "in-situ" humidity to see if the difference C is greater than or equal to some predetermined value D at 20 in the flow chart. This predetermined value for decreasing changing humidity is the range of 10 to 20% relative humidity.

In practical situations when a fire occurs in a microwave oven heating cavity such as by the cook overheating the foods, the humidity takes an abrupt decrease and the temperature takes an abrupt increase over a very short time, measured in a matter of a few seconds. A predetermined time interval is a range of ten to thirty seconds for the humidity to decrease and the temperature to increase for way of example and purposes of

illustration only. By monitoring both the sampled and sensed "in-situ" humidity and temperature environmental conditions over a predetermined interval of time a fire is detected in the microwave oven heating cavity.

Various modifications are contemplated in the method of fire detection in a microwave oven and may obviously be resorted to by those skilled in the art without departing from the apparent scope of the invention as hereinafter defined by the appended claims as only a preferred embodiment thereof has been disclosed.

Having thus described the invention, there is claimed as new and desired to be secured by Letters Patent:

1. A method of fire detection in a microwave oven comprising the steps of:

- a. comparing a sampled and sensed in-situ temperature with a previous sampled and sensed in-situ temperature of a microwave oven heating cavity;
- b. comparing a sampled and sensed in-situ previous relative humidity with a sampled and sensed in situ relative humidity of said microwave oven heating cavity;
- c. indicating that a fire exists when said sampled and sensed temperature is increasing and said sampled and sensed relative humidity is decreasing, and;
- d. turning off the oven.

2. The method according to claim 1 comprising the step of:

- a. said increasing temperature and said decreasing relative humidity occurring within a predetermined time interval.

3. The method according to claim 1 comprising the step of:

- a. turning off a microwave power source coupling microwave energy to said microwave oven heating cavity when a fire is indicated.

4. The method according to claim 1 comprising the step of:

- a. turning off a air exchange control circulating air through said microwave oven heating cavity when a fire is indicated.

5. The method according to claim 1 comprising the step of:

- a. measuring a decrease of said in-situ relative humidity of 10 to 20%.

6. The method according to claim 1 comprising the step of:

- a. measuring an increase of said in-situ temperature of ten to twenty degrees centigrade.

7. The method according to claim 2 comprising the step of:

- a. said predetermined time interval being ten seconds.

8. The method according to claim 2 comprising the step of:

- a. said predetermined time interval being a range of ten to thirty seconds.

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[54] **METHOD OF COOKING FOODS IN A
MICROWAVE OVEN**

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[21] Appl. No.: **829,078**

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[51] Int. Cl.² **A23L 1/00**

[52] U.S. Cl. **426/243; 426/523**

[58] Field of Search **426/241, 243, 233, 523;**
219/10.55 A, 10.55 B, 10.55 R

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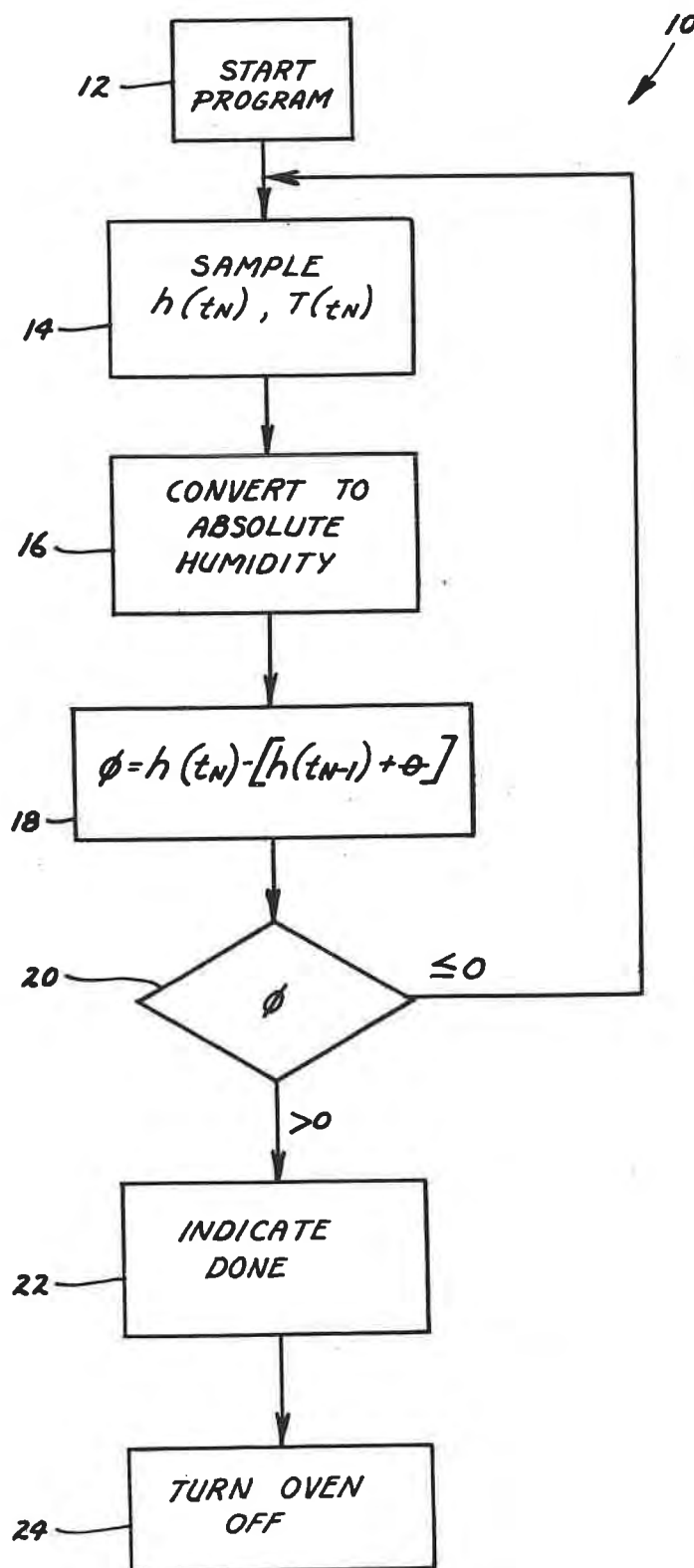
Primary Examiner—Robert A. Yoncoskie
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[57] **ABSTRACT**

A method of cooking foods containing a substantial liquid component by sensing "in-situ" humidity and temperature environmental conditions of a microwave oven heating cavity. The method monitors the rate of change of the slope of the "characteristic humidity curve" to indicate the degree of cooking of the foods. By determining the rate of change of the slope of the "characteristic humidity curve", the value is indicative of the degree of the temperature level of microwave cooking of the foods and can be used to control microwave cooking of the foods.

4 Claims, 2 Drawing Figures

FIG. 1



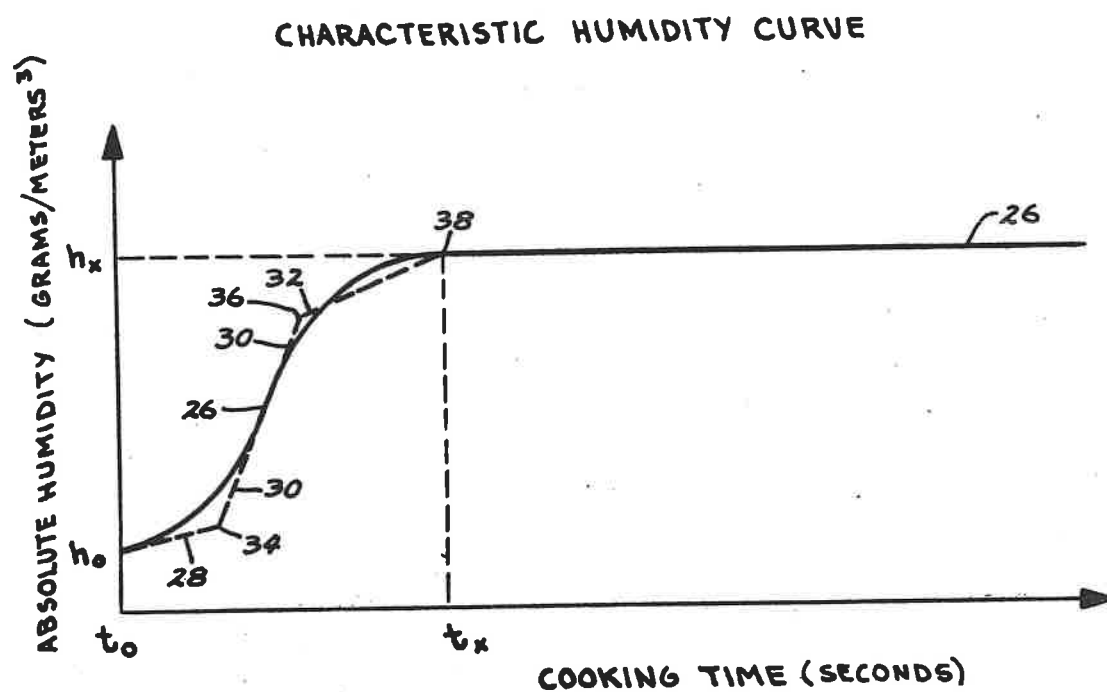


FIG. 2

METHOD OF COOKING FOODS IN A MICROWAVE OVEN

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improvements in microwave cooking, and more particularly, pertains to a new and improved method of cooking juiced foods in a microwave oven.

2. Description of the Prior Art

Those concerned with the development of microwave ovens have long recognized the need for a method of cooking juiced foods in a microwave oven. The present invention fills this need.

The prior art attempts of controlling the cooking of juiced foods in microwave ovens have been less than satisfactory. Juiced foods include canned foods such as vegetables or any food in a liquid such as sauces. The problem in microwave cooking of juiced foods in a microwave oven is that the juiced foods are usually brought to boil and continue to boil thereby causing the foods to lose taste, cooking the nutrients out of the food, and more than often, having juiced foods lose their consistency. It is recognized that to cook juiced foods in a microwave oven, the juice of the foods must not be able to come to boil; otherwise, the palatability of the juiced foods is lost in boiling. The prior art control systems have failed to sense the level of temperature of the juices in which the foods reside during microwave cooking in the microwave oven.

This invention, the method of cooking juiced foods in a microwave oven, overcomes the disadvantages of prior art by providing a method to maintain the temperature of the juiced foods within a desired temperature range through sensing of the time dependent "in-situ" humidity and temperature environmental conditions in the microwave oven heating cavity.

SUMMARY OF THE INVENTION

The present invention obviates the foregoing disadvantages of the prior art by providing a method of cooking juiced foods in a microwave oven.

According to the preferred embodiment of the present invention, there is provided a method for cooking juiced foods in a microwave oven heating cavity wherein the time dependent "in-situ" humidity and temperature environmental conditions are sensed, the relative humidity is converted into absolute humidity, the rate of change of the slope of the "characteristic humidity curve" is determined which indicates the portion of the "characteristic humidity curve" where the juiced food is being cooked, and controlling the microwave heating to maintain the cooking of the juiced foods at a predetermined point on the "characteristic humidity curve" corresponding to a temperature for microwave cooking of the juiced foods.

A significant aspect and feature of the present invention is maintaining the juiced foods at a constant temperature, but less than boiling to cook the foods within the juices to doneness.

Having briefly described the preferred embodiment of the present invention, it is a principal object to provide a new and improved method for cooking juiced foods in a microwave oven.

An object of the present invention is to sense the time dependent "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity

to continually monitor the change of the slope of the "characteristic humidity curve" as the foods are being cooked which indicates the temperature of the juiced foods. The term "in-situ" as used in this application is defined as the actual time dependent environmental conditions which exist in the environment surrounding the food product which is located in and cooked in the microwave oven heating cavity. Although in the present invention, a humidity sensor and a temperature sensor may be positioned outside of the microwave oven heating cavity, the sensors are configured to sense the "in-situ" environmental conditions of the microwave oven heating cavity and provide "in-situ" signal information of the environmental conditions of the microwave oven heating cavity to a programmable controller controlling the microwave oven.

Another object of the invention is to provide for controlling the temperature of the cooking of juiced foods to maintain a desired temperature of the juice in which the foods reside while being cooked.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like elements throughout the figures thereof and wherein:

FIG. 1 illustrates a flow chart of the steps for the method of cooking juiced foods in a microwave oven in accordance with the present invention, and;

FIG. 2 illustrates a typical "characteristic humidity curve" for the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a flow chart 10 of the steps for the method of cooking juiced foods in accordance with the present invention showing a start program condition 12. The "in-situ" humidity at time N, shown as $h(t_N)$ and temperature at time N, shown as $T(t_N)$ 14 are sampled. The sampled humidity $h(t_N)$ at step 14 is converted to absolute humidity at step 16. Next, the factor ϕ is determined at step 18 by subtracting the absolute humidity at time N minus one, shown as $h(t_N - 1)$ plus θ , a constant in grams per cubic meter chosen to indicate at what point the proper degree of cooking of juiced foods has occurred, from the absolute humidity 16 at time t_N . If ϕ greater than zero 20 condition exists, the algorithm indicates a cooking done condition 22 and the oven is turned off at step 24.

PREFERRED MODE OF OPERATION

The method of cooking juiced foods in a microwave oven can be implemented in accordance with the flow chart 10 of FIG. 1 as an algorithm stored in a programmable controller such as an Intel 8080 Microprocessor in the microwave oven. This algorithm determines when ϕ during microwave cooking in the microwave oven heating cavity is greater than zero to indicate doneness of juiced foods. ϕ is the rate of change of the slope of the "characteristic humidity curve" for the particular juiced food being cooked.

The "characteristic humidity curve" 26 of absolute humidity in grams per cubic meter versus cooking time in seconds of FIG. 2 is determined by sensing the time dependent "in-situ" humidity and temperature environ-

mental conditions of the microwave oven heating cavity during microwave cooking of juiced foods. The time dependent "in-situ" environmental conditions are defined as the sensed humidity and temperature of the microwave oven heating cavity by humidity and temperature sensors. Each particular juiced food has its own particular "characteristic humidity curve". h_0 is the initial absolute humidity and h_x is the peak absolute humidity at time t_x of the "characteristic humidity curve" 26.

The "characteristic humidity curve" 26 of FIG. 2 can be approximated as a three segment 28, 30 and 32 piecewise linear curve prior to time t_x . The slope of the first segment 28 of the three segment piecewise linear curve is proportional to the rise in surface temperature of the food up to one hundred degrees centigrade. Once the hottest section of the surface has reached one hundred degrees centigrade which occurs at the change of slope 34, the humidity increases rapidly as illustrated by the slope of the second segment 30 of the three segment piecewise linear curve which is due to the "latent heat of vaporization" of the food. The change of slope 36 is indicative of the beginning of the surface temperature of the food reaching equilibrium. The slope of the third segment 32 of the three segment piecewise linear curve from points 36 to 38 is equilibrium beginning to occur at the surface temperature of the food. The "characteristic humidity curve" 26 plateaus at the point 38 indicating that surface temperature of the food has reached equilibrium at one hundred degrees centigrade.

Segment 28 of the three segment piecewise linear of the "characteristic humidity curve" 26 represents the portion where the juiced foods cook to a temperature degree of being very hot, but do not reach boiling at the surface of the juice. At the change of slope 34, the top surface temperature of the juice reaches equilibrium at one hundred degrees centigrade and begins boiling. At point 34, the rate of change of the slope of the "characteristic humidity curve" 26 begins rising rapidly indicating that the temperature of the juiced foods is changing from hot to boiling.

The basic premise of the method is to examine ϕ which is an indication of the rate of change of slope of the "characteristic humidity curve" for the juiced food being cooked. The rate of change of slope of relative humidity $h(t_N)$ can be examined instead of examining the rate of change of the absolute humidity 16 of the "characteristic humidity curve" of FIG. 2.

The greater ϕ , the greater the rise in the slope of the "characteristic humidity curve" indicating an increased microwave heating effect of the juiced food. The constant θ is chosen for the ϕ equation of step 18 of the particular type of juiced food being cooked in the microwave oven heating cavity. An approximate value for the constant θ is 5 grams per cubic meter for way of example and purposes of illustration only.

An aluminum oxide humidity sensor, such as a Thunder Scientific TC-2000 Humidity Measurement Module, and a temperature sensor, such as a National Semiconductor Corporation LX 5700, are positioned adjacent to and by the exit ventilation port to the exterior side of the microwave oven heating cavity for way of example and purposes of illustration only to sense the time dependent "in-situ" environmental conditions and connect to the programmable controller to input the sampled and sensed values of humidity and temperature. The sensors are positioned to sense the time dependent "in-situ" environmental conditions of the micro-

wave oven heating cavity and are electromagnetically isolated from the microwave oven heating cavity. The programmable controller connects to the microwave power source and to the air exchange control circuit to indicate done 22 and turn off the oven 24 when a ϕ greater than zero condition is satisfied.

The programmable controller according to the stored algorithm of steps 12-24 of FIG. 1 can be programmed to vary the microwave heating of the juiced foods to maintain ϕ within a desired range to control the microwave cooking of the juiced foods at a predetermined temperature in the microwave oven heating cavity. The programmable controller can be programmed to maintain the value of ϕ on the first segment 28 of the three segment piecewise linear curve for the "characteristic humidity curve" 26 for microwave cooking of juiced foods at a temperature below boiling over a predetermined time interval. Also, the programmable controller can be programmed to indicate done 22 and turn the oven off 24 when the ϕ greater than zero 20 condition is satisfied. Further, if the juiced foods are to be boiled for a predetermined time, then it is necessary to cook the foods in the second segment 30 of the three segment piecewise linear curve of the "characteristic humidity curve" 26.

By controlling the microwave power source control circuit and the air exchange circuit with the programmable controller, the rate of change of the slope ϕ of the "characteristic humidity curve" is controlled to maintain a predetermined temperature of the microwave cooking of the juiced foods. By controlling the value of ϕ through the steps of FIG. 1 and the programmable controller, it is possible to bring the surface of juiced foods to a predetermined temperature just under boiling for cooking the juiced foods or to boiling as desired in cooking the juiced foods.

Various modifications can be contemplated for the method of cooking juiced foods in a microwave oven of the present invention without departing from the apparent scope of the invention.

Having thus described the invention, there is claimed as new and desired to be secured by Letters Patent:

1. A method for cooking foods of the type containing a substantial liquid component in a microwave oven having an oven cooking cavity, a source of microwave energy, means for sensing the humidity in said cooking cavity, and a programmable controller, said method comprising the steps of:

- (a) applying microwave energy from said source to said food in said cooking cavity to heat said food;
- (b) measuring the humidity in said cooking cavity at a plurality of time-spaced intervals while said food is being heated and providing said measurements as an input to said programmable controller;
- (c) calculating in said programmable controller the rate of change of the slope of a humidity-time curve described by said measurements according to a program stored in said programmable controller; and,
- (d) discontinuing the application of microwave energy when said rate of change of said slope becomes greater than zero.

2. The method of claim 1 wherein said rate of change of said slope is determined by the equation:

$$\phi = h(t_N) - [h(t_N - 1) + \theta]$$

wherein

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ϕ is the rate of change of slope
 $h(tN)$ is the absolute humidity at time N
 $h(tN-1)$ is the absolute humidity at time $N-1$
 θ is a predetermined constant.

3. The method of claim 1 wherein said humidity sensing means senses relative humidity in said cooking cavity and wherein said programmable controller converts

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said relative humidity to absolute humidity and wherein said absolute humidity is used to establish said humidity-time curve.

4. The method of claim 2 wherein said equation is stored in the memory of said programmable controller.

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[54] MICROWAVE OVEN SENSING SYSTEM

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[73] Assignee: **Litton Systems, Inc., Beverly Hills, Calif.**

[21] Appl. No.: 829,081

[22] Filed: Aug. 30, 1977

[51] Int. Cl.² H05B 9/06

**[52] U.S. CL 219/10.55 B; 219/10.55 M;
426/243**

[58] **Field of Search** 219/10.55 B, 10.55 R,
219/10.55 C, 494, 499, 510; 236/44 C, DIG. 8;
340/227 R, 227 D, 228, 2; 426/241, 242, 243

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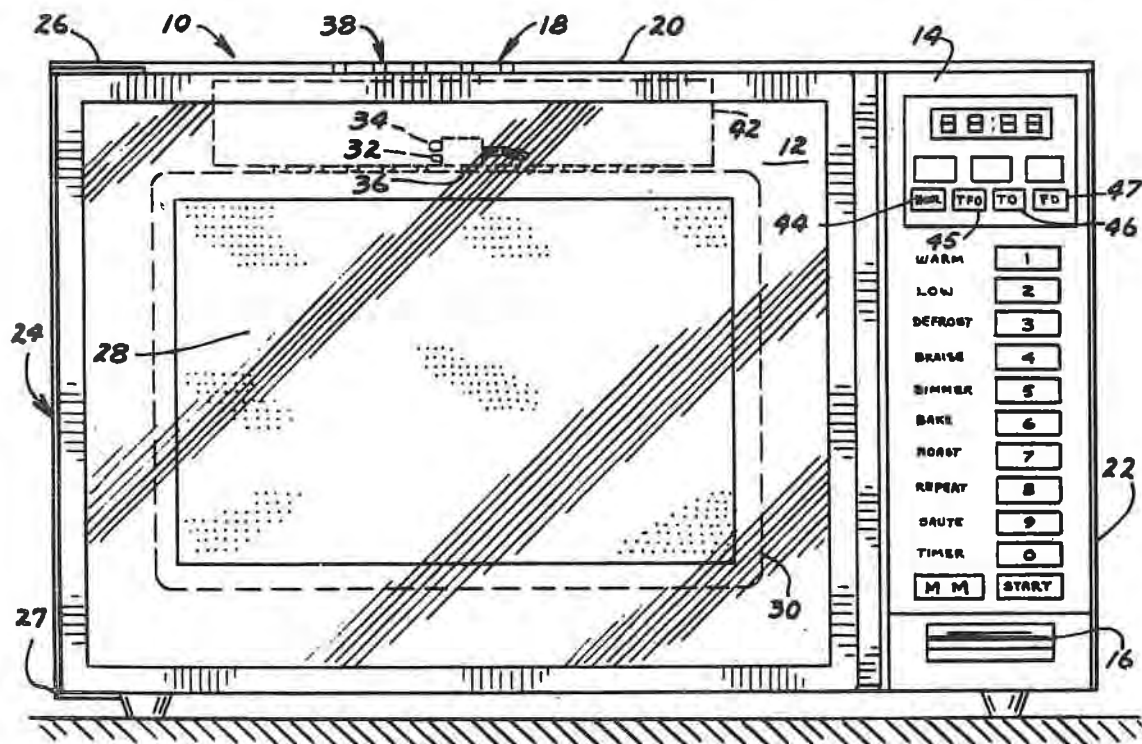
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Primary Examiner—Arthur T. Grimley
Attorney, Agent, or Firm—Robert E. Lowe

[57] **ABSTRACT**

A microwave oven sensing system having a humidity sensor and a temperature sensor at an exit ventilation port of a microwave oven heating cavity to sense the exiting humidity and the air temperature of the microwave oven heating cavity. The humidity sensor and the temperature sensor are positioned to sense the "in-situ" environmental conditions of the microwave oven heating cavity such as adjacent to and by the exterior of the exit ventilation port of the microwave oven heating cavity. The sensors connect to a programmable controller and input the sensed "in-situ" environmental conditions of the microwave oven heating cavity to the programmable controller. "Characteristic humidity curves" for microwave cooking of different types of foods are stored as algorithms in a memory of the programmable controller and the programmable controller controls the microwave cooking in accordance with a selected algorithm for the sensed "in-situ" environmental conditions. A numeric keyboard control panel inputs to the programmable controller the microwave cooking parameters and selects the microwave cooking algorithm. The programmable controller controls a microwave power source control circuit and an air exchange circuit according to the selected algorithm in the programmable controller. An additional humidity sensor may be positioned in a nonhostile environment within the frame structure of the microwave oven to provide a calibration reference for the humidity sensor positioned at the exit ventilation port of the microwave heating cavity.

21 Claims, 9 Drawing Figures



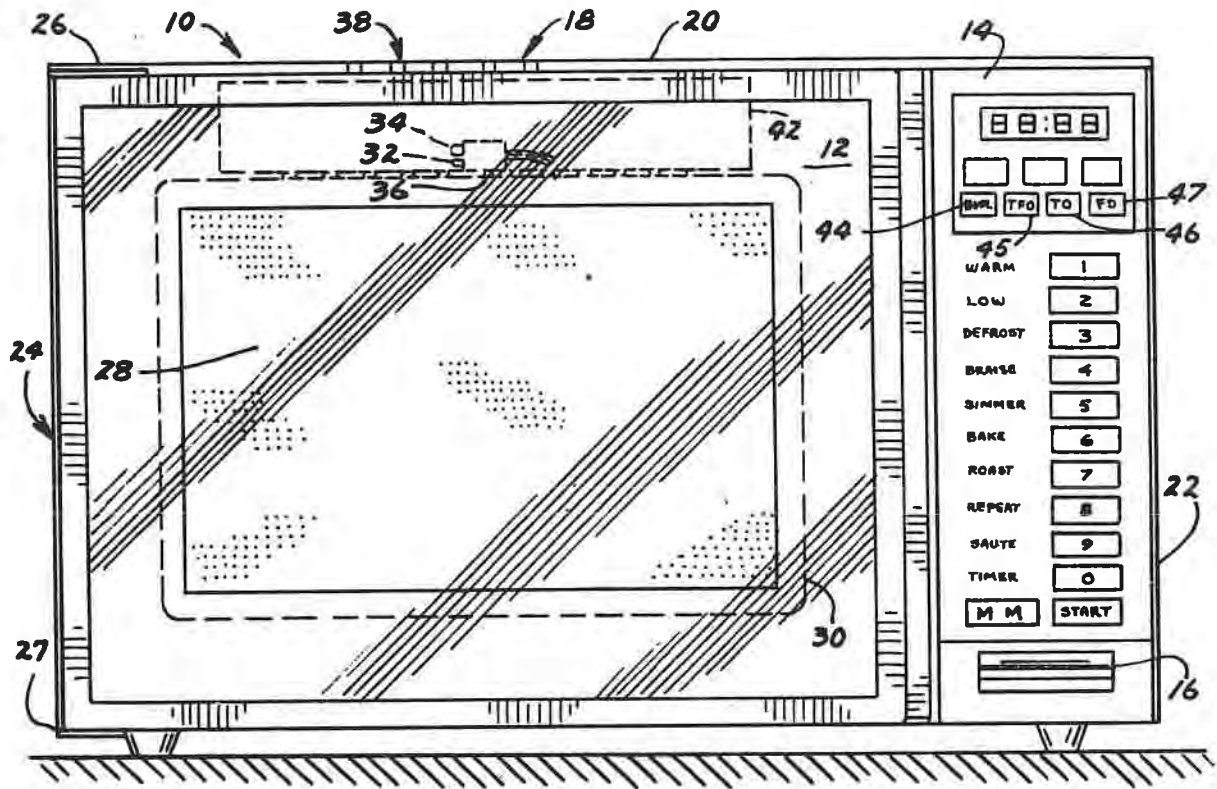


FIG. 1

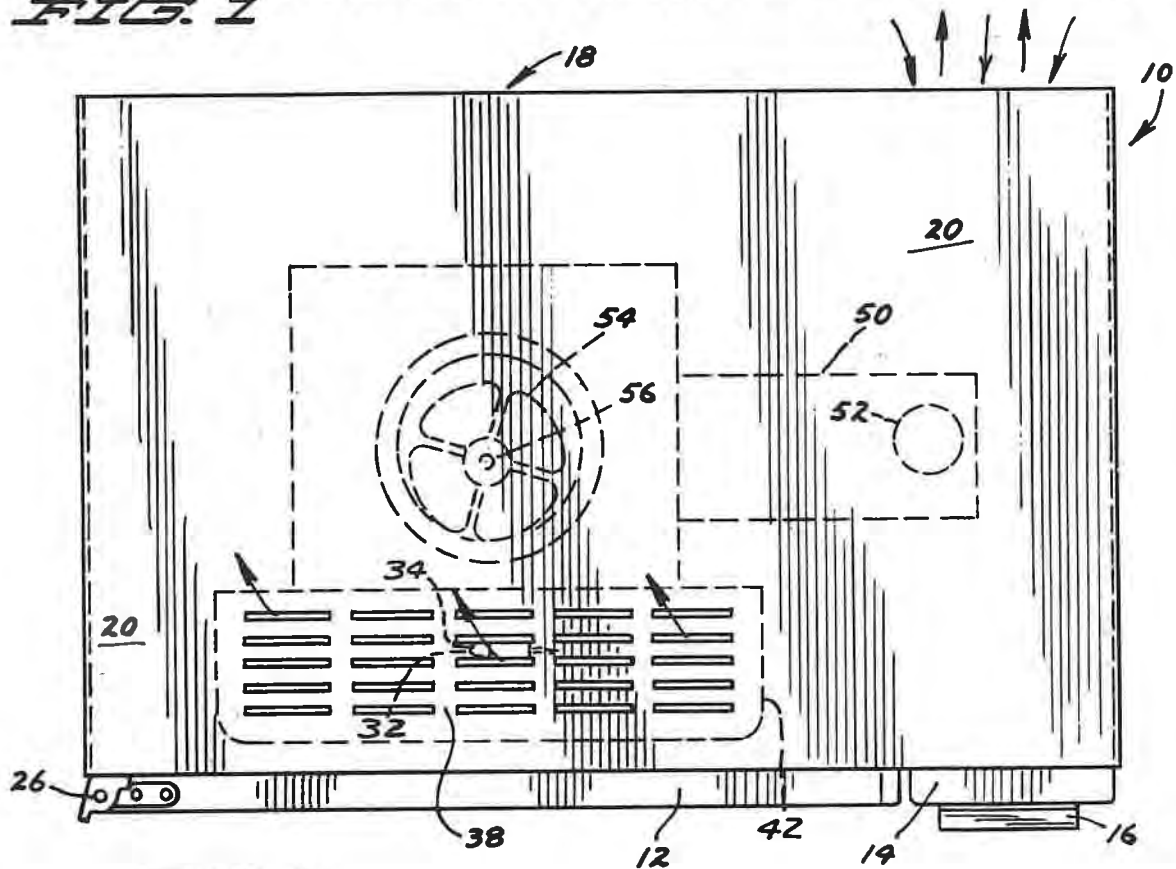
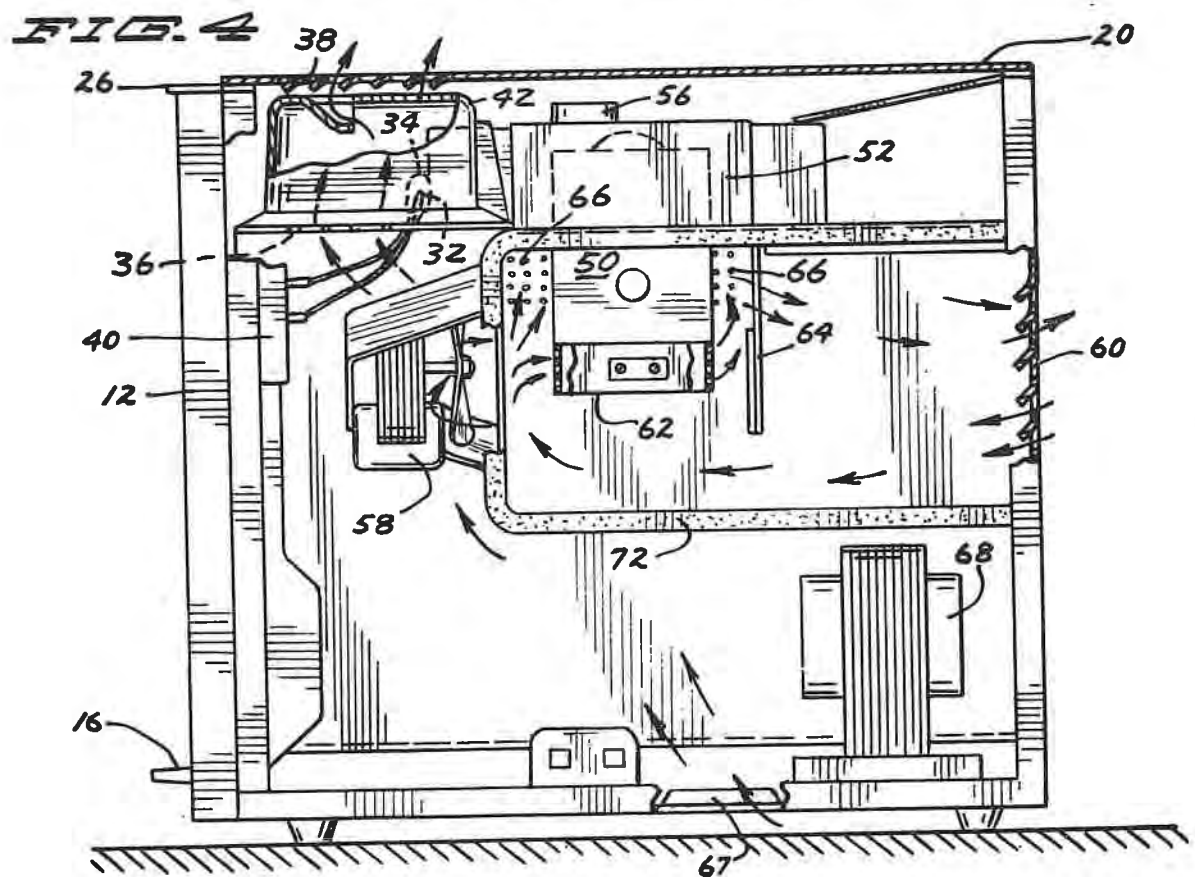
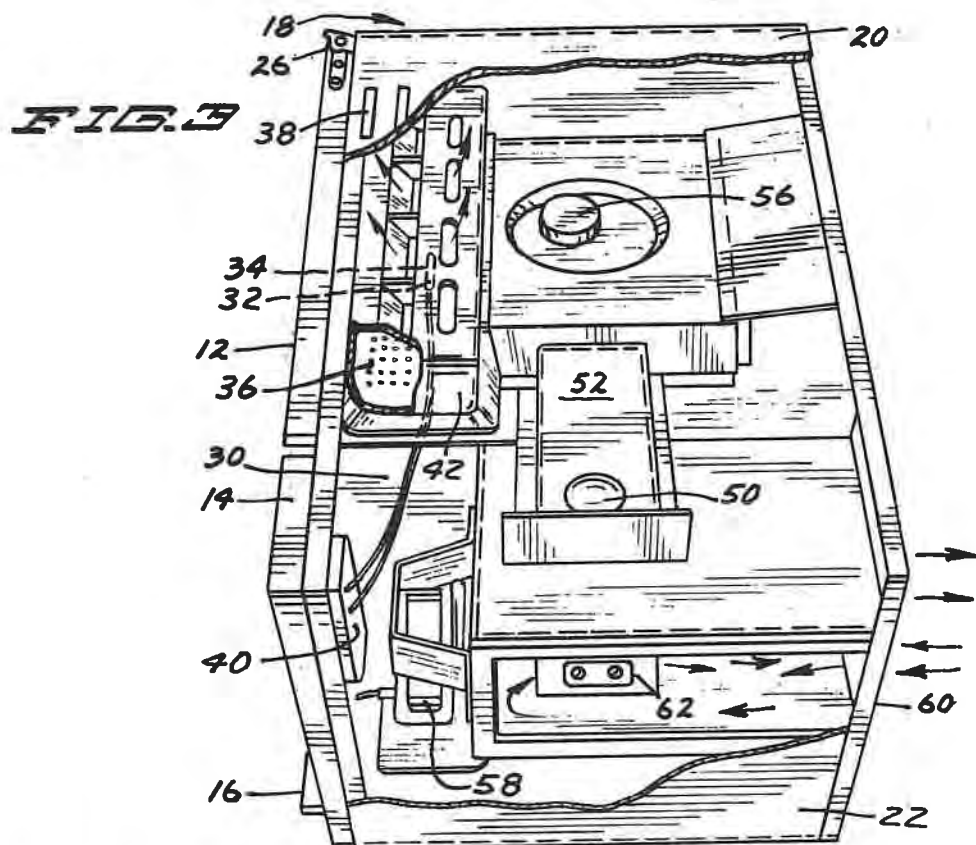


FIG. 2



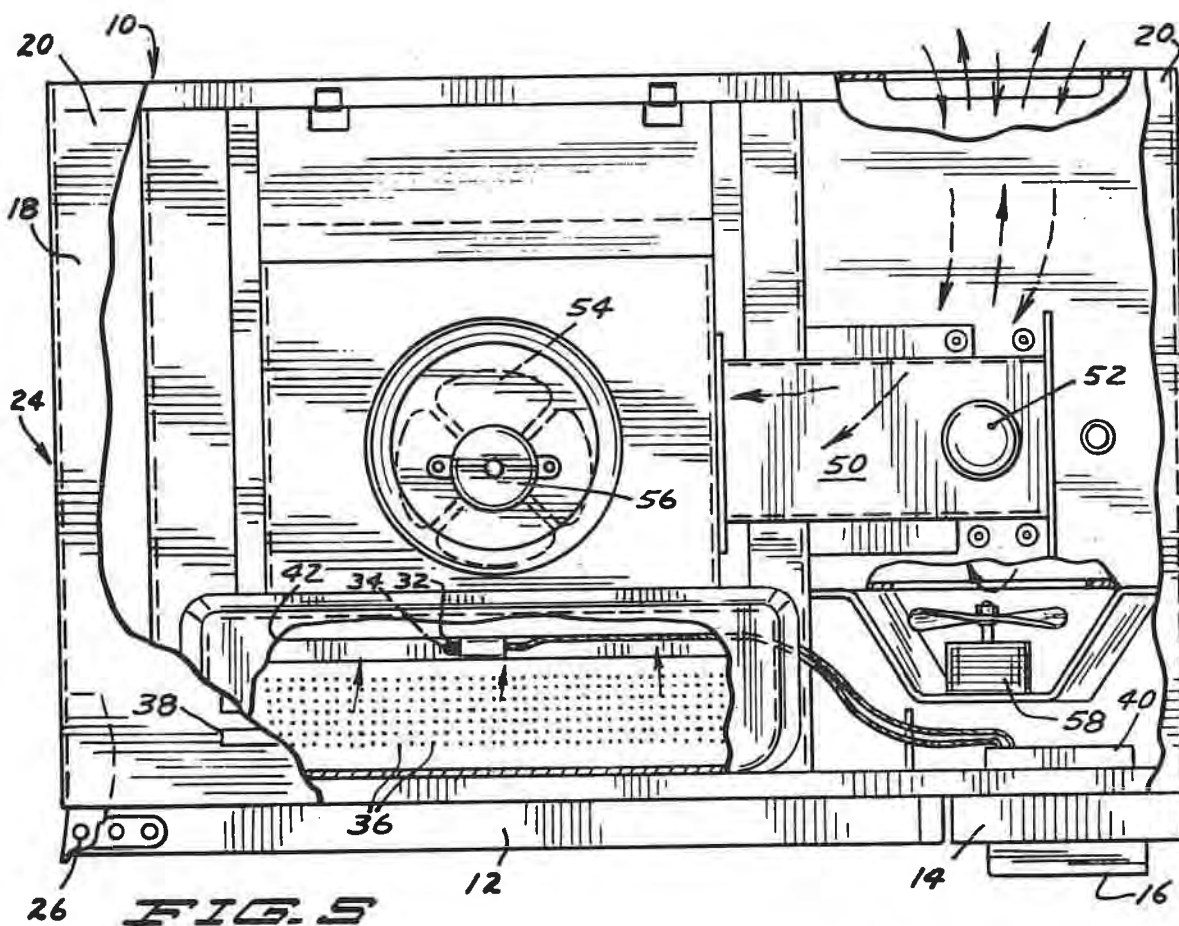
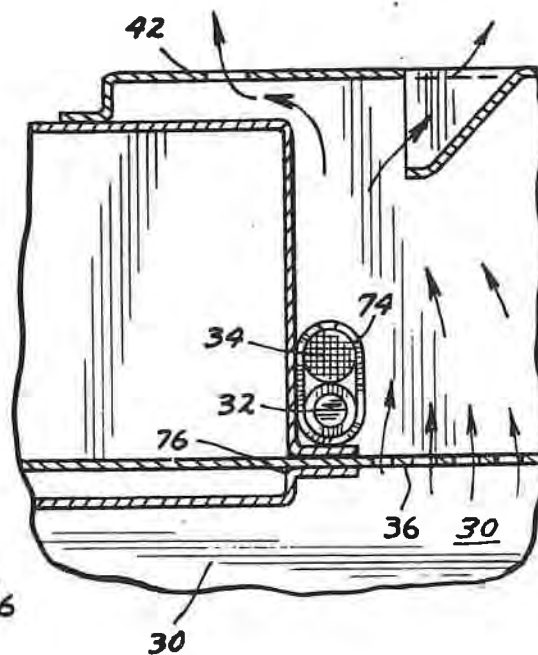
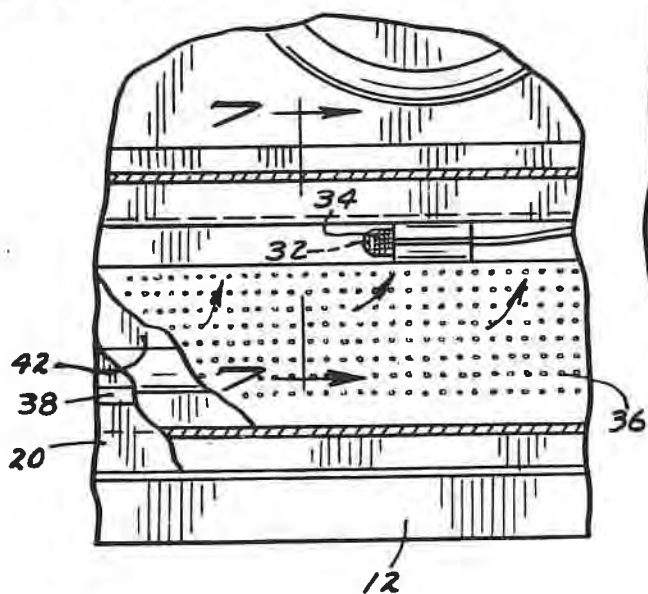
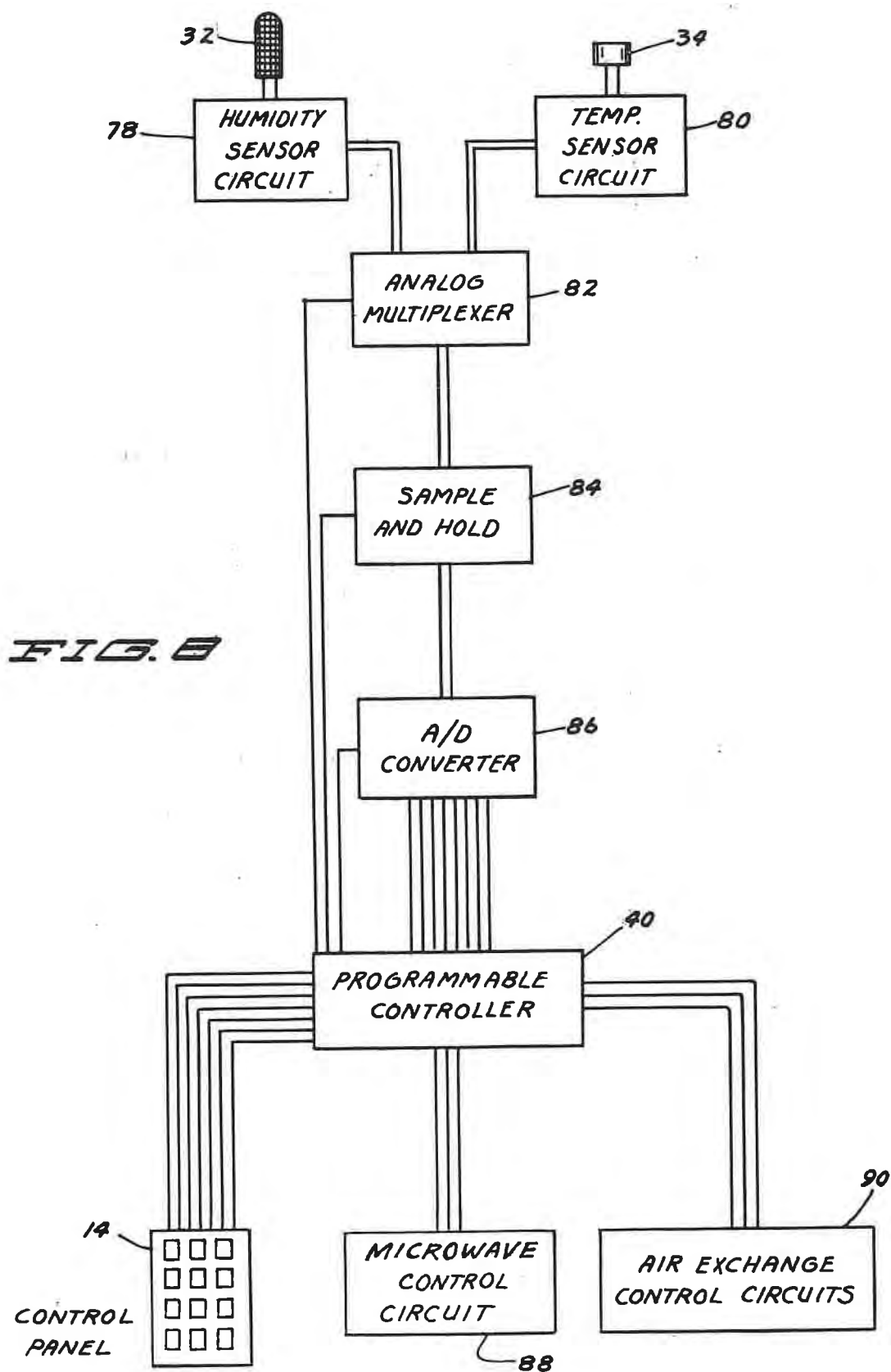


FIG. 6





CHARACTERISTIC HUMIDITY CURVE

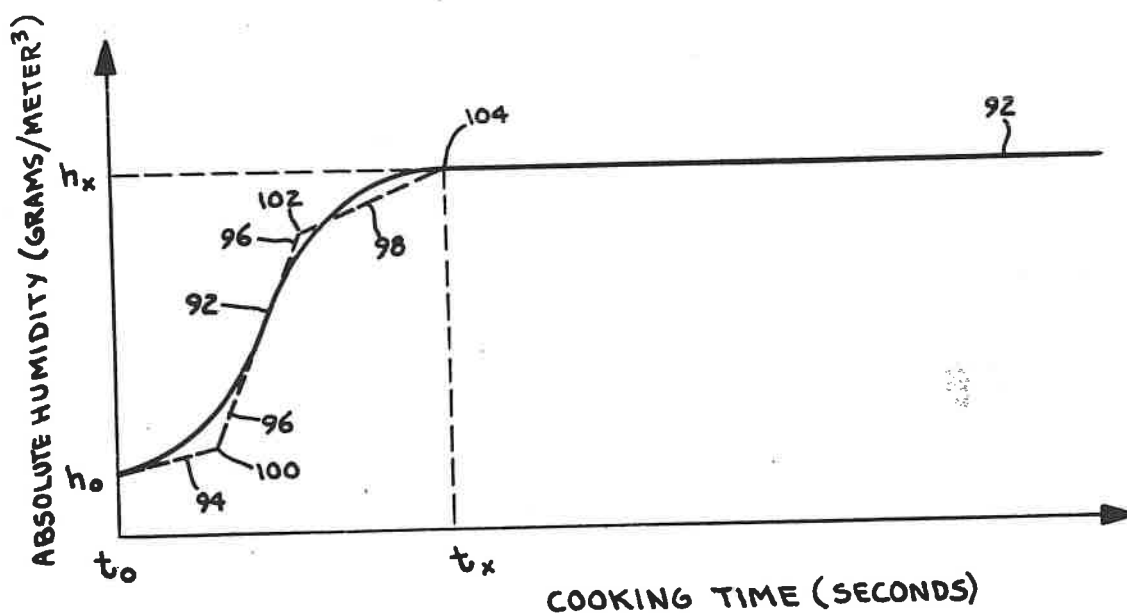


FIG. 9

MICROWAVE OVEN SENSING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to improvements in a microwave oven and more particularly, pertains to a new and improved microwave oven sensing system wherein humidity and temperature sensors are positioned to sense the "in-situ" humidity and temperature environmental conditions in the microwave oven heating cavity of the microwave oven.

2. Description of the Prior Art

In the field of microwave ovens, it has been a general practice to sense environmental conditions of the microwave oven heating cavity in which foods are cooking with sensing devices which have been positioned external to the cavity, usually in an exhaust duct exiting from the microwave oven heating cavity to prevent electromagnetic interference to the sensors. Such sensing devices have been unsatisfactory in that the sensors, to operate properly, require a continuous flow of gas in the duct and therefore suffer from the dynamics of the gas flow in the duct system. Also, the response time and accuracy of the measurement by the sensors depended upon the degree of equilibrium reached in the exhaust duct system. Further, other factors affected the accuracy of the sensors such as the gas pressure and flow rate from the microwave oven heating cavity through the duct system to the outside environment, the diameter and length of the duct system itself, and the susceptibility of the sensor itself to large concentrations of pollutants in the gases being expelled from the oven cavity.

Prior art sensing systems have not been able to accurately measure temperature and more importantly, humidity, in an "in-situ" environment as the sensors which were located in the ducts for electromagnetic interference considerations were subject to large numbers of water molecules carrying grease and carbon particles from the wet, moist environment of the microwave oven heating cavity through the exhaust duct system to the outside environment. The sensors were not able to endure the water molecules and the exhausted gases from the hostile environment of the microwave oven heating cavity over extended time periods as sometimes, the temperature of the exhausted gases exceeded sixty to seventy degrees centigrade further degrading the sensors. As a result of the severe environmental conditions in the microwave oven heating cavity, the sensors would go out of calibration in addition to suffering from sensor degradation.

Past prior art humidity sensors have been of the variety such as lithium chloride humidity sensors which are affected by continuous abrupt humidity and temperature changes in addition to exposure to humidity saturation conditions. These sensors are further subject to concentration of gases, freons, sulfides, ozones, dioxides and monoxides, nitrogen, as well as saturated water vapor. These prior art humidity sensors further did not have long term stability in use and storage in addition to being subject to degradation from continued cycling over wide humidity ranges.

This invention, a microwave oven sensing system, overcomes the disadvantages of the prior art by providing an accurate sensing system of the "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity.

SUMMARY OF THE INVENTION

The present invention obviates the foregoing disadvantages of the prior art by providing a microwave oven sensing system to sense the time dependent "in-situ" humidity and temperature environmental conditions in the microwave oven heating cavity and control the microwave cooking in accordance with cooking algorithms of characteristic humidity curves stored in a programmable controller according to the selected algorithm for the sensed time dependent "in-situ" humidity and temperature environmental conditions by the sensors.

According to the preferred embodiment of the present invention, there is provided a microwave oven sensing system having humidity and temperature sensors positioned to sense time dependent "in-situ" environmental conditions of the microwave oven heating cavity, a programmable controller having a memory which stores a microwave cooking algorithm of a "characteristic humidity curve" connected between the sensors and the microwave power supply control circuit whereby the programmable controller receives signals from the sensors of sensed "in-situ" environmental conditions of the microwave oven heating cavity and controls the microwave power supply circuit according to the microwave cooking algorithm for the sensed time dependent "in-situ" environmental conditions. The humidity sensor for sensing the "in-situ" humidity is an aluminum oxide sensor. The sensors and associated circuitry connect to the programmable controller through analog signal conditioner interface circuitry. The programmable controller has stored microwave cooking algorithms in the memory corresponding to "characteristic humidity curves" for different types of foods. Each "characteristic humidity curve" for a particular type of food is selected by a numeric keyboard on a control panel of the microwave oven from the memory of the programmable controller. The programmable controller also controls the air exchange rate, and increases or decreases the incoming air temperature by preheating the air with a coil of an infrared lamp or a resistance heater or other heating element.

A significant aspect and feature of the present invention is a microwave oven sensing system to accurately sense time dependent "in-situ" environmental conditions of humidity and temperature in a microwave oven heating cavity. The term "in-situ" as used in this application is defined as the actual time dependent environmental conditions which exist in the environment surrounding the food product which is located in and cooked in a microwave oven heating cavity. Although in the present invention, a humidity sensor and a temperature sensor may be positioned outside of the microwave oven heating cavity, the sensors are configured to sense the "in-situ" environmental conditions of the microwave oven heating cavity and provide "in-situ" signal information of the environmental conditions of the microwave oven heating cavity to a programmable controller controlling the microwave oven.

Another significant aspect and feature of the present invention is a system which controls the operation of the microwave power supply control circuit and the air exchange control circuit for time dependent sensed "in-situ" humidity and temperature environmental conditions according to stored microwave cooking algorithms of "characteristic humidity curves" for different types of foods.

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A further significant aspect and feature of the present invention is a humidity control on a numeric keyboard control panel to preset a predetermined humidity to be maintained within the microwave oven heating cavity during microwave cooking.

Having briefly described the preferred embodiment of the present invention, it is a principal object to provide a new and improved microwave oven sensing system which senses time dependent "in-situ" environmental conditions of the microwave oven cooking cavity. The time dependent "in-situ" environmental conditions are the humidity and temperature of the microwave oven cooking cavity.

An object of the present invention is to provide a humidity sensor and a temperature sensor positioned adjacent to and by the exit ventilation port exterior to a microwave oven heating cavity to sense time dependent "in-situ" environmental conditions of the microwave oven heating cavity.

Another object of the invention is to provide a programmable controller which receives the time dependent "in-situ" sensed humidity and temperature signals from the sensors and controls the microwave power supply control circuit and the air exchange control circuit according to selected microwave cooking algorithms of "characteristic humidity curves" for different types of food which have been stored in a memory of the programmable controller. Each particular type of food has its own individual "characteristic humidity curve" for microwave cooking.

A further object of the invention is to provide a numeric keyboard connected to the programmable controller to permit an individual to select the cooking algorithm for the particular type of food being cooked and to preset a predetermined humidity to be maintained within the microwave oven heating cavity. By properly maintaining the humidity at a predetermined level, food can be browned and cooked to doneness.

Still another object of the invention is to provide memory storage in the programmable controller for the "characteristic humidity curves" corresponding to the microwave cooking algorithms which the programmable controller compares to the sensed time dependent "in-situ" environment conditions to control cooking of particular foods in the microwave oven heating cavity. The sensed time dependent "in-situ" humidity and temperature environmental conditions indicate the internal doneness of the food being cooked in the microwave oven heating cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like elements throughout the figures thereof and wherein:

FIG. 1 illustrates a front plan view of a preferred embodiment of a microwave oven in accordance with the present invention;

FIG. 2 illustrates a top plan view of the microwave oven;

FIG. 3 illustrates a side and top perspective view of the microwave oven with a portion of a housing wrap removed and illustrating a cutaway portion of a ventilation hood;

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FIG. 4 illustrates a side view of the microwave oven with the housing wrap removed and showing the cutaway portion of the vent hood;

FIG. 5 illustrates a top plan view of the microwave oven with a portion of the top of the housing wrap cutaway and also showing a top cutaway portion of the ventilation hood;

FIG. 6 illustrates a top enlarged and expanded view of a humidity sensor and a temperature sensor positioned adjacent to and by an exit ventilation port of the microwave oven with the housing wrap removed;

FIG. 7 illustrates a section of the present invention taken on line 7-7 of FIG. 6 looking in the direction of the arrows showing the humidity and temperature sensor positioned by the exit ventilation port;

FIG. 8 illustrates an electrical circuit schematic block diagram for the present invention, and;

FIG. 9 illustrates a typical "characteristic humidity curve" for the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 which illustrates a front plan view of a preferred embodiment of a microwave oven 10 in accordance with the present invention shows an oven door 12, a numeric keyboard control panel 14, and a push bar door release handle 16. A three sided housing wrap cover 18 having a top 20, a right side 22 and a left side 24 encloses the top, the right hand side and the left hand side respectively of the microwave oven 10 frame structure. Upper and lower hinges 26 and 27 respectively hinge the door 12 to the left hand side 24 of the microwave oven 10 frame structure. The oven door 12 includes a window 28 consisting of a microwave radio frequency screen sandwiched between two panes of door glass to enable an operator to view cooking in the microwave heating cavity 30, the outline of which is shown in dashed lines. A humidity sensor 32 and a temperature sensor 34 are positioned adjacent to and by a plurality of exit port ventilation holes 36 in the top of the microwave heating cavity 30 and below a plurality of ventilation holes 38 in the top 20 of the housing wrap 18. The humidity sensor 32 and the temperature sensor 34 connect to a programmable controller 40 as shown in FIGS. 3-5 located behind the control panel 14 by electrical cables and interface with analog signal conditioner circuitry as required. A ventilation hood 42 shown in dashed lines is positioned between the plurality of exit port ventilation holes 36 in the top of the heating cavity 30 and the plurality of ventilation holes 38 in the top 20 of the housing wrap 18.

The numeric keyboard control panel 14 which connects to the programmable controller 40 is similar to the microwave oven control panel of the Litton Model 420 Microwave Oven, assignee of the present invention. The control panel 14 has a lighted digital display countdown timer and numeric controls to input cooking parameters to the programmable controller 40. In addition to the existing numeric controls on the numeric keyboard control panel 14, a "Humidity" control 44 to set a predetermined humidity in the microwave oven heating cavity 30, a "Turn Food Over" control 45 to indicate that the food is to be turned over, a "Time Out" control 46 to indicate that the door 12 is to be closed after turning food over after a predetermined time has elapsed, and a "Done" control 47 to indicate internal doneness of the food are positioned on the control panel 14.

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FIG. 2 illustrates a top plan view of the microwave oven 10 showing the door 12, the numeric keyboard control panel 14, the push bar door release handle 16, an upper hinge 26, the plurality of ventilation holes 38 in the top 20 of the housing wrap 18, the outline of the ventilation hood 42 as shown in dashed lines, the humidity sensor 32 and the temperature sensor 34. A waveguide 52 couples energy from a microwave power source 50, a magnetron for way of example and purposes of illustration only, past a mode stirrer 54 driven by a mode stirrer motor 56 to the microwave heating cavity 30, these elements being illustrated in imaginary lines.

FIG. 3 illustrates a side and top perspective view of the microwave oven 10 with a portion of the housing wrap 18 removed and illustrating a cutaway portion of the ventilation hood 42 showing the top side 20 and the right side 22 of the housing wrap 18, the door 12, the control panel 14, the push bar door release handle 16, the upper hinge 26, the exterior side of the exit ventilation port 36 of the microwave heating cavity 30, the humidity sensor 32 and the temperature sensor 34, both shown in imaginary lines, positioned adjacent to and by the exterior side of the plurality of exit ventilation port holes 36 and connected to the programmable controller 40, the magnetron 50, the waveguide 52, and the mode stirrer 54 driven by the mode stirrer motor 56. A circulation fan 58 draws air through the lower portion of a rear intake ventilation port 60, past the underside of a diode rectifier 62 and turns the air around to circulate past the microwave power source 50 to cool the electrical components, finally exhausting the air out the upper portion of the rear intake ventilation port 60. A diverter 64 as shown in FIG. 4 further diverts the air flow into a plurality of entrance port ventilation holes 66 to introduce air through the side of and into the microwave heating cavity 30. The air circulates in the microwave heating cavity 30 around the food being cooked and is exhausted through the exit port ventilation holes 36, past the humidity sensor 32 and the temperature sensor 34 which are positioned adjacent to and by the plurality of exit port ventilation holes 36 in the top of the microwave heating cavity 30, and through the plurality of the ventilation holes 38 in top 20 of the housing wrap 18 via way of the ventilation hood 42.

FIG. 4 illustrates the side view of the microwave oven 10 with the right side 22 of the housing wrap 18 removed illustrating the air circulation fan 58 which also draws air up through a bottom intake ventilation port 67, past a power transformer 68 and a capacitor 70, and around horizontal frame member 72 which divides the microwave power source 50—diode bridge 62 compartment from the power transformer 68—capacitor 70 compartment. The air from the bottom intake ventilation port 67 joins the air circulation path of the air pulled in through the lower portion of the rear intake ventilation port. This air circulation is also introduced into the microwave heating cavity 30 through the entrance port ventilation holes 66, which after circulating within the heating cavity 30, is exhausted through the plurality of exit ventilation port holes 36 past the humidity sensor 32 and the temperature sensor 34 into the outside environment through the plurality of exit ventilation holes 36 via way of the ventilation hood 42 which is partially cutaway. The described path of air circulation in the microwave oven heating cavity is for way of example and purpose of illustration of the invention.

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FIG. 5 illustrates a top plan view of the microwave oven showing a portion of the top 20 of the housing wrap 18 cutaway and showing a portion of the ventilation hood 42 cutaway. The humidity sensor 32 and the temperature sensor 34 are shown positioned adjacent to the plurality of exit port ventilation holes 36 in the top of the microwave heating cavity 30. Electrical cables connect the humidity and temperature sensors 32 and 34 respectively to the programmable controller 40 positioned behind the numeric keyboard control panel 14 through the analog signal conditioner interface circuitry. The air flow circulation path is shown by the arrows in the figure corresponding to the air flow circulation path through the rear intake ventilation port 60 and through the microwave oven heating cavity 30, the air being exhausted through the plurality of the exit port ventilation holes 36 to the plurality of ventilation holes 38 via way of the ventilation hood 42. All other numerals correspond to those elements previously described.

FIG. 6 illustrates a top enlarged and expanded view of the humidity sensor 32 and the temperature sensor 34 as shown in FIG. 5 positioned adjacent to and by the plurality of exit port ventilation holes 38 in the top of the microwave heating cavity 30 with the top 20 of the housing wrap 18 and the ventilation hood 42 partially cutaway. All other numerals correspond to those elements previously described.

FIG. 7 illustrates a section of the present invention taken on line 7—7 of FIG. 6 looking in the direction of the arrows showing the humidity sensor 32 and the temperature sensor 34 held by friction in a bracket 74 positioned adjacent to and by the plurality of exit port ventilation holes 36 in the top of the microwave heating cavity 30 with the bracket 74 being affixed to the oven frame structure 76 by any structure in the art such as adhesive. The humidity sensor 32 and the temperature sensor 34 can affix directly to the oven frame 76 by any suitable structure instead of being retained in the bracket 74.

FIG. 8 illustrates an electrical circuit schematic block diagram of the present invention showing the humidity sensor 32 connected to a humidity circuit 78. The humidity sensor 32 and the humidity circuit 78 consist of an "off the shelf" package such as a Thunder Scientific Corporation PC-2000 Humidity Measurement module for the humidity circuit 78 and the BR-101B Aluminum Oxide humidity sensor 32. The temperature sensor 34 and the temperature circuit 80 consist of an "off the shelf" package such as a National Semiconductor Corporation LX 5700 Temperature Transducer. The humidity sensor 32 and the temperature sensor 34 can be integrated into a single unitary package such as an integrated circuit also containing the humidity circuitry 78 and the temperature circuitry 80 forming a single sensor package and eliminating the need for separate sensor elements and associated circuitry.

The humidity sensor 32 through the humidity circuit 78 and the temperature sensor 34 through the temperature circuit 80 connect to the programmable controller 40 through a series connection of an analog multiplexer 82, a sample and hold gate 84, and an analog to digital converter 86. The analog multiplexer 82, the sampler and hold gate 84, and the analog to digital converter 86 may consist of an analog signal conditioner circuit to properly interface the sensed temperature and humidity signals to the programmable controller 40. In the alternative, the interface circuitry can be directly incorporated in the programmable controller 40 to provide

interfacing for input of the sensed and sampled humidity and the temperature signals.

A microwave control circuit 88 such as a silicon controlled rectifier power supply for the microwave power source 50 is controlled by the programmable controller 40. An air exchange control circuit for the fan 58 is also controlled by the programmable controller 40. The air exchange control circuit can further consist of an infrared lamp or a resistance heating coil not shown in the drawings to preheat the air temperature of the air being introduced at the entrance ventilation port 66 of the microwave oven heating cavity 30 during microwave cooking.

Preferred Mode of Operation

Time dependent "in-situ" environmental conditions of the microwave oven heating cavity 30 are sensed during microwave cooking of foods such as hot dogs, hamburgers, pork roasts, beef roasts, beef steaks, pork chops, poultry, fish, french fries, cakes, cookies, meat loafs, bread, vegetables, etc. The time dependent "in-situ" environmental conditions are defined as the sensed humidity and temperature environmental conditions of the microwave heating cavity 30 by humidity and temperature sensors. During the process of cooking foods with microwave energy, various energy conversions occur that modify the combined physical and chemical state of the food. These state changes directly determine the "doneness" or acceptable "palatability" of the cooked food. Since these states are electronically sensed and pragmatically correlated to the doneness of the food, then a microwave oven sensing system of the time dependent "in-situ" environmental conditions of the microwave oven heating cavity is achieved to control the microwave cooking of food. The purpose of implementing the microwave oven sensing system with the programmable controller having stored algorithms of "characteristic humidity curves" for different foods is to improve the "convenience and efficiency" of the microwave oven as well as the "palatability" of the food.

The humidity sensor 32 and the temperature sensor 34 are appropriately positioned as later described to sense the environmental conditions in an "in-situ" environment of the microwave oven heating cavity 30. Statically and dynamically, the exhaust air through the exterior of the exit ventilation port of the microwave oven heating cavity 30 is most depictive of the time dependent "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity 30. The environment on the exterior side of the exit ventilation port holes 36 for all practical considerations is equal to the environment on the interior side of the exit ventilation port holes 36 of the microwave oven heating cavity 30 permitting sensing of the time dependent "in-situ" environmental conditions of the microwave oven heating cavity 30 even though the humidity sensor 32 and the temperature sensor 34 are not located within the microwave oven heating cavity 30.

While the humidity sensor 32 and the temperature sensor 34 have been illustrated in FIGS. 1-7 as being positioned adjacent to and by the exterior side of the exit ventilation port holes 36 of the microwave oven heating cavity 30 for way of example and purposes of illustration only, the sensors 32 and 34 can be positioned directly above the exit port ventilation holes 36 of the microwave oven heating cavity 30 so long as the surface of the humidity sensor 32 is shielded against con-

densation preventing saturation of the sensor 32 from the steam and condensation gases being vented from the microwave oven heating cavity 30. In the alternative, if the humidity sensor 32 is positioned above the exit port ventilation holes 36 of the microwave oven heating cavity 30 and not shielded against condensation, then it is necessary to program the programmable controller 40 to account for saturated humidity sensor 32 conditions resulting from condensation on the humidity sensor 32.

The descriptive "words and phrases" in describing the positioning of the humidity sensor 32 as illustrated in FIGS. 1-7 of the drawings, also includes the terms near, at, on top of, to one side of, in the general vicinity of, etc., the exit port ventilation holes 36 of the microwave oven heating cavity 30.

The main thrust of placement of the sensors is to position the humidity sensor 32 and the temperature sensor 34 to sense and sample the time dependent "in-situ" environmental conditions of the microwave oven heating cavity 30, and one of the preferred positions is where the humidity and temperature sensors 32 and 34 respectively are positioned adjacent to and by the exit port ventilation holes 36 of the microwave oven heating cavity 30 as being most depictive and in equilibrium with the microwave oven heating cavity 30. The humidity sensor 32 and the temperature sensor 34 are positioned on the exterior side of the exit port ventilation holes 36 so as not to be subjected to electromagnetic interference and because the environment on the exterior side of the exit port ventilation holes 36 is for all practical considerations is equal to the environment of the interior of the microwave oven heating cavity 30 permitting time dependent "in-situ" sensing of the humidity and temperature environment conditions of the microwave oven heating cavity 30.

The humidity and the temperature sensors 32 and 34 respectively can also be positioned within the interior confine of the ventilation hood 42 but yet near enough to the exit port ventilation holes 36 of the microwave oven heating cavity 30 to sense the time dependent "in-situ" environmental conditions of the microwave oven heating cavity 30.

The humidity sensor 32 and the temperature sensor 34 can further be positioned anywhere in the interior of the microwave oven heating cavity 30 instead of positioning the sensors 32 and 34 at the exterior of the exit ventilation port 36 so long as the sensors have proper electromagnetic interference shielding to isolate the sensors 32 and 34 from interference by the microwave energy source 50.

The humidity sensor 32 and the temperature sensor 34 can additionally be positioned in an exhaust duct not shown in the drawings of the microwave oven 10 if utilized to exhaust the steam and gases from the microwave oven heating cavity 30 through the frame structure to the front, back, bottom, side or top of the microwave oven 10. The humidity sensor 32 and the temperature sensor 34 can be positioned directly in the exhaust duct structure of the microwave oven 10 but the humidity and temperature equilibrium conditions in the duct should be compensated for by either second humidity and temperature sensors located at a distance from the first humidity and temperature sensors or by programming equilibrium constant conditions into cooking algorithms stored in memory of the programmable controller 40.

The microwave oven sensing system derives from the most fundamental microwave cooking principles. That

is, as microwave energy is converted to thermal energy, the internal temperature of the food increases. As the internal temperature of the food increases, some of the thermal energy is used to break the bonding forces holding the water molecules to the food's cell structure. When the latent heat of vaporization has been added to the food, these free water molecules are vaporized and released locally. Thus, the rate of evaporation is directly proportional to the rate of temperature rise, and the integration of the rate of evaporation is proportional to the weight loss of the food. By monitoring the humidity and the temperature in the microwave oven heating cavity 30, the food's internal temperature, surface temperature, and weight loss can be determined.

The absolute humidity in grams per cubic meter in the microwave oven heating cavity 30 as a function of time in seconds yields a "Characteristic Humidity Curve" 92 as illustrated in FIG. 9 for the microwave cooking of foods which is expressed by the equation 1 as

$$h(t) = h_0 + (h_x - h_0) (1 - e^{-(Bt)^n}) \quad n > 1 \quad \text{eq. 1}$$

where h_0 is the initial absolute humidity, h_x is the peak absolute humidity, B is a constant in one over seconds, t is time in seconds and n is an integer. Absolute humidity is also known as vapor density. The "characteristic humidity curve" is determined by sensing the time dependent "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity 30 for a product being heated.

The "characteristic humidity curve" 92 of FIG. 9 of the absolute humidity in grams per cubic meters versus time in seconds can be approximated as a three segment 94, 96 and 98 piecewise linear curve prior to time t_x . The slope of the first segment 94 of the three segment piecewise linear curve is proportional to the rise in surface temperature of the food up to one hundred degrees centigrade. Once the hottest section of the surface has reached one hundred degrees centigrade at the change of slope 100, the humidity increases rapidly as illustrated by the slope of the second segment 96 of the three segment piecewise linear curve which is due to the "latent heat of vaporization" of the food. The change of slope 102 is indicative of the beginning of the surface temperature of the food reaching equilibrium. The slope of the third segment 98 of the three segment piecewise linear curve from point 102 to 104 is equilibrium occurring of the surface temperature of the food. The "characteristic humidity curve" 92 plateaus at point 104 indicating that the surface temperature of the food has reached equilibrium of one hundred degrees centigrades. While the peaked out plateau portion of the curve 92 is represented as a smooth curve, in reality there are "noise-like" perturbations on the curve due to surface boiling of water of the food. Any point on the "characteristic humidity curve" 92 is indicative of the surface temperature of the food while the integral of the area under the curve 92 at that point is indicative of the "internal doneness" of the food being cooked in the microwave oven heating cavity 30. Each particular type of food has its own individual "characteristic humidity curve" and the food during microwave cooking follows the "characteristic humidity curve" for that particular food.

In utilizing the microwave oven sensing system in the microwave oven 10, the interfacing circuitry of analog multiplexer 82, sample and hold gate 84, and analog digital converter 86 may not be required depending upon the type of programmable controller 40 utilized.

The humidity sensor 32 and the temperature sensor 34 can connect directly to the programmable controller 40 obviating any need for analog signal conditioner interface circuitry including the need for a humidity sensor circuit 78 and temperature sensor circuit 80. The programmable controller 40 can be an "off the shelf" microprocessor such as an Intel 8080 or TMS 1000 with a read only memory (ROM) storing "characteristic humidity curves" as cooking algorithms in the memory.

The programmable controller 40 is programmed with cooking algorithms based on "characteristic humidity curves" for different types of foods such as meats, etc. to be cooked during microwave cooking. For example, different types of meats have different "characteristic humidity curves" which follow equation 1 and are implemented as cooking algorithms which are stored in the memory of the programmable controller. For example, it is known that meats brown when the surface temperature is rising at a certain rate and the ambient humidity at the surface region of the meat is at a certain humidity level. During microwave cooking, the programmable controller 40 receives the humidity and temperature signals from the humidity and temperature sensors 32 and 34 respectively positioned at the exit ventilation port 36 of the microwave heating cavity 30 sensing the "in-situ" environmental conditions, and follows a selected cooking algorithm of the "characteristic humidity curve" for the particular type and thickness of meat being cooked, thereby optimizing the cooking and browning of the meat. Further, the selected cooking algorithm for the meat being cooked through the programmable controller 40 can indicate to the cook as to the proper time to turn the meat over, indicate that the door 12 has been open for a time exceeding a predetermined time period, and the meat is cooked to doneness.

The programmable controller 40 is also programmed to make electronic decisions as to increasing or decreasing the air exchange rate of the air exchange control circuit 90 which consists of the fan 58; increasing or decreasing the microwave power source duty cycle, in this example, the magnetron control circuit 88, or; increasing or decreasing the incoming air temperature such as controlling preheating of the incoming air temperature with an infrared lamp or by passing the air over a resistance heater such as a Calrod.

Individual cooking algorithms for "characteristic humidity curves" for different types of foods stored in the programmable controller 40 can be selected for the type of food being cooked in the microwave oven 10 through the numeric inputs on the numeric keyboard control panel 14. This control panel contains the additional numeric input operator features for the standard microwave oven control panels currently on the market of a "Humidity" control 44, a "Turn Food Over" control 45, a "Time Out" control 46 and a "Done" control 47. The "Humidity" keyboard control 44 permits the input of the humidity cooking parameter for the selected cooking algorithm stored in the programmable controller 40.

By controlling the humidity in the microwave oven heating cavity 30, the internal temperature of the food, the surface temperature of the food, browning of the food, and the weight loss of the food can all be controlled according to the input humidity parameter by the "Humidity" control 44 on the numeric keyboard control panel 14 or to the selected cooking algorithm

called from storage in the memory of the programmable controller 40. The "Humidity" control 44 permits the presetting of a predetermined humidity to be maintained within the microwave oven heating cavity 30 during microwave cooking.

The humidity sensor 32 sensing the time dependent "in-situ" humidity at the exit ventilation port 36 of the microwave oven heating cavity 30 inputs the sensed humidity to the programmable controller 40 which according to the selected stored cooking algorithm of the "characteristic humidity curve" for the particular type of food being cooked determines how the food is cooked, at what time the food is turned over, and at what time the food is done. The programmable controller 40 receives the sensed time dependent "in-situ" humidity from the humidity sensor 32 which is sensed relative humidity and also receives the sensed time dependent "in-situ" temperature from the temperature sensor 34 to convert the sensed relative humidity to absolute humidity for the cooking algorithm program stored in the programmable controller 40. The programmable controller 40 can then compute the temperature of the food which is indicative of the internal doneness of the food.

The programmable controller 40 also indicates to the cook when the optimum time is reached to turn a food over such as meat and activates a "Turn Food Over" control 45 such as illuminating a control light as well as sounding an audible alarm. This point occurs where the "characteristic humidity curve" 92 of FIG. 9 reaches peak absolute humidity h_x at point 104 as determined by the programmable controller 40. If the cook fails to close the door 12 within a predetermined time as determined by the programmable controller 40 after turning the food over, the "Time Out" control 46 such as an illuminated control light as well as an audible alarm are activated by the programmable controller 40. The programmable controller also indicates to a cook when the food is done by activating the "Done" control 47 such as an illuminating a control light as well as sounding an audible alarm.

In commercial microwave cooking applications such as fast food franchises, it may be desired to cook food samples exactly the same way each time for identical food samples such as hamburgers, bread, pastry, etc. To accomplish the identical microwave cooking of food samples, the desired "characteristic humidity curve" determined empirically or through a previous cooling cycle for a food sample is stored in the memory of the programmable controller 40 as the cooling algorithm for that food. The programmable controller 40 then compares the stored cooking algorithm for the food being cooked to the "characteristic humidity curve" to maintain microwave cooking of the food sample in the microwave oven cavity 30 according to the cooking algorithm for the food.

An additional humidity sensor and associated interface circuitry which connects to the programmable controller 40 can be positioned in a nonhostile environment of the frame structure of the microwave oven 10 to provide calibration for the humidity sensor 32 located adjacent to and by the exterior of the exit ventilation port 36.

Various modifications can be made to the microwave oven sensing system of the present invention without departing from the apparent scope of this invention.

Specifically, the programmable controller 40 can store cooking algorithms to maintain the humidity at a

predetermined level to brown foods, to indicate the temperature and internal doneness of food being cooked, to indicate the optimum time to turn food over, to control the cooking of juiced foods, to detect a fire in the cavity, etc.

Having thus described the invention, what is claimed is:

1. A method of controlling cooking in a microwave oven heating cavity comprising the steps of:

- (a) storing a microwave cooking algorithm in a programmable controller in a microwave oven;
- (b) providing a circulation path from an entrance ventilation port to an exit ventilation port through said microwave oven, said path including said microwave oven heating cavity;
- (c) electromagnetically isolating a humidity sensor and a temperature sensor from said microwave oven heating cavity, said sensors being located in said ventilation path;
- (d) coupling microwave energy to said microwave oven heating cavity;
- (e) sensing the time dependent environmental conditions of said microwave heating cavity with said sensors during microwave heating in said cavity; and
- (f) controlling said microwave energy according to said stored cooking algorithm for said sensed time dependent environmental conditions.

2. A method according to claim 1 comprising the step of:

- a. storing a "characteristic humidity curve" for a particular type of food as said algorithm in said programmable controller.

3. A method according to claim 1 comprising the step of:

- a. storing a plurality of "characteristic humidity curves" for different foods as algorithms in said programmable controller.

4. A method according to claim 1 comprising the step of:

- a. positioning said sensors adjacent to and by an exit ventilation port of said microwave oven heating cavity.

5. A method according to claim 1 comprising the step of:

- a. positioning said sensors in said microwave oven heating cavity.

6. A method according to claim 1 comprising the step of:

- a. positioning said sensors in an exhaust duct of said microwave oven heating cavity.

7. Method for cooking food in a microwave oven comprising the steps of:

- a. storing a "characteristic humidity curve" as an algorithm in a memory of a programmable controller microwave oven;
- b. sensing and sampling the time dependent "in-situ" relative humidity and temperature at an exit ventilation port of a microwave oven heating cavity;
- c. converting the sensed and sampled relative humidity and temperature to absolute humidity;
- d. comparing the absolute humidity to the stored "characteristic humidity curve;" and,
- e. regulating a microwave power coupled to said microwave oven source to maintain the absolute humidity according to said stored algorithm.

8. Method for cooking food in a microwave oven according to claim 7 comprising the step of:

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regulating air flow through said cavity to maintain the absolute humidity according to said stored algorithm.

9. Method for cooking food in a microwave oven according to claim 7 comprising the step of:

a. regulating preheating of air flow through said cavity to maintain the absolute humidity according to said stored algorithm.

10. A microwave oven sensing system comprising:

a. a microwave oven heating cavity

b. microwave power means coupled to said cavity; and

c. sensor means positioned to sense time dependent environmental conditions of humidity and temperature during microwave cooking in said microwave oven heating cavity.

11. The microwave oven of claim 10 wherein said sensor means comprises a humidity sensor and a temperature sensor positioned near an exit ventilation port of said microwave oven heating cavity.

12. The microwave oven of claim 10 wherein said sensor means comprises a humidity sensor and a temperature sensor positioned adjacent to each other at an exit ventilation port of said microwave oven heating cavity.

13. The microwave oven of claim 10 wherein said sensor means comprises an aluminum oxide humidity sensor and a temperature transducer.

14. The microwave oven of claim 10 wherein said sensor means comprises an aluminum oxide humidity sensor and a temperature sensor in a unitary package.

15. The microwave oven of claim 10 further comprising programmable controller means having a memory

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and connected between said microwave power means and said sensor means whereby said programmable controller means controls microwave heating in said microwave oven heating cavity according to an algorithm stored in said memory of said programmable controller.

16. The microwave oven of claim 15, further comprising air exchange control means connected to said programmable controller means whereby said programmable controller means controls air flow through a ventilation port in said microwave oven heating cavity according to said predetermined algorithm for said sensed time dependent environmental conditions.

17. The microwave oven of claim 16 further comprising humidity preset control means operably connected to said programmable controller means whereby a selected humidity is maintained during cooking in said microwave oven heating cavity by said programmable controller means as set by said humidity preset control means.

18. The microwave oven of claim 16 wherein said air exchange control means comprises a variable speed fan.

19. The microwave oven of claim 16 wherein said air exchange control means further comprises means for preheating said air prior to its passage into said microwave oven heating cavity.

20. The microwave oven of claim 19 wherein said preheating means comprises a resistance element heater.

21. The microwave oven of claim 19 wherein said preheating means comprises an infrared lamp.

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[54] **METHOD OF DETERMINING THE
OPTIMUM TIME TO TURN MEATS IN A
MICROWAVE OVEN**

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219/10.55 M

[58] Field of Search **426/233, 241, 243, 523;**
219/10.55 R, 10.55 M, 10.55 B

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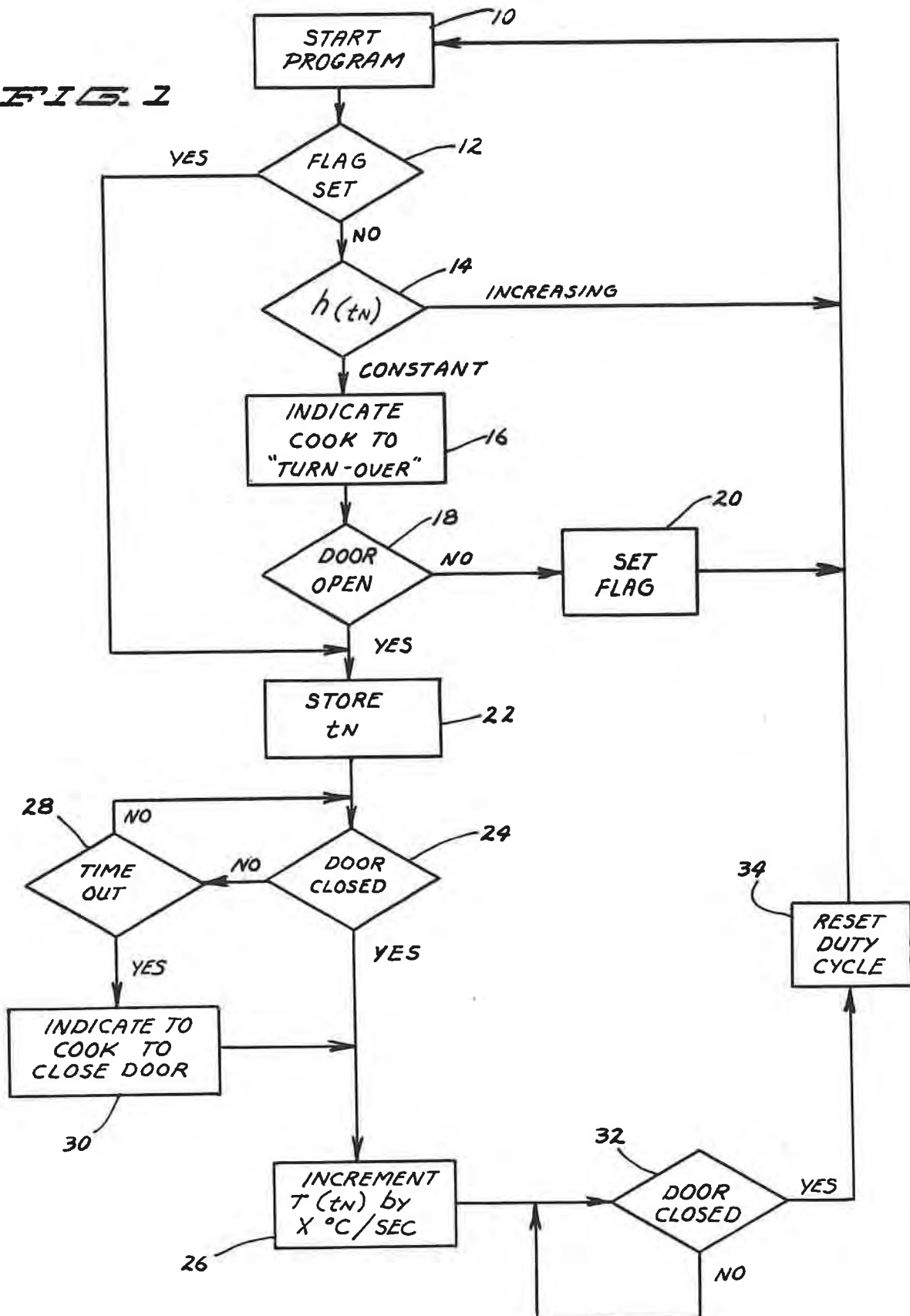
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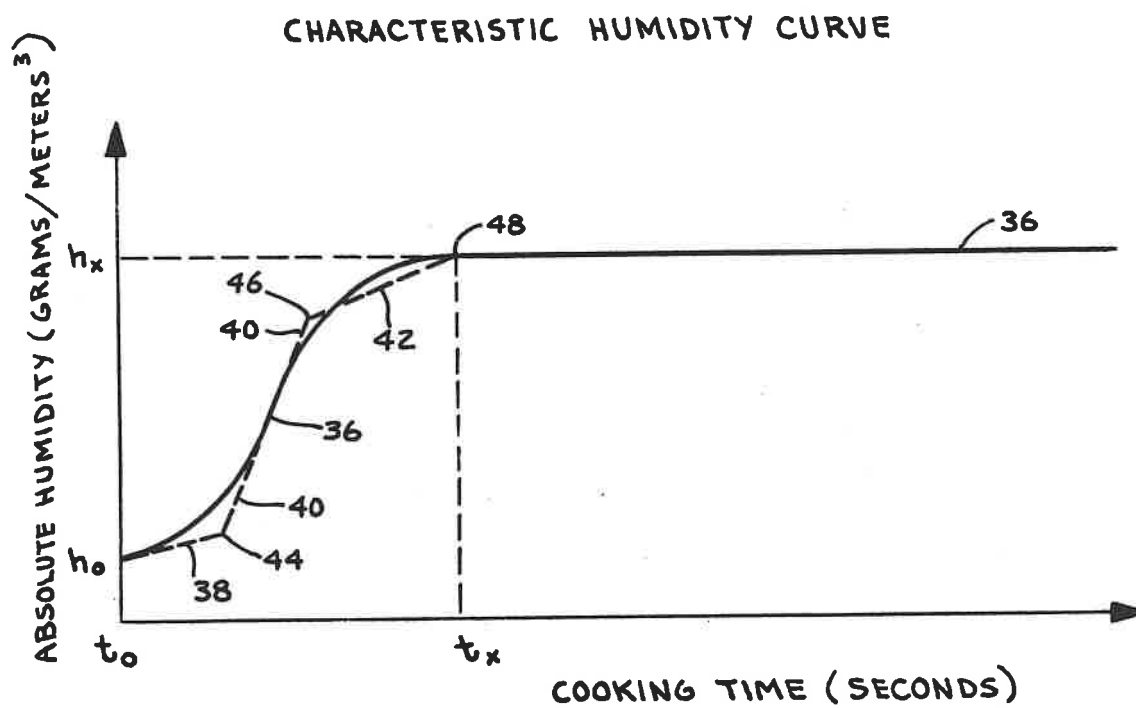
ABSTRACT

A method for indicating the optimum time at which to
turn meat over in a microwave oven. The method de-
tects the point where the absolute humidity remains
constant and no longer increases indicating that the
temperature of the meat has reached an equilibrium
point. At the temperature equilibrium point, the meat is
ready to be turned over.

4 Claims, 2 Drawing Figures

FIG. 2



**FIG. 2**

METHOD OF DETERMINING THE OPTIMUM TIME TO TURN MEATS IN A MICROWAVE OVEN

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to improvements in a method of cooking in a microwave oven, and more particularly, pertains to a new and improved method for determining the optimum time to turn meats in a microwave oven.

2. Description of the Prior Art

In the field of microwave ovens, it has been a general practice to employ probes stuck into a food such as meat indicating the temperature of the meat at that particular location at which the probe is stuck. Such thermometer types of probes have been unsatisfactory in that the probe only indicates the temperature at that one particular location for the piece of meat and is not an indication of the true overall temperature of the piece of meat or more importantly, the doneness of that piece of meat. Also, the accuracy of the probes is sometimes less than desirable as not being a true indication of the surface temperature of the meat or the internal temperature of the meat, especially when the meat has reached an equilibrium temperature. In not indicating the surface temperature of the meat, a cook is not able to tell when to turn the meat over and by not indicating the overall equilibrium of internal temperature of the meat, the cook is not able to determine when the meat is cooked to doneness.

This invention, a method for determining the optimum time for turning meats in a microwave oven, overcomes the disadvantages of the prior art devices by providing an accurate method for determining when the meat is to be turned over, in addition to taking into account the continuity through an increment for the time that the cook opens the door of the microwave oven, turns the meat over, and closes the door to resume microwave heating.

SUMMARY OF THE INVENTION

The present invention obviates the foregoing disadvantages of the prior art by providing a method for determining the optimum time when meat is to be turned over in a microwave oven.

According to the preferred embodiment of the present invention, there is provided a method for determining the optimum time when the meat is to be turned over in a microwave oven having the steps of checking to see whether the humidity is increasing or whether the humidity is remaining constant in the microwave oven heating cavity; upon sensing a constant absolute humidity condition, indicate to the cook to turn the meat over; storing the time difference that the door is open and closed, and lowering the duty cycle on again resuming microwave cooking.

A significant aspect and feature of the present invention is a step which handles the time discontinuity where the cook is turning the meat over when the microwave oven door is open. This method takes the time discontinuity into account and increments the temperature by a small factor of x degrees centigrade per second for the time period that the door is open and microwave cooking of the food is not taking place.

Having briefly described the preferred embodiment of the present invention, it is a principal object to pro-

vide a new and improved method for determining the optimum time to turn meats over in a microwave oven.

An object of the present invention is to determine when the absolute humidity no longer increases but remains constant indicating that it is time for a cook to turn meat over. A "Turn Food Over" control will indicate to a cook through an illuminated panel light and an audible alarm on the microwave oven to turn the meat over before microwave heating can then continue.

Another object of the invention is to provide a step to store the time that the microwave oven door is opened during the time that the cook is turning over the meat. When the door is closed, microwave heating continues but the duty cycle is adjusted accordingly to account for the time that the door was opened while the cook was turning over the food.

A further object of the invention is to indicate to the cook to close the door of the microwave oven after a predetermined time has been exceeded.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like elements throughout the figures thereof and wherein:

FIG. 1 illustrates a flow chart for performing the steps of the method of optimum time to turn meats in a microwave oven in accordance with the present invention; and

FIG. 2 illustrates a typical "characteristic humidity curve" for the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a flow chart of the steps for the method of determining the optimum time to turn meats in a microwave oven in accordance with the present invention showing a start program condition 10. When a NO flag set condition 12 exists, the program proceeds to determine whether absolute humidity is either constant or increasing with respect to the previous sensed and sampled absolute humidity. If an absolute humidity condition 14 is increasing, the program recycles itself returning to start program 10 and again determine absolute humidity. If the humidity condition 14 is constant, an indication condition 16 is given to the cook to turn the meat over such as through a front panel light on the control panel of the microwave oven in addition to an audible alarm as required. If the NO door open condition 18 exists where the microwave oven is not detected as being opened, a set flag condition 20 occurs and the program again recycles itself returning to start program 10. When a YES flag set 12 condition exists and the program returns to start program 10, the sensing and sampling of the humidity 14, the indication to the cook to turn the meat over 16, and the door open 18 is skipped by the YES flag set 12 condition. When the YES door open 18 condition occurs, a store t_n 22 of the door open time occurs. When a YES door closed 24 condition occurs, an increment of $T(t_n)$ by x degrees centigrade per seconds 26 for the time that the door is left opened is taken into account. When the YES door closed 32 condition exists, the reset duty cycle 34 of the microwave power supply occurs for a predetermined cooking algorithm and the program again restarts at

start program 10. The algorithm then senses when the food is cooked to internal doneness. If the door is not closed within a predetermined time interval and a YES time out 28 condition exists, then there is an indication to the cook to close door 30 condition. Again, there is an increment of $T(t_n)$ by x degrees centigrade per second for the time that the door remains open. If the NO door closed 24 condition and the NO time out 28 condition occurs, the program continues to the increment $T(t_n)$ 26 condition when the door is closed before the YES time out 28 condition occurs, otherwise the program proceeds to indicate to the cook to close door condition 30.

PREFERRED MODE OF OPERATION

In theory, there are two primary reasons for turning meats over. First, the meat heats quicker on the bottom than on the top as conductive heat losses on the bottom are much less than convective heat loss on the top of the meat. Second, the other is to reverse gravitational flow of natural meat juices, minimize weight loss, and optimize palatability as well as juices of the meat. Also, when the top of the meat reaches an equilibrium temperature of one hundred degrees centigrade, that is, where the "characteristic humidity curve" plateaus, the bottom of the meat tends to overheat.

The "characteristic humidity curve" 36 of absolute humidity in grams per cubic meter versus cooking time in seconds of FIG. 2 is determined by sensing the time dependent "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity during microwave cooking for a particular type of food. The time dependent "in-situ" environmental conditions are defined as the sensed humidity and temperature conditions of the microwave oven heating cavity by humidity and temperature sensors. The term "in-situ" as used in this application is defined as the actual time dependent environmental conditions which exist in the environment surrounding the food product such as thin meat which is located in and cooked in the microwave oven heating cavity. Although in the present invention, a humidity sensor and a temperature sensor may be positioned outside of the microwave oven heating cavity, the sensors are configured to sense the "in-situ" environmental conditions of the microwave oven heating cavity and provide "in-situ" signal information of the environmental conditions of the microwave oven heating cavity to a programmable controller controlling the microwave oven. Each particular food has its own particular "characteristic humidity curve". h_0 is the initial absolute humidity and h_x is the peak absolute humidity at time, t_x for the "characteristic humidity curve" 36 of FIG. 2.

The "characteristic humidity curve" 36 of FIG. 2 can be approximated as a three segment 38, 40, and 42 piecewise linear curve prior to time t_x . The slope of the first segment 38 of the three segment piecewise linear curve is proportional to the rise in surface temperature of the food up to one hundred degrees centigrade. Once the hottest section of the surface has reached one hundred degrees centigrade which occurs at the change of slope 44, the humidity increases rapidly as illustrated by the slope of the second segment 40 of the three segment piecewise linear curve which is due to the "latent heat of vaporization" of the food. The change of slope 46 is indicative of the beginning of the surface temperature of the food reaching equilibrium. The slope of the third segment 42 of the three segment piecewise linear curve

from points 46 to 48 is equilibrium of the surface temperature of the food occurring. The "characteristic humidity curve" peaks out at 48 and plateaus indicating the surface of the food has reached one hundred degrees centigrade. Point 48 on the "characteristic humidity curve" of FIG. 2, also indicate cook to "turn over" 16 condition on the flow chart of FIG. 1, is the optimum time to turn the meat or food over as complete temperature equilibrium is reached.

The method of optimum time to turn meats in a microwave oven can be implemented as an algorithm in accordance with the flow chart of FIG. 1 with the algorithm of the flow chart stored in a programmable controller such as an Intel 8080 microprocessor.

15 An aluminum oxide humidity sensor, such as a Thunder Scientific TC-2000 Humidity Measurement Module, and a temperature sensor, such as a National Semiconductor Corporation LX 5700 Temperature Transducer, are positioned adjacent to and by the exterior of the exit ventilation port for way of example and purposes of illustration only of the microwave heating oven cavity to sense the time dependent "in-situ" humidity and temperature environmental conditions in the microwave oven heating cavity and connect to the programmable controller. The sensors are positioned to sense the time dependent "in-situ" environmental conditions of the microwave oven heating cavity and are electromagnetically isolated from the microwave oven heating cavity. The programmable controller contains an algorithm to convert the sensed and sampled relative humidity as required for the humidity $h(t_n)$ 14 condition in the flow chart of FIG. 1. Further, the programmable controller connects to the microwave power source power supply, the air exchange control and the indication controls on the front panel of the microwave oven to indicate "Turn Food Over" 16 and "Time Out" 28 conditions.

The algorithm of FIG. 1 stored in the memory of the programmable controller indicates whether the absolute humidity is increasing or constant 14. If a constant absolute humidity 14 condition exists, the programmable controller indicates to the cook through a "Turn Food Over" control in the microwave oven to turn the food such as meat where the one hundred centigrade equilibrium point 48 of FIG. 2 is reached. The programmable controller upon detecting the YES door open 18 condition stores the time t_n 22 that the oven door is opened and if a NO door open 18 condition exists, a set flag 20 condition occurs.

The programmable controller through the algorithm monitors to determine how long it takes the cook to close the door 24. If the door close 24 is not completed within a predetermined set time, the time out 28 condition occurs giving an indication to the cook to close the door 30. When the door closed 32 condition occurs, the temperature of the food is incremented 26 by x degrees centigrade per second for the time that the door remained open. In practice, the incrementation factor is approximately equal to the rate of heating prior to the opening of the door and this factor is computed by an algorithm for the computation of meat temperature. When the door closed 32 condition occurs, the duty cycle reset 34 is performed by the programmable controller to a lower duty cycle taking into account the temperature increment adjustment performed at block 26.

When food is cooking and the temperature is rising at a certain rate, the temperature will continue to rise for

a certain period of time after heating ceases because the heat is pushed into the center of the food by the surface temperature of the food. For this reason, it is necessary to take into account and increment the temperature of the food. The incrementation takes into account the situation when the meat is being turned to account for this heating discontinuity through an increment of temperature by x degrees per centigrade of seconds that the door is open. It has been found that five degrees centigrade per minute is a general practical incrementation factor, but any other suitable incrementation may be substituted which of course depends upon the type and weight of meat being cooked in the microwave oven. Once the meat is turned over, and the flow chart of the figure repeats to indicate when the absolute humidity is again constant, indicating that the food is done as the other side of the meat has reached equilibrium temperature and a food done indication is given to the cook.

Various modifications are contemplated and may obviously be resorted to by those skilled in the art without departing from the apparent scope of the invention as hereinafter defined by the appended claims as only a preferred embodiment thereof has been disclosed. While the method is drawn to the optimum time to turn meat over, this algorithm applies to any food such as poultry, fish, etc. It may also be desired that if the microwave oven door is open for a short time period while turning over the meat, it may be desired not to reset the duty cycle of the microwave power source.

Having thus described the invention, there is claimed as new and desired to be secured by Letters Patent:

1. A method for cooking a foodstuff of the type requiring turning during cooking in a microwave oven having a cooking cavity, a source of microwave energy,

a controller including a programmable microprocessor, and means for sensing the time-dependent humidity in said cooking cavity, said method comprising the steps of:

- (a) placing said foodstuff on a first side thereof into said cooking cavity;
 - (b) applying microwave energy from said source to said cooking cavity to heat said foodstuff;
 - (c) sensing the time-dependent humidity of said cooking cavity with said sensing means while applying microwave energy to heat said foodstuff and providing said sensed humidity as an input to said programmable microprocessor;
 - (d) determining in said microprocessor during the heating step when said time-dependent sensed humidity becomes substantially constant; and
 - (e) providing an oven operator signal to turn said foodstuff to a second side thereof when said substantially constant humidity condition is reached.
2. The method of claim 1 wherein said time-dependent humidity is absolute humidity.
3. The method of claim 1 further comprising the steps of:
- (a) measuring the time period during which the microwave oven door is open and said source of microwave energy is non-operative while said foodstuff is being turned to said second side; and
 - (b) adjusting the food cooking time when said time period exceeds a predetermined time.
4. The method of claim 3 wherein said food cooking time adjusting step is carried out by a program stored in said microprocessor.

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[54] **METHOD OF COOKING MEATS IN A MICROWAVE OVEN**

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[21] Appl. No.: **829,080**

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[52] U.S. Cl. **426/243; 426/523; 219/10.55 E; 219/10.55 M**

[58] Field of Search **426/233, 241, 243, 523; 219/10.55 M, 10.55 B, 10.55 R**

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Primary Examiner—Robert A. Yoncoskie
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[57] **ABSTRACT**

A method of cooking meat in a microwave oven by determining the mean internal temperature of the meat which is indicative of the internal doneness of meat as a function of sensed and sampled time dependent humidity and temperature of the microwave oven heating cavity. The mean internal temperature of the meat is determined as a function of the initial temperature of the meat; a net heat loss due to surface evaporation; a net input of energy by the microwave power source, and a net convective heat loss.

4 Claims, 3 Drawing Figures

FIG. 1A

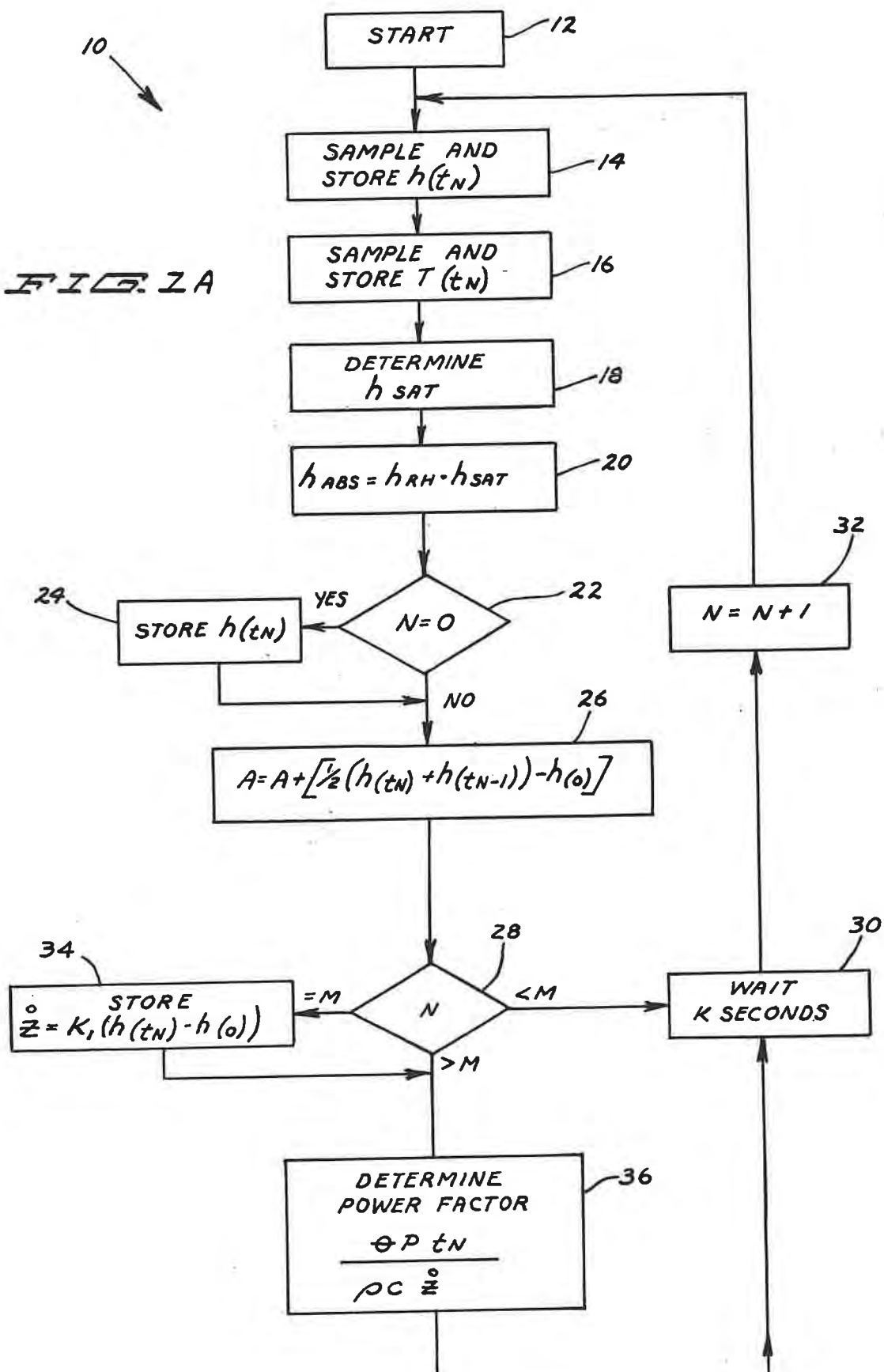
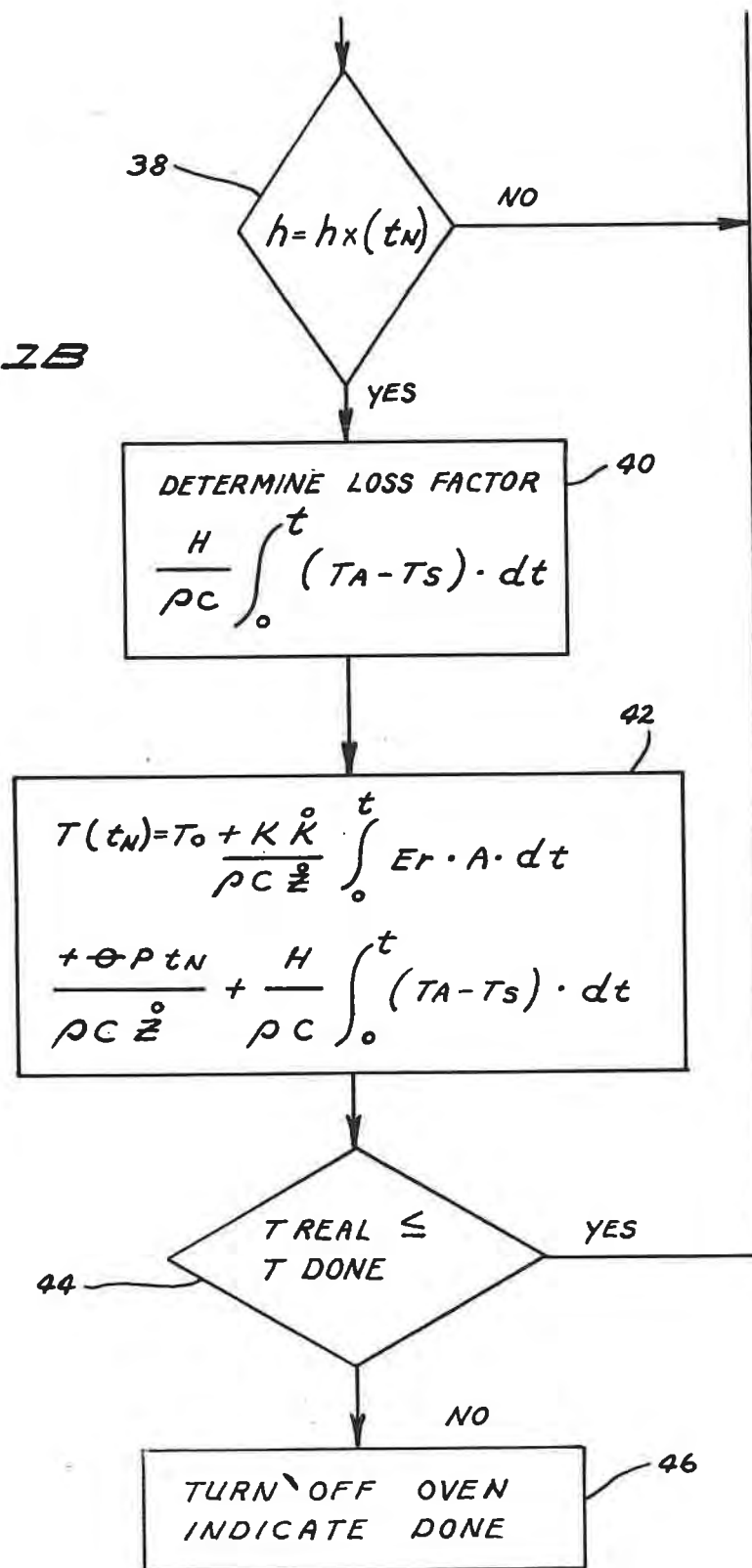


FIG. 1B



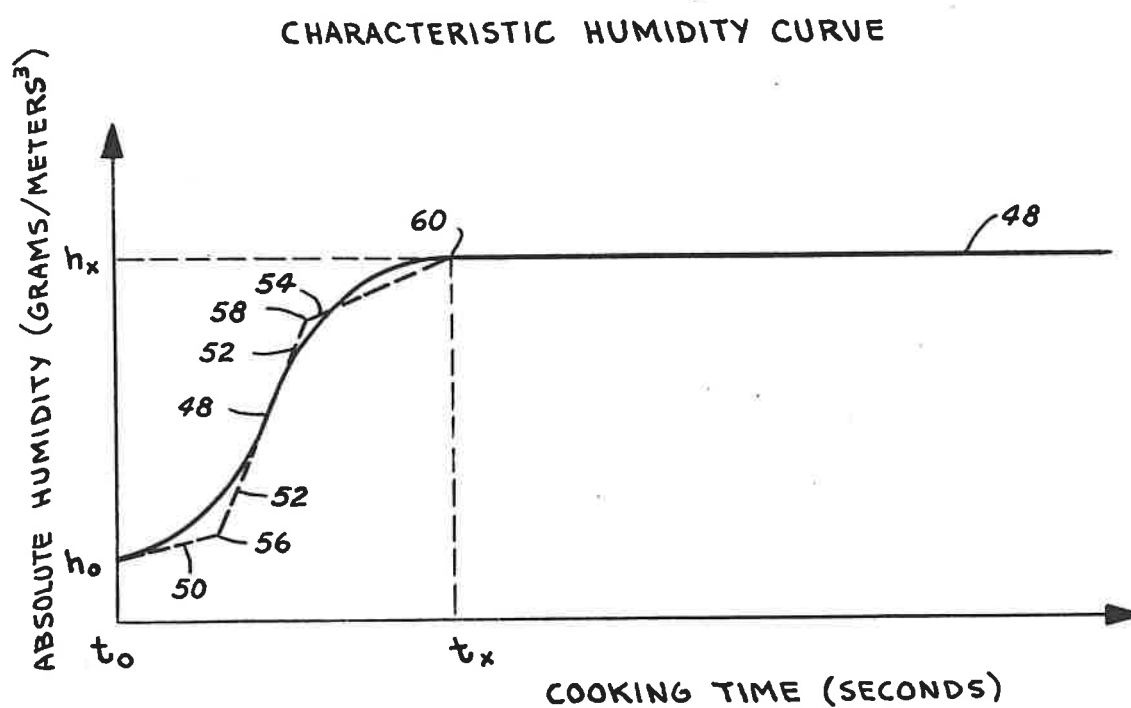


FIG. 2

METHOD OF COOKING MEATS IN A MICROWAVE OVEN

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to improvements in microwave ovens, and more particularly, pertains to a new and improved method of cooking of meat in a microwave oven.

2. Description of the Prior Art

Those concerned with microwave heating of meat have long recognized the need to accurately determine the temperature which is indicative of the internal doneness of the meat being cooked in a microwave oven. The present invention fills this need.

Past prior art devices have not been extremely reliable in determining the temperature of meat being cooked in a microwave oven. Initial prior art attempts at determining the temperature of meat was to insert a thermometer into the piece of meat being cooked which was not affected by the microwave energy radiation, but the disadvantage was that the thermometer only indicated the internal temperature of the meat at one particular location and was not a true overall indication of the equilibrium internal temperature of the meat which is indicative of internal doneness of the meat.

Another current prior art device for measuring the internal temperature of meat being cooked is to insert a temperature probe into the meat while in the microwave oven heating cavity which connects to the control circuitry of the microwave oven. While the temperature probe is accurate in indicating the temperature of the meat being cooked by microwave energy, the probe only senses the temperature of the immediate area surrounding the probe and does not take into account the equilibrium state of the internal temperature of the meat. If the temperature of the meat is not uniform and the probe is placed at a hot spot in the meat, the readings from the temperature probe are not indicative of the mean internal temperature of the meat.

Further, the probe which is inserted into the meat is cumbersome and bulky for the cook who is trying to monitor the temperature of the meat during the microwave cooking in the microwave oven heating cavity.

This invention, a method of cooking meat in a microwave oven, overcomes the disadvantages of prior art by providing an accurate method for determining the temperature of meat which is indicative of the internal doneness of the meat.

SUMMARY OF THE INVENTION

The present invention obviates the foregoing disadvantages of the prior art by providing a method of cooking meat in a microwave oven.

According to the preferred embodiment of the present invention, there is provided a method for cooking of meat in a microwave oven having the steps of sampling the time dependent "in-situ" humidity and temperature environmental conditions of a microwave oven heating cavity, determining the absolute humidity from the sampled "in-situ" humidity and temperature, and determining the mean internal temperature of the meat as a function of the initial temperature, the integral of a "characteristic humidity curve" of the absolute humidity indicative of the net heat loss due to surface evaporation, and the net input of energy by the microwave power source, and the net convective heat loss. If the

temperature of the meat is equal to or greater than a predetermined temperature, then the microwave oven is turned off and an indicate done signal is provided for the cook.

A significant aspect and feature of the present invention is a method which provides for the determination of the temperature of the meat which is indicative of the internal doneness of meat being cooked in a microwave oven. A cook, by knowing the temperature of the meat at any time during the cooking period, can determine the optimum time to turn the meat over, what time to baste the meat, etc., or more importantly, when the meat is done cooking.

Having briefly described the preferred embodiment of the present invention, it is a principal object to provide a method of cooking meat in a microwave oven.

An object of the present invention is to provide a method for determining the mean internal temperature of the meat which is indicative of the internal doneness of the meat while being cooked in a microwave oven.

Another object of the invention is provide a method determining when the piece of meat is cooked to internal doneness by sensing the time dependent "in-situ" humidity and temperature environment conditions of the microwave oven heating cavity with humidity and temperature sensors.

The term "in-situ" as used in this application is defined as the actual environmental conditions which exist in the environment surrounding the food product such as meat which is located in and cooked in the microwave oven heating cavity. Although in the present invention, the humidity sensor and the temperature sensor may be positioned outside of the microwave oven heating cavity, the sensors are configured to sense the time dependent "in-situ" environmental conditions of the microwave oven heating cavity and provide "in-situ" signal information of the time dependent environmental conditions of the microwave oven heating cavity to a programmable controller controlling the microwave oven.

A further object of the invention is to provide for control of the microwave oven to indicate that the piece of meat is cooked to doneness and to turn off the microwave oven upon reaching a predetermined temperature indicating doneness of the meat. This increases the convenience and overall efficiency of the microwave cooking as well as the palatability of the food.

BRIEF DESCRIPTION OF THE DRAWING

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like elements throughout the figures thereof and wherein:

FIGS. 1A and 1B illustrate a flow chart of the method of cooking meat in a microwave oven in accordance with the present invention; and

FIG. 2 illustrates a typical "characteristic humidity curve" for the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a flow chart 10 of an algorithm for the method in accordance with the present invention. The method in algorithm form provides for determining

the mean internal temperature of the meat being cooked in a microwave oven, which is indicative of the internal doneness of the meat.

The generalized equation for the mean internal temperature of meat is expressed by equation 1 where

$$T = T_0 + \frac{\chi}{Z} \int_0^t E_r [H(t) - h(0)] \cdot dt + \frac{\text{Power}}{\text{Factor}} + \frac{\text{Loss}}{\text{Factor}} \quad \text{Eq. 1}$$

and T_0 is the initial temperature of the meat; χ is a constant proportional to the thermal conductivity of the meat, the density of the meat, and the specific heat of the meat; Z is a constant equal to the thickness of the meat; E_r is a constant equal to the air exchange rate through the microwave oven heating cavity, and; $h(t)$ is the absolute humidity at time t_N during the cooking period.

The Power Factor is expressed by equation 2 where the

$$\text{Power Factor} = \frac{\theta P_{tN}}{\rho C Z} \quad \text{Eq. 2}$$

and θ is a constant equal to the power constant of the microwave power source; P_{tN} is a constant equal to the duty cycle constant of the microwave power source during a cooking time interval of the microwave oven; ρ is a constant equal to the density of the meat; C is a constant equal to the specific heat of the meat; and Z is a constant equal to thickness of the meat.

The loss factor of the convective heat loss is expressed by equation 3 where the

$$\text{Loss Factor} = \frac{H}{\rho C} \int_0^t (T_A - T_s) \cdot dt \quad \text{Eq. 3}$$

and H is a constant equal to the convective heat transfer coefficient of the meat; ρ is a constant equal to the density of the meat; C is a constant equal to the specific heat of the meat; T_A is equal to the ambient temperature of the microwave oven heating cavity at time T_N ; and T_s is equal to the surface temperature of the meat at time T_N .

The generalized equation 1 for the temperature of meat is rewritten as equation 4 which is the equation for the mean internal temperature of meat which is indicative of the internal doneness of the meat where

$$T = T_0 + \frac{K \bar{K}}{\rho C Z} \int_0^t E_r [h(t) - h(0)] \cdot dt + \frac{\theta P_t}{\rho C Z} + \frac{H}{\rho C} \int_0^t (T_A - T_s) \cdot dt \quad \text{Eq. 4}$$

where K is the thermal conductivity constant of the meat and $\bar{K}$ is the evaporation loss constant of the meat.

The first component, T_0 , of equation 4 is the initial temperature of the meat; the second component of equation 4 is the component which effects the internal temperature of the meat by a net heat loss due to evaporation; the third component of equation 4, the power factor, is the component which effects internal temperature of the meat by a net input of energy by the microwave power source, and; the fourth component of equation 4, the loss factor, is the component which effects internal temperature of the meat by a net convective

heat loss. The addition of the four components of equation 4 equal the mean internal temperature of meat being cooked in a microwave oven.

The flow chart 10 of FIG. 1 provides the algorithmic steps to determine the mean internal temperature which is indicative of the internal doneness of the meat being cooked in the microwave oven and initiates at start 12. The relative humidity $h(t_N)$ 14 and the temperature $T(t_N)$ time dependent "in-situ" environmental conditions of the microwave oven heating cavity are sampled and stored. The saturated humidity 18 is determined from the sensed time dependent "in-situ" environmental conditions of relative humidity and temperature of the microwave oven heating cavity. The absolute humidity 20 is then determined from the sampled and stored time dependent "in-situ" relative humidity $h(t_N)$ 14 of the microwave oven heating cavity times the saturated humidity 18. If an N equal zero YES condition 22 exists at t_N , the absolute humidity at t_N is stored at step 24, but if a N equal zero NO condition 22 exists at t_N , then the absolute humidity determined at step 20 is utilized in the subsequent computations. The area "A" at step 26 under the "characteristic humidity curve" of the absolute humidity determined at step 20 in grams per cubic meter versus cooking time in seconds is computed at time t_N . If an N less than M condition 28 exists, the algorithm waits K seconds at step 30 where K is a predetermined time constant, increments N by one at step 32, and again samples and stores the relative humidity $h(t_N)$ 14 and temperature $T(t_N)$ 16 in repeating the steps of the algorithm. If an N equals M condition 28 exists, then Z is equal to the initial slope of the "characteristic humidity curve" times a predetermined constant K_1 . If an N greater than M condition exists, the power factor 36 is determined. If a peak absolute humidity NO condition 38 exists where peak absolute humidity has not been reached, then the algorithm advances to the wait K seconds at step 30. If a peak absolute humidity YES condition 38 exists, then the algorithm advances to the determination of the convective loss factor 40. The mean internal temperature 42, equation 4, of the meat is subsequently determined from the components of the initial temperature of the meat; the component of the internal temperature by a net heat loss due to evaporation; the component of the internal temperature by a net input of energy from the microwave power source, and; the component of the internal temperature by a net convective heat loss. If a temperature is less than or equal to temperature done, a YES 44 condition exists and the algorithm repeats through step 30. If the temperature is greater than temperature done, a NO 44 conditions exists and the microwave oven is turned off by a programmable controller and an indicate done signal is provided for the cook.

Preferred Mode of Operation

The method of cooking meat in a microwave oven is premised on the sensing concept based on the most fundamental cooking principles. That is, as microwave energy is converted to thermal energy, the mean internal temperature of the meat increases, some of the thermal energy is used to break the bonding forces holding the water molecules to the food's cell structure. When sufficient heat equal to the latent heat of vaporization has been added to the food, these free water molecules are vaporized and released locally. Thus, the rate of evaporation is directly proportional to the rate of tem-

perature rise. By monitoring the microwave oven heating cavity time dependent "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity, it is possible to determine the meat's mean internal temperature for a piece of meat in conjunction with "characteristic humidity curve" 48 of FIG. 2.

The "characteristic humidity curve" 48 of absolute humidity in grams per cubic meters versus cooking time in seconds of FIG. 2 is determined by sensing the time dependent "in-situ" relative humidity and temperature environmental conditions of the microwave oven heating cavity during microwave cooking of meat. The time dependent "in-situ" environmental conditions are defined as the sensed humidity and temperature of the microwave oven heating cavity and are determined by humidity and temperature sensors. Each particular type of meat has its own particular "characteristic humidity curve". h_0 is the initial absolute humidity and h_x is the peak absolute humidity at the time t_x of the "characteristic humidity curve" 48.

The "characteristic humidity curve" 48 of FIG. 2 may be approximated as a three segment 50, 52 and 54 piecewise linear curve prior to time t_x . The slope of the first segment 50 of the three segment piecewise linear curve is proportional to the rise in surface temperature of the food up to one hundred centigrade. Once the hottest section of the surface has reached one hundred degrees centigrade which occurs at the change of slope 56, the humidity increases rapidly as illustrated by the slope of the second segment 52 of the three segment piecewise linear curve which is due to the "latent heat of vaporization" of the food. The change of slope 58 is indicative of the beginning of the surface temperature of the food reaching equilibrium. The slope of the third segment 54 of the three segment piecewise linear curve from point 58 to 60 is equilibrium occurring of the surface temperature of the food. The "characteristic humidity curve" 48 plateaus at point 60, the peak absolute humidity indicating that the surface temperature of the meat has reached equilibrium of one hundred degrees centigrade.

The rate of surface evaporation of the meat is proportional to the rate of temperature rise, and that the total rate of surface evaporation is proportional to the sum of the rates of evaporation of each incremental segment of the internal temperature gradient. The integral of the "characteristic humidity curve" of FIG. 2 is directly related to the component which effects the internal temperature of the meat by a net heat loss due to evaporation.

The method is implemented in accordance with the flow chart 10 of FIGS. 1A and 1B as an algorithm stored in a programmable controller such as an Intel 8080 Microprocessor. The algorithm of FIGS. 1A and 1B determines the mean internal temperature of the meat which is indicative of internal doneness.

An aluminum oxide humidity sensor, such as a Thunder Scientific TC-2000 Humidity Measurement Module, and a temperature sensor, such as a National Semiconductor Corporation LX 5700 Temperature Transducer, may be positioned adjacent to and by the exit ventilation port to the exterior side of the microwave oven heating cavity for way of example and for purposes of illustration only to sense the time dependent "in-situ" environmental conditions internal to the microwave oven heating cavity. The sensors are positioned to sense the time dependent "in-situ" environ-

mental conditions of the microwave oven heating cavity and are electromagnetically isolated from the microwave oven heating cavity. The humidity sensor and the temperature sensor connect to the programmable controller having the steps of the algorithm of FIG. 1 stored in the memory of the programmable controller. The programmable controller connects to the microwave power source power supply and the air exchange circuit and turns the oven off when a NO condition 46 exists indicating that temperature done has been reached.

The algorithm of the method of FIG. 1A and 1B determines the mean internal temperature according to the equation of step 42 as a function of the initial temperature of the meat, the first component of the equation of step 42; the internal temperature of the meat which is effected by a net heat loss due to evaporation, the second component of the equation of step 42; the power factor which effects the internal temperature of the meat by a net input of energy by the microwave power source as determined at step 36, the third component of equation of step 42; and the loss factor which effects the internal temperature of the meat by a net convective heat loss. The four factors are determined from the sampled and sensed humidity and temperature "in-situ" environmental conditions of the microwave oven heating cavity according to steps 14-26. The programmable controller performing the steps 12-46 of the algorithm turns the microwave oven off and indicates done at step 46 upon determining a t_{real} which is greater than a t_{done} at step 46 indicating that the meat has reached its desired mean internal temperature indicative of the internal doneness of the meat.

Various modifications can be made to the method of cooking meat in a microwave oven of the present invention without departing from the apparent scope of this invention.

Having thus described the invention, what is claimed is:

1. A method for cooking meat in a microwave oven of the type having means for measuring the humidity and temperature of the oven heating cavity, and having oven control means including a programmable microprocessor for receiving signals indicative of said measured humidity and temperature, said method comprising the steps of:
 - (a) energizing a microwave energy source to provide microwave energy to said oven heating cavity whereby a substantial portion of said energy is absorbed by a meat body located in said oven heating cavity;
 - (b) measuring the humidity and temperature of said oven heating cavity at a plurality of time-spaced intervals as said meat body is heated and providing signals indicative of said measured quantities to said microprocessor;
 - (c) calculating in said microprocessor a humidity-time curve described by said measured quantities and determining in said microprocessor the area under said curve;
 - (d) comparing in said microprocessor said calculated area with the area of a predetermined characteristic humidity-time curve for meat bodies stored in a memory portion of said microprocessor and calculating in said microprocessor from said comparison the net heat loss due to evaporation, a microwave power absorption factor and a power loss factor for said meat body;



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- (e) further calculating in said microprocessor the mean internal temperature of said meat body as a function of the sum of its initial temperature said net evaporative heat loss, said microwave power absorption factor and said power loss factor; 5
- (f) comparing in said microprocessor said calculated mean internal temperature with an operator selected doneness temperature for said meat body; 10 and,
- (g) de-energizing said microwave energy source when said operator selected doneness temperature is reached. 15

2. The method of claim 1 wherein said net heat loss due to evaporation is calculated by integrating in said microprocessor the rate of change of humidity with respect to time and multiplying said integral in said microprocessor by a constant derived from the physical 20

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properties of said meat body and stored in said memory portion of said microprocessor.

3. The method of claim 1 wherein said microwave power absorption factor is calculated from the expression:

$$\text{Power factor} = \frac{\theta P_N}{\rho C Z}$$

wherein θ is a constant proportional to the power output of said microwave energy source; P_N is the duty cycle of the oven at time interval N ; ρ is the density of the meat; C is the specific heat of the meat; and Z is a constant proportional to the thickness of the meat.

4. The method of claim 1 wherein steps (b) through (f) are repeated at consecutive intervals and wherein said calculated mean internal temperature is recalculated at each said interval for the purpose of determining the required done temperature. 20

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[54] **ABNORMAL TEMPERATURE DETECTION
AND MICROWAVE GENERATION
SUPPRESSION IN A MICROWAVE OVEN**

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[21] Appl. No.: **911,153**

[22] Filed: **May 31, 1978**

[30] **Foreign Application Priority Data**

May 31, 1977 [JP] Japan 52/65341

[51] Int. Cl.² **H05B 9/06**

[52] U.S. Cl. **219/10.55 C; 219/10.55 R;**
219/10.55 B

[58] Field of Search 219/10.55 R, 10.55 B,
219/10.55 C, 10.55 M, 10.55 A

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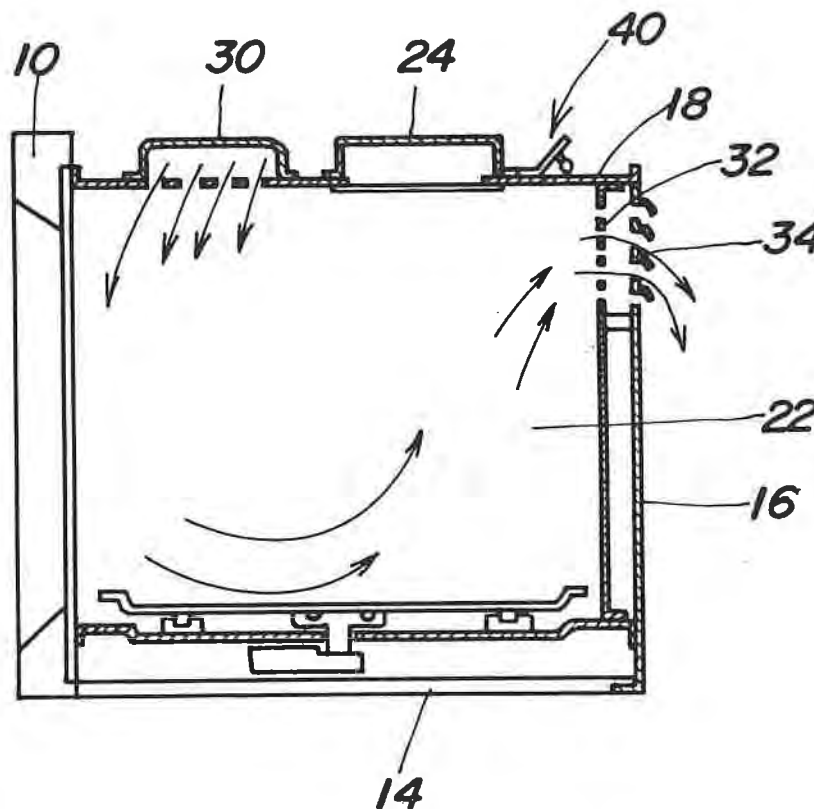
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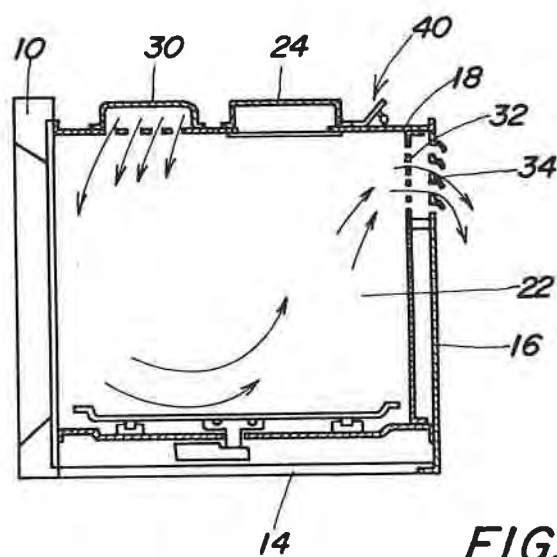
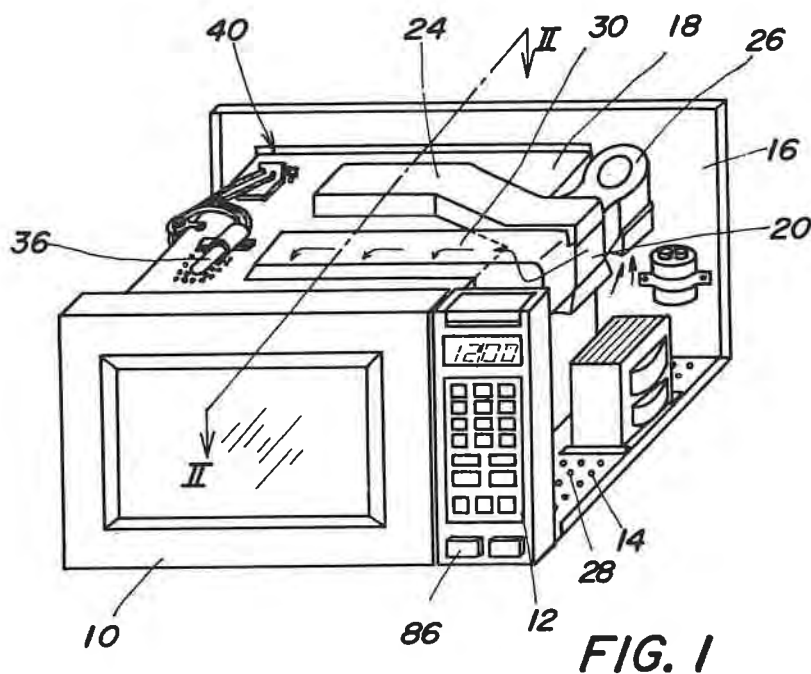
Primary Examiner—Arthur T. Grimley
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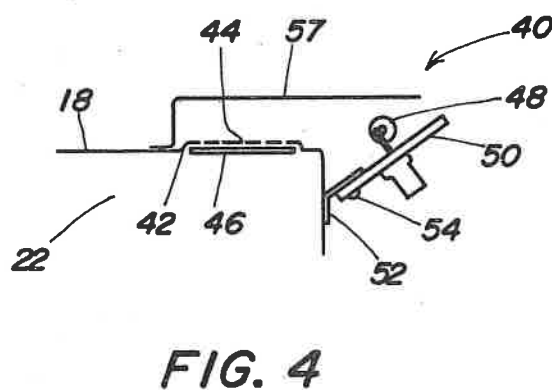
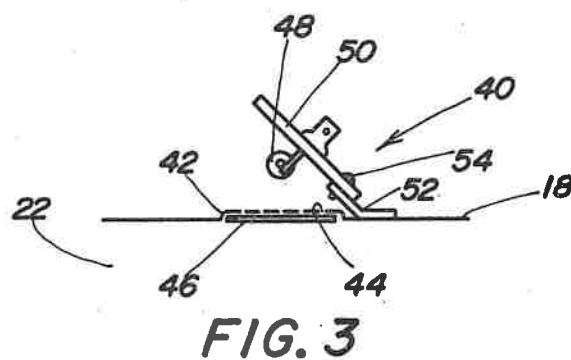
[57] **ABSTRACT**

A hot air exhaustion opening is formed in an oven wall of a microwave oven. A heat-sensitive film is disposed at the hot air exhaustion opening to close the hot air exhaustion opening when the microwave oven is in the normal operation mode. When the oven cavity temperature rises to an abnormal value, the heat-sensitive film is fused to conduct hot air toward the outside of the microwave oven cavity through the hot air exhaustion opening. A heat-sensitive fuse is disposed on the downstream side of the heat-sensitive filter film so that the heat-sensitive fuse receives the hot air exhausted through the hot air exhaustion opening when the heat-sensitive film is fused. The heat-sensitive fuse is associated with a microwave generation control circuit so that the microwave generation is suppressed when the oven cavity temperature rises to the abnormal value.

6 Claims, 7 Drawing Figures







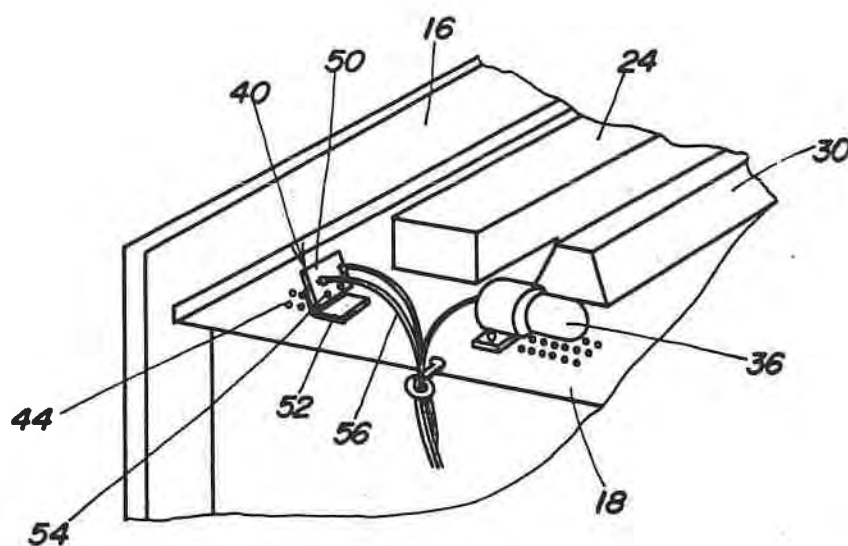


FIG. 5

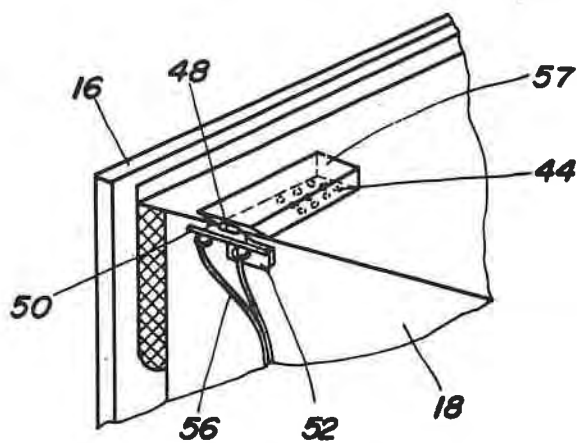
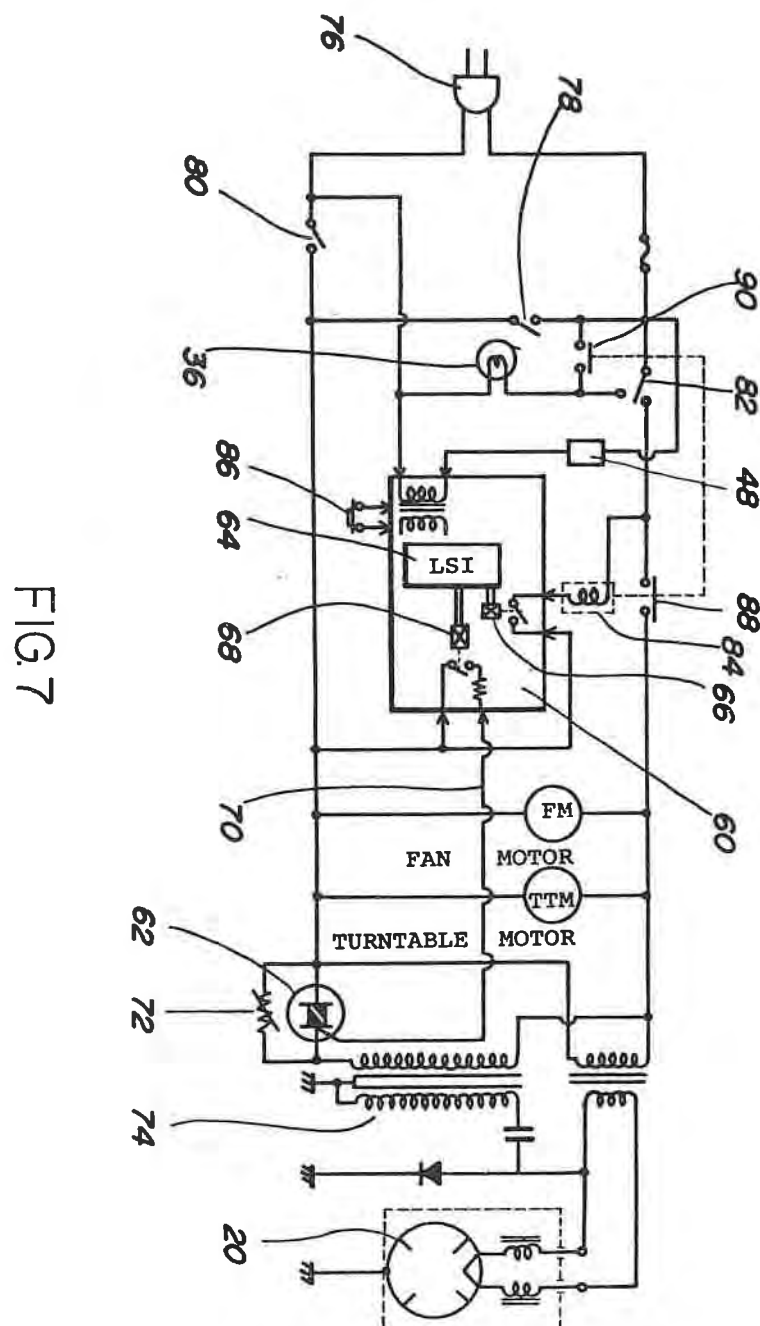


FIG. 6



ABNORMAL TEMPERATURE DETECTION AND MICROWAVE GENERATION SUPPRESSION IN A MICROWAVE OVEN

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a microwave oven and, more particularly, to a microwave generation suppression system in a microwave oven when a microwave oven cavity temperature rises to an abnormal value.

There is the possibility that an oven cavity temperature can rise to an abnormal value due to the combustion of foodstuff or under a no load operation. It is important that the microwave generation be suppressed when the oven cavity temperature rises to an abnormal value.

In the conventional microwave oven, a heat-sensitive fuse is disposed in a power supply circuit for the microwave generation control circuit for suppressing the microwave generation when the oven cavity reaches an abnormally high temperature. In the prior art system the heat-sensitive fuse is disposed on the oven wall, on a wall of an exhaust duct, or in the oven cavity.

For example, U.S. Pat. No. 3,527,915 entitled "NO LOAD SENSING DEVICE FOR MICROWAVE OVENS", disclosed a microwave oven, on Sept. 8, 1970, wherein the no load sensing thermostat is placed within the cavity of the microwave oven.

The electrical isolation between the heat-sensitive fuse and the microwave oven wall or a duct wall must be strictly performed to ensure stable operation of the microwave oven and the heat-sensitive fuse. The heat-sensitive fuse must be tolerant of high temperature moisture, since the heat-sensitive fuse of the prior art is always exposed to the high temperature moisture. Moreover, it is very difficult in the prior art system to determine the set temperature of the heat-sensitive fuse, because the heat-sensitive fuse is always exposed to the high temperature moisture even when the microwave oven is in the normal condition.

Accordingly, an object of the present invention is to provide a microwave oven wherein microwave generation is suppressed when an oven cavity reaches an abnormally high temperature.

Another object of the present invention is to provide a novel temperature detection system for suppressing microwave generation when an oven cavity reaches an abnormally high temperature.

Still another object of the present invention is to stabilize the operation of a heat-sensitive fuse for detecting the abnormally high temperature of an oven cavity.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a hot air exhaust opening is formed in an oven wall of a microwave oven in addition to a normal exhaust opening. A heat-sensitive filter film made of, for example, a polyester film is disposed at the hot air exhaust opening so as to close

the hot air exhaust opening when the microwave oven is placed in the normal operating mode. When the oven cavity reaches an abnormally high temperature, the heat-sensitive film is fused, thereby conducting hot air toward the outside of the microwave oven cavity through the hot air exhaust opening.

A heat-sensitive fuse is disposed on the downstream side of the heat-sensitive film so that the heat-sensitive fuse receives and senses the hot air exhausted through the hot air exhaust opening when the heat-sensitive film is fused, that is, only when the oven cavity reaches an abnormally high temperature. The heat-sensitive fuse is associated with a microwave generation control circuit in such a manner that the microwave generation is suppressed when the heat-sensitive fuse is fused.

In a preferred form, the heat-sensitive film becomes fused at about 260° C., and the heat-sensitive fuse is broken at about 115° C. Therefore, when the heat-sensitive film is fused, the heat-sensitive fuse functions to suppress the microwave generation.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. 1 is an exploded perspective view of a microwave oven employing an embodiment of the abnormal temperature detection system of the present invention;

FIG. 2 is a cross-sectional view taken along the line II-II of FIG. 1;

FIG. 3 is a front view of one embodiment of the abnormal temperature detection system of the present invention;

FIG. 4 is a front view of another embodiment of the abnormal temperature detection system of the present invention;

FIG. 5 is a perspective view of a portion of a microwave oven employing the abnormal temperature detection system of FIG. 3;

FIG. 6 is a perspective view of a portion of a microwave oven employing the abnormal temperature detection system of FIG. 4; and

FIG. 7 is a circuit diagram of a control circuit of the microwave oven of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 show a microwave oven employing an embodiment of an abnormal temperature detection system of the present invention.

In FIGS. 1 and 2, upper and side casings of the microwave oven are omitted from the drawings for the purpose of simplicity. The microwave oven mainly comprises an oven door 10, a control panel 12, a bottom casing 14, a rear casing 16, and an oven housing 18. A magnetron 20 is supported on the oven housing 18, and the microwave energy developed from the magnetron 20 is introduced into an oven cavity 22 through a waveguide 24. A blower 26 is also supported on the oven housing 18 to recirculate fresh air in the oven cavity 22.

The blower 26 introduces fresh air through openings 28 formed in the bottom casing 14. The thus introduced fresh air is developed from the blower 26 toward an supply duct 30 through the magnetron 20. Therefore, the magnetron 20 is cooled by the fresh air developed

from the blower 26. The thus transferred fresh air is introduced into the oven cavity 22 along the oven door 10 and exhausted, for recirculation purposes, through exhaust openings 32 formed in the rear wall of the oven housing 18 and an exhaust outlet 34 formed in the rear casing 16.

An illumination lamp 36 is disposed on the upper wall of the oven housing 18 in order to illuminate the oven cavity 22. The abnormally high temperature detection system 40 of the present invention is disposed at the upper wall of the oven housing 18.

FIGS. 3 and 5 show an embodiment of the abnormally high temperature detection system 40. Like elements corresponding to those of FIGS. 1 and 2 are indicated by like numerals.

The abnormally high temperature detection system 40 is disposed near the exhaust openings 32 formed in the rear wall of the oven housing 18. The abnormally high temperature detection system 40 comprises an indent 42 formed in the upper wall of the oven housing 18, openings 44 formed in the indent 42, and a heat-sensitive filter film 46 attached to the indent 42 to close the openings 44. The heat-sensitive filter film 46 is made of a polyester film of 30 mm×30 mm size and 0.05 mm thick. The heat-sensitive filter film 46 is distorted at about 150° C. and fused at about 260° C.

The abnormally high temperature detection system 40 further comprises a heat-sensitive fuse 48 supported by a supporting plate 50, which is fixed to an angle 52 through the use of screws 54. The angle 52 is attached to the upper wall of the oven housing 18 through the use of a spot welding method. The heat-sensitive fuse 48 is supported in such a manner that the heat-sensitive fuse 48 is positioned above the openings 44. The heat-sensitive fuse 48 is in electrical communication with a control circuit of the microwave oven via lead wires 56. The heat-sensitive fuse 48 is constructed so as to fuse at around 115° C.

When the microwave oven is in the normal operation condition, the heat-sensitive fuse 48 does not receive hot air generated from foodstuff disposed within the oven cavity 22, because the oven cavity temperature is held below about 100° C. and the heat-sensitive filter film 46 functions to isolate the heat-sensitive fuse 48 from the oven cavity 22.

When the oven cavity 22 reaches an abnormally high temperature because of defective operation or combustion of the foodstuff disposed within the oven cavity 22, the heat-sensitive filter film 46 is fused at around 260° C., whereby the hot air is exhausted through the openings 44 toward the heat-sensitive fuse 48. The heat-sensitive fuse 48 is thus fused by the hot air, and the microwave generation is suppressed.

FIGS. 4 and 6 show another embodiment of the abnormally high temperature detection system 40. Like elements corresponding to those of FIGS. 3 and 5 are indicated by like numerals.

The heat-sensitive fuse 48 is fixed to a side wall of the oven housing 18. A duct 57 is attached to the upper wall of the oven housing 18 through the use of a spot welding method so that the hot air is conducted toward the heat-sensitive fuse 48 when the heat-sensitive filter film 46 is fused.

FIG. 7 shows the control circuit of the microwave oven.

The control circuit mainly comprises a control unit 60, a triac 62, and a microwave generation circuit including the magnetron 20. The control unit 60 com-

prises an LSI 64, and two relays 66 and 68 controlled by the LSI 64. The relay 66 controls the power supply, and the relay 68 controls a current flow of a gate line 70 to control the microwave generation. That is, a gate signal developed from the control unit 60 is applied to the triac 62 through the gate line 70 to control the microwave generation of the magnetron 20. The triac 62, in combination with a varistor 72, controls a current flow to a primary winding of a high voltage transformer 74.

The control circuit further comprises a plug 76 for receiving commercial power supply, a monitor switch 78 which is mechanically placed in its OFF condition when the oven door is closed and is mechanically placed in its ON condition when the oven door is opened, and a primary interlock switch 80 and a secondary interlock switch 82 which are mechanically placed in the ON condition when the oven door is closed and are mechanically placed in the OFF condition when the oven door is opened. That is, the interlock switches 80 and 82 function to allow the power supply to the remaining portions of the circuit only when the oven door is closed.

A timer for cooking is set at a desired value through the use of touch keys included within the control panel 12. When a coil 84 of a cook relay is energized by the relay 66 which is closed by a start switch 86 on the control panel 12, the energization is held and functions to close relay contacts 88 and 90. When the relay contact 90 is closed, the illumination lamp 36 is enabled. When the relay contact 88 is closed, a current path to the high voltage transformer 74 is established.

The heat-sensitive fuse 48 is installed between the control unit 60 and the power supply plug 76. That is, when the heat-sensitive fuse 48 is fused, the control unit 60 is not power supplied and, therefore, the microwave generation is suppressed.

As discussed above, in accordance with the present invention, the electrical insulation of the heat-sensitive fuse is not strictly required, since the heat-sensitive fuse is placed outside of the oven cavity and the heat-sensitive fuse does not receive the hot air in the normal operation condition. The temperature detection is stable, because the heat-sensitive filter film is located within the oven cavity. The operation of the heat-sensitive fuse is stable and rapid, because the heat-sensitive fuse receives the hot air only when the oven cavity reaches the abnormally high temperature.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A microwave oven comprising a microwave oven housing for defining an oven cavity, a microwave generation means for applying microwave energy to a material disposed within said oven cavity, and an abnormally high temperature detection system for suppressing microwave generation when said oven cavity reaches an abnormally high temperature, said abnormally high temperature detection system comprising:

a hot air exhaust opening formed in a wall of said oven housing;

a heat-sensitive film attached to said hot air exhaust opening to close said hot air exhaust opening, said heat-sensitive film being fusible when said oven cavity reaches an abnormally high tempera-

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ture in order to open said hot air exhaustion opening;
a heat-sensitive fuse disposed outside of said oven cavity and at a position near said hot air exhaustion opening; and
a control circuit means for suppressing the microwave generation when said heat-sensitive fuse is fused.
2. The microwave oven of claim 1, wherein said hot air exhaustion opening is formed in an upper wall of said

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oven housing, and said heat-sensitive fuse is fixed to the upper surface of said upper wall of said oven housing.

3. The microwave oven of claim 1 or 2, wherein said heat-sensitive film comprises a polyester film.

4. The microwave oven of claim 3, wherein said polyester film has a thickness of about 0.05 mm.

5. The microwave oven of claim 3, wherein said polyester film is fusible at about 260° C.

6. The microwave oven of claim 5, wherein said heat-sensitive fusible is fused at about 115° C.

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[54] **METHOD OF COOKING THIN MEATS IN A MICROWAVE OVEN**

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[73] Assignee: **Litton Systems, Inc.**, Beverly Hills, Calif.

[21] Appl. No.: **20,696**

[22] Filed: **Mar. 15, 1979**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 829,075, Aug. 30, 1977, abandoned.

[51] Int. Cl.³ **A23L 1/31; H05B 9/06**

[52] U.S. Cl. **426/233; 426/523; 426/243; 219/10.55 M; 219/10.55 B**

[58] Field of Search **426/233, 241, 243, 523; 219/10.55 M, 10.55 B, 10.55 R**

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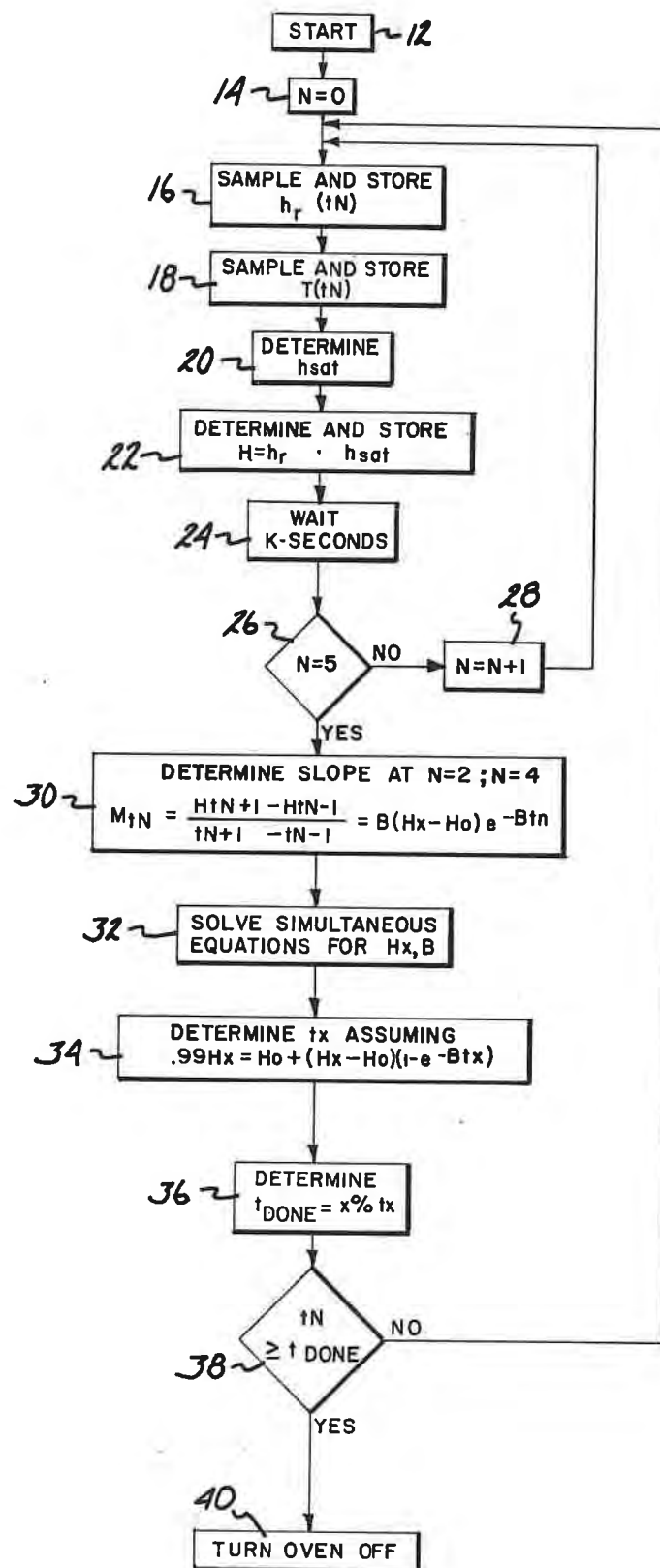
Primary Examiner—Robert A. Yoncoskie
Attorney, Agent, or Firm—Robert E. Lowe; Edward P. Heller, III

[57] ABSTRACT

A method of cooking thin meat in a microwave oven by determining the temperature of the thin meat as a function of humidity and temperature environmental conditions of a microwave oven heating cavity. The relative humidity of the oven heating cavity is continuously sampled during cooking, and signals indicative of the humidity are provided to a digital computing device having a memory such as a programmable microprocessor. The slope of the curve of humidity as a function of elapsed time is compared to the slope of a characteristic curve for thin meats stored in the microprocessor. The doneness time is calculated from the comparison of the curves and cooking is terminated when the calculated doneness time is reached.

5 Claims, 2 Drawing Figures

FIG. 1



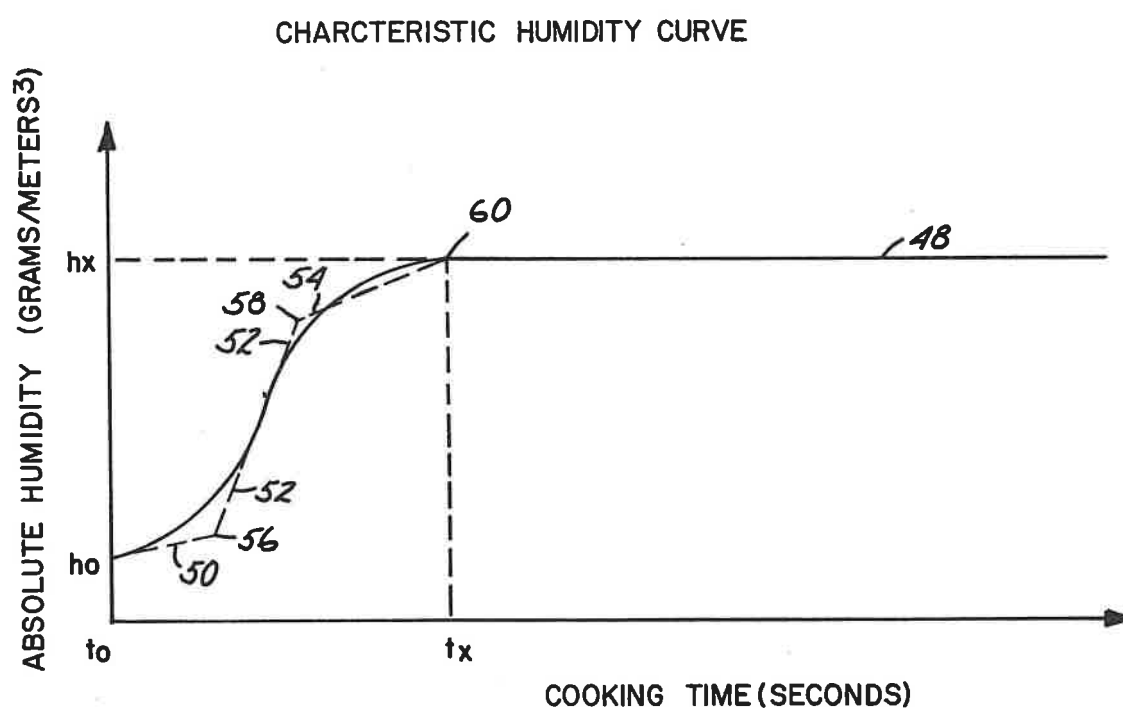


FIG. 2

METHOD OF COOKING THIN MEATS IN A MICROWAVE OVEN

CROSS REFERENCES TO COPENDING APPLICATIONS

This application is a continuation-in-part of my copending application entitled "Method of Cooking Thin Meats in a Microwave Oven", Ser. No. 829,075, filed Aug. 30, 1977 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to improvements in a microwave oven, and more particularly, pertains to a new and improved method of cooking thin meat in a microwave oven.

2. Description of the Prior Art

Those concerned with microwave cooking of a thin piece of meat in a microwave oven have long recognized the need to accurately determine the temperature of the meat. The present invention fills this need.

Past prior art devices have been extremely unreliable in determining the surface and internal temperature of meat. One initial prior art attempt at determining the internal doneness of meat was to insert a thermometer which was not affected by the microwave energy into the piece of meat being cooked. The disadvantage was that the thermometer only indicated the internal temperature of the meat at one particular location and was not a true overall indication of the equilibrium internal doneness of the meat.

Another current prior art device for measuring the internal temperature of meats being cooked is to insert a temperature probe into the meat while in the microwave oven heating cavity which connects to the control circuitry of the microwave oven. While the temperature probe is accurate in indicating the temperature of the meat being cooked by microwave energy, the probe only senses the temperature of the immediate area surrounding the probe and does not take into account the equilibrium state of the internal temperature of the meat. If the temperature of the meat is not uniform and the probe is placed at a hot spot in the meat, the readings from the temperature probe are not indicative of the internal doneness of the meat.

Further, the probe which is inserted into the meat is cumbersome and bulky for the cook who is trying to monitor the internal doneness of the meat during the microwave cooking in the microwave oven heating cavity. For a thin piece of meat being approximately equal to or less than one skin depth, it is difficult for a cook, if not impossible, to insert a temperature probe into the meat as the thickness may be less than one centimeter.

It has also been suggested to measure the humidity of the exhaust air from a microwave oven cavity to give certain indications of cooking conditions within the cavity. (See, for example, U.S. Pat. No. 3,839,616.) However, the technique disclosed is largely limited to detection of an abrupt rise in humidity when boiling occurs, at which time the power is interrupted.

It has also been suggested to measure cooking time as a function of some "trigger" humidity in combination with a progressive-regressive timer.

SUMMARY OF THE INVENTION

The present invention obviates the foregoing disadvantages of the prior art by providing a more accurate method of cooking thin meat in a microwave oven.

According to the preferred embodiment of the present invention, there is provided a method for cooking thin meat in a microwave oven wherein the time dependent humidity and temperature environmental conditions of a microwave oven heating cavity are sensed and sampled; the absolute humidity is determined from the sampled humidity and temperature, the determination being repeated at a plurality of time-spaced points; and the curve thus derived is compared with a "characteristic humidity curve". The temperature of the meat is determined from the curve comparison, especially the slope of the curves.

Thin meat is defined as a piece of meat having a thickness approximately equal to or less than one skin depth of the wavelength of the microwave energy. Since the meat is thin, that is being approximately equal to or less than one skin depth, the surface temperature of the meat is presumed to be approximately equal to the internal temperature of the meat.

BRIEF DESCRIPTION OF THE DRAWING

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like elements throughout the figures thereof and wherein:

FIG. 1 illustrates a flow chart of the method of cooking thin meat in a microwave oven in accordance with the present invention, and;

FIG. 2 illustrates a typical "characteristic humidity curve" for the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention provides a method of determining when a thin piece of meat is cooked to doneness by sensing the time dependent "in-situ" humidity and the temperature environmental conditions of the microwave oven heating cavity. The term "in-situ" as used in this application is defined as the actual time dependent environmental conditions which exist in the environment surrounding the food product such as thin meat which is located in and cooked in the microwave oven heating cavity. Although in the present invention a humidity sensor and a temperature sensor may be positioned outside of the microwave oven heating cavity, the sensors are configured to sense as nearly as possible the environmental conditions of the microwave oven heating cavity itself. The signal information provided to a programmable controller controlling the microwave oven is indicative of cooking cavity conditions.

FIG. 1 illustrates a flow chart of the method of cooking thin meat in accordance with the present invention.

The flow sequence start is indicated at 12, the first step being a zeroing indication to the controller indicating N=0 as shown at box 14. The symbol "N" indicates the sequential number of the sample being processed by the controller so that the controller can determine, for example, that the sample at sequence N=5 occurs after N=4 and before N=6. In this manner "N" is also a relative measurement of time and will be referred to in

that aspect from time to time as the specification proceeds.

Box 16 calls for sampling and storing the relative humidity h_r at time "N", written as " t_N ". The sampling is made by a humidity sensor configured as described hereinafter, and the sample is provided to a digital computing device having a memory, such as a programmable microprocessor. Next the oven cavity temperature at time "N" is sampled and stored in the microprocessor as indicated at box 18.

The computing device next determines the saturated humidity at box 20 and then calculates the absolute humidity as a function of the sensed relative humidity and the calculated saturated humidity at box 22. The capital letter "H" is used to denote absolute humidity at box 22 and thereafter in order to diminish the number of subscripts necessary.

After determining absolute humidity at time "N" at box 22, the method waits some arbitrary time interval denoted as K seconds at box 24. The program interrogates to determine if five sequences of the foregoing steps have been accomplished. Since at this point $N=0$ because this is the first sequence, the interrogatory reply is NO, wherein the aforementioned steps are repeated and "N" is increased by one unit. These steps are pictorially represented at boxes 26 and 28.

The sequence of sampling, storing and calculating steps is continued until $N=5$ at which time the program proceeds along the YES branch from step 26. The absolute humidities determined in each sequence together form points on a humidity versus time curve, such as that shown in FIG. 2. The slope of the curve can be determined at points $N=2$ and $N=4$ by observing the changes between $N=1$ and $N=3$ and $N=3$ and $N=5$ respectively. The slope M at any time N is indicated by the equations at step 30.

It has been empirically determined and observed that a thin meat body being heated in a microwave oven will follow a characteristic humidity curve as that shown in FIG. 2. The precise characteristics defining that curve can be stored in the memory of a programmable microprocessor. The curve has been found to be defined by the equation:

$$H_{tN} = H_o + (H_x - H_o)(1 - e^{-BtN}) \quad (\text{Eq. 1})$$

Wherein H_o is the absolute humidity at time $N=0$, H_x is the absolute humidity at thermal equilibrium (peak absolute humidity) and B coefficient characteristic of meats.

At time intervals $N=2$ and $N=4$ equation 1 can be written:

$$H_{t2} = H_o + (H_x - H_o)(1 - e^{-Bt2}) \quad (\text{Eq. 2})$$

and

$$H_{t4} = H_o + (H_x - H_o)(1 - e^{-Bt4}) \quad (\text{Eq. 3})$$

Simultaneous equations can now be solved at box 32 by taking the derivatives of equations 2 and 3 and rearranging terms to isolate the exponential quantities, which yields:

$$e^{-Bt2} = \frac{M_{t2}}{B(H_x - H_o)}$$

and

$$e^{-Bt4} = \frac{M_{t4}}{B(H_x - H_o)}$$

Substituting equation 4 into equation 2 yields:

$$H_{t2} = H_o + (H_x - H_o) \left[1 - \frac{M_{t2}}{B(H_x - H_o)} \right]$$

Similarly substituting equation 5 into equation 3 yields: or:

$$\text{or: } H_{t2} - H_x = -\frac{M_{t2}}{B}$$

$$H_{t4} - H_x = -\frac{M_{t4}}{B}$$

Subtracting equation 6 from equation 7 and isolating B yields:

$$B = \frac{M_{t2} - M_{t4}}{H_{t4} - H_{t2}}$$

Accordingly it can be seen that the determination of absolute humidity at points $N=0$ through $N=5$ allows the mathematical solution of the slope of the curve at two spaced points. Comparison of that slope with the stored slope of the characteristic curve allows computation of B, the characteristic coefficient for the food being cooked. Equations 6 and 7 can then be solved for H_x .

Having determined H_x , the time t_x that the thin meat will reach thermal equilibrium is calculated at box 34. Thereafter, any desired doneness time can be calculated as a percentage of t_x at box 36. The "x%" shown can be stored in the memory of the microprocessor or can be operator enterable if desired. For example, if it is empirically determined that for hamburger 80% of the time required to reach thermal equilibrium, t_x , will yield a rare hamburger, then t_{done} equals 80% of t_x for that application. Appropriate function pads located on the oven control panel would allow the operator to select, for example, "hamburger rare". That selection would cause 80% of t_x to be input to the microprocessor as " t_{done} ".

Finally the method determines at block 38 if the time t_N is equal to or greater than t_{done} . If it is not, the NO branch is followed and the entire sequence is performed again. If it is, then t_{done} has been reached and the oven is turned off at block 40.

PREFERRED MODE OF OPERATION

The method of cooking thin meat in a microwave oven is premised on the sensing concept based on the most fundamental cooking principles. That is, as microwave energy is converted from thermal energy, the internal temperature of the meat increases. As the internal temperature of the meat increases, some of the thermal energy is used to break the bonding forces holding the water molecules to the food's cell structure. When the latent heat of vaporization has been added to the food, these free water molecules are vaporized and released locally. Thus, the rate of evaporation is di-

rectly proportional to the rate of temperature rise. By monitoring time dependent environmental conditions of the microwave oven heating cavity with sensors, the meat's internal temperature and surface temperature for a thin piece of meat are determined.

The "characteristic humidity curve" 48 of absolute humidity in grams per cubic meter versus cooking time in seconds of FIG. 2 for the thin meat equation 1 is determined by sensing the time dependent "in-situ" humidity and temperature environmental conditions of the microwave oven heating cavity during microwave cooking of thin meats. The time dependent "in-situ" environmental conditions are defined as the sensed humidity and temperature of the microwave oven heating cavity by humidity and temperature sensors.

FIG. 2 depicts a characteristic humidity curve derived from a plot of absolute humidity versus elapsed cooking time. The changes in slope of the curve are indicative of the rate of evaporative water loss from the thin meat body effecting the absolute humidity in the cooking cavity. For purposes of the present method, the point of peak absolute humidity, h_x , indicated at 60 is of primary interest. The "characteristic humidity curve" 48 plateaus at point 60 indicating that surface temperature of the meat has reached equilibrium at one hundred degrees centigrade.

For small meat samples or with thicknesses small as compared to the microwave depth of penetration, that is, being approximately equal to or less than one skin depth, the internal temperature is approximately and for all practical considerations the same as the surface temperature. Thus, the temperature for a thin piece of meat can be monitored for internal doneness finding the temperature from equation 1 for any point of the "characteristic humidity curve" of FIG. 2.

The basic premise of the method is that as the relative humidity and temperature are sampled and stored, h_x and B are computed by solving simultaneous equation 32 to predict when the one hundred degree centigrade point 60 occurs. The temperature is assumed linear between h_0 and one hundred degrees centigrade so that once t_x is computed, the corresponding time for any other temperature may be computed such as to determine when t_{done} is reached.

The method may be implemented in accordance with the flow chart of FIG. 1 as an algorithm stored in a programmable controller such as an Intel 8080 Microprocessor in the microwave oven. This algorithm of FIG. 1 determines the temperature for a thin piece of meat for any point on the "characteristic humidity curve" of FIG. 2.

An aluminum oxide humidity sensor, such as a Thunder Scientific PC-2000 Humidity Measurement Module, and a temperature sensor, such as a National Semiconductor Corporation LX 5700 Temperature Transducer, are positioned adjacent to and by the exit ventilation port to the exterior side of the microwave oven heating cavity by way of example and for purposes of illustration only to sense the time dependent "in-situ" environmental conditions of the microwave oven heating cavity. The sensors can be positioned anywhere as long as the time dependent "in-situ" environmental conditions of the microwave oven heating cavity are sensed, and the sensors are electromagnetically protected from the microwave oven heating cavity. The humidity sensor and

the temperature sensor connect to the programmable controller having the steps of the algorithm of FIG. 1 stored in the memory of the programmable controller. The programmable controller connects to control the microwave power supply and turns the oven off when a YES condition for block 38 is determined.

Various modifications can be contemplated for the method of cooking thin meat in a microwave oven of the present invention without departing from the apparent scope of this invention.

Having thus described the invention, what is claimed is:

1. A method for cooking thin meat bodies in a microwave oven having means for measuring the humidity of the microwave oven cooking cavity environment associated therewith comprising the steps of:

- (a) energizing a microwave energy source to provide microwave energy to said cooking cavity whereby at least a portion of said energy is absorbed by a thin meat body located in said cooking cavity;
- (b) measuring the humidity of said cooking cavity environment at a plurality of time-spaced intervals while said thin meat body is being heated and storing said measurements in a microprocessor forming part of the controls for said oven;
- (c) calculating the slope of a humidity-time curve described by said measurements;
- (d) comparing said calculated slope with the slope of a characteristic humidity-time curve stored in said microprocessor and obtaining from said comparison the time when said thin meat body will reach thermal equilibrium at 100° C.;
- (e) calculating in said microprocessor the time said thin meat body will reach a preselected doneness as a predetermined percentage of said thermal equilibrium time; and,
- (f) de-energizing said microwave energy source at said calculated doneness time.

2. The method of claim 1 wherein said measuring the humidity of the microwave oven cooking cavity environment comprises sensing the cavity environment relative humidity and temperature and wherein said humidity measuring step includes the calculation of absolute humidity of said cavity environment from the sensed relative humidity and temperature.

3. The method of claim 1 wherein said characteristic humidity-time curve is described by the equation:

$$H_{tN} = H_0 + (H_x - H_0)(1 - e^{-BtN})$$

wherein H_{tN} =absolute humidity at time interval N

H_0 =absolute humidity at time interval $N=0$

H_x =peak absolute humidity at thermal equilibrium

B =a coefficient, characteristic of said thin meat body, and

t_N =elapsed time at interval N .

4. The method of claim 1 wherein said predetermined percentage is stored in said microprocessor.

5. The method of claim 1 further including a step performed after step (e) and before step (f) of

- (e') comparing a total elapsed heating time with said calculated doneness time and repeating steps (b) through (e') if said elapsed time is less than said calculated doneness time.

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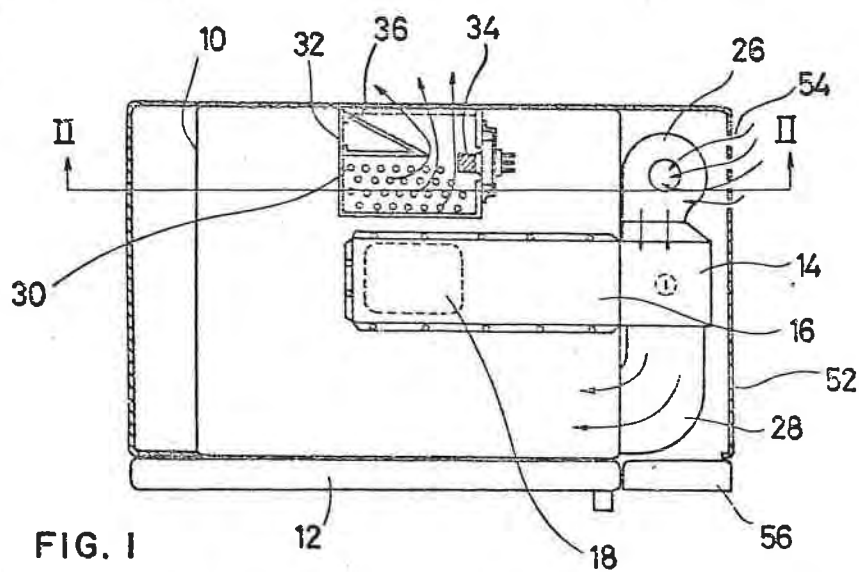


FIG. 1

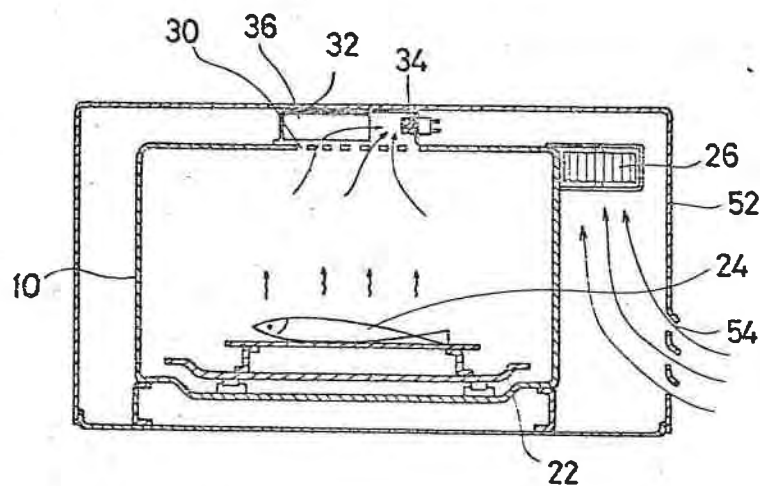


FIG. 2

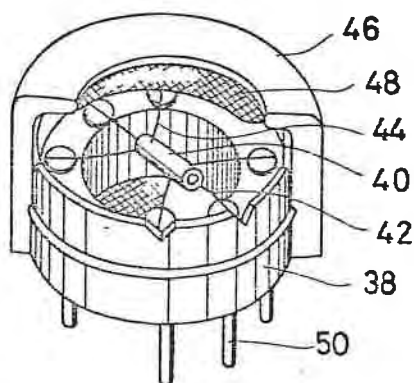


FIG. 3

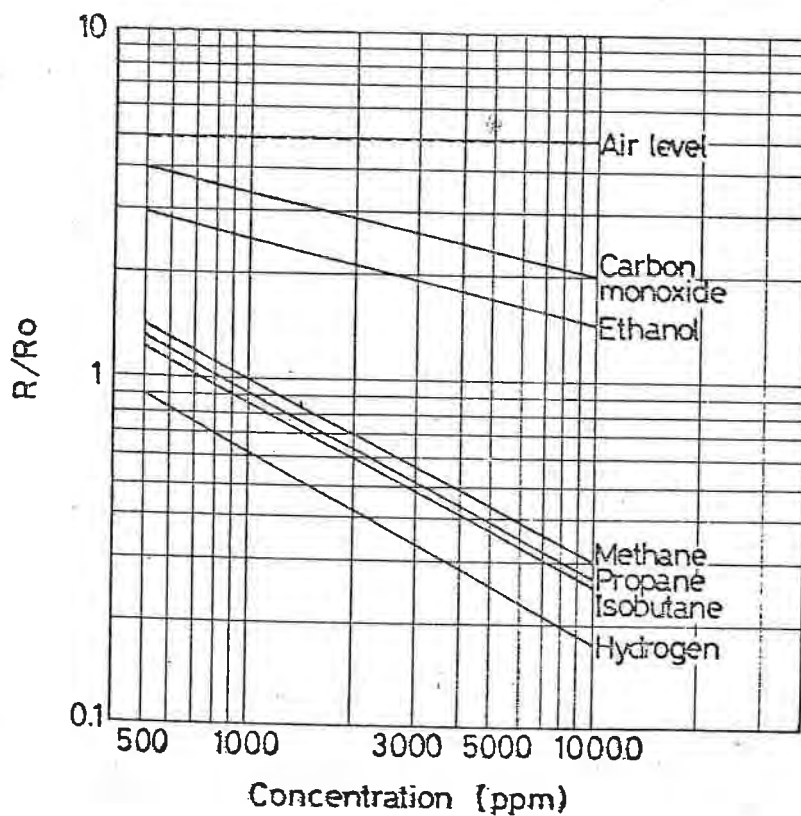


FIG. 4

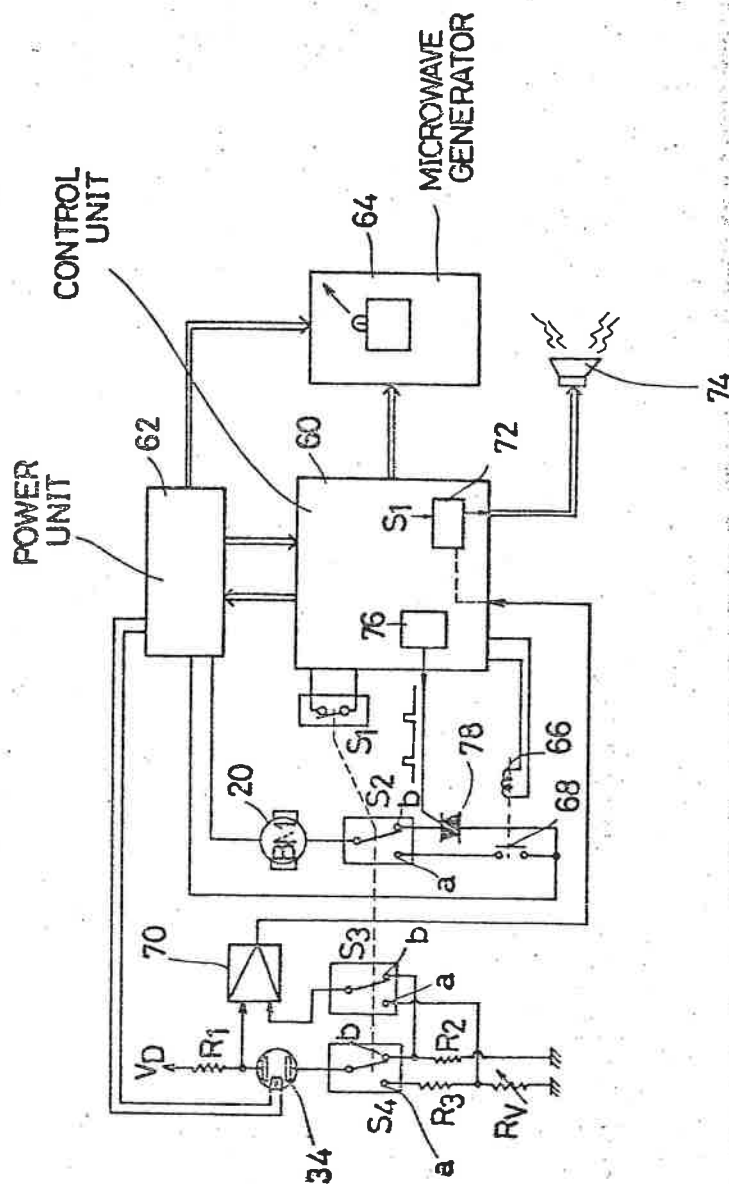


FIG. 5

COMBINATION OF GAS SENSOR CONTROLLED COOKING UTENSIL AND GAS LEAK ALARM

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a cooking utensil which includes a gas sensor for automatic cooking control purposes.

A microwave oven is proposed in my copending application Ser. No. 71,179, "COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT", filed on Aug. 31, 1979, wherein a gas sensor is disposed in an exhaust duct for detecting a gas concentration developed from an oven cavity. When the gas concentration reaches a preselected value, the gas sensor output shows a preselected value, and in response thereto the microwave generation is terminated.

Since the gas sensor is also effective to detect the gas leakage, it is desirable to make such a microwave oven operate as a gas leak alarm when the microwave oven does not perform the cooking operation. However, the system must be constructed so that an ambience gas is properly introduced near the gas sensor while the microwave oven does not perform the cooking operation.

Accordingly, an object of the present invention is to provide a combination of a gas sensor output controlled cooking utensil and a gas leak alarm.

Another object of the present invention is to provide a control circuit for making a cooking utensil employing a gas sensor to operate as a gas leak alarm when the cooking utensil does not perform an actual cooking operation.

Still another object of the present invention is to provide a gas leak alarm system incorporated in a microwave oven which includes a gas sensor for automatic cooking control purposes.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a gas sensor is disposed in a path of the gas exhausted from an oven cavity. A control circuit is provided for terminating the microwave generation when an output voltage signal of the gas sensor reaches a preselected value.

A blower fan system is provided for introducing fresh air into the oven cavity and for developing the exhaust gas from the oven cavity while the microwave oven performs the actual cooking operation. When the microwave oven does not perform the actual cooking operation, the gas sensor control system is continuously supplied with power for gas leakage detection purposes, and the blower fan system is intermittently activated to intermittently introduce the ambience air toward the gas sensor for gas leakage detection purposes. The intermittent activation of the blower fan system ensures an accurate detection operation of the gas sensor, and minimizes the power consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. 1 is a sectional view of an embodiment of a combined cooking utensil and gas leak alarm of the present invention;

FIG. 2 is a sectional view of the combined cooking utensil and gas leak alarm taken along line II—II of FIG. 1;

FIG. 3 is a perspective view of an embodiment of a gas sensor included in the combined cooking utensil and gas leak alarm of FIG. 1;

FIG. 4 is a chart showing the gas concentration response characteristic of the gas sensor of FIG. 3; and

FIG. 5 is a block diagram of an embodiment of a control circuit of the combined cooking utensil and gas leak alarm of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 show an embodiment of a combination of a gas sensor output controlled cooking utensil and a gas leak alarm of the present invention.

The combination of the present invention mainly comprises an oven wall 10 for defining an oven cavity, and an oven door 12. A magnetron 14 is secured to the oven wall 10 for supplying the microwave energy into the oven cavity through a wave guide 16 and an energy supply outlet 18. A tray 22 is disposed at the bottom of the oven cavity for supporting a foodstuff 24 to be cooked in the oven cavity. A blower fan 26 is provided to cool the magnetron 14. The air flow generated by the blower fan 26 is introduced into the oven cavity through an air duct 28. The thus introduced air is exhausted from the oven cavity through exhaust openings 30 which are formed in the upper wall of the oven cavity. An exhaust duct 32 is secured to the upper wall of the oven cavity to cover the exhaust openings 30. A gas sensor 34 is secured to the exhaust duct 32 for detecting the concentration of the gas exhausted from the oven cavity. A guide plate 36 is disposed in the exhaust duct 32 for directing the exhausted gas toward the gas sensor 34.

The combination of FIG. 1 further comprises a casing 52 for accommodating the above-mentioned elements. An air inlet opening 54 is formed in the casing 52 for introducing the ambience air toward the blower fan 26. A control panel 56 is disposed on the front wall of the cooking utensil for introducing various control commands into the combination of the cooking utensil and the gas leak alarm.

FIG. 3 shows an embodiment of the gas sensor 34.

The gas sensor 34 mainly comprises a resin block 38, a sensor 40, a heater coil 42, lead wires 44, a cover 46 including a gauze 48, and an input/output socket 50. A preferred gas sensor is "TGS#813" manufactured by Figaro Engineering Inc.

FIG. 4 shows the relationship between the gas concentration (along the abscissa axis) and the ratio of resistance (R/R_0) of the sensor (along the ordinate axis), wherein " R_0 " is the sensor resistance in air containing 1000 ppm of methane, and " R " is the sensor resistance at different concentrations of gases.

The present invention is to utilize the above variations of the sensor resistance for determining the completion of the cooking operation, and for detecting an abnormal gas concentration due to the gas leakage while the cooking utensil does not perform the cooking operation. To properly detect a dangerous gas leakage from gas combustion apparatus disposed in the kitchen, a control circuit must be constructed to develop an alarm signal when the gas concentration of propane or isobutane exceeds 2,000 ppm, or when the gas concentration of methane exceeds 5,000 ppm.

FIG. 5 shows an embodiment of a control circuit of the present invention, which responds to the gas sensor output.

The control circuit mainly comprises a semiconductor control unit 60, a power supply unit 62, a microwave generation control circuit 64 to activate the magnetron 14 (See FIG. 1) for cooking purposes, and a blower motor 20 for activating the blower fan 26 (See FIG. 1).

An output voltage signal of the gas sensor 34 is applied to a detection input terminal of a comparator 70. As already discussed above the output voltage signal of the gas sensor 34 varies in response to the concentration of the gas introduced near the gas sensor 34.

When the combination cooking utensil and gas leak alarm operates as the cooking utensil, a manual switch S_1 is open and, therefore, interlocked switches S_2 , S_3 and S_4 are placed in the condition where movable contacts thereof are made contact with first terminals a. A variable resistor R_v determines a reference voltage to be applied to a reference input terminal of the comparator 70. When a cook start switch is actuated, the semiconductor control unit 60 develops control signals for activating the microwave generation control circuit 64, and for activating a relay 65, thereby closing a relay switch 63. Accordingly, the blower motor 20 is continuously activated to introduce a fresh air into the oven cavity and to force the gas exhausted from the foodstuff to flow toward the gas sensor 34. When the gas sensor output voltage signal reaches a preselected reference level determined by the variable resistor R_v , the comparator 70 develops a detection output.

Upon development of the detection output from the comparator 70, the semiconductor control unit 60 develops control signals for deenergizing the microwave generation control circuit 64 and the relay 66, thereby completing the cooking operation. An alarm circuit 72 activates a buzzer 74 to announce the completion of the cooking operation.

The resistance value of the variable resistor R_v is selected at a desired value in accordance with the kind of foodstuff to be cooked. Resistors R_1 and R_3 are provided for ensuring a stable detection operation of the gas sensor 34. A typical cooking control operation in the microwave oven including a gas sensor is disclosed in my copending application Ser. No. 71,179, "COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT", filed on Aug. 31, 1979.

When the actual cooking operation is not performed, the manual switch S_1 is closed to place the system in a gas leak alarm operation mode. The movable contacts of the interlocked switches S_2 , S_3 and S_4 are made contact with second terminals b. A resistor R_2 functions to apply a reference voltage signal to the reference input terminal of the comparator 70, the reference voltage signal being a preferred level suited for detecting the dangerous gas leakage.

When the manual switch S_1 is closed, a timer circuit 76 included in the semiconductor control unit 60 devel-

ops a control signal having a predetermined time interval for switching a thyristor 78. Accordingly, the blower motor 20 is intermittently energized to intermittently introduce the ambience air into the combination cooking utensil and the gas leak alarm for ensuring a reliable detection operation of the gas sensor 34. When an abnormal gas concentration is detected by the gas sensor 34, the comparator 70 develops a detection output to activate the alarm circuit 72. Since the alarm circuit 72 receives another control signal from the manual switch S_1 , the alarm circuit 72 develops an activation signal, which is different from the signal for announcing the completion of the cooking operation, toward the buzzer 74. In this way, the buzzer 74 develops an alarm sound for alarming the gas leakage.

The above-mentioned present invention will be effectively accomplished in a microcomputer controlled microwave oven, which includes a time keeping circuit to which the electric power is continuously supplied even when the actual cooking operation is not performed.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A combined cooking utensil and gas leak alarm comprising:

an oven cavity;

a cooking energy source for conducting the cooking operation of a foodstuff disposed in said oven cavity;

a blower fan system for introducing a fresh air into the oven cavity and exhausting gas from said oven cavity;

a gas sensor disposed in a path of the gas developed from said oven cavity for detecting the gas concentration;

a control circuit for controlling the operation of said cooking energy source in response to an output signal derived from said gas sensor when said combined cooking utensil and gas leak alarm is placed in a cooking operation mode;

a monitor circuit for detecting an ambience gas concentration through the use of said gas sensor when said combined cooking utensil and gas leak alarm is placed in a gas leak alarm operation mode, said monitor circuit developing an alarm instruction output when the ambience gas concentration exceeds a preselected value; and

an alarm system responding to said alarm instruction output derived from said monitor circuit.

2. The combined cooking utensil and gas leak alarm of claim 1, wherein said blower fan system is intermittently energized when the combined cooking utensil and gas leak alarm is placed in said gas leak alarm operation mode.

3. The combined cooking utensil and gas leak alarm of claim 1 or 2, wherein said cooking energy source comprises a magnetron for conducting the microwave cooking.

4. The combined cooking utensil and gas leak alarm of claim 3, wherein said blower fan system functions to cool the magnetron when the combined cooking utensil and gas leak alarm is placed in said cooking operation mode.

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[54] COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT

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[73] Assignee: Sharp Kabushiki Kaisha, Osaka, Japan

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[22] Filed: Aug. 31, 1979

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Dec. 19, 1978 [JP] Japan 53/158008
Dec. 20, 1978 [JP] Japan 53/159626

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[52] U.S. Cl. 219/10.55 B; 219/497;
99/325; 236/46 A; 340/634; 426/243
[58] Field of Search 219/10.55 R, 10.55 B,
219/10.55 E, 492, 497; 99/325; 236/46 A, 46 D,
15 E; 426/243; 340/632, 633, 634

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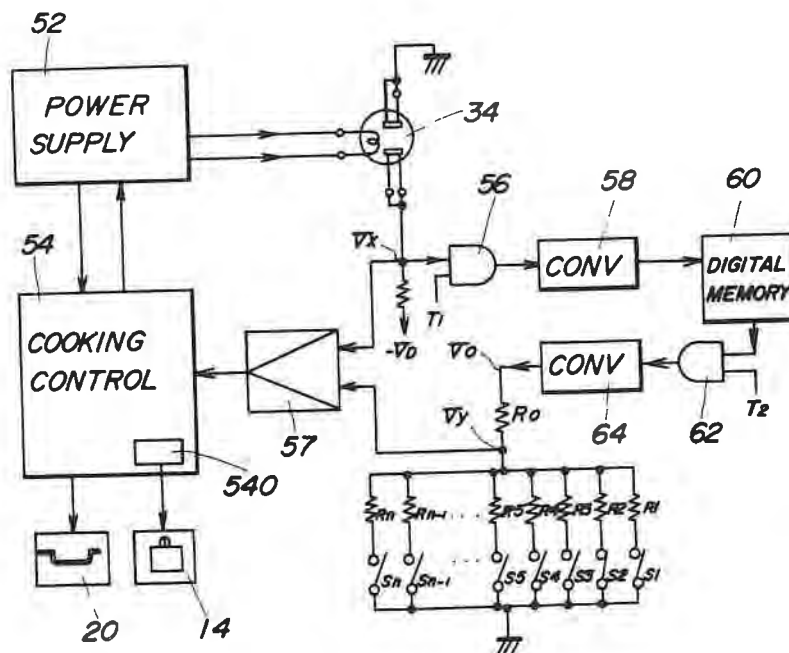
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Primary Examiner—Gene Z. Robinson
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ABSTRACT

[57] A combined microwave and electric heating cooking apparatus comprising a magnetron for microwave cooking purposes, a sheath heater for electric heating cooking purposes, and a cooking control circuit for controlling operations of the magnetron and the sheath heater. A gas sensor is disposed in an exhaust gas path for detecting the concentration of the gas generated from a foodstuff. When an output signal of the gas sensor indicates that the gas concentration reaches a preselected value, the cooking control circuit develops a control signal for terminating the cooking. Selection switches are provided for determining the above-mentioned preselected value in accordance with the kind of the foodstuff to be cooked.

10 Claims, 6 Drawing Figures



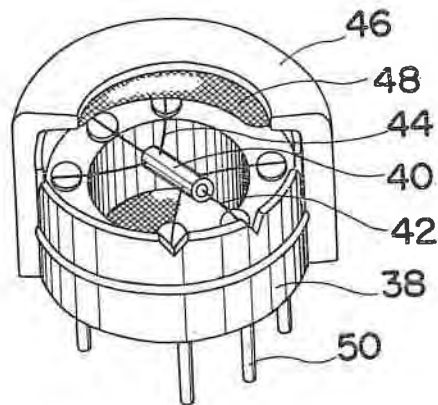


FIG. 3

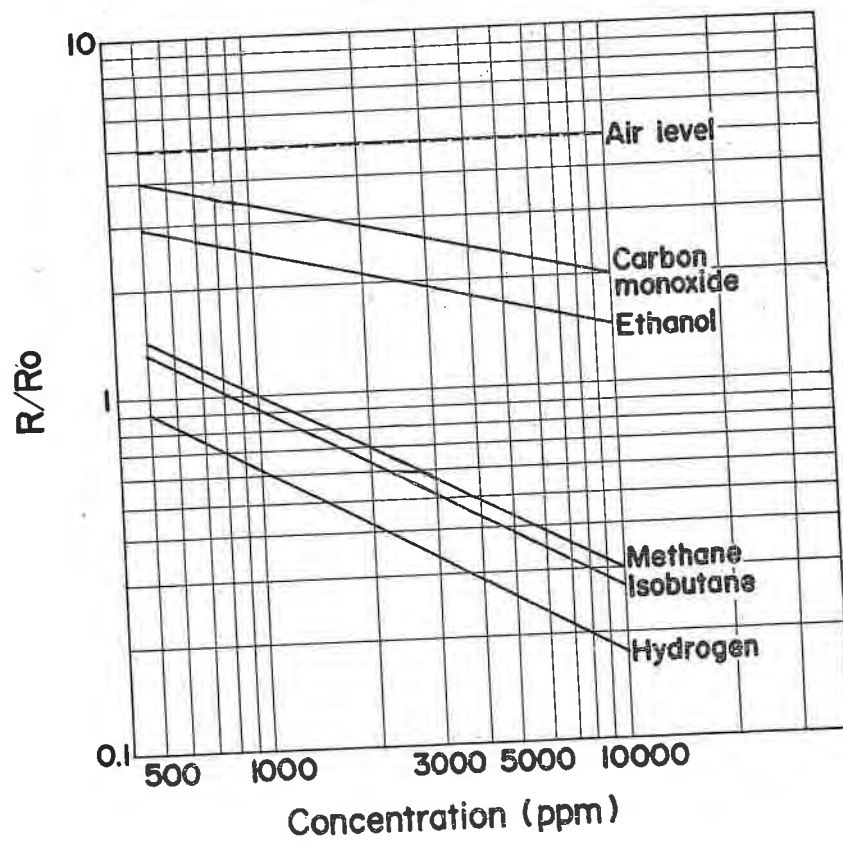


FIG. 4

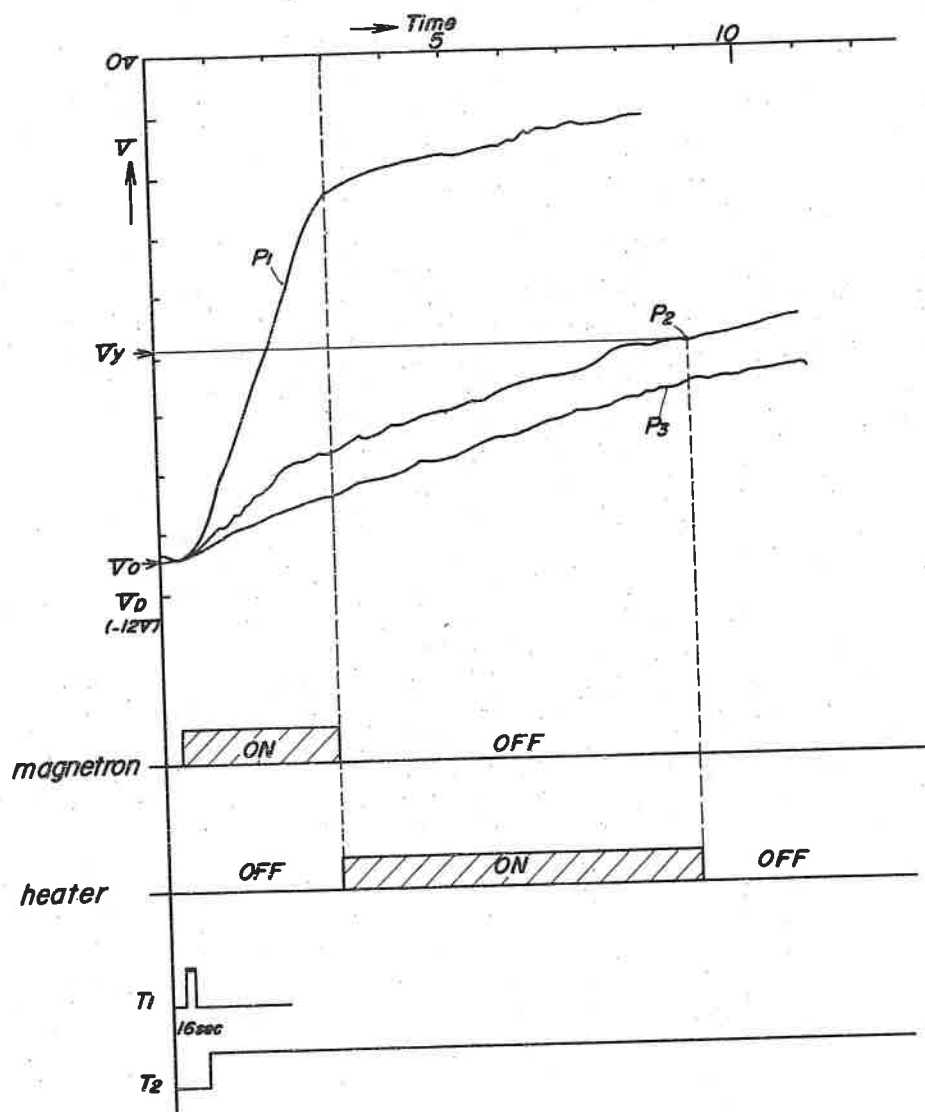


FIG. 6

COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a cooking utensil and, more particularly, to a control circuit responding to an output signal derived from a gas sensor in a cooking utensil, for example, a microwave oven.

Recently, a combined microwave and electric heating cooking oven has been developed. In such a cooking oven it is very difficult to determine a preferred cooking time period. The cooking time period must be determined in accordance with the kind of foodstuff to be cooked, the initial condition of the foodstuff, the amount of the foodstuff, the output energy level of the cooking apparatus, the environment condition, etc.

One approach is to detect the food temperature or the oven temperature to control the microwave generation or the heater energization. However, the temperature responsive control is not perfectly satisfactory.

Accordingly, an object of the present invention is to provide a novel control system for a cooking utensil.

Another object of the present invention is to provide a combined microwave and electric heating cooking oven including a gas sensor and a control circuit responding to an output signal derived from the gas sensor.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects pursuant to an embodiment of the present invention, a gas sensor is disposed in a path of the gas exhausted from an oven cavity. A control circuit is provided for terminating the microwave generation or the heater energization when an output voltage signal of the gas sensor reaches a preselected value.

A plurality of selection switches are provided for determining the above-mentioned preselected value, at which the control circuit responds, in accordance with the kind of foodstuff to be cooked. More specifically, the selection switches are associated with resistors for selecting the preselected value by dividing an output voltage level of the gas sensor in an initial condition.

The present control is based on the fact that the concentration of the gas developed from the foodstuff being cooked reaches a predetermined value when the foodstuff has been cooked. The predetermined value of the gas concentration varies in a fashion depending on the kind of foodstuff being cooked. The output voltage signal of the gas sensor represents the gas concentration and, therefore, the completion of the cooking can be detected by detecting whether the gas sensor output reaches the preselected value.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illus-

tration only, and thus are not limitative of the present invention and wherein:

FIG. 1 is a schematic plan view of an embodiment of a combined microwave and electric heating cooking apparatus including a gas sensor;

FIG. 2 is a sectional view of the combined microwave and electric heating cooking apparatus taken along line II—II of FIG. 1;

FIG. 3 is a perspective view of an embodiment of the gas sensor included in the combined microwave and electric heating cooking apparatus of FIG. 1;

FIG. 4 is a chart showing the gas concentration response characteristic of the gas sensor of FIG. 3;

FIG. 5 is a block diagram of an embodiment of a control circuit of the present invention; and

FIG. 6 is a time chart for explaining the operation mode of the control circuit of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 show an embodiment of a combined microwave and electric heating cooking apparatus.

The combined microwave and electric heating cooking apparatus mainly comprises an oven wall 10 for defining an oven cavity, and an oven door 12. A magnetron 14 is secured to the oven wall 10 for supplying the microwave energy into the oven cavity through a wave guide 16 and an energy supply outlet 18. Sheath heaters 20 are disposed in the oven cavity for conducting the electric heating cooking. A tray 22 is disposed at the bottom of the oven cavity for supporting a foodstuff 24 to be cooked in the oven cavity. A blower fan 26 is provided to cool the magnetron 14. The air flow generated by the blower fan 26 is introduced into the oven cavity through an air duct 28. The thus introduced air is exhausted from the oven cavity through exhaust openings 30 which are formed in the upper wall of the oven cavity. An exhaust duct 32 is secured to the upper wall of the oven cavity to cover the exhaust openings 30. A gas sensor 34 is secured to the exhaust duct 32 for detecting the concentration of the gas exhausted from the oven cavity. A guide plate 36 is disposed in the exhaust duct 32 for directing the exhausted gas toward the gas sensor 34.

FIG. 3 shows an embodiment of the gas sensor 34.

The gas sensor 34 mainly comprises a resin block 38, a sensor 40, a heater coil 42, lead wires 44, a cover 46 including a gauze 48, and an input/output socket 50. A preferred gas sensor is "TGS#813" manufactured by Figaro Engineering Inc.

FIG. 4 shows the relationship between the gas concentration (along the abscissa axis) and the ratio of resistance (R/R_0) of the sensor (along the ordinate axis), wherein " R_0 " is the sensor resistance in air containing 1000 ppm of Methane, and " R " is the sensor resistance at different concentrations of gases. As shown in FIG. 4, various reducing gases are shown, such as ethanol, methane, isobutane, carbon monoxide and hydrogen.

The present invention utilizes the above variations of the sensor resistance for determining the completion of the cooking.

FIG. 5 shows an embodiment of a control circuit of the present invention, which responds to the gas sensor output.

The control circuit mainly comprises a power supply circuit 52, and a cooking control circuit 54 for controlling the operations of the magnetron 14 and the sheath heaters 20. The output voltage signal V_x of the gas

sensor 34 is applied to one input terminals of an AND gate 56 and a coincidence detection circuit 57. As already discussed above, the output voltage signal V_x varies in response to the concentration of the gas exhausted from the oven cavity.

The control circuit includes an initial condition setting means comprising an analog-to-digital converter 58, a digital memory 60, and an AND gate 62 which is controlled by a timing signal T_2 , and a digital-to-analog converter 64. More specifically, the output voltage signal V_x of the gas sensor 34 is introduced into the analog-to-digital converter 58 through the AND gate 56 at a timing of a timing signal T_1 for determining the initial reference level. The thus introduced reference voltage signal is converted into a digital value by the analog-to-digital converter 58, and memorized in the digital memory 60. The thus stored reference value is continuously applied to the digital-to-analog converter 64 through the AND gate 62 for providing a reference voltage signal V_o .

The control circuit further includes a plurality of manual selection switches $S_1, S_2, \dots, S_n$ for instructing the kind of foodstuff to be cooked. For example, the selection switch S_1 is for warming "SAKE", the selection switch S_2 is for browning the fish, the selection switch S_3 is for baking the cake, etc. Resistors $R_1, R_2, \dots, R_n$ are connected to each of the manual selection switches $S_1, S_2, \dots, S_n$. The resistance value of each of the resistors $R_1, R_2, \dots, R_n$ is determined through experimentation so that a divided voltage level

$$V_y (= V_o \times \frac{R_i}{R_o + R_i})$$

where $i=1, 2, \dots, n$ represents a desired voltage level at which the cooking should be terminated.

Operation of the control circuit of FIG. 5 will be described in detail with reference to FIG. 6.

When the cook start switch is actuated, only the blower fan 26 is energized to clean the air in the oven cavity. Sixteen second (16 sec) later, the timing signal T_1 is developed to set the initial reference level. It will be clear from FIG. 6 that the output voltage signal V_x of the gas sensor 34 gradually reduces while only the blower fan 26 is energized. Thereafter, the cooking control circuit 54 activates the magnetron 14. In this way, the digital value corresponding to the reference voltage signal V_o is stored in the digital memory 60. The timing signal T_2 is continuously developed after, for example, 30 sec. from the actuation of the cook start switch to develop the reference voltage signal V_o through the digital-to-analog converter 64.

The cooking control circuit 54 includes a cooking mode selector 540 for changing the cooking mode between the microwave cooking mode and the electric heating cooking mode. In a preferred form, the cooking is first performed by the microwave cooking mode for, for example, three minutes and, then, by the electric heating cooking mode. In another preferred form, the cooking is first performed by the microwave generation and, then, by the electric heating when the gas sensor output reaches a preselected value.

In FIG. 6, a curve P_1 represents output voltage signal V_x when "SAKE" is warmed in the oven cavity.

Another curve P_2 represents the output voltage signal V_x when the fish is browning in the oven cavity, and

still another curve P_3 represents the output voltage signal V_x when the cake is baked in the oven cavity.

Now assume that the fish is desired to be browned, and the manual selection switch S_2 is closed. The divided voltage level

$$V_y (= V_o \times \frac{R_2}{R_o + R_2})$$

is continuously applied to the other input terminal of the coincidence detection circuit 57. When the output voltage signal V_x (the curve P_2) becomes identical with the level V_y , the coincidence detection circuit 57 develops the detection output, whereby the cooking control circuit 54 deenergizes the sheath heater 20 to terminate the cooking.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A cooking apparatus comprising:

oven cavity means for receiving a foodstuff to be cooked;

cooking energy source means for conducting a cooking operation on said foodstuff disposed in said oven cavity means, said foodstuff producing a reducing gas in amounts representative of the cooked state thereof;

gas sensor means responsive to the presence of said reducing gas generated from said foodstuff, for providing an output signal representative of the concentration of said reducing gas in said oven cavity;

control circuit means for controlling the operation of said cooking energy source means as a function of said concentration of reducing gas, said control circuit comprising:

reference means for providing a reference signal of a selected value;

comparing means for comparing said output signal from said gas sensor means with said reference signal; selection means for selecting said reference signal in accordance with the kind of foodstuff to be cooked; and

control signal developing means responsive to said comparing means for deenergizing said cooking energy source means when a corresponding value of said output signal derived from said gas sensor means reaches said preselected value of said reference signal.

2. The cooking apparatus of claim 1, further comprising storing means for storing an initial corresponding value level of said output signal derived from said gas sensor means, determinative of a desired cooking termination temperature; and wherein said selection means comprises a voltage divider means for developing a reference voltage signal representing the said initial corresponding value level to be stored in said storing means and comprising said reference signal.

3. The cooking apparatus of claim 2, wherein said storing means comprises:

gate circuit means for developing said output signal from said gas sensor means at a desired timing;

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analog-to-digital converter means for developing a digital value signal in response to said output signal from said gate circuit means;
digital memory means for storing said digital value signal; and
digital-to-analog converter means for developing a reference voltage signal corresponding to said digital value signal stored in said digital memory means, said reference voltage signal representing said initial corresponding value level of said output signal derived from said gas sensor means.

4. The cooking apparatus of claim 2 or 3, wherein said selection means comprises;
a plurality of selection switches; and a plurality of resistors connected to each of said plurality of selection switches for determining division ratios of said voltage dividing means.

5. The cooking apparatus of claim 1, 2 or 3, wherein said cooking apparatus comprises a microwave oven and wherein said cooking energy source means com-

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prises a magnetron for conducting microwave cooking in said microwave oven.

6. The cooking apparatus of claim 1, 2 or 3, wherein said cooking energy source comprises a sheath heater disposed in said oven cavity means.

7. The cooking apparatus of claims 1 or 3, wherein said reducing gases produced by said foodstuff include organic gases.

8. The cooking apparatus of claim 7, wherein said organic gases belong to the group consisting of Ethanol, Methane and Isobutane.

9. The cooking apparatus of claims 1 or 3 wherein said reducing gas produced by said foodstuff belongs to the group consisting of Carbon Monoxide, Ethanol, Methane, Isobutane, and Hydrogen.

10. The invention of either of claims 1, 2 or 3 wherein said gas sensor means comprises a variable resistance means for providing a resistance value representative of said concentration of said reducing gas.

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FILING DATE

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EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
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me	AB	4 3 1 9 1 1 0	5/9/82	Tanabe et al	219	10.55B	
me	AC	4 3 3 1 8 5 5	5/25/82	Tanabe	219	10.55B	
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[54] **COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT AND THERMISTOR OUTPUT**

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[73] Assignee: Sharp Kabushiki Kaisha, Osaka, Japan

[21] Appl. No.: 113,073

[22] Filed: Jan. 17, 1980

[30] **Foreign Application Priority Data**

Jan. 25, 1979 [JP] Japan 54-7729

[51] Int. Cl.³ H05B 6/68; H05B 1/02

[52] U.S. Cl. 219/10.55 B; 219/10.55 R; 219/497; 340/634

[58] Field of Search 219/10.55 B, 10.55 R, 219/502, 490, 497; 340/634, 632

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Primary Examiner—B. Dobeck

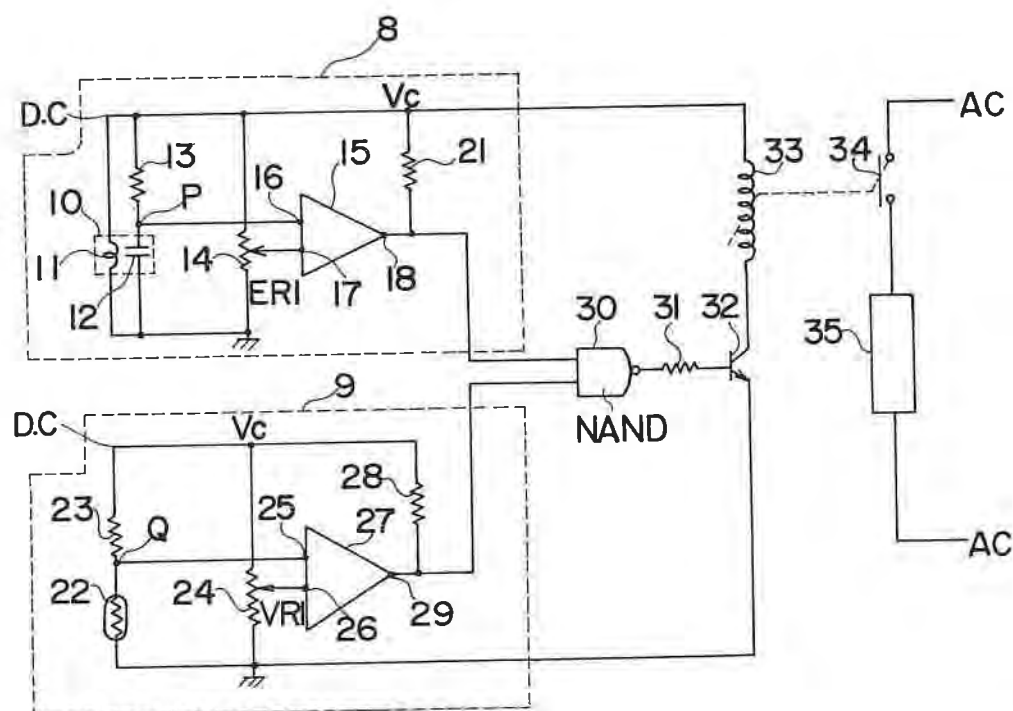
Assistant Examiner—Keith E. George

Attorney, Agent, or Firm—Birch, Stewart, Kolasch and Birch

[57] **ABSTRACT**

A combined microwave and electric heating oven comprises a gas sensor disposed in an exhaust duct for detecting an exhaust gas concentration, and a thermistor disposed in the exhaust duct for detecting an exhaust air temperature. A control circuit is connected to receive output signals derived from the gas sensor and the thermistor for terminating a cooking operation when both of the exhaust gas concentration and the exhaust air temperature exceed preselected reference levels, respectively.

5 Claims, 14 Drawing Figures



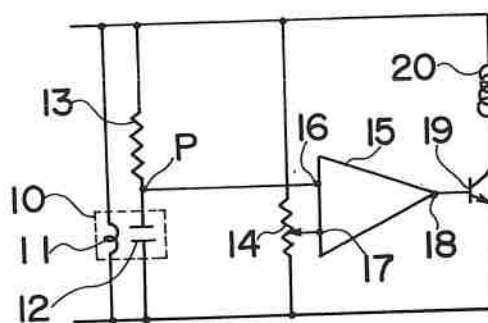


FIG. 1

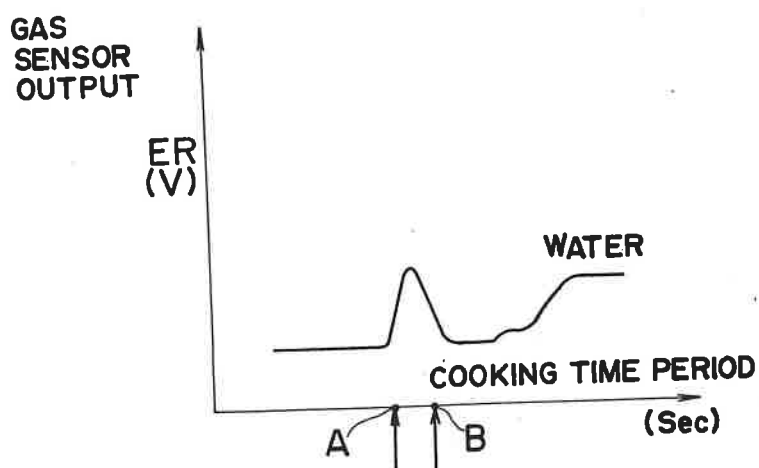
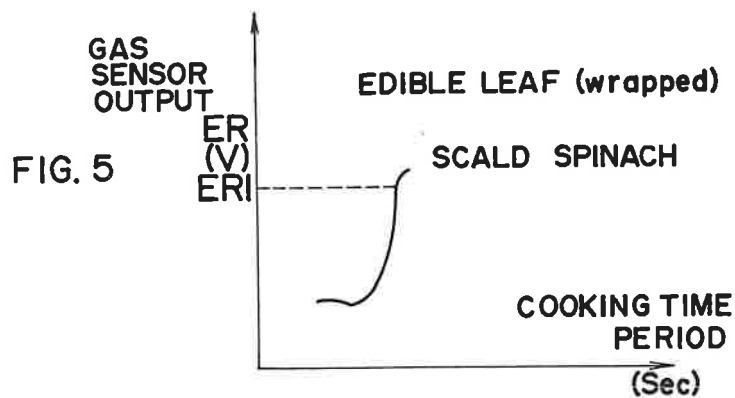
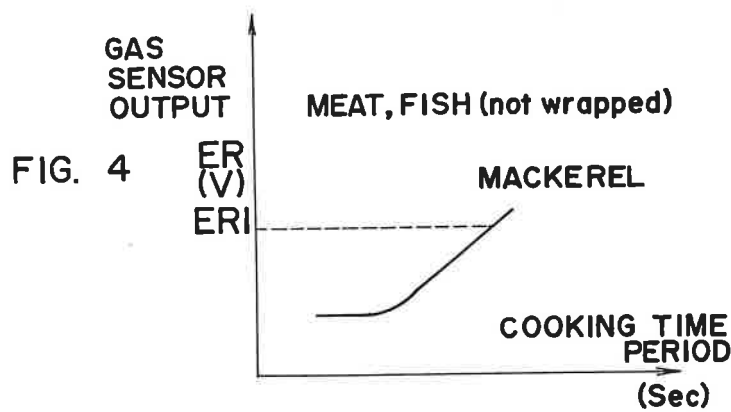
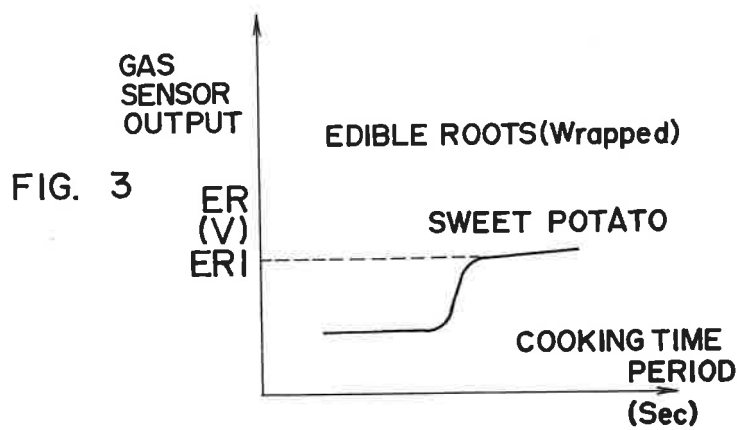
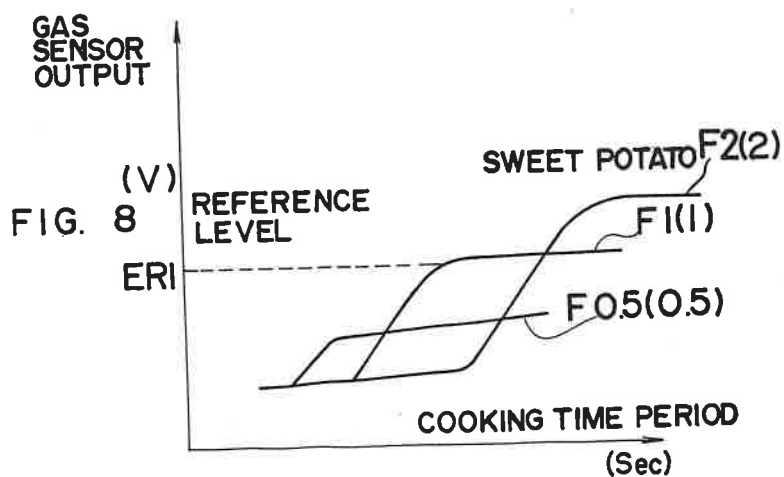
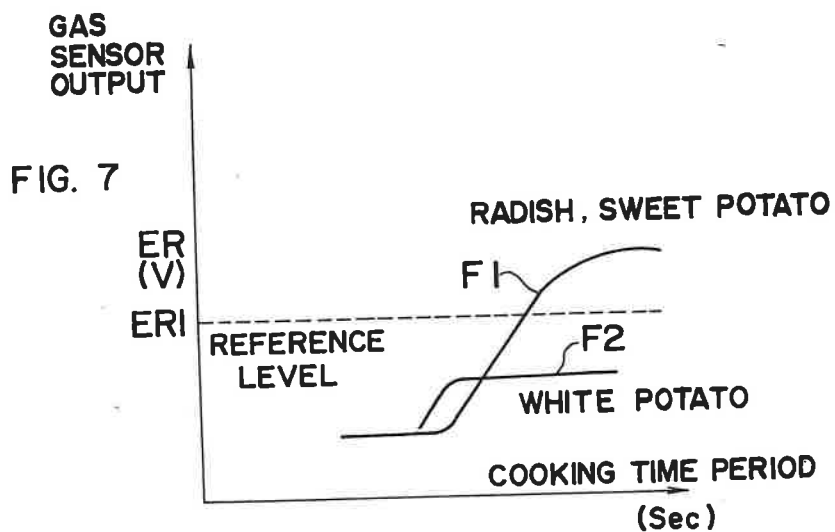
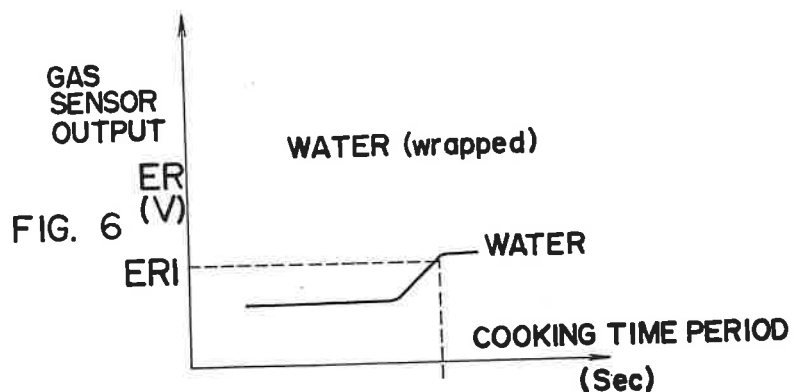


FIG. 2





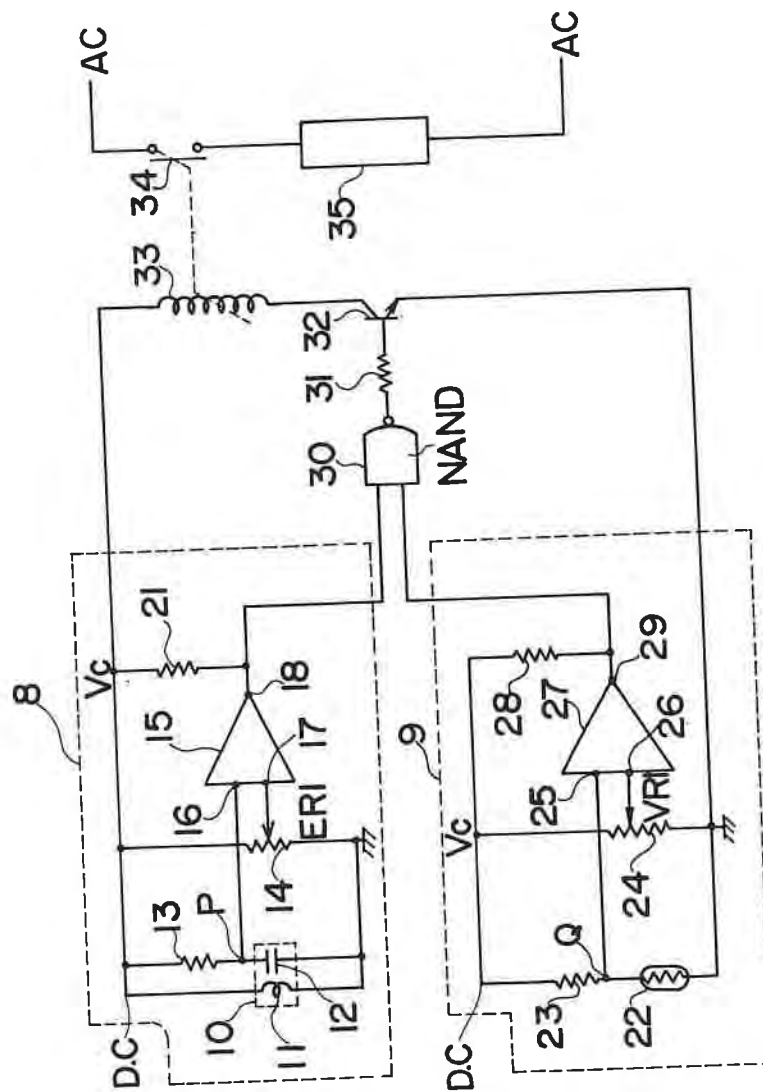
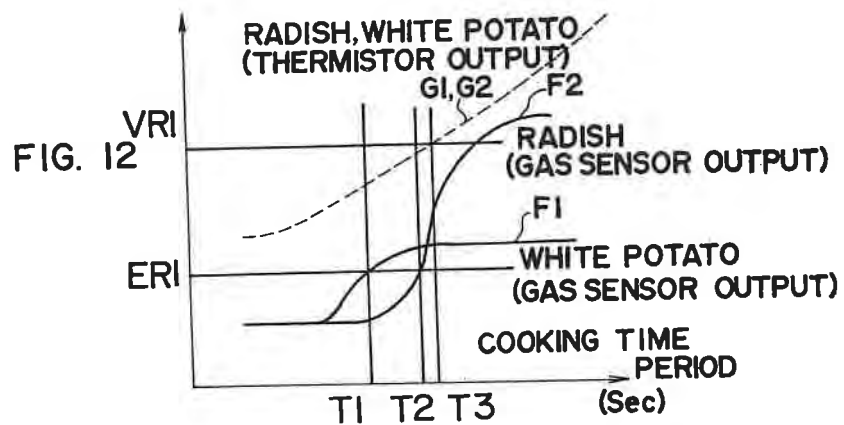
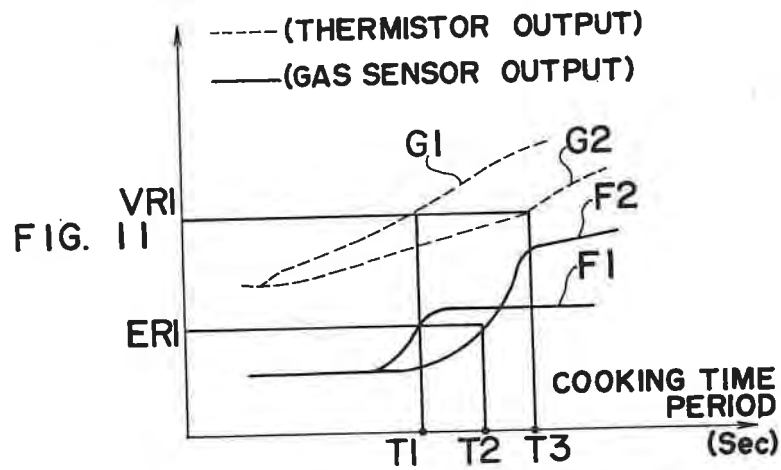
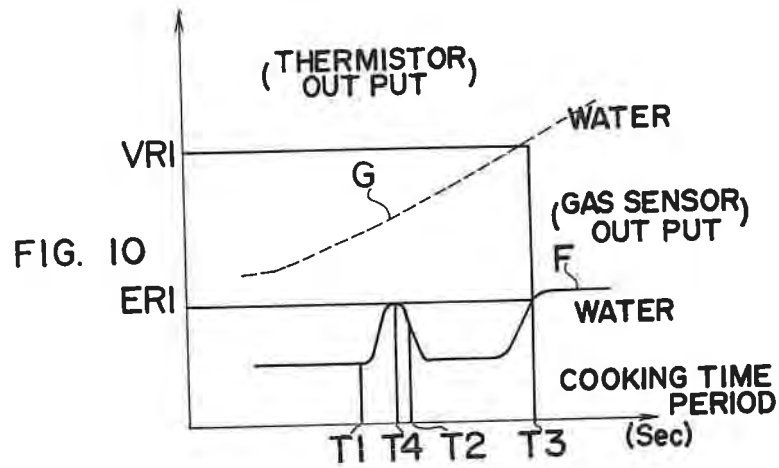


FIG. 9



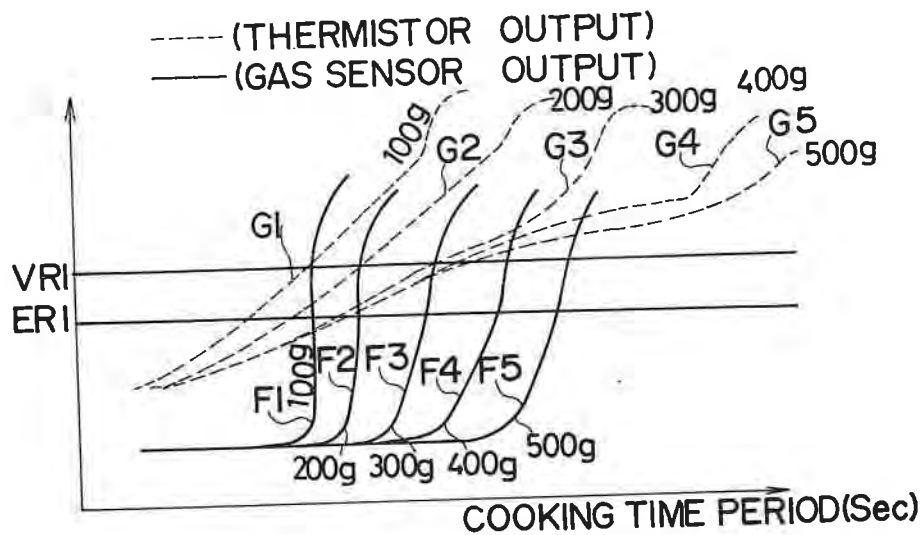


FIG. 13

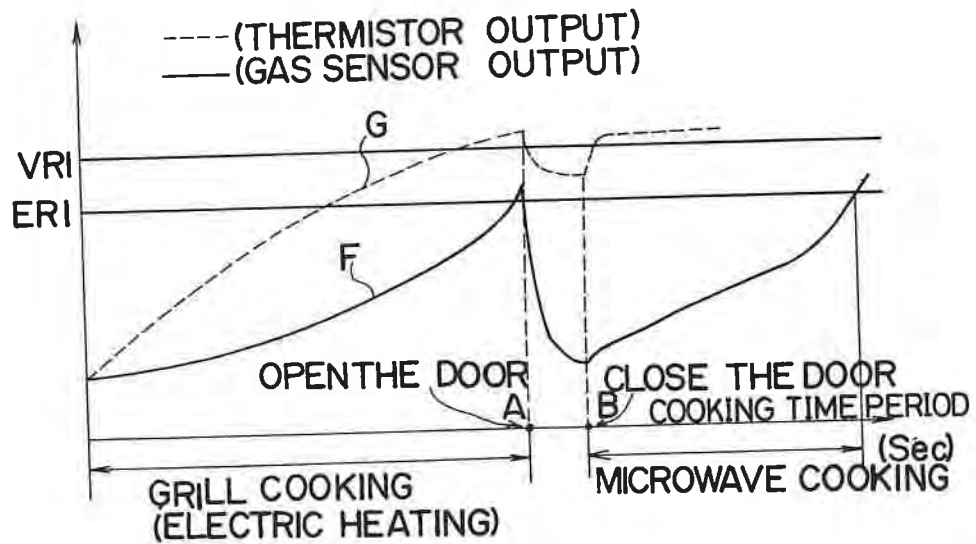


FIG. 14

COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT AND THERMISTOR OUTPUT

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a cooking operation control system in a cooking utensil including at least two sensors, for example, a thermistor and a gas sensor.

Various kinds of sensors are proposed to control the cooking operation in a cooking utensil such as a combined microwave and electric heating cooking oven. For example,

(1) a thermistor is disposed in an exhaust duct for detecting an exhaust air temperature;

(2) a humidity sensor is disposed in an oven cavity or in an exhaust duct for detecting a humidity in the oven cavity; or

(3) a gas sensor is disposed in an exhaust duct for detecting an exhaust gas concentration.

The thermistor and the humidity sensor can not detect the browning condition and, therefore, the thermistor and the humidity sensor are not suited for controlling the grill operation. The gas sensor is suited for controlling the grill operation, but the gas sensor will erroneously develop an output signal in an abnormal condition when, for example, alcohol is positioned near an air inlet of the cooking utensil. Moreover, the gas sensor output is dependent on the initial condition of the foodstuff being cooked and the amount of the foodstuff disposed in the oven cavity.

Accordingly, an object of the present invention is to provide a novel cooking operation control system in a cooking utensil.

Another object of the present invention is to provide a cooking operation control circuit for a combined microwave and electric heating cooking oven.

Still another object of the present invention is to provide a cooking operation control circuit in a combination microwave and electric heating cooking oven including a thermistor and a gas sensor.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a thermistor and a gas sensor are disposed in an exhaust duct of a combined microwave and electric cooking oven for detecting a cooking condition. When both of the thermistor output and the gas sensor output exceed preselected reference levels, a microwave generation operation or a heater cooking operation is terminated to complete the cooking.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not illustrative of the present invention and wherein:

FIG. 1 is a circuit diagram of a basic detection system including a gas sensor;

FIG. 2 is a graph showing an output of a gas sensor employed in a microwave oven;

FIGS. 3 through 8 are graphs showing output characteristics of a gas sensor employed in a microwave oven;

FIG. 9 is a circuit diagram of an embodiment of a cooking operation control system of the present invention; and

FIGS. 10 through 14 are graphs for explaining operation modes of the cooking operation control system of FIG. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A microwave oven controlled by a gas sensor output is disclosed in my copending application Ser. No. 71,179, "COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT" filed on Aug. 31, 1979.

FIG. 1 shows a basic construction of a gas concentration detection circuit.

A gas sensor 10 comprises a heater 11 and a sensor element 12. A resistor 13 is connected to the sensor element 12 in a series fashion, a node thereof being connected to a data input terminal 16 of a comparator 15. A reference voltage input terminal 17 of the comparator 15 is connected to receive a reference voltage from a variable resistor 14. When the gas concentration reaches a preselected value, a detection output is developed from an output terminal 18 of the comparator 15 to turn on a switching transistor 19. A relay 20 is connected to the switching transistor 19 to control the following circuit.

A preferred gas sensor suited for the microwave oven is "TGS#813" manufactured by Figaro Engineering Inc.

When the above-mentioned gas concentration detection circuit is installed in a microwave oven, the cooking condition can be detected. However, the gas sensor output is dependent on the ambience condition. When, for example, alcohol is positioned near an air inlet of the microwave oven, the gas concentration detection circuit will erroneously operate. FIG. 2 shows an output signal of the gas sensor disposed in an exhaust duct of the microwave oven, wherein alcohol is positioned near the air inlet at the point A, and the alcohol is spaced apart from the air inlet at the point B. It will be clear from FIG. 2 that the detection circuit may erroneously develop a detection signal even though the foodstuff (in FIG. 2, water) has not been completely cooked.

Moreover, the gas sensor output is dependent on the initial condition of the foodstuff and the amount of foodstuff disposed in the microwave oven. This is not preferable to ensure an accurate operation.

FIGS. 3 through 8 show output characteristics of the gas sensor disposed in the exhaust duct of the microwave oven.

It will be clear from FIGS. 3 through 8, with respect to certain kinds of foodstuff, for example, sweet potato (FIG. 3) and water (FIG. 6), that the gas sensor output is saturated at a preselected value. Contrarily, the gas sensor output is not saturated when, for example, mackerel (FIG. 4) or spinach (FIG. 5) is cooked in the microwave oven. In addition, the gas sensor output is greatly influenced by the amount of foodstuff in the case where the foodstuff showing the characteristics of FIG. 3 or FIG. 6 is disposed in the microwave oven.

Accordingly, it is very difficult to determine a reference voltage level at which the detection circuit must operate. FIG. 7 shows that the saturation value of the gas sensor output is dependent on the kind of foodstuff. FIG. 8 shows that the saturation value of the gas sensor output is dependent on the number of sweet potatoes disposed in the microwave oven, wherein a curve F_2 shows an output signal of the gas sensor when two sweet potatoes are disposed in the microwave oven, a curve F_1 shows a gas sensor output when one sweet potato is disposed, and a curve $F_{0.5}$ shows a gas sensor output when a half of a sweet potato is disposed therein.

Therefore, it is desirable to combine output signals of the gas sensor and a thermistor to ensure an accurate cooking control.

FIG. 9 shows an embodiment of a cooking operation control system of the present invention. Like elements corresponding to those of FIG. 1 are indicated by like numerals.

The cooking operation control system mainly comprises a gas concentration detection circuit 8 and an exhaustion air temperature detection circuit 9.

The gas concentration detection circuit 8 comprises the gas sensor 10 including the heater 11 connected to a D.C. power source and the sensor element 12 connected to the D.C. power source through the resistor 13. The node P of the sensor element 12 and the resistor 13 is connected to the data input terminal 16 of a first comparator 15, and the reference voltage input terminal 17 of the first comparator 15 is connected to the variable resistor 14, which is connected to the D.C. power source, for receiving a reference voltage ER_1 . The output terminal 18 of the first comparator 15 is connected to the D.C. power source via a resistor 21, and to one input terminal of a NAND gate 30.

The exhaustion air temperature detection circuit 9 comprises a thermistor 22, which is connected to the D.C. power source via a resistor 23. The node Q of the thermistor 22 and the resistor 23 is connected to a data input terminal 25 of a second comparator 27. A variable resistor 24 is also connected to the D.C. power source, of which the slidable terminal is connected to a reference voltage input terminal 26 of the second comparator 27 for applying a reference voltage VR_1 thereto. An output terminal 29 of the second comparator 27 is connected to the D.C. power source via a resistor 28, and to the other input terminal of the NAND gate 30.

An output terminal of the NAND gate 30 is connected to a base electrode of a switching transistor 32 via a resistor 31. The collector electrode of the switching transistor 32 is connected to the D.C. power source through a relay 33, and the emitter electrode thereof is grounded. A relay switch 34 is associated with the relay 33 for controlling the power supply to a microwave generation circuit 35.

The microwave generation circuit 35 can be substituted by a heater driver in case of an electric heating oven. Moreover, the microwave generation circuit and the heater driver must be controlled by the relay switch 34 in case of the combined microwave and electric heating oven.

The above-mentioned gas sensor 10 and the thermistor 22 are disposed in an exhaustion duct of the cooking utensil such as a microwave oven. When the gas concentration detected by the gas sensor 10 reaches a preselected value determined by the variable resistor 14, the first comparator 15 develops a detection output of the logic high. When the exhaustion air temperature de-

tected by the thermistor 22 reaches a preselected value determined by the variable resistor 24, the second comparator 27 develops a detection output of the logic high.

When both of the first and second comparators 15 and 27 develop the detection outputs of the logic high, the NAND gate 30 terminates the development of a control signal of the logic high to turn off the switching transistor 32. Upon turning off of the switching transistor 32 the relay switch 34 is opened, whereby the power supply to the microwave generation circuit 35 is terminated. That is, the cooking operation is conducted till both of the gas concentration and the exhaustion air temperature exceed preselected values, respectively.

Since the cooking operation control system of the present invention responds to both of the gas sensor output and the thermistor output, the operation is quite stable. FIG. 10 shows the gas sensor output (F) and the thermistor output (G) when water is warmed in the microwave oven. When alcohol is positioned near the air inlet of the microwave oven at the time T_1 , the gas sensor output (F) exceeds the reference level ER_1 at the time T_4 . However, the microwave generation is not terminated, because the thermistor output (G) is below the reference level VR_1 at the time T_4 . The alcohol is spaced apart from the air inlet at the time T_2 . At the time T_3 , both of the gas sensor output (F) and the thermistor output (G) exceed the reference levels ER_1 and VR_1 , respectively, and therefore, the microwave generation is terminated.

FIG. 11 shows the gas sensor output F_1 and the thermistor output G_1 when one sweet potato is cooked in the microwave oven, and the gas sensor output F_2 and the thermistor output G_2 when two sweet potatoes are cooked in the microwave oven.

The cooking operation is terminated at the time T_1 , at which the gas sensor output F_1 reaches the reference level ER_1 , when one sweet potato is cooked, even though the thermistor output G_1 exceeds the reference level VR_1 in advance. The cooking operation is terminated at the time T_3 , at which the thermistor output G_2 reaches the reference level VR_1 , when two sweet potatoes are cooked, even though the gas sensor output F_2 reaches the reference level ER_1 at the time T_2 earlier than the time T_3 .

FIG. 12 shows the gas sensor output F_1 and the thermistor output G_1 when white potato is cooked in the microwave oven, and the gas sensor output F_2 and the thermistor output G_2 when radish is cooked in the microwave oven.

Although the gas sensor output F_1 reaches the reference level ER_1 at the time T_1 , the cooking operation is continued until the time T_3 at which the thermistor output G_1 reaches the reference level VR_1 . In case of the radish, even though the gas sensor output F_2 reaches the reference level ER_1 at the time T_2 , the cooking operation is continued until the time T_3 .

FIG. 13 shows the gas sensor output variation (F_1 through F_5) and the thermistor output variation (G_1 through G_5) depending on the amount of foodstuff.

It will be clear from FIG. 13 that the thermistor output takes a substantially same curve when the amount of foodstuff is above 300 grams. Accordingly, the cooking operation is properly controlled in response to the gas sensor output when the amount of foodstuff is above 300 grams.

FIG. 14 shows the gas sensor output F and the thermistor output G in a combined microwave and electric

heating oven, wherein the electric heating is first performed and the microwave cooking is last performed.

First, the electric heating cooking is performed. Upon completion of the electric heating cooking, the oven door is opened at a point A. Under these conditions, the gas sensor output F is suddenly reduced by opening the oven door at the point A, but the thermistor output G does not immediately fall due to the heat retained in the oven cavity. Thus, when the microwave cooking is initiated at a point B, the thermistor output G exceeds the reference level VR₁ in a short time. However, in accordance with the present invention, the gas sensor output F is also monitored to continue the microwave generation till the gas sensor output F reaches the reference level ER₁.

The above-mentioned variable resistors 14 and 24 are preferably interlocked so that the reference levels ER₁ and VR₁ are set when a desired menu is selected through a menu selection lever.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A cooking utensil comprising:

- heat generating source means for cooking a foodstuff disposed in the cooking utensil;
- gas sensor means for detecting the concentration of a gas emitted from the foodstuff being cooked in the cooking utensil and developing a first detection signal when the concentration of said gas exceeds a first reference level;
- temperature sensor means for detecting the temperature of the foodstuff being cooked in the cooking utensil and developing a second detection signal when the temperature of the foodstuff exceeds a second reference level; and
- a control circuit for controlling the operation of said heat generating source means, said control circuit comprising:
 - determination means responsive to the first and second detection signals for developing a control signal when both said gas sensor means and said temperature sensor means develop said first and second detection signals, respectively; and
 - driver means responsive to said control signal for terminating the operation of said heat generating source means in response thereto.

2. The cooking utensil of claim 1, wherein air is exhausted from an oven cavity of said cooking utensil during the cooking of said foodstuff, and wherein said

temperature sensor means comprises a thermistor for detecting the temperature of the air exhausted from the oven cavity of said cooking utensil.

3. A microwave oven for cooking a foodstuff disposed therein, comprising:

- microwave generation source means for generating microwave energy to cook said foodstuff;
- gas sensor means for detecting the concentration of an exhaustion gas developed from said foodstuff during the cooking thereof in the microwave oven and developing a first detection signal when the concentration of said exhaustion gas exceeds a first selected value;
- thermistor means for detecting the temperature of an exhaustion air exhausted from an oven cavity of said microwave oven and developing a second detection signal when the temperature of said exhaustion air exceeds a second selected value; and
- a control circuit for controlling the operation of said microwave generation source means, said control circuit comprising:
 - determination means responsive to the first and second detection signals for developing a control signal when both said gas sensor means and said thermistor means develop said first and second detection signals, respectively; and
 - switching means responsive to said control signal for terminating the generation of said microwave energy from said microwave generation source means in response thereto.

4. The microwave oven of claim 3, wherein said determination means comprises:

- first comparator means for receiving said first detection signal from said gas sensor means and a first reference level voltage signal and for developing a first determination signal when the first detection signal exceeds said first reference level voltage signal;
- second comparator means for receiving said second detection signal from said thermistor means and a second reference level voltage signal and for developing a second determination signal when the second detection signal exceeds said second reference level voltage signal; and
- gate means responsive to the first and second determination signals for developing said control signal when both said first and said second determination signals are received from said first and second comparators, respectively.

5. A microwave oven in accordance with claim 3, wherein said exhaustion gas comprises reducing gases, said gas sensor means detecting the concentration of said reducing gases developed from said foodstuff.

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KN 0506774 X014

[54] **MICROWAVE OVEN EMPLOYING A GAS SENSOR**

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Japan

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[22] Filed: May 22, 1980

[30] **Foreign Application Priority Data**

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[52] U.S. Cl. 219/10.55 B

[58] Field of Search 219/10.55 B, 10.55 R,
219/10.55 M; 73/421 R

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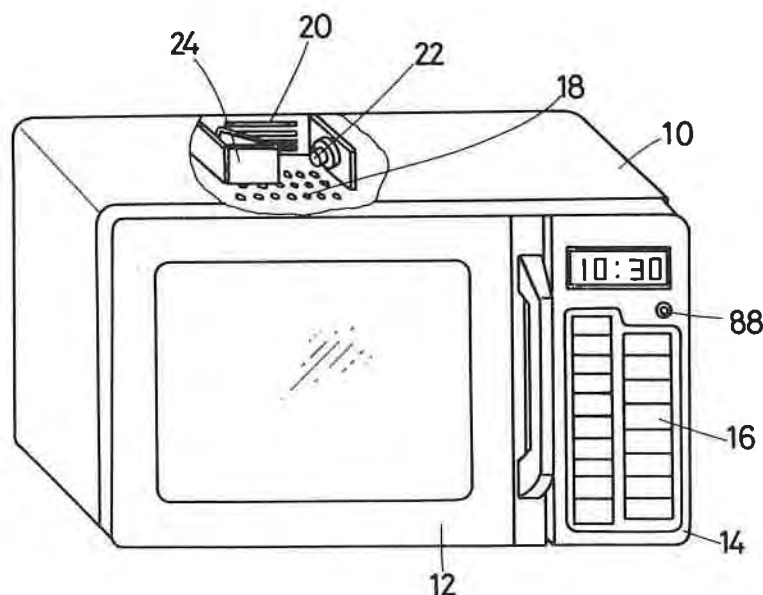
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Primary Examiner—Arthur T. Grimley
Attorney, Agent, or Firm—Birch, Stewart, Kolasch and
Birch

[57] **ABSTRACT**

A microwave oven includes a gas sensor for detecting the concentration of gas developed from a foodstuff disposed in an oven cavity. When the cooking operation is conducted to a desired level, the gas concentration reaches a preselected level and, hence, an output signal of the gas sensor shows a predetermined output level at which the microwave generation is terminated. An abnormal condition detection circuit is provided for detecting an abnormally high resistance created in the gas sensor due to, for example, disconnection of a warming heater included in the gas sensor. When an abnormal condition is detected by the abnormal condition detection circuit, the microwave generation is terminated and an alarm display is conducted to inform the operator of the abnormal condition.

5 Claims, 5 Drawing Figures



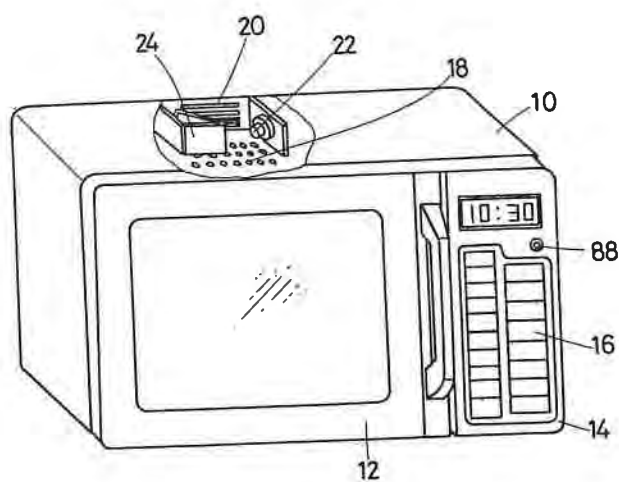


FIG. 1

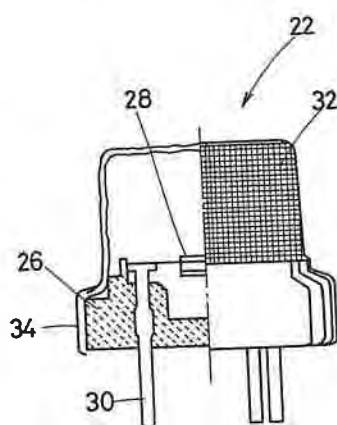


FIG. 2

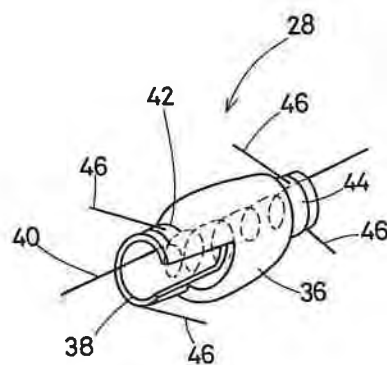


FIG. 3

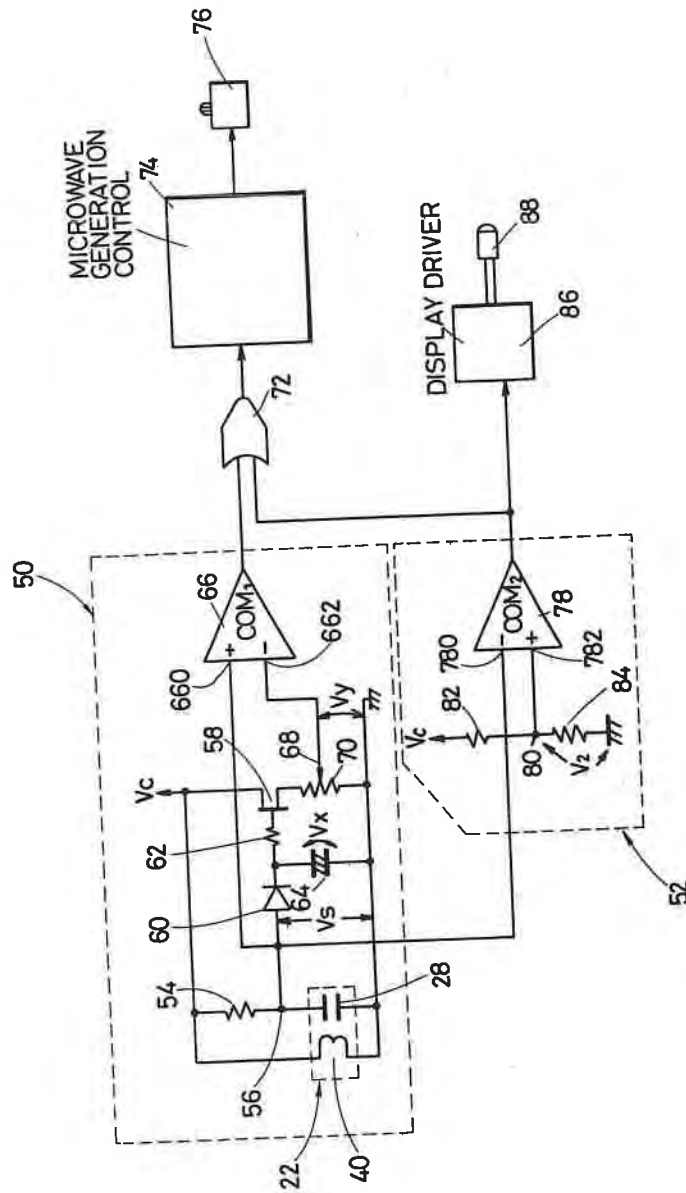


FIG. 4

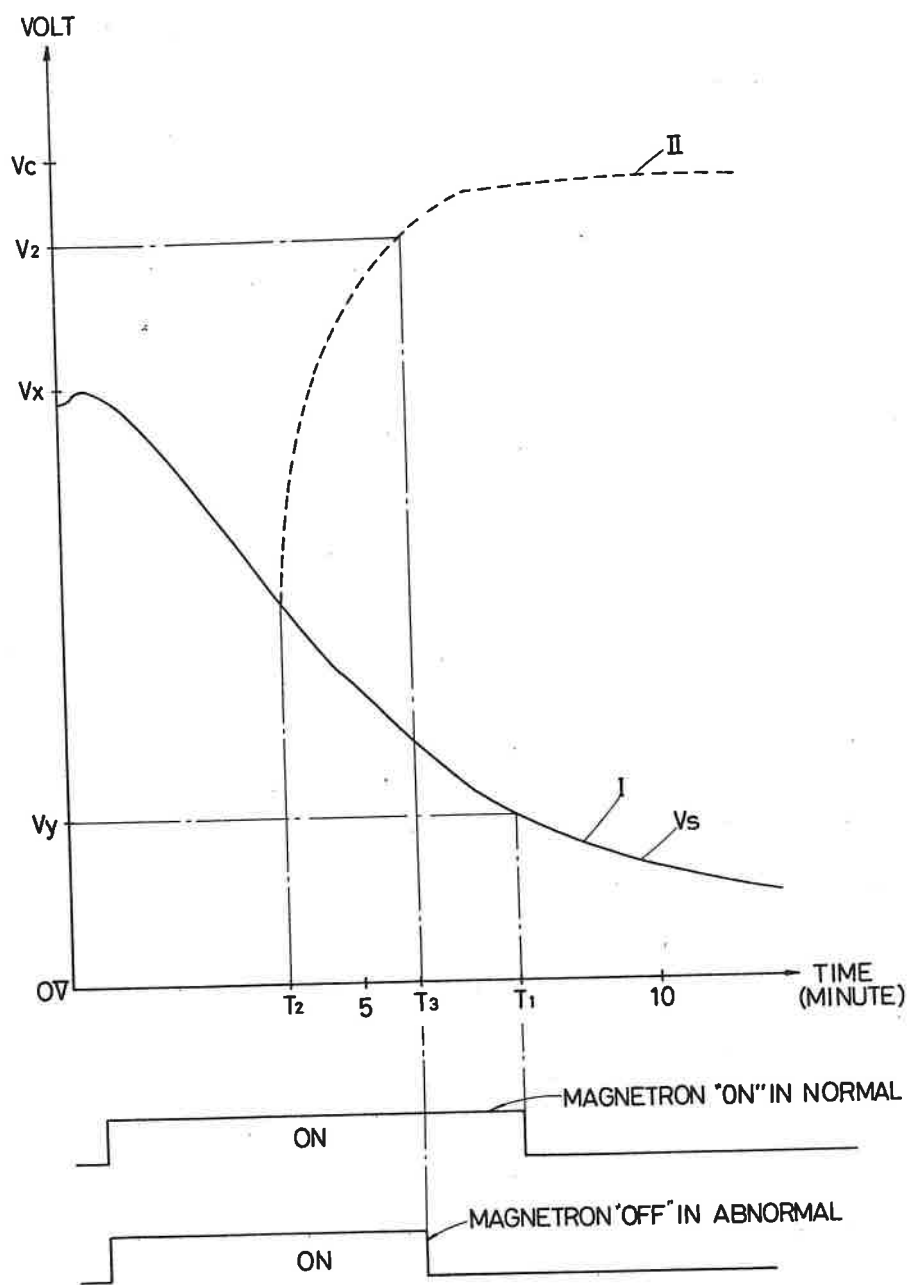


FIG.5

MICROWAVE OVEN EMPLOYING A GAS SENSOR

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a microwave oven and, more particularly, to a microwave oven including a control circuit responsive to an output signal derived from a gas sensor disposed in an exhaust gas path of the microwave oven.

Recently, a gas sensor output controlled microwave oven has been developed, wherein the microwave generation is terminated when a gas sensor output reaches a preselected level. A typical control circuit is described in copending application, "COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT", Ser. No. 71,179, filed on Aug. 31, 1979 by Takeshi Tanabe and assigned to the same assignee as the present application.

In such a gas sensor output controlled microwave oven, a stable operation of the gas sensor is strictly required to ensure a stable operation of the microwave cooking. However, there is a possibility that a warming heater included in the gas sensor is disconnected while the microwave cooking operation is performed.

Accordingly, an object of the present invention is to provide a gas sensor output controlled microwave oven of a stable operation.

Another object of the present invention is to provide a detection system for detecting an abnormal condition of a gas sensor included in a microwave oven.

Still another object of the present invention is to provide a control circuit for automatically terminating the microwave generation when an abnormal condition is detected in a gas sensor included in a microwave oven.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a level detection system is provided for detecting an abnormal level of an output signal derived from a gas sensor disposed in a microwave oven. When an abnormal output level of the gas sensor is detected, the microwave generation is automatically terminated and an alarm display is achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. 1 is a partially cut-away perspective view of an embodiment of a microwave oven of the present invention;

FIG. 2 is a partially sectional front view of a gas sensor included in the microwave oven of FIG. 1;

FIG. 3 is a perspective view of a sensor element included in the gas sensor of FIG. 2;

FIG. 4 is a circuit diagram of a control circuit included in the microwave oven of FIG. 1; and

FIG. 5 is a time chart for explaining an operation mode of the control circuit of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A microwave oven of the present invention mainly comprises a casing 10, an oven door 12, and a control panel 14 on which a plurality of key switches 16 are disposed for introducing a desired command into the microwave oven. The microwave oven further includes an oven wall for defining an oven cavity, and a magnetron disposed in the clearance formed between the casing 10 and the oven wall for supplying the microwave energy into the oven cavity. A blower fan system is provided for introducing a fresh air into the casing 10, cooling the magnetron, and introducing the air into the oven cavity for recirculation purposes while the microwave cooking is performed.

An exhaust path is provided between the oven wall and the casing 10. More specifically, openings 18 are formed in the upper wall of the oven cavity, and an exhaust outlet 20 is formed in the rear wall of the casing 10. An exhaust gas developed from the foodstuff disposed in the oven cavity is exhausted through the exhaust path due to the forced air flow created by the blower fan system. A gas sensor 22 is disposed in the exhaust path for detecting the concentration of the gas exhausted from the oven cavity. A guide plate 24 is disposed in the exhaust path for directing the exhaust gas toward the gas sensor 22 in order to ensure a stable detection.

FIG. 2 shows the gas sensor 22 in detail.

The gas sensor 22 mainly comprises a base member 26 for supporting a sensor element 28, and lead pins 30 for connecting the sensor element 28 to the control circuit of the microwave oven. A gauze 32 is secured to the base member 26 through the use of a coupling ring 34 for protecting the sensor element 28 but for exposing the sensor element 28 to the exhaust gas.

The sensor element 28 mainly comprises, as shown in FIG. 3, a SnO_2 sintered block 36 secured around a ceramic pipe 38, and a warming heater 40 disposed through the ceramic pipe 38 for warming the SnO_2 sintered block 36 for ensuring the stable detection operation. Electrode terminals 42 and 44 are secured to the both ends of the SnO_2 sintered block 36. Lead wires 46 are connected to the electrode terminals 42 and 44, and the other ends of the lead wires 46 are connected to the lead pins 30, respectively.

The resistance value of the sensor element 28 decreases as the gas concentration increases. The variation of the sensor element resistance is converted into a voltage level variation for providing a sensor output signal.

FIG. 4 shows an embodiment of a control circuit included in the microwave oven of FIG. 1.

The control circuit mainly comprises a cooking condition detection unit 50 and an abnormal condition detection unit 52. The sensor element 28 is connected to a power supply terminal V_c via a resistor 54. A node 56 provided between the sensor element 28 and the resistor 54 functions as an output terminal of a voltage signal V_s . The node 56 is connected to a gate electrode of a field effect transistor 58 through a diode 60 and a resistor 62. A capacitor 64 is connected between the ground terminal and a node provided between the diode 60 and the

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resistor 62. The capacitor 64 functions to memorize the initial maximum output level V_x of the voltage signal V_s derived from the gas sensor 22.

A first comparator 66 is included in the cooking condition detection unit 50. A data input terminal 660 of the first comparator 66 is connected to the node 56 in order to receive the voltage signal V_s . A reference signal input terminal 662 of the first comparator 66 is connected to an output terminal 68 of a variable resistor 70. The variable resistor 70 is interposed within the source-drain path of the field effect transistor 58. The output terminal 68 develops a reference voltage level V_y , which is determined by the initial maximum output level V_x of the voltage signal V_s and the division ratio determined by the variable resistor 70. By properly selecting the division ratio of the variable resistor 70 in accordance with the kind of foodstuff to be cooked, a preferred reference voltage level V_y is applied to the reference signal input terminal 662 of the first comparator 66.

In the above constructed cooking condition detection unit 50, the voltage signal V_s can be expressed as follows:

$$V_s = V_c \times R_s / (R_s + R_L)$$

where:

V_c is the power supply level;

R_s is the resistance value of the sensor element 28; and

R_L is the resistance value of the resistor 54.

As already discussed above, the resistance value R_s of the sensor element 28 reduces as the gas concentration increases. Therefore, the level of the voltage signal V_s decreases as the concentration of the gas developed from the foodstuff increases. When the voltage signal V_s drops to the reference voltage level V_y , the first comparator 66 develops a detection output toward an OR gate 72. The thus obtained detection output is applied to a microwave generation control circuit 74 to terminate the operation of a magnetron 76, thereby completing the microwave cooking operation.

In such a system, if the warming heater 40 is accidentally disconnected, the resistance value R_s of the sensor element 28 becomes abnormally high. More specifically, the normal resistance value of the sensor element 28 is around 10 through 100K Ω . However, the resistance value of the sensor element 28 becomes about 10 M Ω when the warming heater 40 does not operate. Such an abnormally high resistance also occurs when an abnormal condition is created in the sensor element 28. When the sensor element 28 shows the abnormally high resistance, the level of the voltage signal V_s becomes substantially identical with the power supply level V_c . It is apparent that the first comparator 66 never develops the detection output when the sensor element 28 shows the abnormally high resistance. In this case, the microwave generation will be continuously performed even though the foodstuff has been cooked to a preferred level.

To prevent the occurrence of the above-mentioned undesirable condition, the control circuit of FIG. 4 includes the abnormal condition detection unit 52. The abnormal condition detection unit 52 mainly comprises a second comparator 78, of which a data input terminal 780 is connected to receive the voltage signal V_s from the node 56, and a reference voltage input terminal 782 is connected to receive a reference voltage V_2 from a node 80 which is provided between two resistors 82 and 84. The reference voltage V_2 is selected slightly smaller than the power supply level V_c .

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Accordingly, when the voltage signal V_s becomes abnormally high and reaches the reference level V_2 , the second comparator 78 develops a detection output. The thus obtained detection output is applied to the microwave generation control circuit 74 through the OR gate 72 for terminating the microwave generation. The detection output derived from the second comparator 78 is also applied to a display driver circuit 86 in order to activate a light emitting diode 88 which is disposed on the control panel 14, thereby informing the operator of the abnormal condition.

FIG. 5 shows the operational mode of the control circuit of FIG. 4.

A solid curve I represents the normal condition, wherein the microwave cooking operation is controlled by the cooking condition detection unit 50. When the level of the voltage signal V_s is reduced to the preferred reference voltage level V_y determined by the variable resistor 70, the first comparator 66 develops the detection output at a time T_1 to terminate the microwave generation. Now assume that the warming heater 40 is disconnected at a time T_2 . Then, the voltage signal V_s follows a dotted line curve II. When the level of the voltage signal V_s reaches the reference level V_2 at a time T_3 , the second comparator 78 detects the abnormal condition to terminate the microwave generation and activate the alarm display.

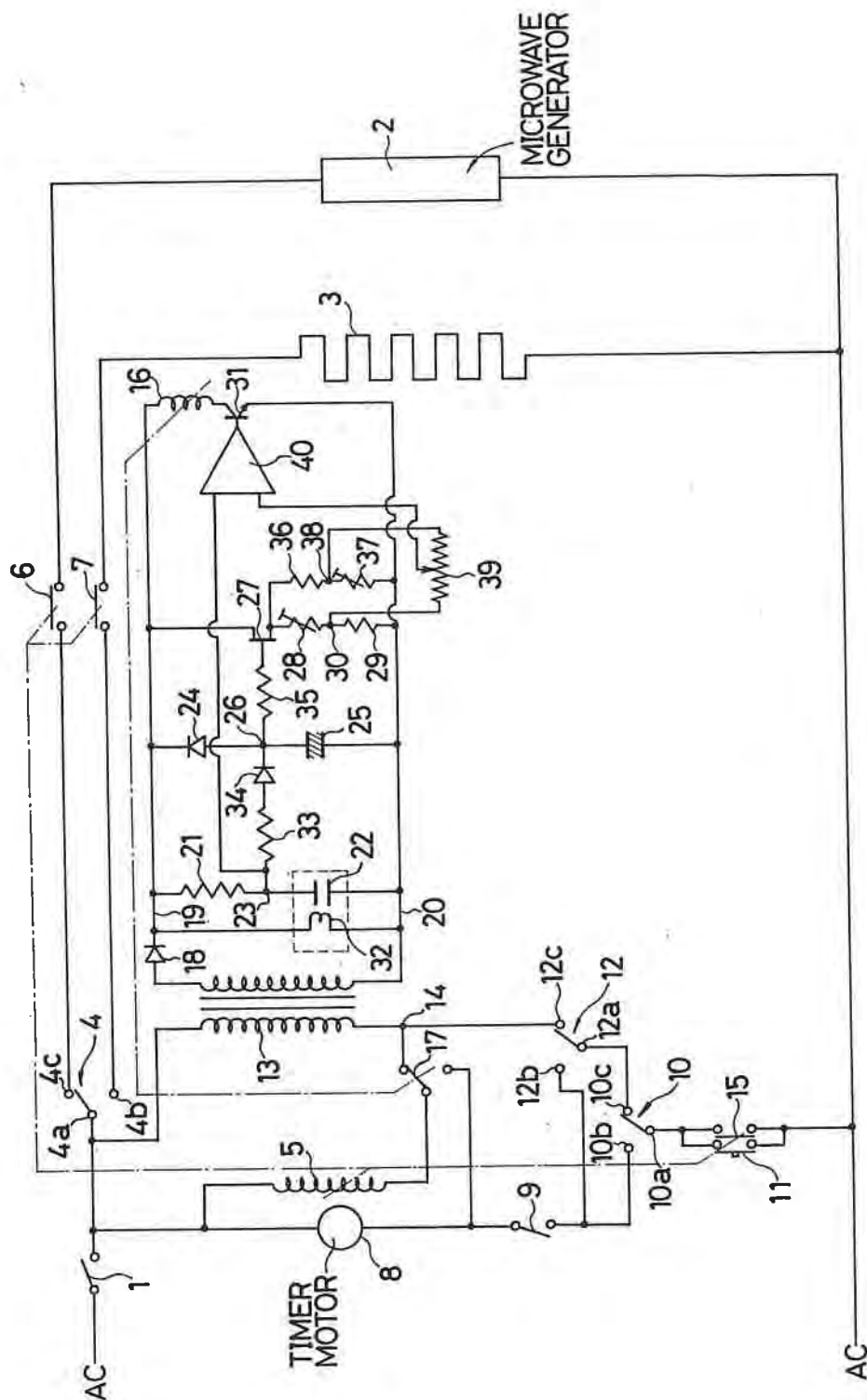
The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A microwave oven comprising:
 - a microwave generation source;
 - a gas sensor disposed in an exhaustion gas path for detecting the concentration of a gas developed from a foodstuff disposed in an oven cavity;
 - microwave generation control means for activating said microwave generation source in accordance with an output signal derived from said gas sensor;
 - abnormal condition detection means for detecting an abnormal condition occurring in said gas sensor; and
 - control means for precluding the activation of said microwave generation source when a detection output is developed from said abnormal condition detection means.
2. The microwave oven of claim 1, wherein said abnormal condition detection means detects an abnormally high resistance created in said gas sensor.
3. The microwave oven of claim 1, wherein said abnormal condition detection means comprises:
 - a comparator having a data input terminal receiving an output voltage signal derived from said gas sensor; and
 - a reference voltage applying means for applying a reference voltage signal to a reference input terminal of said comparator.
4. The microwave oven of claim 3, wherein said reference voltage signal has a level substantially identical with the power supply level of said abnormal condition detection means.
5. The microwave oven of claim 1, 2, 3 or 4, further comprising:
 - an indicator for alarm display; and
 - driver means for activating said indicator when said detection output is developed from said abnormal condition detection means.

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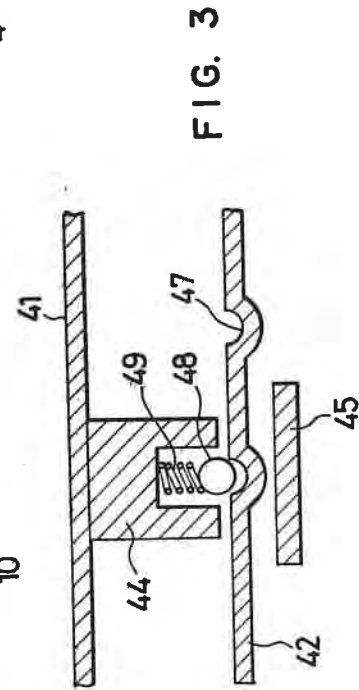
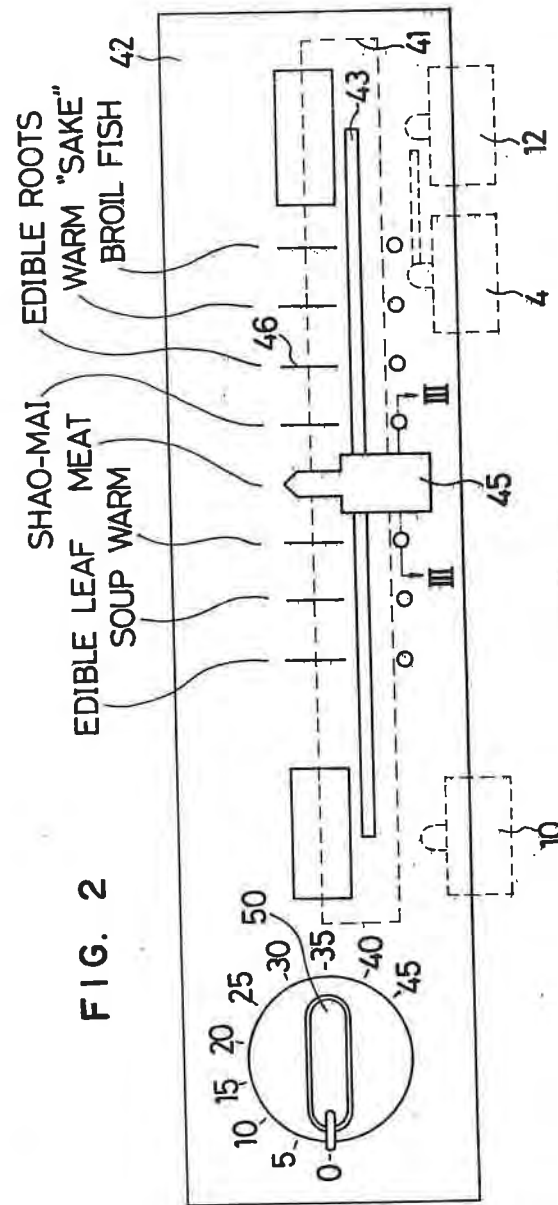


FIG. 4

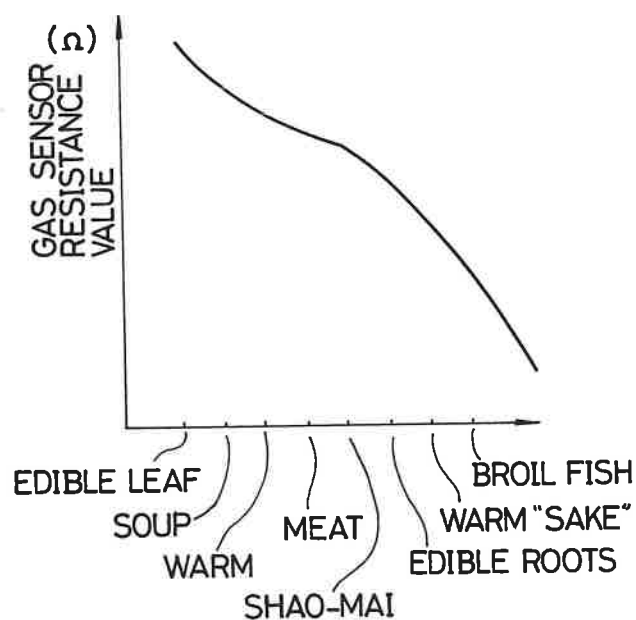
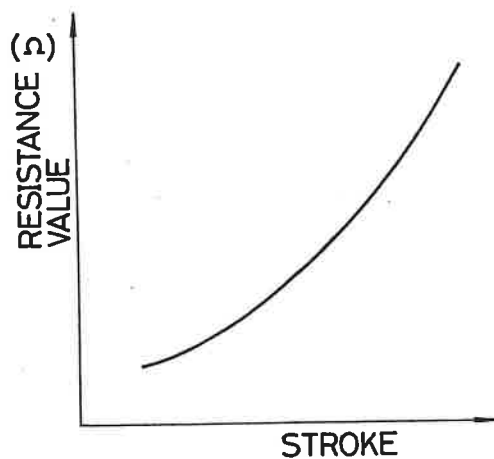


FIG. 5



GAS SENSOR OUTPUT/TIMER OUTPUT CONTROLLED COOKING UTENSIL

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a cooking utensil which includes a gas sensor for automatic cooking control purposes.

A microwave oven is proposed in my copending application Ser. No. 71,179, "COOKING UTENSIL CONTROLLED BY GAS SENSOR OUTPUT", filed on Aug. 31, 1979, wherein a gas sensor is disposed in an exhaust duct for detecting a gas concentration developed from an oven cavity. When the gas concentration reaches a preselected value, the gas sensor output shows a preselected value, and in response thereto the microwave generation is terminated.

To achieve the automatically controlled cooking operation, the preselected value should be varied in response to the kind of foodstuff to be cooked. In addition to the automatic cooking operation controlled by the gas sensor output, it is preferable that the conventional timer controlled cooking operation be performed for a specific kind of cooking.

Accordingly, an object of the present invention is to provide a novel selection system in a cooking utensil for selecting a desired operation mode of cooking.

Another object of the present invention is to provide a cooking mode selection system of a simple construction and ensuring easy handling.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a slidable lever is provided on a control panel of a cooking utensil, for example, a microwave oven for selecting a desired cooking menu. In response to the selected cooking menu, a reference level, which is compared with an output voltage signal derived from a gas sensor, is varied to perform the automatic cooking control. When the slidable lever is slid to the end of the predetermined course of movement, the control circuit is placed in another mode of operation, wherein the cooking operation is controlled by an output signal derived from a timer.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

FIG. 1 is a circuit diagram of a control circuit of an embodiment of a cooking utensil of the present invention;

FIG. 2 is a schematic front view of a cooking mode selection panel included in the cooking utensil of FIG. 1;

FIG. 3 is a sectional view taken along line III—III of FIG. 2;

FIG. 4 is a graph showing a resistance value of a gas sensor at which the cooking operation should be terminated depending on the kind of foodstuff to be cooked; and

FIG. 5 is a graph showing resistance value of a volume resistor versus selection lever stroke characteristics of the cooking mode selection panel of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows an embodiment of a control circuit of a cooking utensil of the present invention.

The control circuit mainly comprises a door switch 1 which is closed when an oven door of the cooking utensil is closed, a microwave generator 2 such as a magnetron and the driver circuit thereof, a heater 3 for electric heating cooking purposes, and a selection switch 4. The microwave generator 2 is connected to receive an A.C. power supply through the door switch 1, the selection switch 4 and a normally open relay contact 6 which is closed by a relay coil 5. The heater 3 is connected to receive the A.C. power supply through the door switch 1, the selection switch 4 and a normally open relay contact 7 which is closed by a relay coil 5.

The control circuit further comprises a timer motor 8, a selection switch 10, and a cook start manual switch 11. The timer motor 8 is connected to the A.C. power source through the door switch 1, a timer contact 9, a normally open terminal 10b of the selection switch 10, and the cook start manual switch 11. A normally closed terminal 10c of the selection switch 10 is connected to a primary winding of a transformer 13 via a normally close terminal 12c of another selection switch 12. A series circuit of the relay coil 5 and a normally close terminal of a relay contact 17, which is activated by a relay coil 16, is connected to the timer motor 8 in a parallel fashion. A normally open terminal of the relay contact 17 is connected to a node 14 of the transformer 13 and the normally close terminal 12c of the selection switch 12. The normally open terminal 10b of the selection switch 10 is connected to a normally open terminal 12b of the selection switch 12. And, a normally open relay contact 15, which is closed by the relay coil 5, is connected with the cook start switch 11 in a parallel fashion.

A diode 18 is connected to the secondary winding of the transformer 13 to provide a positive voltage terminal 19 and a negative voltage terminal 20. A series circuit of a resistor 21 and a gas sensor 22 is disposed between the positive voltage terminal 19 and the negative voltage terminal 20. A series circuit of an inversely connected diode 24 and a capacitor 25 is also disposed between the positive voltage terminal 19 and the negative voltage terminal 20. And, a series circuit of an anode-cathode path of a field effect transistor 27, a variable resistor 28 and a resistor 29 is also disposed between the terminals 19 and 20. Further, a series circuit of the relay coil 16 and a collector-emitter path of a transistor 31 is disposed between the terminals 19 and 20. A warming heater 32 for the gas sensor 22 is also connected to receive the power supply via the terminals 19 and 20.

A node 23 of the resistor 21 and the gas sensor 22 is connected to a node 26 of the diode 24 and the capacitor 25 through a resistor 33 and a diode 34. The node 26 is connected to the gate electrode of the field effect transistor 27 via a resistor 35. A series circuit of a resistor 36

and a variable resistor 37 is connected to the series circuit of the variable resistor 28 and the resistor 29 in a parallel fashion. A node 30 of the variable resistor 28 and the resistor 29 is connected to a node 38 of the resistor 36 and the variable resistor 37 through a volume resistor 39. A variable output terminal of the volume resistor 39 is connected to a reference voltage input terminal of a comparator 40. An output terminal of the comparator 40 is connected to the base electrode of the transistor 31. The node 23 is connected to a data input terminal of the comparator 40.

The above-mentioned volume resistor 39, and the selection switches 4, 10 and 12 are correlated with each other as shown in FIGS. 2 and 3.

A resistor plate 41, on which a carbon film is coated, is provided for the volume resistor means. A control panel 42 is disposed in front of the resistor plate 41. The control panel 42 is provided with a slit 43 in which a lever 45 is slidably secured. A slidable member 44, which is fixed to the lever 45 through the slit 43, is disposed between the resistor plate 41 and the control panel 42 in such a manner that one end of the slidable member 44 contacts the resistor plate 41. Indications 46 are provided on the control panel 42 for selecting a desired cooking mode of operation in accordance with the kind of foodstuff to be cooked. Click stop indents 47 are formed on the control panel 42 for temporarily holding the slidable member 44 at a desired position in the course of the sliding movement. A click ball 48 is secured to the slidable member 44 via a spring 49, the click ball 48 being associated with the click stop indents 47.

The slidable member 44 functions to determine the reference voltage level to be applied to the comparator 40. More specifically, the indicators 46 are aligned in the order of the kind of foodstuff of which the preferred cooking operation be completed at preselected gas concentrations which gradually increases (the resistance value of the gas sensor 22 gradually decreases). In this example, the kind of foodstuff to be selected is aligned rightward in the order of EDIBLE LEAF, SOUP, REWARM, MEAT, SHAO-MAI, EDIBLE ROOTS, WARM "SAKE", and BROIL FISH. FIG. 4 shows the resistance value of the gas sensor 22 at which the cooking operation should be completed depending on the kind of foodstuff to be cooked.

FIG. 5 shows the variation of the resistance value of the volume resistor 39 depending on the stroke distance of the slidable member 44 from the left end of the sliding course.

The selection switch 10 is positioned at the left end of the slidable movement of the slidable member 44, and the selection switch 12 is positioned at the right end of the slidable movement of the slidable member 44. The selection switch 4 is positioned near the location of the indicator 46 for the "BROIL FISH".

Movable terminals 4a, 10a and 12a of the selection switches 4, 10 and 12 are normally connected to a normally close terminal 4c and the normally close terminals 10c and 12c, respectively. When the slidable member 44 contacts the movable terminals 4a, 10a or 12a, the movable contacts are made contact with the normally open terminals 4b, 10b and 12b, respectively. The selection switch 4 is constructed so that the movable terminal 4a is made contact with the normally open terminal 4b when the slidable lever 45 is positioned right than the indication 46 for the "BROIL FISH".

When the oven door is closed after disposing the foodstuff within the oven cavity, the door switch 1 is closed. Then, the selection lever 45, which is associated with the volume resistor 39, is slid to select a desired reference voltage level to be applied to the comparator 40 in accordance with the kind of foodstuff to be cooked. Under these conditions when the cook start switch 11 is actuated, the microwave generator 2 or the heater 3 is energized for cooking purposes.

Now assume that the "MEAT" cooking is desired to be performed. The slidable lever 45 is held at the indication 46 for "MEAT", and the reference voltage signal suited for the "MEAT" cooking is applied to the reference voltage input terminal of the comparator 40 from the volume resistor 39. Since the slidable member 44 does not contact any one of the movable terminals of the selection switches 4, 10 and 12, the movable terminals 4a, 10a and 12a are made contact with the normally close terminals 4c, 10c and 12c, respectively. Accordingly, the microwave generator 2 is supplied with power through the normally open relay contact 6, which is closed by the relay coil 5. The transformer 13 also receives the power supply and, therefore, the gas sensor detection circuit is enabled.

At the moment shortly after the actuation of the cook start switch 11, the gas concentration is considerably low and, hence, the relay coil 16 receives the power supply. The relay contact 17 is inclined toward the normally open terminal and, therefore, the relay coil 5 is energized to close the relay contacts 6, 7 and 15. When the cooking operation is performed to a desired level determined by the volume resistor 39, the data signal derived from the gas sensor 22 shows the same value as the reference voltage signal and, therefore, the comparator 40 develops a detection output to turn off the transistor 31. The relay coil 16 is deenergized, whereby the relay contact 17 is connected to the normally close terminal. Accordingly, the relay coil 5 is deenergized to open the relay contacts 6, 7 and 15, thereby completing the cooking operation.

When the timer controlled cooking operation is desired to be performed instead of the gas sensor output controlled automatic cooking operation, the slidable lever 45 is slid to either end of the sliding course to make contact with the movable terminal of the selection switch 10 or 12, with the normally open terminal. A timer lever 50 is wound to set a desired cooking time period. The timer contact 9 is closed, and the relay coil 5 is energized through the normally close terminal of the relay contact 17 upon actuation of the cook start switch 11. Accordingly, the relay contacts 6, 7 and 15 are closed to activate the microwave generator 2 or the heater 3 until the preselected time period has been counted by the timer motor 8.

When the slidable lever 45 is positioned at the indication of the "BROIL FISH", the movable terminal 4a of the selection switch 4 is made contact with the normally open terminal 4b, whereby the heater 3 is energized. The capacitor 25 is provided for compensating for the initial condition of the cooking operation when the cooking operation is sequentially conducted with a short time interval.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. In a cooking utensil for cooking a foodstuff including a timer, a gas sensor for detecting the concentration of a gas emitted from said foodstuff and for developing an output in response thereto, said gas including reducing gases, said gas sensor detecting the concentration of said reducing gases emitted from said foodstuff, and manual selection means for selecting a desired cooking condition for said foodstuff when said selection means is placed in one of a plurality of desired positions, said selection means being disposed on a control panel, said control panel comprising:

volume resistor means responsive to the selection of said desired cooking condition by said selection means for determining a desired reference signal, said reference signal being compared with said output from said gas sensor for controlling said cooking utensil; and

first switch means responsive to the placement of said selection means at a preselected position other than said desired positions for enabling said timer and disabling said gas sensor thereby removing said cooking utensil from a gas sensor controlled cooking operation mode and placing said cooking utensil in a timer controlled cooking operation mode.

2. The cooking utensil of claim 1, wherein said selection means is slidably secured on said control panel, and said first switch means is disposed at an end of the slidable course of the selection means.

3. The cooking utensil of claim 1 or 2, wherein said cooking utensil comprises a cooking energy source, said cooking energy source including a microwave generation source for developing microwave energy for cooking purposes and an electric heater for developing electric heat energy for cooking purposes.

4. The cooking utensil of claim 3, further comprising second switch means for automatically selecting either the microwave generation source or the electric heater in response to the location of said selection means.

5. A cooking utensil for cooking a foodstuff, comprising:

a cooking energy source developing means;
gas sensor means for detecting the concentration of a gas emitted from said foodstuff and developing an output signal in response thereto thereby controlling the operation of said cooking utensil in a gas sensor controlled cooking operation mode, said gas including reducing gases, said gas sensor detecting the concentration of said reducing gases emitted from said foodstuff;

manual selection means for selecting a desired cooking condition for said foodstuff when said selection means is placed in one of a plurality of desired positions;

volume resistor means responsive to the selection of said desired cooking condition by said selection means for determining a reference signal level;

comparator means responsive to the output from said gas sensor and to said reference signal from said volume resistor means for developing a resultant output when the output from said gas sensor exceeds said reference signal level; and

controlling means responsive to said resultant output for controlling the energization of said cooking energy source developing means.

6. A cooking utensil in accordance with claim 5, further comprising a timer for controlling the operation of said cooking utensil in a timer controlled cooking operation mode; and

switch means responsive to the placement of said selection means at a preselected position other than said desired positions for enabling said timer and disabling said gas sensor in response thereto, said controlling means energizing said cooking energy source developing means for a time period determined by said timer during the enablement thereof.

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06/21 KN 0506776 XU14

- [54] METHOD AND SYSTEM FOR PROVIDING AN AUDIBLE ALARM RESPONSIVE TO SENSED CONDITIONS
- [76] Inventor: John R. Martin, 2345 W. Mill Rd., Milwaukee, Wis. 53209
- [21] Appl. No.: 75,218
- [22] Filed: Sep. 13, 1979
- [51] Int. Cl.³ G08B 17/10
- [52] U.S. Cl. 340/634; 179/1 SM; 340/692; 340/628
- [58] Field of Search 340/632, 633, 634, 628, 340/506, 692; 360/12; 179/1 SG, 1 SM; 422/94, 95, 96, 97; 73/23

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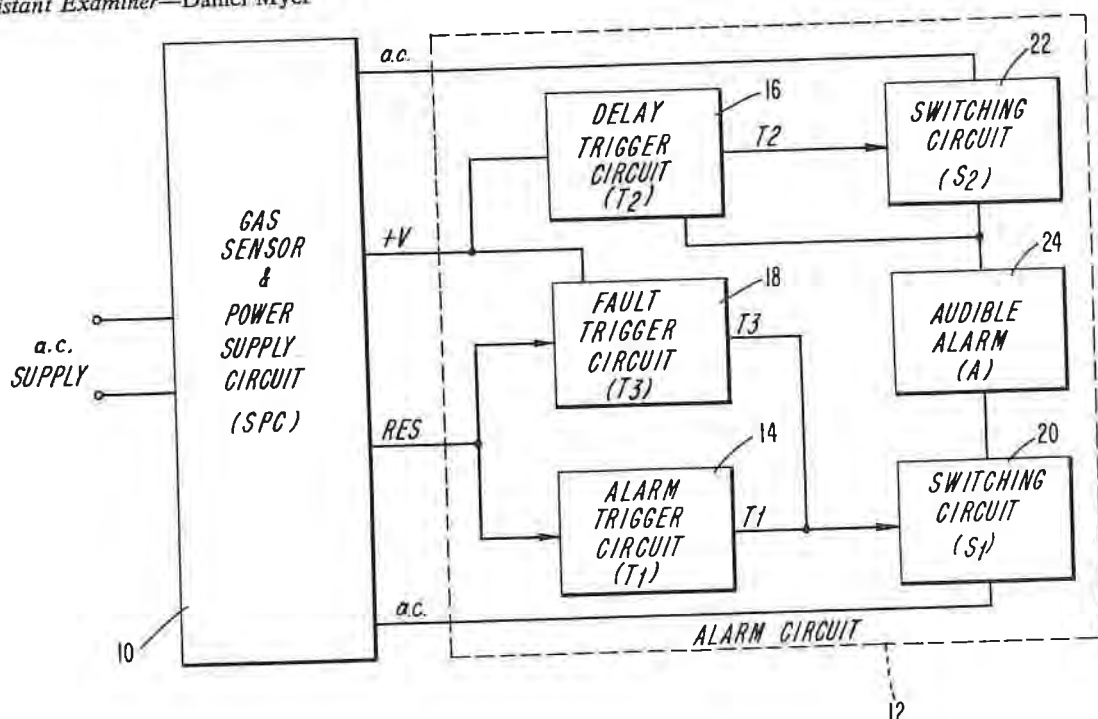
Primary Examiner—John W. Caldwell, Sr.
Assistant Examiner—Daniel Myer

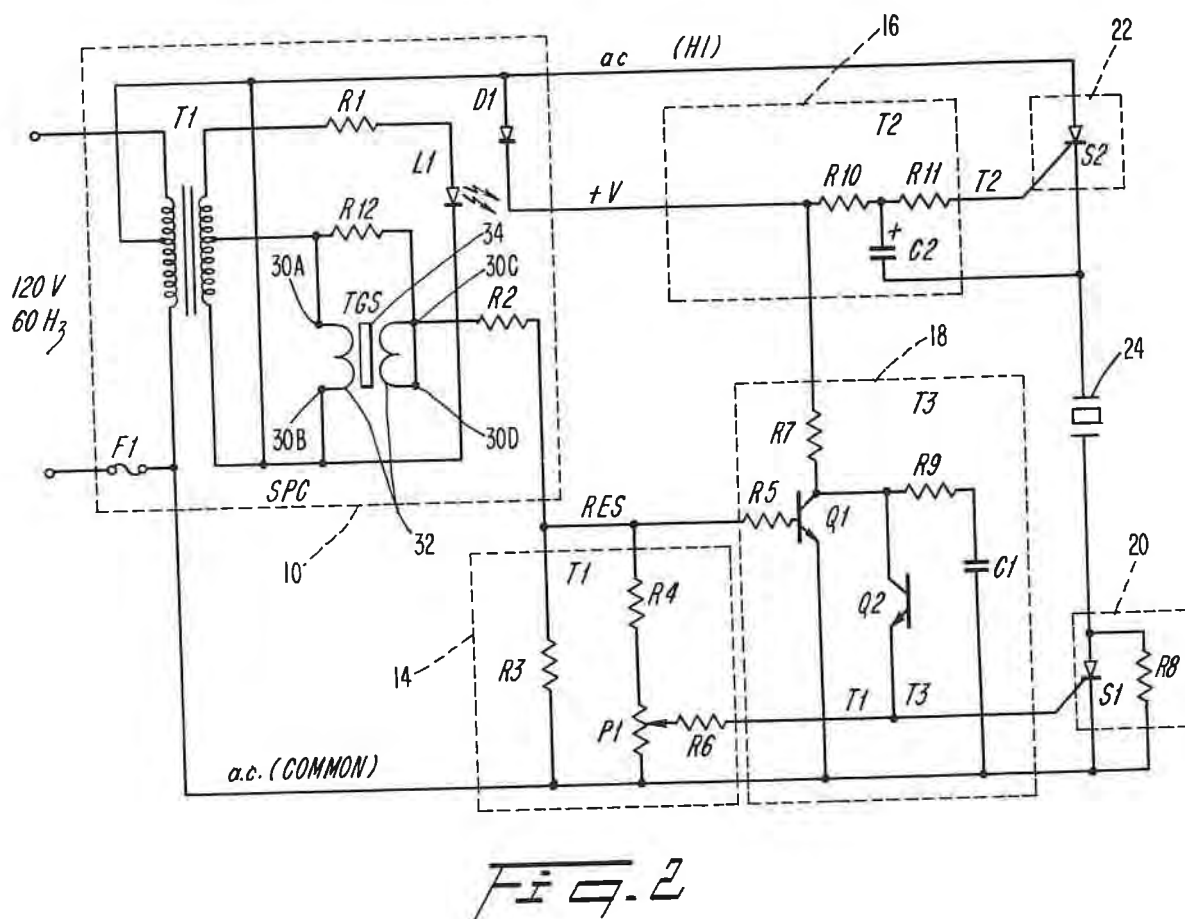
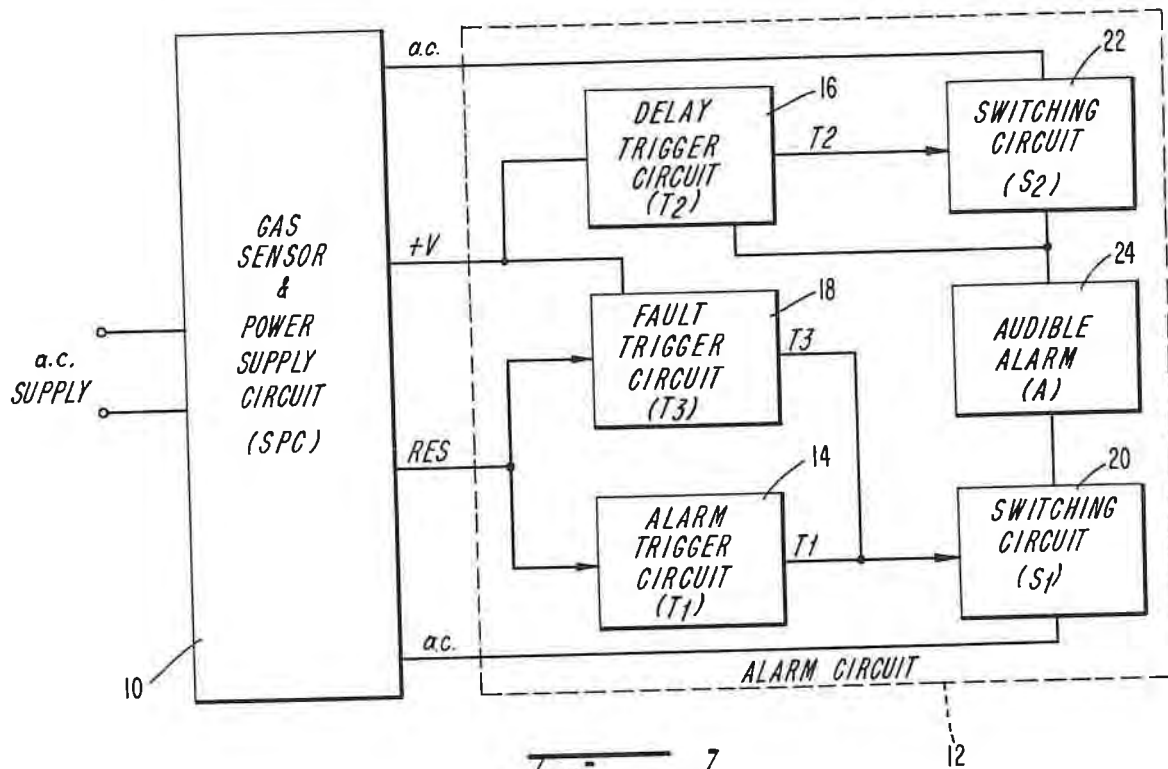
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

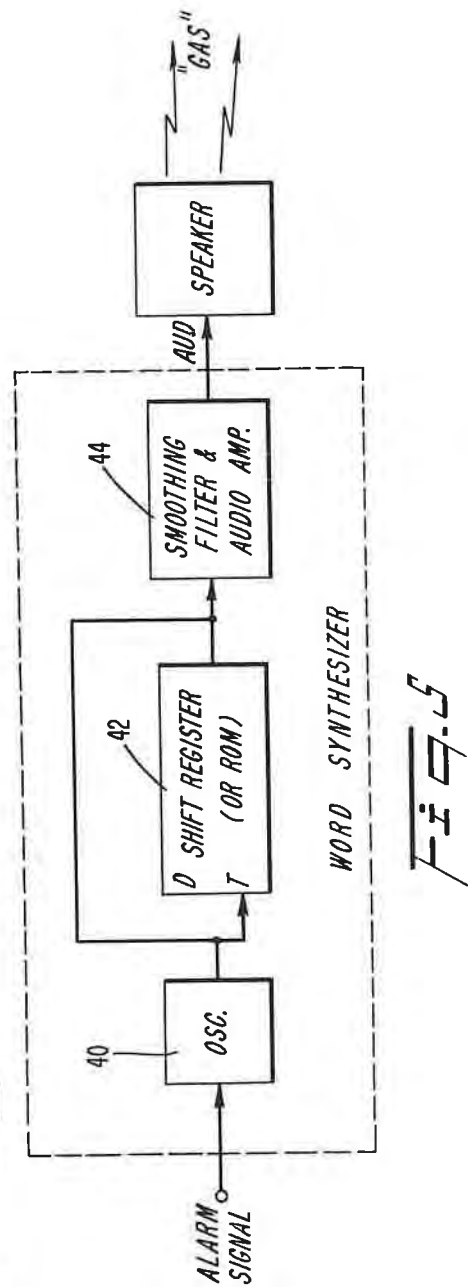
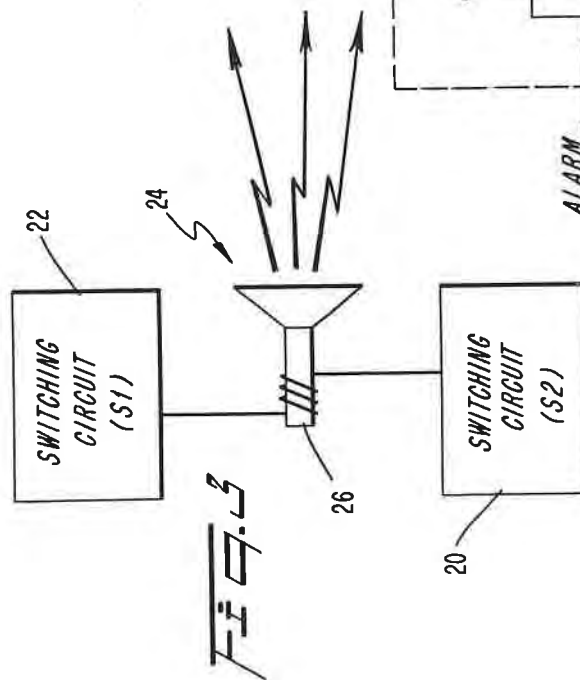
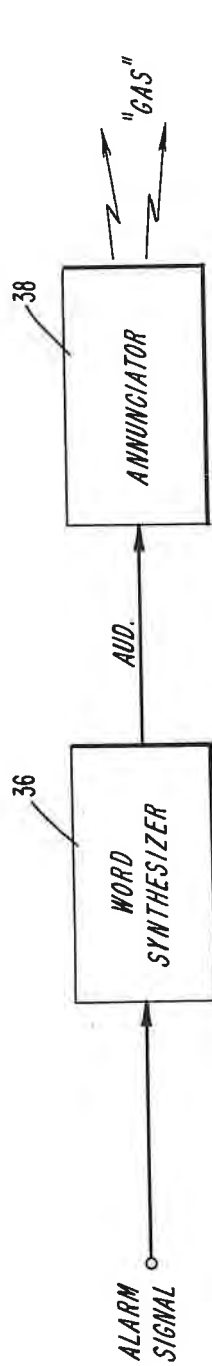
[57] ABSTRACT

An alarm system responsive to a predetermined concentration of gaseous hydrocarbon in an area. A gaseous hydrocarbon responsive variable resistance element having a heater has resistance characteristics that are relatively stable upon energization of the heater beyond an initial heating period, decrease from the relatively stable value as a function of the concentration of gaseous hydrocarbons in the vicinity of the sensor, and decrease to an initial action resistance value substantially below the stable value during the initial heating period. First and second switching devices connected in series with a power source produce an audible alarm signal with both in their conductive condition. A first trigger circuit triggers the first switching device into its conductive condition in response to the variable resistance element decreasing from the relatively stable value at least to a predetermined resistance value above the initial action resistance value to indicate a predetermined concentration of gaseous hydrocarbons in the vicinity of the resistance element. A second trigger circuit includes a capacitor connected to be charged to at least a predetermined charge level upon energization of the heater and triggers the second switching device into its conductive condition in response to the capacitor achieving the predetermined charge level. A third trigger circuit is connected to the first switching device to intermittently trigger the first switching device into its conductive condition in response to the occurrence of an abnormal condition of the sensor. The alarm circuit can synthesize and annunciate a predetermined spoken message in response to a sensed alarm condition.

5 Claims, 6 Drawing Figures







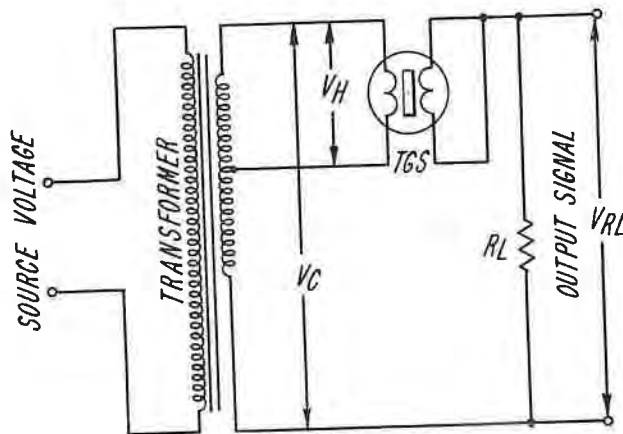


Fig. 6A

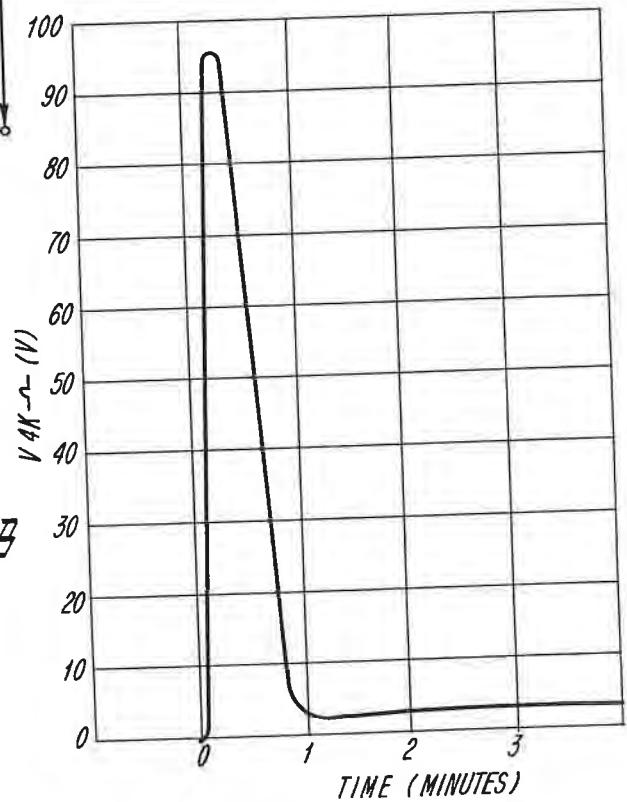


Fig. 6B

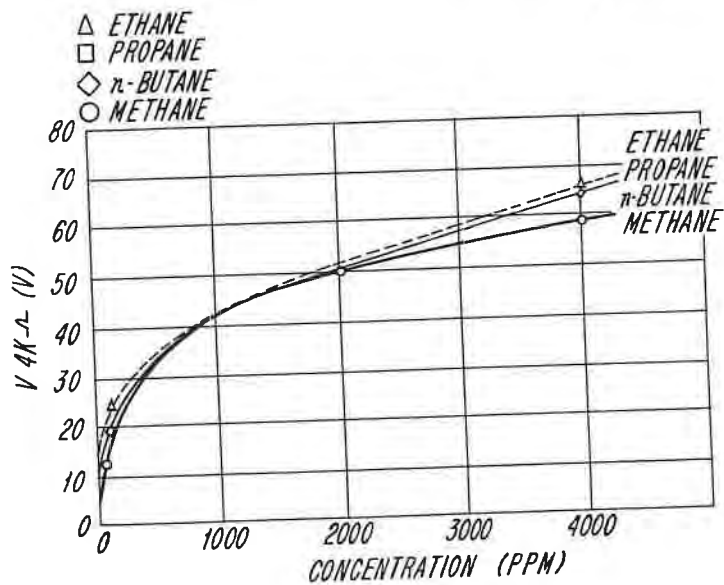


Fig. 6C

METHOD AND SYSTEM FOR PROVIDING AN AUDIBLE ALARM RESPONSIVE TO SENSED CONDITIONS

BACKGROUND OF THE INVENTION

The present invention relates to alarm systems and, more particularly, to a method and system for providing an audible alarm to alert occupants of a building and/or authorities to the presence of an abnormal condition such as an excess concentration of potentially combustible gaseous hydrocarbons within a building or area.

It has become desirable and, in many instances, even mandatory to provide alarm systems that sense abnormal or undesirable conditions and alert the occupants of a building to the presence of the abnormal condition so that appropriate action may be taken. Numerous types of smoke and fire detectors, gas detectors, intrusion detectors and other such alarm systems are currently in use for such purposes. In a typical residence, for example, three or four such systems for detecting different conditions may be in use.

The typical alarm system utilizes a sensor to sense a condition such as smoke or gas concentration and an audible alarm such as a buzzer, horn or siren to provide an alerting sound when the sensed condition is abnormal. The type of sensor employed will, of course, depend upon the condition being sensed. For smoke alarm systems, various types of photoelectric and ionization type sensors are employed to determine when the concentration of smoke in the air exceeds some predetermined value. Intrusion detectors utilize a large number of different types of sensors while typical gas alarms, usually for indicating the presence of gaseous hydrocarbons, employ a sensor which is basically a bulk semi-conductor material composed mainly of tin dioxide which, when heated, exhibits a resistance drop related to the concentration of gaseous hydrocarbons in the vicinity of the sensor.

One aspect of this invention relates broadly to various alarm systems. Within a single residence or other occupied space, there may be several alarms for different conditions. For example, there may be a burglar alarm to detect intrusion, a smoke alarm to detect combustion and a gas alarm to detect gas leaks. The usual alarm system provides an audible alarm through the energization of a transducer such as a piezoelectric or electromagnetic "buzzer". While there may be some difference between the sounds produced by the various alarms, they are heard very infrequently and it may be difficult to readily ascertain which alarm is sounding when the alarm condition is detected. It is, of course, extremely important to take relatively fast action when one of the alarms sounds so any delay in ascertaining which alarm has been triggered could be extremely dangerous or even fatal.

It is accordingly one object of the present invention to provide a novel method and system for providing an alarm signal which permits the immediate recognition of the sensed alarm condition through the provision of a spoken message.

Another more specific aspect of the present invention relates to alarm systems for detecting the occurrence of a predetermined concentration of gaseous hydrocarbons in an occupied area and providing an alarm. The usual gas detection system employs a sensor that is composed mainly of tin dioxide and exhibits certain

variable resistance characteristics when heated and exposed to gaseous hydrocarbons. Typical of such gas sensors are the TGS 109, TGS 812 and TGS 813 gas sensors available from Figaro Engineering, Inc., of Japan. The Figaro gas sensors have a variable resistance element and a heater connected to electrodes in such a manner that the variable resistance element (the bulk semi-conductor tin dioxide) is heated when the sensor is energized. The resistance between two of the electrodes connected to the resistance element varies in accordance with known characteristics and can be sensed as an indication of gaseous hydrocarbon concentration.

Specifically, the resistance characteristics of this type of gas sensor are such that the resistance value is very high when the semi-conductor material is unheated and is also at a relatively high, stable resistance value after the semi-conductor has been heated for a predetermined time period, usually from 1 to 3 minutes. The resistance value remains at this relatively stable value as long as the heater is energized (barring failure) and decreases from the relatively stable value as a function of the concentration of gaseous hydrocarbons in the vicinity of the resistance element. However, upon initial energization of the heating element, there is a substantial decrease in the resistance value between the time of initial energization of the heating element and the end of the initial 1 to 3 minute heating interval.

In known gas alarms, the value of the resistance element is sensed in order to provide an alarm when the concentration of gaseous hydrocarbons exceeds some predetermined value, usually about 10% of the lower explosive level of the most common gas expected to be encountered. It will be appreciated that if the resistance of the sensor is directly sensed to provide an alarm, an alarm will occur sometime within the first second of initial turn-on as well as when the undesirable level of gas concentration is reached since the resistance at the undesirable gas concentration level is higher than the low value reached during initial turn-on. This is undesirable and, in fact, is not permitted in accordance with U. L. specifications.

Various circuits have been devised to prevent an alarm condition from occurring except after the resistance element has been heated and has reached its relatively stable value. These circuits are extremely complex and therefore are costly and more likely to fail in normal use. Moreover, when fault circuitry is added to detect common malfunctions of such alarm systems, they become even more complex, costly and prone to failure.

It is accordingly another object of this invention to provide a method and circuit for producing a first audible alarm only when the concentration of gaseous hydrocarbon in a protected area reaches a predetermined level and a second audible alarm upon occurrence of common malfunctions in the circuit, wherein complexity is minimized resulting in decreased cost and size, and increased reliability.

BRIEF SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, there is provided a relatively simple, economical and reliable alarm system for providing an alarm upon the occurrence of a predetermined concentration of gaseous hydrocarbon in an area. The alarm system employs a conventional sensor including a gaseous hydrocarbon responsive variable resistance element con-

nected between two electrodes and a heating element for heating the variable resistance element. The resistance between the electrodes is related in value to the resistance of the variable resistance element, which resistance assumes a predetermined, relatively stable resistance value upon energization of the heating means beyond an initial heating (initial action) period. The resistance value of the resistance element decreases from the relatively stable value as a function of the concentration of gaseous hydrocarbons in the vicinity of the sensor and also exhibits a decrease in resistance to an initial action resistance value substantially below the stable value during the initial heating period. A series circuit arrangement comprising first and second switching means each operable between conductive and non-conductive conditions in response to a trigger signal is connected in series with a power source. The switching means produce an alarm signal with both the first and second switching means in the conductive condition and an alarm means is provided to sound an audible alarm in response to the alarm signal. An alarm trigger circuit triggers the first switching means into its conductive condition in response to the variable resistance element decreasing at least to a predetermined resistance value, which resistance value is below the stable value by an amount signifying a predetermined concentration of gaseous hydrocarbons in the vicinity of said resistance element. The predetermined resistance value is above the initial action resistance value occurring during the initial heating period. A delay trigger circuit, including a capacitor having a charging path which is connected to at least a predetermined charge level, upon energization of the heating element. The delay trigger circuit triggers the second switching means into its conductive condition in response to the capacitor achieving the predetermined charge level.

A fault trigger circuit means is connected to the first switching circuit means and intermittently triggers the first switching circuit means into its conductive condition in response to the occurrence of an abnormal condition of the sensor.

In accordance with another aspect of the invention there is provided an alarm system comprising a sensing means for sensing a predetermined alarm condition and generating an alarm signal in response to the sensed condition. An audible alarm means synthesizes and annunciates a predetermined spoken message related to the sensed alarm condition in response to the alarm signal from the sensing means. In one embodiment of the alarm system, the sensing means comprises a gas sensor for sensing the presence of gaseous hydrocarbons in excess of a predetermined concentration. The sensed alarm condition is a concentration of gaseous hydrocarbons above the predetermined concentration and the annunciated message contains the spoken word "gas".

The various features and aspects of the invention with their attendant advantages will be more fully understood with reference to the following detailed description when read in conjunction with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram of a gas alarm system in accordance with one aspect of the present invention;

FIG. 2 is a detailed schematic diagram of one embodiment of the alarm system of FIG. 1;

FIG. 3 is a schematic diagram illustrating one embodiment of the audible alarm of FIGS. 1 and 2 in greater detail;

FIG. 4 is a functional block diagram illustrating an audible alarm according to another aspect of the present invention wherein a spoken message is produced in response to an alarm signal;

FIG. 5 is a functional block diagram illustrating the audible alarm of FIG. 4 in greater detail; and

FIGS. 6B and 6C are graphs illustrating the resistance characteristics of a TGS 109 gas sensor as measured in terms of the signal drop across a load in a measuring circuit such as is illustrated in FIG. 6A.

DETAILED DESCRIPTION

Certain aspects of the present invention are broadly applicable to alarm systems in general but for convenience will be described hereinafter in connection with a specific gas alarm embodiment. The broader applicability of such inventive features will be appreciated by those skilled in the art to which the invention pertains and the coverage of such features is not intended to be limited to the gas alarm environment. Specifically, the spoken word synthesizer and annunciator described hereinafter in greater detail may be used with a variety of alarm systems to ensure immediate recognition of the alarm condition which has been sensed.

Referring now to FIG. 1, a gas sensor and power supply circuit 10 receives power from an a.c. source (e.g., 110 volts 50 or 60 cycle a.c.) and provides power signals (a.c. and +V) and sensor signals RES to an alarm circuit 12. The alarm circuit 12 includes an alarm trigger circuit 14, a delay trigger circuit 16 and a fault trigger circuit 18. Also, included in the alarm circuit are two switching circuits 20 and 22 and an audible alarm 24.

The switching circuits 22 and 20 are connected in a series circuit arrangement across an a.c. power source supplied from the circuit 10. As will be described hereinafter in detail, the switching circuits may be triggered from a non-conductive condition to a conductive condition and, when both switching circuits are conducting, an alarm signal is produced between the circuits 20 and 22. This alarm signal, when produced, is used to sound the audible alarm 24 as will be subsequently described.

The alarm trigger circuit 14 receives the sensor signal RES from the circuit 10. The sensor signal RES is indicative of the resistance value of the gas sensor in the circuit 10, which resistance value is related to the concentration of gaseous hydrocarbons in the vicinity of the sensor. A trigger signal T1 is produced by the trigger circuit 14 in response to a resistance value below a predetermined level representative of a predetermined level of gaseous hydrocarbons. The trigger signal T1 is applied to the trigger input terminal of the switching circuit 20 and this triggers the switching circuit 20 into its conductive state when the sensor signal RES indicates a resistance value below the predetermined level.

As was previously mentioned, the gas sensor resistance characteristic is such that during an initial action or initial heating period of the sensor immediately subsequent to turn-on, the gas sensor resistance drops drastically and then returns to a relatively stable value. This drop in resistance will be below the level required to enable the alarm trigger circuit 14 so the trigger signal T1 will be produced and the switching circuit 20 (S1)

will be triggered to its conductive state. During the initial action period, however, the switching circuit 22 will be non-conductive and an alarm signal will not be produced.

More specifically, the delay trigger circuit 16 is essentially a timing circuit which produces a trigger signal T2 only after the gas sensor and power supply circuit has been energized for a predetermined time period. This delay time is selected such that the delay trigger circuit 16 produces the trigger signal T2 at a time equal or subsequent to the end of the initial action period. Accordingly, the delay trigger signal T2 is produced, and triggers the switching circuit 22 (S2) into conduction after the gas sensor has been energized and has reached its relatively stable resistance value. At that time, the switching circuit 20 is non-conductive, assuming there is no excessive concentration of gaseous hydrocarbons in the vicinity of the sensor. Therefore, the alarm 24 does not sound during the initial action period. Since the switching circuit 22 is held in its conductive state by the delay trigger circuit at the end of the delay period, any subsequent generation of the alarm trigger T1 will trigger the switching circuit 20 into conduction and cause the sounding of a gas alarm.

The fault trigger circuit receives the power supply voltage +V and also receives the sensor signal RES and monitors this signal. One common fault which occurs in gas alarm systems is that the gas sensor becomes open-circuited. The fault trigger circuit monitors this condition as well as other abnormal open circuit conditions and produces the trigger signal 13 when such a condition occurs. As will be seen hereinafter, the trigger signal T3 is a periodic (pulsed) signal and therefore periodically triggers the switching circuit 20 into its conductive state in response to a sensed abnormality. The alarm 24 thus produces a fault signal different from an alarm signal when a fault is sensed.

FIG. 2 illustrates one embodiment of the gas alarm system of FIG. 1 in greater detail. Referring now to FIG. 2, a suitable a.c. power source is connected to a transformer T1 through a fuse F1. A suitable value of a.c. voltage (e.g., 100 volts) is supplied from the primary winding of the transformer via terminals designated a.c. (HI) and a.c. (common) to conventional SCR switches S1 and S2 which are connected in a series circuit arrangement between the a.c. voltage terminals.

A conventional piezoelectric or electromagnetic transducer providing a suitable audible alarm 24 is connected in series between the SCR's 20 and 22 to provide an audible alerting signal when the SCR's are both triggered into conduction. For example, as is illustrated in FIG. 3, the coil of a suitable electromagnetic transducer 26 may be connected in series with the SCR switches 20 and 22 so that current flowing through the switches when both are conducting will be sufficient to drive the transducer and produce an alarm sound.

With continued reference to FIG. 2, the secondary of the transformer T1 produces a voltage suitable to energize the heater of a conventional gas sensor TGS. With a Figaro model TGS 109 the necessary heater voltage is about 1.0 volts a.c., and thus the secondary voltage applied to the heater of the gas sensor from a center tap on the secondary winding is preferably of this value. The voltage across the entire secondary winding with this illustrated arrangement is on the order of 2.0 volts a.c., and is connected across a series limiting resistor R1 and a light emitting diode L1 to provide a "power on" indication.

In the embodiment illustrated in FIG. 2, the gas sensor is a TGS 109 sensor available from Figaro Engineering, Inc. The gas sensor includes electrodes 30A-30D, a heating element 32 and a bulk semi-conductor resistance element 34 composed mainly of tin dioxide. The heater voltage of about 1.0 volts a.c. is connected to the electrodes 30A and 30B. The 100 volt a.c. line voltage a.c. (HI) is connected to terminal 30B and terminals 30C and 30D are connected together and through resistors R2 and R3 to the a.c. (common) terminal. Thus the heater 32 is energized by 1.0 volts and there is a 100 volt potential across the series combination of the resistance element 34 and the resistors R2 and R3. A limiting resistor R12 is connected across the resistance element 34 between terminals 30A and 30C of the sensor.

The resistors R2-R3 junction is connected through a resistor R4 and a potentiometer P1, in series, to the a.c. (common) terminal and through a resistor R5 to the base electrode of a conventional NPN transistor Q1. The collector electrode of transistor Q1 is connected through a resistor R7 and a diode D1 to the transformer terminal a.c. (HI). The emitter electrode of the transistor Q1 is connected to the a.c. (common) terminal.

The arm of the potentiometer P1 is connected through a current limiting resistor R6 to the trigger electrode of the SCR switch 20 and to the cathode or emitter electrode of a conventional voltage sensitive trigger device Q2 (e.g., a trigger transistor or neon bulb). The anode or collector electrode of the trigger device Q2 is connected to the collector electrode of the transistor Q1 and through a series RC network comprising a resistor R9 and a capacitor C1.

The junction of the cathode of the diode D1 and the resistor R7 is connected through series resistors R10 and R11 to the trigger input terminal of the SCR switch 22. The resistor R10-R11 junction is connected through a capacitor C2 to the junction of the SCR switch 22 cathode and the alarm 24. A resistor R8 is connected in parallel with the SCR switch 20 so that a charging path for the capacitor C2 is established through the SCR switch 20 (when conducting) or the resistor R8, the resistor R10 and the diode D1.

To facilitate an understanding of the operation of the FIG. 2 embodiment of the present invention, reference may be had to FIGS. 6A-6C. The gas sensor TGS of FIG. 2 has resistance characteristics approximately as illustrated in FIGS. 6B and 6C when measured (in terms of conductance—the output signal across a load) with the circuit of FIG. 6A. Using the circuit of FIG. 6A, with a heater voltage VH of 1.0 volts and a circuit voltage VC of 100 volts, an output signal VRL across a 4 Kohm resistor RL indicative of variations in resistance of the gas sensor resistance element can be measured.

FIG. 6B shows the initial heating or initial action period of the gas sensor wherein the heater is initially energized at time 0. The graph of FIG. 6B illustrates, for example, that the gas sensor resistance element is essentially an open circuit value (i.e., zero conductivity and thus zero volt output signal) before the heater is energized. At time 0 when the heater is energized, the resistance almost immediately decreases (i.e., conductivity and thus output voltage increases) dramatically to an initial action value. After the initial action or initial heating period which is approximately one minute with the TGS 109 sensor, the resistance value of the resistance element increases and assumes a relatively stable,

high value (i.e., the conductivity drops and the output signal assumes a low value of about 2 to 3 volts).

FIG. 6C illustrates the resistance of the gas sensor resistance element when operating in the relatively stable region after initial heating (i.e., after about 1 minute and preferably after about 3 minutes) and when various types of lower gaseous hydrocarbons are introduced in various concentrations in the vicinity of the sensor. It can be seen from FIG. 6C that when concentrations of from 0 to 4000 parts per million (ppm) of various lower hydrocarbon gases are introduced, the resistance of the gas sensor resistance element decreases (the output signal increases) as a function of the concentration of the gas in the vicinity of the sensor.

Ordinary household gas primarily contains the low hydrocarbons and thus these gases (e.g., methane, propane, butane and ethane) are of primary interest in a residential or office building setting. In this regard, the alarm circuit is preferably set so as to provide an audible signal when the concentration of such gases in the vicinity of the sensor reaches a level of about 10% of the lower explosive limit (e.g., about 2000 ppm). It will be appreciated, however, that other hydrocarbons in gaseous states also cause the sensor to exhibit similar resistance changes in their presence. Thus, for example, the resistance of the gas sensor resistance element will vary inversely with the concentration of hydrogen, ammonia and carbon monoxide as well as the fumes of common organic solvents such as ethanol, acetone, n-hexane and benzene.

With reference once again to FIG. 2, the operation of the gas alarm is as follows. Power is initially supplied to the transformer T1, energizing the gas sensor TGS and the alarm circuit. When the heater 32 is initially energized, there is a substantial decrease in the resistance value of the resistance element 34 and the voltage at the arm of potentiometer P1 increases in a manner similar to that illustrated in FIG. 6B. Accordingly, during the initial heating interval (i.e., for about the first minute of energization), the SCR switch 20 is triggered into conduction by the trigger circuit 14.

Simultaneously, the SCR switch 22 is in a non-conductive condition since the capacitor C2 is uncharged and the voltage from the trigger circuit 16 is initially zero. Current flows through the resistor R8 (and the switch S1 when conducting), through the alarm 24, through the capacitor C2, through the resistor R10 and through the diode D1. These elements form an RC timing circuit, and the capacitor C2 charges through the above charging path to a level sufficient to trigger the SCR switch 22 into conduction over a period of time in excess of the initial action or heating period of the gas sensor. In the illustrated embodiment, the capacitor C2 and the components in the charging path are selected such that the capacitor C2 charges to the appropriate trigger level after about 2 to 3 minutes, well beyond the end of the initial action period.

When the initial action period ends, the resistance of the resistance element 34 assumes a relatively stable value sufficiently high to lower the voltage of the trigger signal T1 to a level insufficient to trigger the SCR switch 20. The SCR switch 20 becomes non-conductive and the capacitor C2 continues to charge through the resistor R8. Shortly thereafter, the capacitor C2 reaches a level of charge sufficient to trigger the SCR switch 22 into conduction, in which state it remains while the alarm circuit is energized.

It will thus be appreciated that the SCR switches 20 and 22 are alternately conductive during the initial action period but do not conduct simultaneously. The charging current of capacitor C2 passing through the alarm 24 is insufficient to sound the alarm and thus no audible signal occurs during the initial action period despite the substantial drop in the resistance of the resistance element 34 during this period. However, after the capacitor C2 is charged and the SCR switch 22 is conductive, any triggering of the SCR switch 20 will sound the alarm.

With the above conditions established (i.e., after about three minutes from energization), gaseous hydrocarbons in the vicinity of the sensor TGS will cause a decrease in sensor resistance and an increase in the voltage level of the trigger signal T1. The potentiometer P1 is preferably adjusted so that when the concentration of the most common household gaseous hydrocarbons (the lower hydrocarbons C1 to C4) in the vicinity of the sensor is about 2000 ppm (10% of the lower explosive limit), the trigger signal T1 is of a sufficient voltage to trigger the SCR switch 20 into conduction. Accordingly, in the presence of gaseous hydrocarbons of a predetermined concentration or greater, the SCR switch 20 will be triggered and, since the SCR switch 22 is already conductive, an alarm signal will be produced at the junction of the switches 20 and 22 and an alarm will be sounded. This alarm will be a steady tone in the illustrated embodiment and will continue until the gas concentration decreases below the predetermined value.

Since one of the most common failures of the type of gas sensor illustrated is for the sensor resistance element to be open-circuited, the trigger circuit 18 (T3) is provided to detect such a condition and sound a failure alarm. When the gas alarm circuit is energized, the transistor Q1 is turned on as long as there is a certain detectable current flow through the gas sensor resistance element. These resistance elements may vary widely in resistance and some, even though they are good, may be quite high. A limiting resistor R12 is thus provided in parallel with the sensor so that the parallel combination of sensor resistance element 34 and resistor R12 will provide the necessary current flow to maintain the transistor Q1 in conduction as long as the circuit is energized and the gas sensor resistance element is not open-circuited.

With the transistor Q1 on, the capacitor C1 remains discharged and the trigger device Q2 remains non-conductive. However, if the gas sensor resistance element opens or if some other open circuit fault occurs in the sensing circuit and the RES signal drops below the level required to hold the transistor Q1 on, then the transistor Q1 is cut off and the voltage across resistor R9 and capacitor C1 is allowed to increase toward the voltage +V. The capacitor C1 thus charges and, when the trigger level of the trigger device Q2 is reached, the capacitor C1 discharges through the device Q2, producing the trigger signal T3 and triggering the SCR switch 20 into conduction. Conduction of the SCR switch 20 causes the production of an alarm signal, sounding the alarm 24.

Eventually, the capacitor C1 discharges sufficiently to allow the trigger device Q2 to turn off. In this regard, it should be noted that the trigger device is a conventional device such as a semi-conductor trigger or neon bulb that has a trigger level higher than its sustaining level. The trigger signal T3 is thus removed and the

alarm turns off. Of course, when the device Q2 becomes non-conductive, the capacitor C1 again charges and, after a predetermined time, again triggers the trigger device Q2 and sounds the alarm. Thus, a periodic or intermittent audible alarm, different from the steady gas alarm sound, is produced when a fault is detected.

Typical circuit values to achieve operation of the gas alarm as described above with a Figaro TGS 109 gas sensor may be as listed below:

D1 Diode, 1N4004 or equiv.

C1 Capacitor, 2 mfd. Aluminum Electrolytic, 50 volt

C2 Capacitor, 1000 mfd. Aluminum Electrolytic, 6.3 volt

H1 Horn, Kobishi Type CLB 26 or Edwards Type 123-N5, 120 VAC

L1 LED, red

P1 Potentiometer, 500 ohms.

Q1 Transistor, 2N2925 or equiv.

Q2 Trigger, 1N5160 Motorola

Q3 SCR, 2N5064 Motorola

Q4 SCR, 2N5064 Motorola

R1 Resistor, 47 ohms, $\frac{1}{4}$ watt

R2 Resistor, 3.3 Kohms, 2 watt

R3 Resistor, 920 ohms, $\frac{1}{2}$ watt

R4 Resistor, 3.9 Kohms, $\frac{1}{4}$ watt

R5 Resistor, 22 Kohms, $\frac{1}{4}$ watt

R6 Resistor, 4.7 Kohms, $\frac{1}{4}$ watt

R7 Resistor, 1 Meg ohms, $\frac{1}{4}$ watt

R8 Resistor, 100 Kohms, $\frac{1}{4}$ watt

R9 Resistor, 10 Kohms, $\frac{1}{4}$ watt

R10 Resistor, 10 Meg ohms, $\frac{1}{4}$ watt

R11 Resistor, 100 Kohms, $\frac{1}{4}$ watt

R12 Resistor, 220 Kohms, $\frac{1}{2}$ watt

T1 Transformer, to desired specifications

As was previously mentioned, the alarm 24 may be a suitable piezoelectric or electromagnetic transducer such as that illustrated in FIG. 3. With such a transducer, the alarm signal, in the form of current above a predetermined level flowing when both switches are conductive, may be supplied directly to the transducer through a coil, as illustrated or through the piezoelectric element. Alternatively, an alarm signal may be developed across a suitable load and supplied to an audible alarm device (not shown).

According to another aspect of the present invention, the audible alarm may be provided in the form of a spoken message. Since several alarm systems for different conditions may be located within a building, the spoken message will assist in an immediate determination of which alarm has been triggered.

One embodiment of a circuit for providing such a system is illustrated in FIGS. 4 and 5. As is shown in FIG. 4, the alarm signal produced by an alarm circuit such as a gas alarm circuit may be applied to a word synthesizer 36 which, when triggered, provides an audio signal AUD representing a spoken message. The audio signal AUD may be applied to a suitable annunciator 38 for conversion to an audible message.

The word synthesizer 36 is preferably a digital device including a memory for storing an encoded spoken message. As is illustrated in FIG. 5, for example, the alarm signal may be a d.c. level which, when high on binary ONE, enables an oscillator 40. The oscillator 40 clocks a suitable memory such as a circulating shift register 42 in order to clock the digitally encoded message to a speaker 46 or other suitable annunciator by way of a smoothing filter 44, if required by the annunciator to smooth the digital signal from the memory.

It will be appreciated that a spoken message such as the word "gas" can be stored in a register or other memory as a series of pulses of various spacing, width or, in sample and hold type memories, various amplitudes. These pulses, when read out of the memory in a prearranged sequence, produce an average d.c. level that electrically represents the modulation involved in the production of a spoken message such as the word "gas". Accordingly, when the pulses are applied to a suitable annunciator (after filtering to produce an average d.c. level, if required), a desired spoken message is produced.

The memory will, of course, vary in capacity depending upon the length and complexity of the spoken message and the type of encoding employed. Moreover, it will be appreciated that various types of commercially available memories or even commercially available word synthesizers may be utilized. Thus, for example, the oscillator 40 or other suitable timing device may clock an address generator which, in turn, may address a read only memory (ROM) in a predetermined sequence. Moreover, various sequences or plural synthesizers may be used to provide various messages in each alarm device. Thus, a gas alarm may produce the messages "gas", "fault" and "replace battery" (if it is a battery operated device). A smoke detector may have one or more synthesizers to produce the messages "fire" (or "smoke"), "fault" and "replace battery". An intrusion alarm may have synthesizers to produce messages such as "intruder-rear door", "intruder-front door", "intruder-rear window", etc., depending upon which alarm sensor is triggered.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore considered in all respects as illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. An alarm system for providing an alarm upon the occurrence of a predetermined concentration of gaseous hydrocarbon in an area comprising:

a sensor including a gaseous hydrocarbon responsive variable resistance element connected between two electrodes and means for heating said variable resistance element, the resistance between said electrodes being related in value to the resistance of said variable resistance element, the resistance of said variable resistance element assuming a predetermined, relatively stable resistance value upon energization of said heating means beyond an initial heating period, and said resistance value decreasing from said relatively stable value as a function of the concentration of gaseous hydrocarbons in the vicinity of said sensor, and a decrease in said resistance value to an initial action resistance value substantially below said stable value during the initial heating period;

a series circuit arrangement comprising first and second switching means connected in series with a power source, each of said switching means being operable between conductive and non-conductive conditions in response to a trigger signal, said switching means producing an alarm signal with

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both the first and second switching means in the conductive condition;
alarm means for sounding an audible alarm in response to said alarm signal;
first trigger circuit means for triggering said first switching means into its conductive condition in response to said variable resistance element decreasing at least to a predetermined resistance value, which resistance value is below said stable value by an amount signifying a predetermined concentration of gaseous hydrocarbons in the vicinity of said resistance element, said predetermined resistance value being above said initial action resistance value occurring during said initial heating period;
second trigger circuit means including a capacitor having a charging path which includes said first switching means and connected to be charged to at least a predetermined charge level upon energization of said heating means, said second trigger circuit means triggering said second switching means into its conductive condition in response to said capacitor achieving said predetermined charge level; and

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third trigger circuit means connected to said first switching circuit means for intermittently triggering said first switching circuit means into its conductive condition in response to the occurrence of an abnormal condition of said sensor.

2. The alarm system of claim 1 wherein said alarm means is connected in series between said first and second switching means and comprises a current responsive audible alarm for generating an audible tone in response to current flow therethrough above a predetermined value.

3. The alarm system of claim 2 wherein said current responsive audible alarm is a piezoelectric transducer.

4. The alarm system of claim 1 including a limiting resistor connected in parallel with said sensor between said first and second electrodes to maintain said stable value of resistance of said resistance element at a value below an apparent open circuit value.

5. The alarm system of claim 1 wherein said alarm means is connected to receive said alarm signal produced between said first and second switching means and comprises means for synthesizing and annunciating a predetermined spoken message related to a sensed alarm condition.

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EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
de	AA	3 8 3 9 6 1 6	10/1/74	Risman	219	10.55	
pre	AB	4 0 9 7 7 0 7	6/27/78	Kobayashi et al	219	10.55B	
me	AC	4 1 3 3 9 9 5	1/9/79	Buck	219	10.55M	
mp	AD	4 1 5 4 8 5 5	5/15/79	Buck	426	243	
me	AE	4 1 6 2 3 8 1	7/24/79	Buck	219	10.55B	
pf	AF	4 1 6 6 1 3 7	8/28/79	Buck	426	243	
me	AG	4 1 7 1 3 8 2	10/16/79	Buck	426	243	
me	AH	4 2 2 1 9 4 9	9/9/80	Minakawa	219	10.55C	
pf	AI	4 2 8 1 0 2 2	7/28/81	Buck	426	233	
me	AJ	4 2 9 5 0 2 8	10/13/81	Tanabe	219	10.55B	
me	AK	4 3 1 1 8 9 5	1/19/82	Tanabe	219	10.55B	

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION	
							YES	NO
AL								
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OTHER PRIOR ART (Including Author, Title, Date, Pertinent Pages, Etc.)

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EXAMINER
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PETER H. SMITH

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U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	AA	3 8 3 9 6 1 6	10/1/74	Risman	219	10.55	
	AB	4 0 9 7 7 0 7	6/27/78	Kobayashi et al	219	10.55B	
	AC	4 1 3 3 9 9 5	1/9/79	Buck	219	10.55M	
	AD	4 1 5 4 8 5 5	5/15/79	Buck	426	243	
	AE	4 1 6 2 3 8 1	7/24/79	Buck	219	10.55B	
	AF	4 1 6 6 1 3 7	8/28/79	Buck	426	243	
	AG	4 1 7 1 3 8 2	10/16/79	Buck	426	243	
	AH	4 2 2 1 9 4 9	9/9/80	Minakawa	219	10.55C	
	AI	4 2 8 1 0 2 2	7/28/81	Buck	426	233	
	AJ	4 2 9 5 0 2 8	10/13/81	Tanabe	219	10.55B	
	AK	4 3 1 1 8 9 5	1/19/82	Tanabe	219	10.55B	

FOREIGN PATENT DOCUMENTS

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APPLICANT

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AMINER TIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	AA	4 3 1 6 0 6 8	2/16/82	Tanabe	219	10.55B	
	AB	4 3 1 9 1 1 0	5/9/82	Tanabe et al	219	10.55B	
	AC	4 3 3 1 8 5 5	5/25/82	Tanabe	219	10.55B	
	AD	4 3 3 5 3 7 9	5/15/82	Martin	340	634	
	AE						
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	AG						
	AH						
	AI						
	AJ						
	AK						

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION	
							YES	NO
	AL	0 0 3 1 1 5 6	1/7/81	Europe			X	
	AM							
	AN							
	AO							
	AP							

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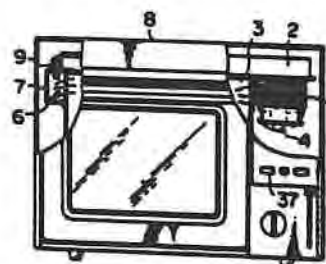
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14 Cooking oven with multifunctional gas sensor.

17 A cooking oven in which a ceramic gas sensor (9) is disposed in an exhaust guide (7) guiding air from within the oven chamber (3) toward the exterior of the oven casing (8) and the surface temperature of the ceramic gas sensor is changed to change the sensing characteristic of the sensor, so that the single sensor can sense both of water vapor and soot given off from food being cooked. A voltage source including a stabilized direct current voltage source and a non-stabilized or alternating current voltage source is provided for supplying power to the ceramic gas sensor. In the soot sensing mode, the surface of the ceramic gas sensor is heated by the power supplied from the stabilized direct current voltage source to stabilize the soot sensing characteristic of the sensor. An electronic circuit controlling the cooking operation includes a plurality of amplifiers having different gains which are suitably selected to deal with the humidity sensing mode and the soot sensing mode.

FIG.1



1 This invention relates to a cooking oven having a microwave generator and a heater.

 With the progress of the technology of transducer elements or so-called sensors used for
5 transducing temperature, humidity and other information into corresponding electrical signals and also with the progress of the microcomputer technology, a great progress has also been made in the field of cooking apparatus, and an automatic microwave oven has become
10 put into practical use in which, after the user puts materials to be cooked in the oven chamber and merely orders to start required cooking operation, a sensor installed in the microwave oven senses a change in the relative humidity of air in the oven chamber due to
15 vapor given off from the foodstuff, and a microcomputer makes necessary data processing and generates a command signal instructing the end of the cooking operation or changing the output level of the microwave power required for cooking. However, in spite of the fact
20 that a variety of information of components including vapor, soot and volatile matters of very small amounts must be sensed for the attainment of successful cooking, the unifunctional sensor employed in the prior art microwave oven of automatic type above described
25 has not been capable of sensing the components such as

1 the soot and volatile matters of very small amounts.

It is an object of the present invention to realize an automatic microwave oven having a heater function and provided with a multifunctional gas sensor
5 which can singly sense both of humidity and soot, given off from a foodstuff.

It is another object of the present invention to provide a microwave oven including a foodstuff heater means and a microwave energy generating means,
10 in which a ceramic gas sensor, whose sensing part is made of a ceramic compositions and which is provided with a heater heating the sensing part, is disposed in an exhaust guide, and the temperature level of heat applied to the sensing part of the sensor is varied by
15 a control signal applied from an electronic circuit controlling the foodstuff heater means and microwave energy generating means thereby changing the sensing characteristic of the sensor, so that the single sensor can sense both of humidity and soot which are different
20 from each other in character and are required as information for the achievement of successful cooking.

Another object of the present invention is to provide a microwave oven of the above character in which the sensing part of the sensor is heated at one
25 of temperature levels depending on the cooking information to be sensed by the sensor, that is, the sensing part is heated at a low temperature level to prevent dewing thereon when a change in the relative humidity

1 of air in the oven chamber due to vapor given off from
a foodstuff is to be sensed, while it is heated up to
a relatively high but stable temperature level when the
soot given off from the foodstuff is to be sensed.

5 Still another object of the present invention
is to provide a microwave oven of the above character,
in which, in spite of the fact that the level of the
sensor output signal during the soot sensing operation
differs greatly from that of the sensor output signal
10 during the humidity sensing operation, the electronic
circuit can process the individual sensor output
signals with the substantially same reliability.

The above and other objects, features and
advantages of the present invention will become more
15 apparent from the following detailed description taken
in conjunction with the accompanying drawings, in which:

Fig. 1 is a partly cut-away front elevation
view of an embodiment of the microwave oven provided
with a ceramic gas sensor according to the present
20 invention;

Fig. 2 is a partly cut-away front perspective
view of the microwave oven provided with the ceramic
gas sensor according to the present invention;

Fig. 3 is a partly cut-away rear perspective
25 view of the microwave oven provided with the ceramic
gas sensor according to the present invention;

Fig. 4 is an external general view of the
microwave oven provided with the ceramic gas sensor

1 according to the present invention;

Fig. 5 is a perspective view of the ceramic gas sensor;

Fig. 6 is an enlarged detail view of the sensing part of the ceramic gas sensor shown in Fig. 5;

Fig. 7 is a graph showing the relative humidity vs. resistance characteristic of the ceramic gas sensor;

Fig. 8 is a graph showing the output voltage characteristic of the amplifiers relative to the resistance of the ceramic gas sensor;

Fig. 9 is a graph showing the soot sensing characteristic of the ceramic gas sensor;

Fig. 10 is a sketch of the structure of the electronic circuit;

Fig. 11 is a circuit diagram showing the structure of the voltage source supplying power to the heater heating the surface of the ceramic gas sensor;

Fig. 12 is a circuit diagram of the electronic circuit when the ceramic gas sensor is making its humidity sensing operation;

Fig. 13 is a graph showing the time-depending change of the comparator input voltage when the ceramic gas sensor is making the humidity sensing operation;

Fig. 14 is a circuit diagram of the electronic circuit when the ceramic gas sensor is making its soot sensing operation;

Fig. 15 is a graph showing the time-depending

- 1 change of the comparator input voltage when the ceramic
gas sensor is making the soot sensing operation;

Fig. 16 is a circuit diagram of the microwave
oven control circuit including a microcomputer;

- 5 Fig. 17 is a circuit diagram similar to Fig.
16 but including means for switching over the gain of
the amplifiers;

Fig. 18 is a flow chart showing the steps of
cooking carried out under control of the microwave oven
10 control circuit; and

Fig. 19 is a perspective view of a modifica-
tion of the ceramic gas sensor in which the heater is
replaced by a plane one.

Referring now to Figs. 1 to 4, the microwave
15 energy generated by a magnetron 1 is guided by a wave
guide 2 to be directed toward and into an oven chamber
3 of a microwave oven and is absorbed by materials
placed in the oven chamber 3 to be cooked by the micro-
wave energy. An air stream produced by a cooling fan
20 4 provided for cooling the magnetron 1 passes through
a punched portion 5 of one of the side walls of the
oven chamber 3 to flow into the oven chamber 3. Then,
the air stream passes through a punched portion 6 of
the other side wall of the oven chamber 3 to flow out
25 from the oven chamber 3 and is guided by an exhaust
guide 7 to be discharged to the exterior of the casing
8 of the microwave oven. A sensor 9 as shown in Fig.
5 is installed in the exhaust guide 7, and its sensing

1 part 13 is made of a ceramic composition. This sensor
9 will therefore be called a ceramic gas sensor herein-
after. An electronic circuit 10 is installed in the
casing 8 of the microwave oven so as to control all the
5 functions of the microwave oven on the basis of cooking
parameter information sensed by the ceramic gas sensor
9. A plurality of punchings 10a are provided in the
rear wall of the oven chamber 3 so that heat generated
by a heater element 11 can be transmitted into the oven
10 chamber 3 through the punchings 10a by the rotation of
a fan 12 which directs a stream of hot air.

The sensing part 13 of the ceramic gas sensor
9, which is an important element of the microwave oven
according to the present invention, is made of a metal-
15 oxide ceramic composition having a porous structure as
shown in Fig. 6. In the present invention, the fact
that the electro-conductivity of the metal-oxide ceramic
composition is variable depending on the amount of
water adsorbed to the porous ceramics, is utilized to
20 sense the relative humidity of the internal air of the
oven chamber 3 of the microwave oven cooking a foodstuff
or the soot given off from the foodstuff being cooked.
The metal-oxide ceramic composition employed in the
present invention is a sintered porous ceramic mixture
25 of MgCr_2O_4 (magnesium chromate) and TiO_2 (titanium
oxide). In the ceramic gas sensor 9, a heater 14 is
associated with the sensing part 13 to apply heat to
the sensing part 13 to burn out contaminants

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1 accumulating on or adhering to the surface of the sensing
part 13 thereby keeping clean the surface of the sensing
part 13, so that the ceramic gas heater 9 can fully
exhibit its performance even under a severe operating
5 condition in which it may be exposed to oil vapor and
other organic vapor given off from a foodstuff being
cooked on it may be subject to dewing during cooking.

This ceramic gas sensor 9 shows its sensitivity
to a change in the relative humidity from 0% to 100% as
10 shown in Fig. 7, and the resistance of its sensing part
13 changes over a considerably wide range of from about
 $10^8 \Omega$ to about $10^4 \Omega$ as shown by the curve in Fig. 7.
Therefore, in order to transduce the resistance changing
over such a wide range into an output voltage changing
15 correspondingly, an amplifier providing such an output
voltage which changes generally smoothly all over the
changeable resistance range as shown by the solid curve
in Fig. 8, is essentially required. The dotted curve
represents the soot sensing characteristic.

20 The dotted curve in Fig. 9 shows a resistance
change in the sensing part 13 relative to the tempera-
ture when the ceramic gas sensor 9 is exposed to air
containing soot. The solid curve in Fig. 9 represents
the temperature vs. resistance characteristic of the
25 ceramic gas sensor 9 when it is exposed to soot-free
air. Fig. 9 shows that, when soot is present in the
ambient air, the sensing part 13 of the ceramic gas
sensor 9 senses volatile matters such as hydrocarbons

1 and aldehydes of very small amounts contained in the
soot, and the resistance of the sensing part 13 becomes
higher than when such matters are not present. The
higher the temperature, the more is the rate of change
5 of the resistance of the sensing part 13. This rate
 ΔR of change of the resistance of the sensing part 13
is such that the resistance value changes from about
 $10^4 \Omega$ to about $10^5 \Omega$ in the vicinity of 450°C and is
thus very small compared with that observed when the
10 relative humidity of air or the content of water vapor
in air changes from 0% to 100%. Therefore, another
amplifier used in the soot sensing operation need not
exhibit its amplification performance over a wide
resistance range unlike that used in the humidity
15 sensing operation, but it is required to provide a large
gain in a resistance range of from about $10^4 \Omega$ to about
 $10^6 \Omega$. The level of the voltage applied across the
heater 14 during the humidity sensing operation is also
selected to differ from that applied across the heater
20 14 during the soot sensing operation. In the case of
the humidity sensing operation, the level of the voltage
applied across the heater 14 to heat the sensing part
13 is such that the temperature of the heated sensing
part 13 is higher by about 5°C than room temperature so
25 that the sensing part 13 may not be subject to dewing
thereby preventing or avoiding degradation of the
humidity sensing characteristic. On the other hand,
in the case of the soot sensing operation, it is

- 9 -

1 necessary to heat the sensing part 13 up to about 450°C
at which the ceramic gas sensor 9 shows its high
sensitivity to soot.

Fig. 10 is a sketch of the structure of the
5 electronic circuit 10. The circuit 10 acts as a
humidity sensing circuit when a switch 15 is switched
to the position connecting the sensor 9 to an amplifier
16 participating in the humidity sensing operation, and
another switch 17 is switched to the position connecting
10 the heater 14 to a low-voltage source 18 which supplies
power of low level consumed by the heater 14 to avoid
dewing. On the other hand, the circuit 10 functions as
a soot sensing circuit when the switch 15 is switched
to the position connecting the sensor 9 to another
15 amplifier 19 participating in the soot sensing operation,
and the switch 17 is switched to the position connecting
the heater 14 to a high-voltage source 20 which supplies
power of high level consumed by the heater 14. The
output voltage generated from each of these amplifiers
20 16 and 19 is compared in a comparator 21 with an output
voltage generated from a reference voltage generator 22,
and the resultant output voltage appears from the
comparator 21. On the basis of the relation between
the reference voltage and the output voltage of the
25 comparator 21, the present level of the output voltage
or the resistance value of the sensing part 13 of the
ceramic gas sensor 9 can be detected.

Fig. 11 is a circuit diagram of the voltage

- 10 -

1 source for the heater 14. When a switch 23 is switched
to the position N.O. and another switch 24 is closed,
the secondary voltage of a transformer 25 is applied
across the heater 14, and the heater 14 heats the sensing
5 part 13 of the ceramic gas sensor 9 up to a temperature
higher than about 500°C to burn out contaminants such
as oil vapor and dust accumulating on or adhering to the
surface of the sensing part 13. This is the so-called
refreshing operation which is necessarily carried out
10 prior to cooking so as to prevent or avoid degradation
of the sensitivity of the sensor 9. On the other hand,
when the switch 24 is opened with the switch 23
maintained in the position N.O., the voltage obtained
by dividing the secondary voltage of the transformer 25
15 by a resistor 26 and the resistance of the heater 14 is
applied across the heater 14, and the heater 14 warms
up the sensing part 13 of the ceramic gas sensor 9 to
avoid dewing on the sensor 9 making the humidity sensing
operation. When the switch 23 is then switched to the
20 position N.C., the secondary AC voltage of the trans-
former 25 is applied across the heater 14 after being
converted into a stabilized direct current voltage by
a stabilized direct current voltage supply circuit 25-a,
and the heater 14 heats the sensing part 13 of the
25 ceramic gas sensor 9 up to about 450°C. Such a power
supply system is thus effective in stabilizing the soot
sensing characteristic of the ceramic gas sensor 9
regardless of variations of the power supply voltage.

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1 Fig. 12 is a circuit diagram of the electronic
circuit 10 when the ceramic gas sensor 9 is making the
humidity sensing operation. The circuit includes
capacitors 13-a and 13-b which are provided so that
5 direct current components, which may be superposed on
the pulse input or signal and applied to the sensing
part 13 of the ceramic gas sensor 9, may not cause
electrolysis of the metal-oxide ceramic composition
resulting in degradation of the sensitivity of the
10 sensor 9. The signal voltage divided by the resistance
of the sensing part 13 and a resistor 27 is applied to
a first operational amplifier 14-a in which the signal
voltage is amplified by the factor determined by the
ratio between the resistance values of resistors 14-c
15 and 14-d and has its phase inverted. The output voltage
of the first operational amplifier 14-a is then
amplified by a second operational amplifier 14-b by the
factor determined by the ratio between the resistance
values of a resistor 28 and a feedback resistor group
20 29 and has its phase similarly inverted. The resultant
output voltage of the second operational amplifier 14-b
is applied as an input to the comparator 21. Thus, the
signal voltage is applied as one of the inputs to the
comparator 21 after being subjected to the two-stage
25 inverting amplification. Diodes 30 and 31 are connected
in series with the associated resistors respectively in
the feedback resistor group 29 to function as switching
diodes. These switching diodes act to suitably change

1 over the resistance of the feedback resistor group 29
depending on the level of the amplifier output voltage
so that the amplifier output voltage can make a generally
smooth change during a change of the resistance of the
5 sensing part 13 of the ceramic gas sensor 9 between
about $10^4 \Omega$ and about $10^8 \Omega$.

Fig. 13 shows the time-depending change of the
input voltage applied to the comparator 21. In the
range (A), the comparator input voltage increases due
10 to the fact that the temperature of the sensing part 13
rises owing to the refreshing operation and the
resistance value of the sensing part 13 becomes small.
Upon attainment of the cleaning temperature, the voltage
source for the heater 14 is switched over so that it
15 serves the dewing preventive function. Thus, in the
range (B), the resistance value of the sensing part 13
becomes large and the comparator input voltage
decreases. In the range (C), the sensing part 13 is
sufficiently cooled by the air stream to show the
20 humidity sensing characteristic, and the comparator
input voltage increases again. Cooking is continued in
such a condition resulting in a rise of the temperature
of the air in the oven chamber 3 and in a decrease of
the relative humidity of the air in the oven chamber.
25 Thus, in the range (D), the resistance value of the
sensing part 13 of the ceramic gas sensor 9 becomes
gradually large, and the comparator input voltage
decreases gradually. Then, when water vapor begins to

- 13 -

1 be given off from materials being cooked, the relative
humidity of air in the oven chamber 3 increases rapidly,
and the resistance value of the sensing part 13 of the
ceramic gas sensor 9 begins to become small. Thus, in
5 the range (E), the comparator input voltage starts to
increase again. The increment ΔV of the comparator
input voltage from its lowest level in the range (E) is
detected so as to control the cooking operation.

Fig. 14 is a circuit diagram of the electronic
10 circuit 10 when the ceramic gas sensor 9 is making the
soot sensing operation. The amplification characteristic
of the amplifiers in this circuit is as represented by
the dotted curve in Fig. 8.

Fig. 15 shows the time-depending change of
15 the comparator input voltage when the ceramic gas sensor
9 is making the soot sensing operation. In the range
(A) in Fig. 15, the comparator input voltage increases
because of the refreshing operation. Upon complete
burn-out of contaminants accumulating on or adhering
20 to the surface of the sensing part 13 of the ceramic
gas sensor 9, the voltage source for the heater 14 is
switched over to carry out the heating function for
heating the sensing part 13 up to about 450°C. The
resistance value of the sensing part 13 becomes
25 gradually large as the ceramic gas sensor 9 is exposed
to soot containing volatile matters such as hydrocarbons
and aldehydes. Thus, in the range (B), the comparator
input voltage starts to decrease. It is the detection

- 14 -

1 level at which the voltage level is lowered by the
decrement ΔV from that applied to the heater 14 to
start heating of the sensing part 13 up to about
450°C.

5 Fig. 16 is a circuit diagram of one form of
the microwave oven control circuit including a micro-
computer 31-a as a control means. Upon depression of
a start button 32 (Fig. 4), a start switch 33 is closed
to close a contact 34-a and open a contact 34-b of a
10 semiconductor switch 34, and an amplifier 35 for the
humidity sensing purpose is selected, while, at the
same time, a refreshing operation relay 36 is energized.
Upon attainment of the refreshing temperature, the
refreshing operation relay 36 is deenergized to change
15 over the voltage applied across the heater 14. When, on
the other hand, the start button 32 is depressed after
depression of a grill key 37 (Fig. 4), a grill switch
38 is turned on to open the contact 34-a and close the
contact 34-b of the semiconductor switch 34 after the
20 refreshing operation. An amplifier 39 for the soot
sensing purpose is now selected, and a heating relay
40 is energized to change over the voltage applied
across the heater 14. A D-A converter 41 includes a
C-MOS IC 42 and a ladder type resistance network 43
25 connected to five output terminals of the IC 42, so
that a 5-bit information output from the microcomputer
31-a can be converted into one of 2^5 (= 32) voltage
levels. Further, depression of the start button 32

- 15 -

1 energizes the coil of a relay 44. Therefore, when a
door switch 46 of the microwave oven is in its closed
position, the power supply voltage is applied across
the primary side of a high-voltage transformer 45 to
5 induce a high voltage in the secondary side of the
transformer 45 thereby causing oscillation of the
magnetron 1. The microcomputer 31-a detects or
calculates ΔV in Fig. 13 on the basis of the information
including the output voltage of a comparator 47 and the
10 reference voltage applied to the comparator 47 and
finally deenergizes the relay 44 to end the cooking
operation.

When the start button 32 is depressed after
depression of the grill key 37, the coil of a relay 48
15 is energized to energize the heater 11 disposed outside
of the oven chamber 3. The microcomputer 31-a detects
or calculates ΔV in Fig. 15 on the basis of the infor-
mation including the output voltage of the comparator
47 and the reference voltage applied to the comparator
20 47 and finally deenergizes the relay 48 to end the
cooking operation.

Fig. 17 shows a partial modification of the
circuit shown in Fig. 16. In this modification, a pair
of switches 47-a and 47-b are provided for switching
25 over the resistors in the feedback resistance group 29
associated with the operational amplifier 14-b. The
operational amplifier 14-b functions as a humidity
sensing purpose amplifier when the switch 47-a is closed

- 16 -

1 and the switch 47-b is opened, and as a soot sensing
purpose amplifier when the switch 47-a is opened and
the switch 47-b is closed. Fig. 18 is a flow chart
showing the aforementioned steps of cooking carried out
5 under control of the microcomputer 31-a.

Fig. 19 shows a modification of the ceramic
gas sensor 9 shown in Fig. 5. In Fig. 19, the coil
heater 14 is replaced by a plane one 48, and such a
plane heater 48 is mounted on the surface of the sensing
10 part 13 of the ceramic gas sensor 9.

It will be understood from the foregoing
detailed description that the present invention comprises
a ceramic gas sensor, means for changing the level of
heat applied to the sensing part of the ceramic gas
15 sensor, and amplifiers having different gains. Accord-
ing to the present invention, the single sensor can
sense both of a change in the relative humidity of air
in the oven chamber due to vapor given off from materials
being cooked and volatile matters contained in soot given
20 off from the materials being cooked. The present
invention is therefore advantageous in that the state
of cooking a "grill menu", which could not be sensed by
resorting only to the humidity sensing characteristic
of a prior art unifunctional gas sensor, can be auto-
25 matically sensed so that the microwave oven can be used
for the cooking of a variety of menus.

- 1 -

WHAT IS CLAIMED IS:

1. A cooking oven with a multifunctional gas sensor comprising:

a casing (8);

an oven chamber (3) accomodating food to be cooked;

a microwave generator (1) supplying microwave energy toward and into said oven chamber accommodating the food therein;

a heater element (11) heating the food placed in said oven chamber;

an air guide (7) guiding air from within said oven chamber toward the exterior of said casing;

a ceramic gas sensor (9) disposed in said air guide;

heater means (14) for heating the surface of said ceramic gas sensor;

a control circuit (10) controlling the operation of said microwave generator and said heater element selectively in response to the output signal from said ceramic gas sensor and changing over the heating temperature level of said sensor-heating heater means depending on the kind of gas to be sensed; and

switching means (17) for changing the surface temperature of said ceramic gas sensor in response to a control signal applied from said control circuit.

2. A microwave oven as claimed in Claim 1, wherein said heater means (14) for heating the surface

- 2 -

of said ceramic gas sensor (9) is connected to power source means including a stabilized direct current power source (25-a) and an alternating current power source (25) which are selectively switched over by said switching means.

3. A microwave oven as claimed in Claim 1, wherein said control circuit includes a plurality of amplifiers (16, 19) having different gains for amplifying the output signal from said ceramic gas sensor.

□

□

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FIG. 1

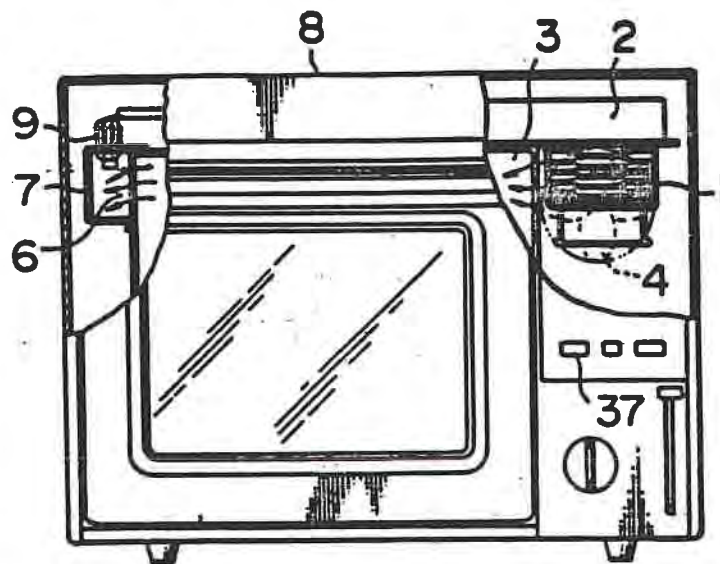
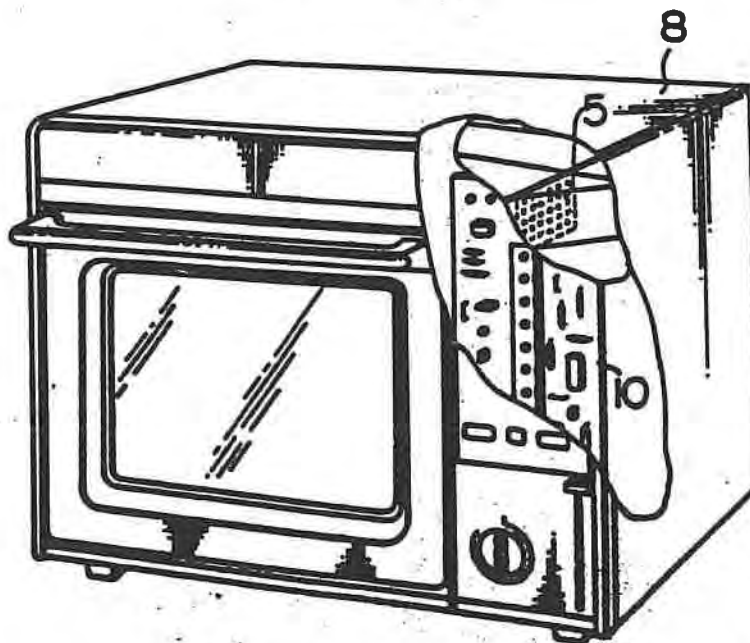


FIG. 2



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FIG. 3

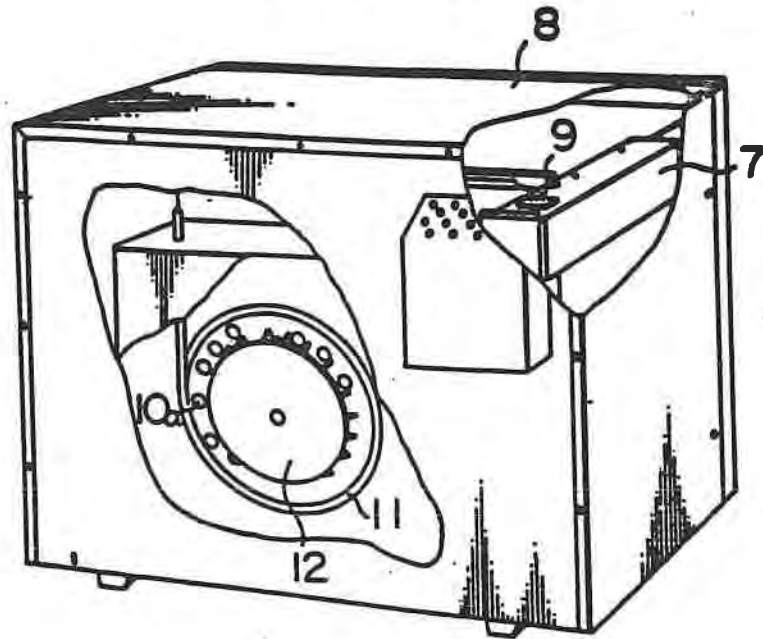


FIG. 4

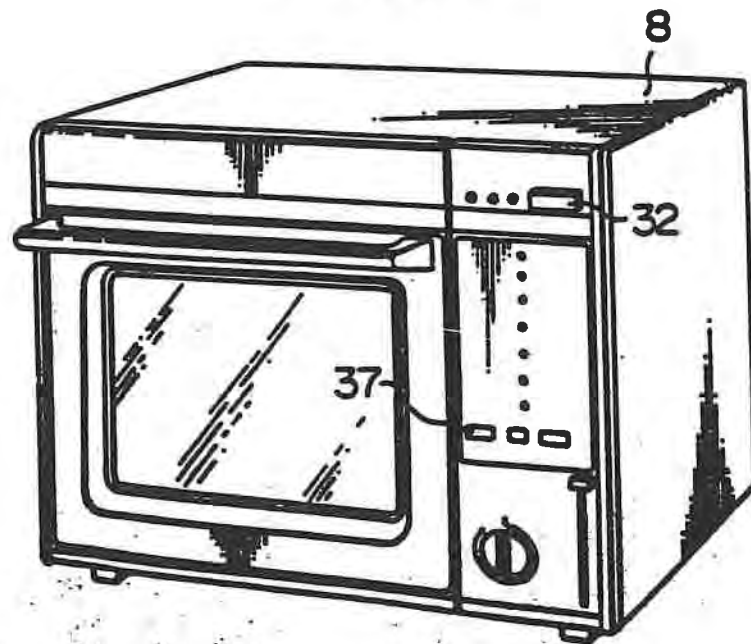


FIG. 5

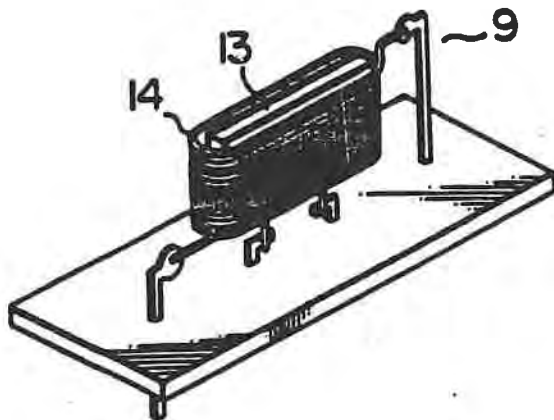


FIG. 6

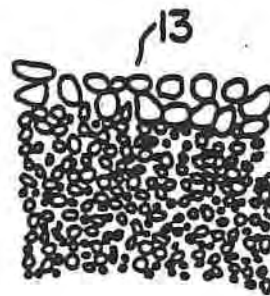
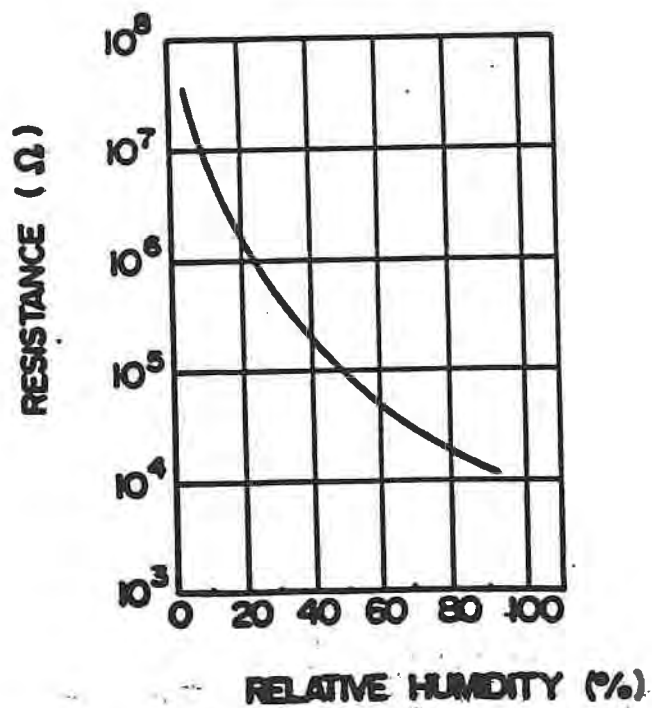


FIG. 7



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FIG. 8

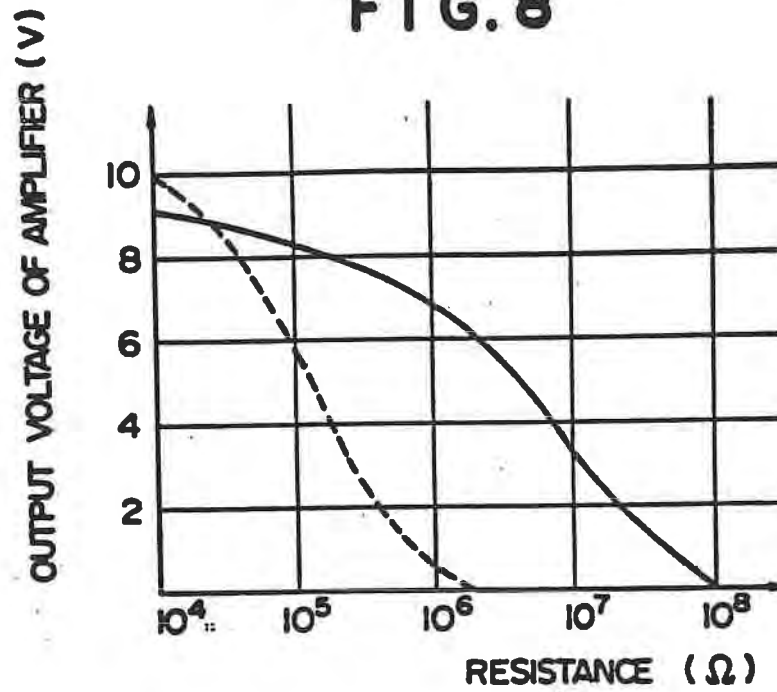
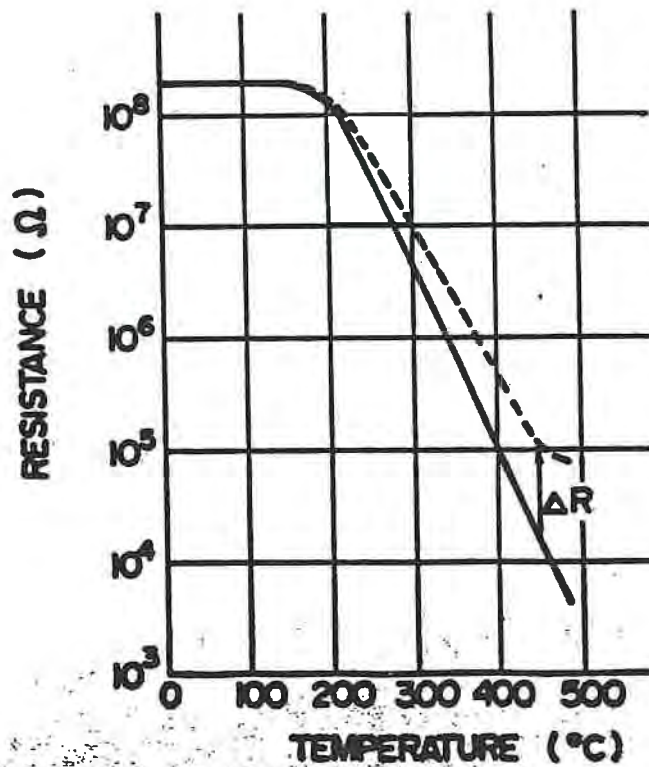


FIG. 9



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FIG. 10

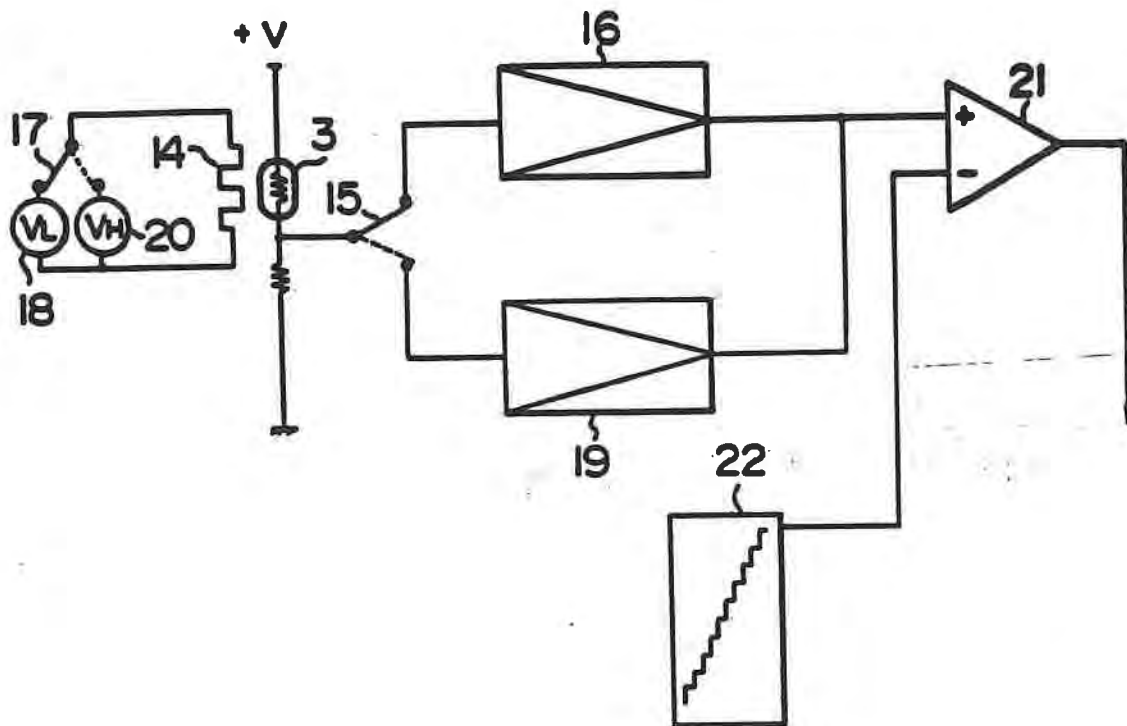
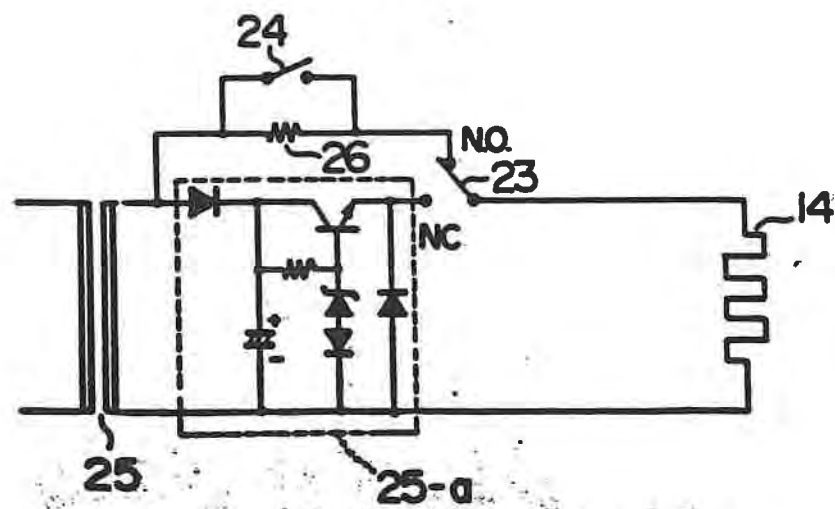


FIG. 11



6/12
FIG. 12

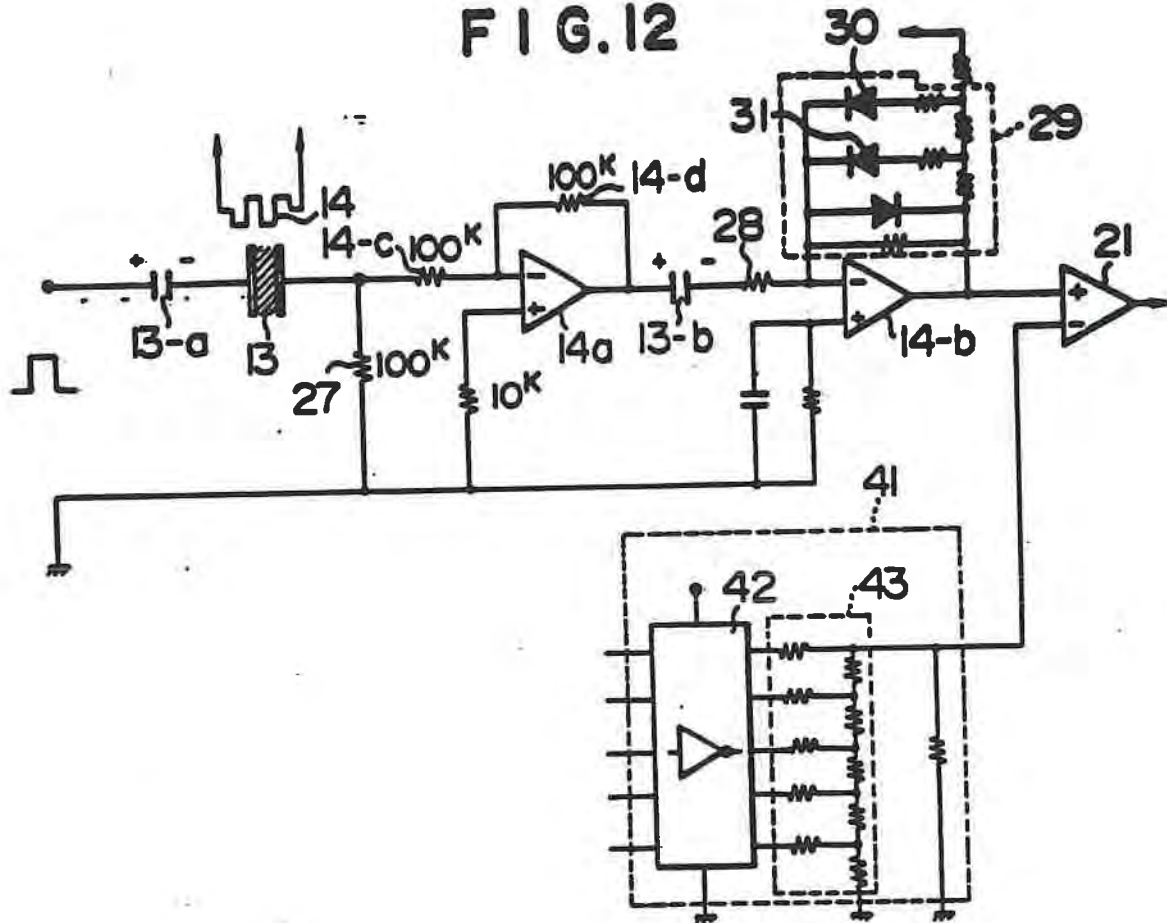
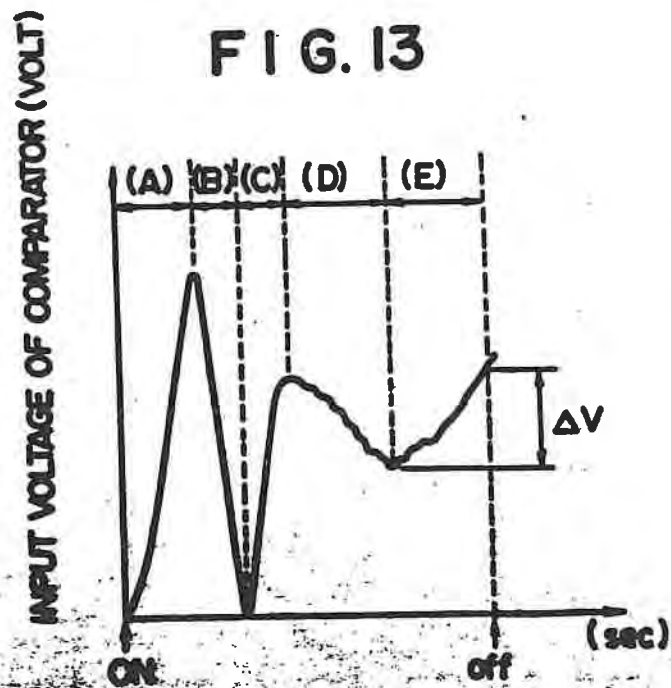


FIG. 13



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FIG. 14

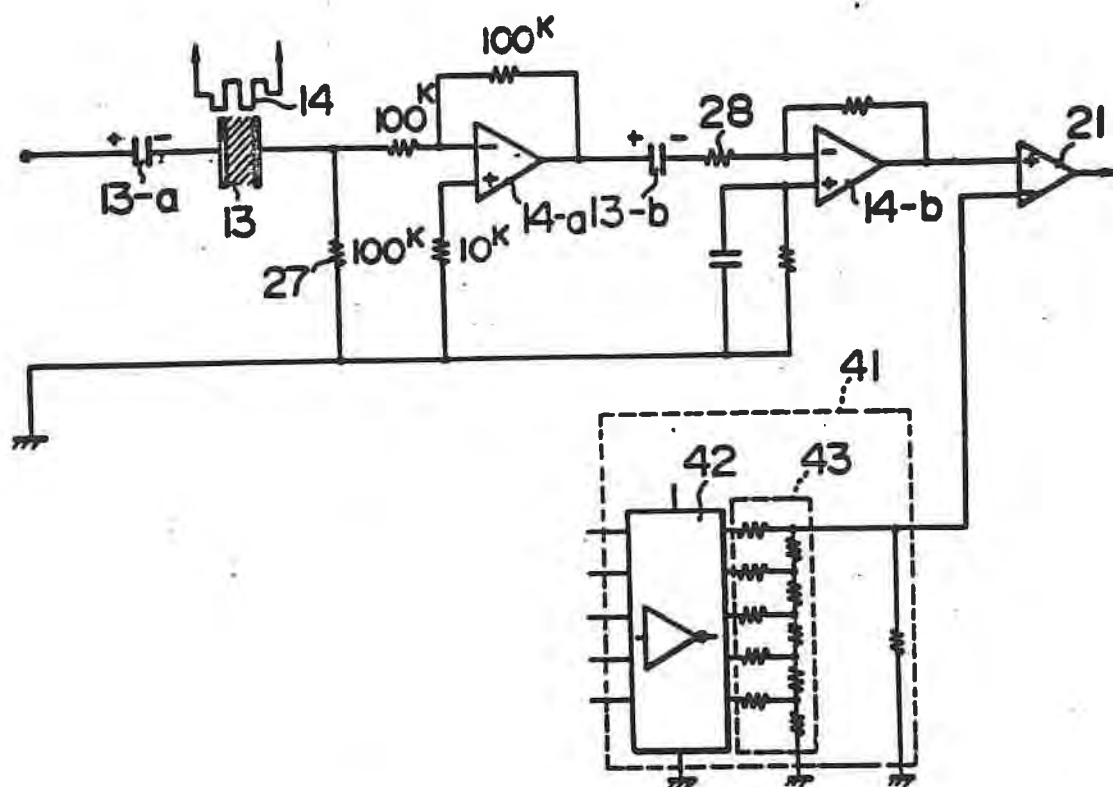


FIG. 15

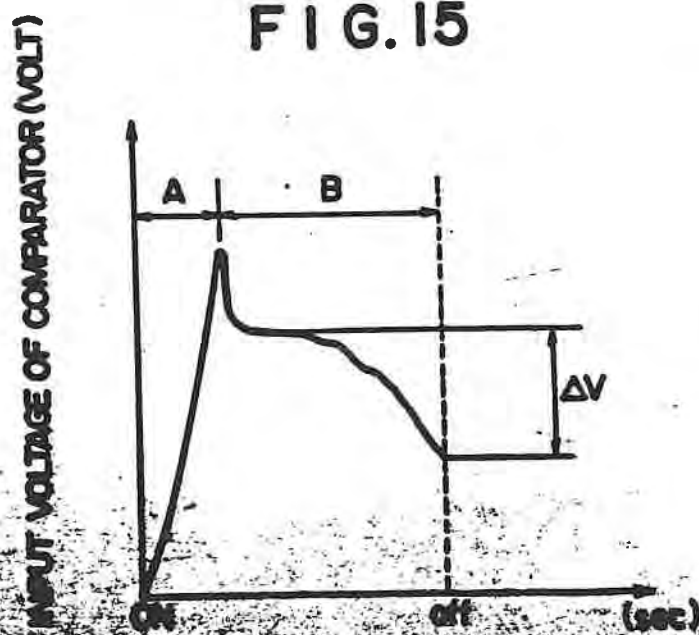


FIG. 16A

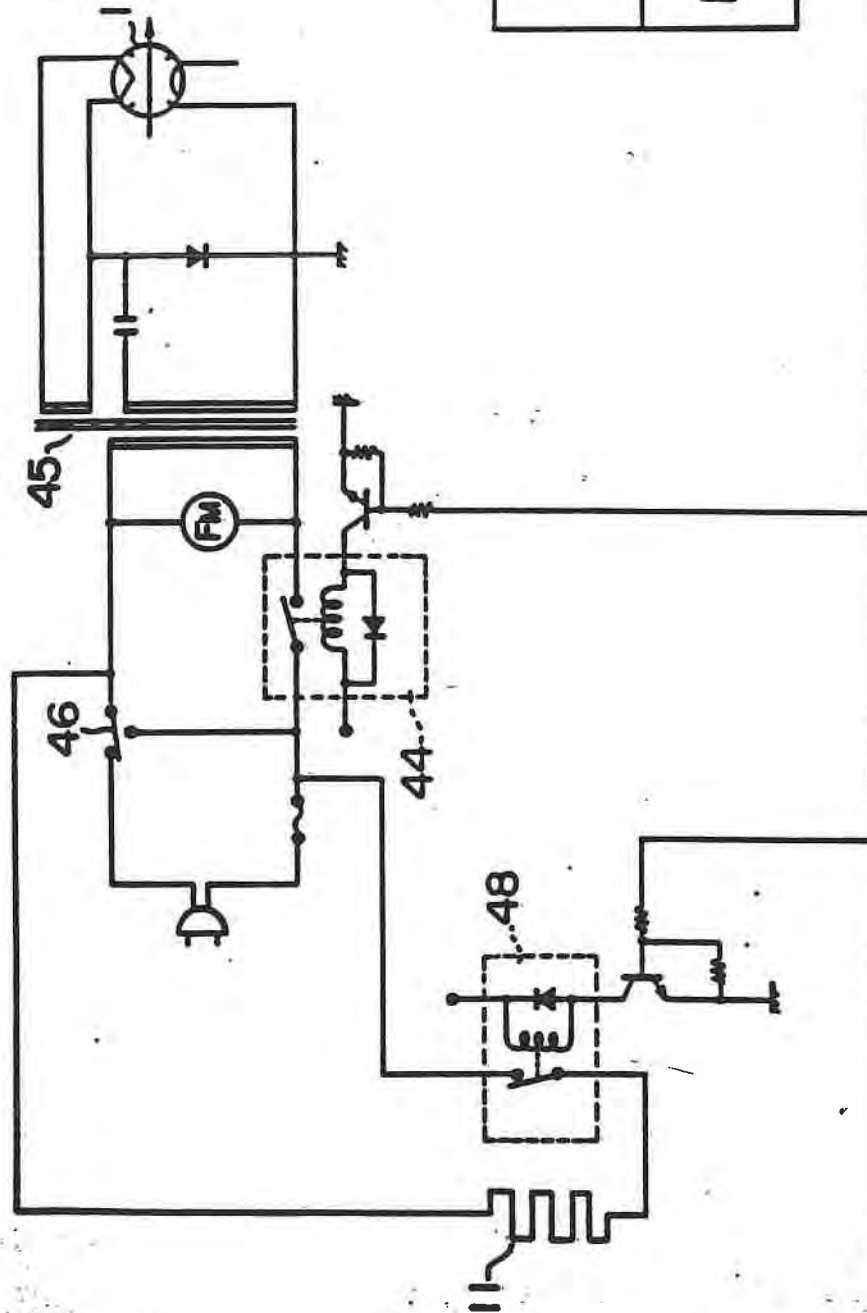


FIG. 16

FIG. 16A

FIG. 16B

F1 G. 16B

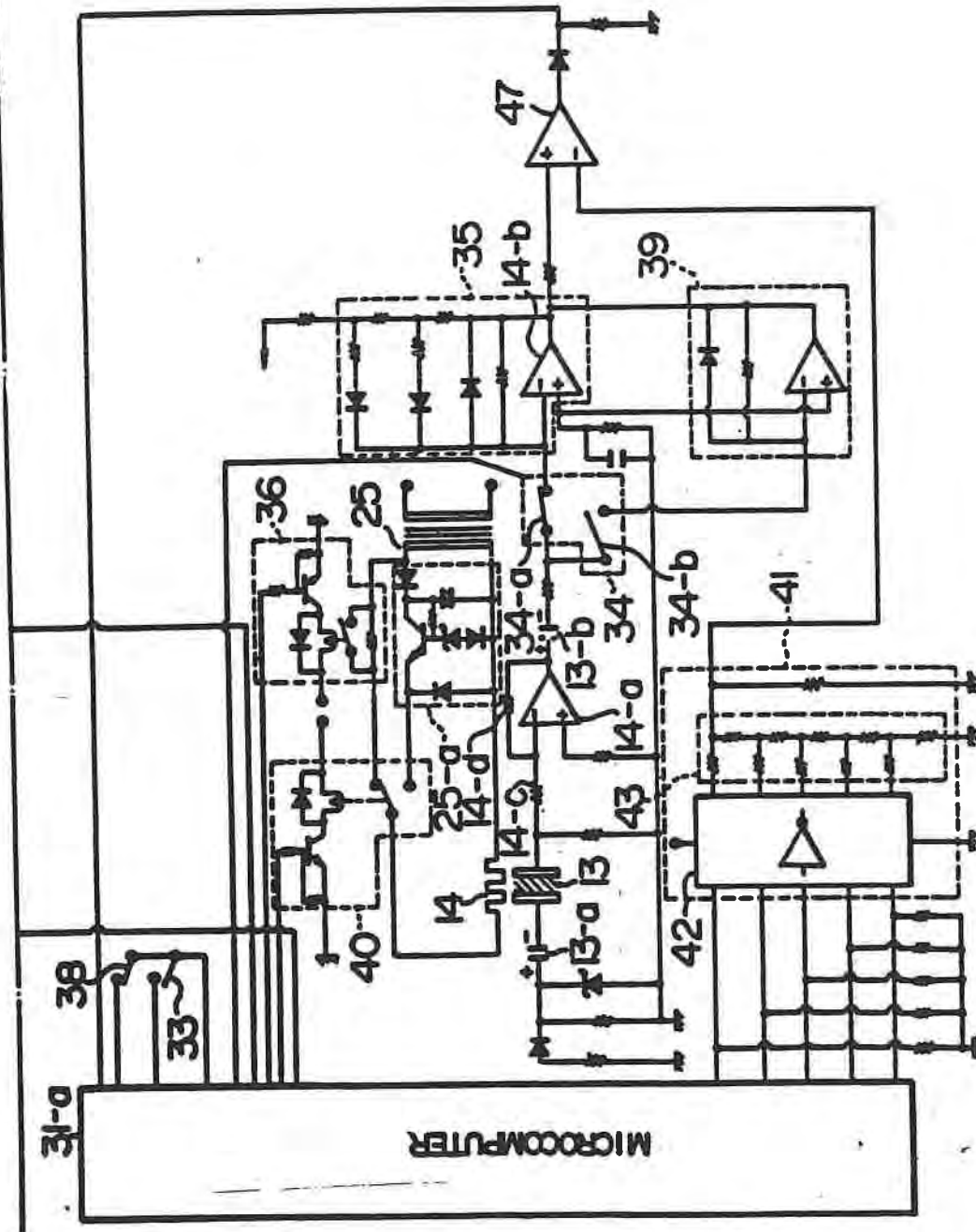


FIG. 17A

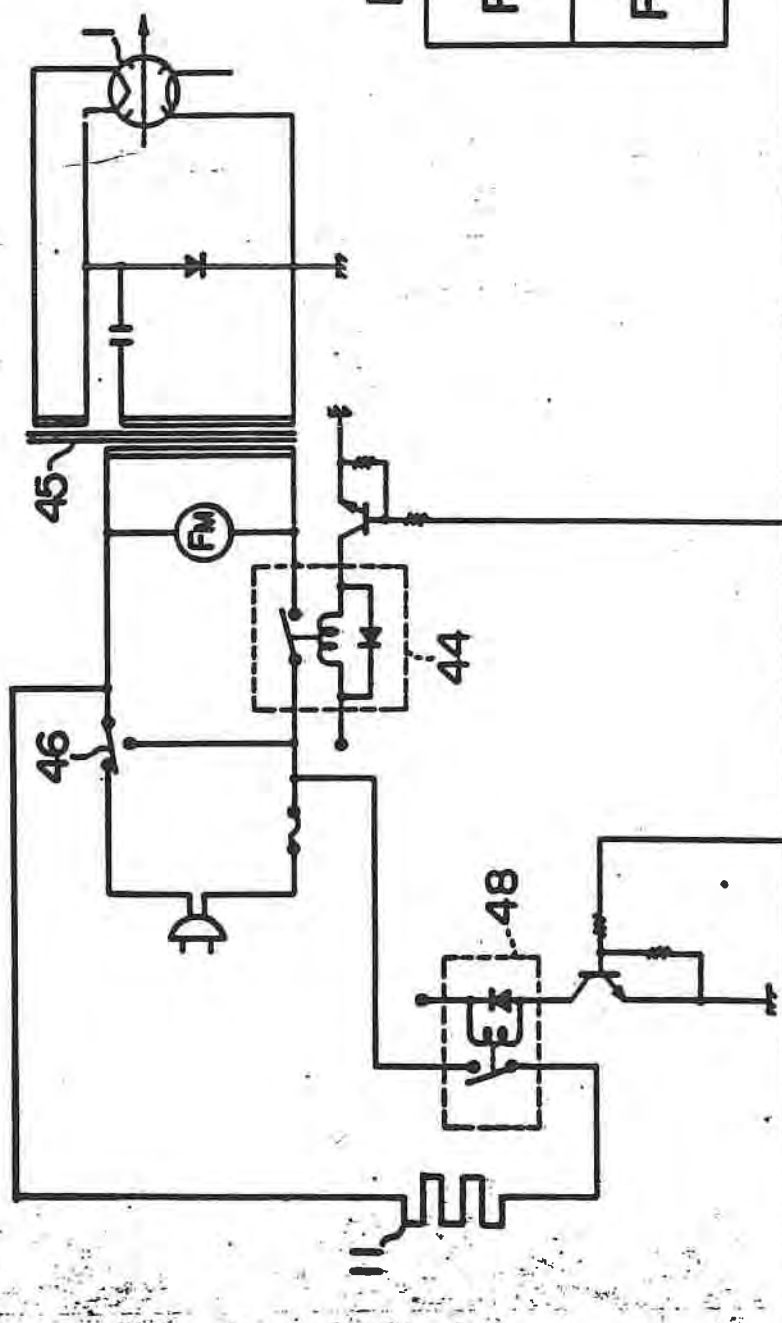
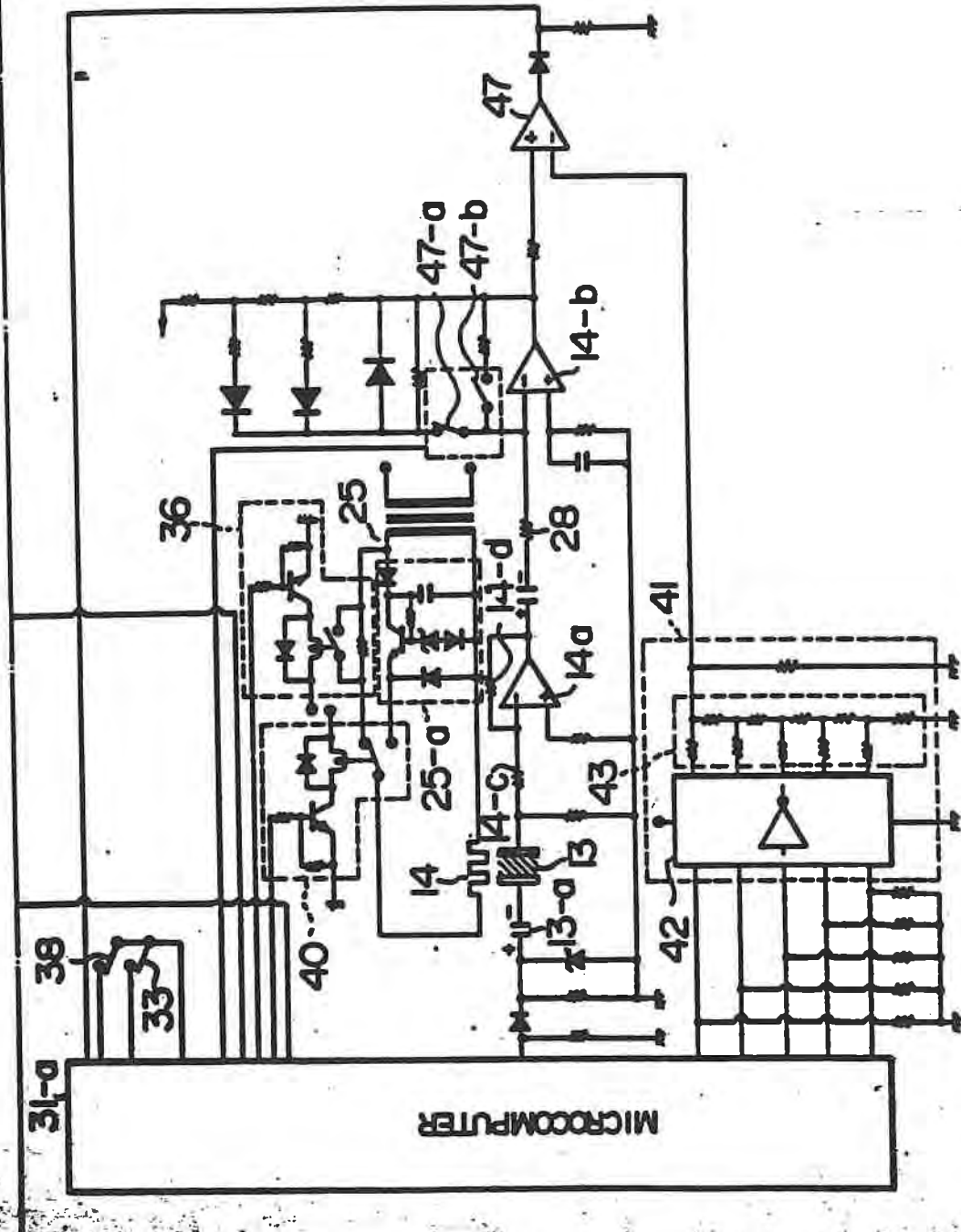


FIG. 17

FIG. 17A

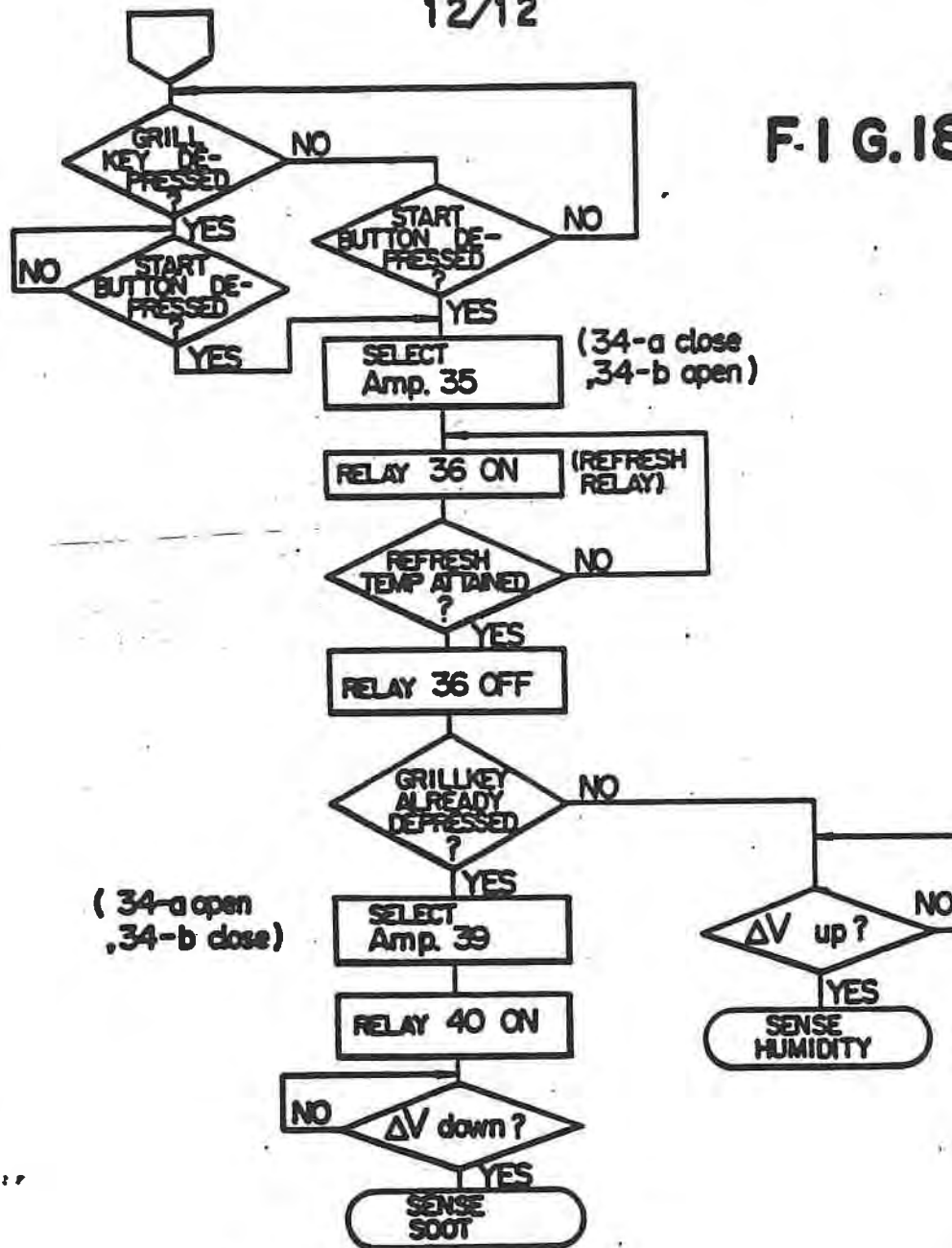
FIG. 17B

FIG. 17B

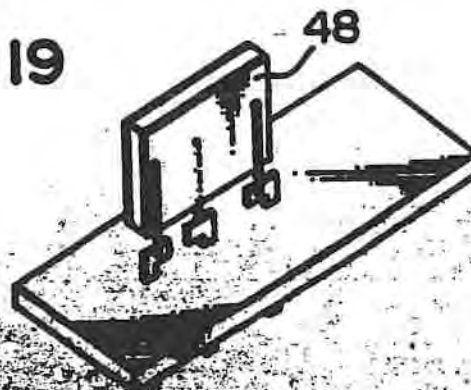


12/12

F I G. 18



F I G. 19





European Patent
Office

EUROPEAN SEARCH REPORT

0031158

Application Number

EP 80 10 8055.7

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	Patents Abstracts of Japan Vol. 3, No. 65, 6 June 1979, page 163M61 * JP - A - 54 - 43347 * complete document *	1,2	F 24 C 7/08 F 24 C 7/02 G 05 D 23/19 G 05 D 23/30
	Patents Abstracts of Japan Vol. 3, No. 116, 27 September 1979 page 13M74 * JP - A - 54 - 89345 * complete document *	1,2	
	Patents Abstracts of Japan Vol. 3, No. 97, 17 August 1979 page 53M69 * JP - A - 54 - 71445 * complete document *	1	
	DE - A1 - 2 622 308 (MATSUSHITA ELEC- TRIC INDUSTRIAL CO.) * fig. 2b and 5 * * US - A - 4 097 707	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.)
			F 24 C 7/00 G 05 D 23/00
			CATEGORY OF CITED DOCUMENTS
			X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application C: document cited in the application L: citation for other reasons
			*: member of the same patent



European Patent
Office

EUROPEAN SEARCH REPORT

0081186

Application number

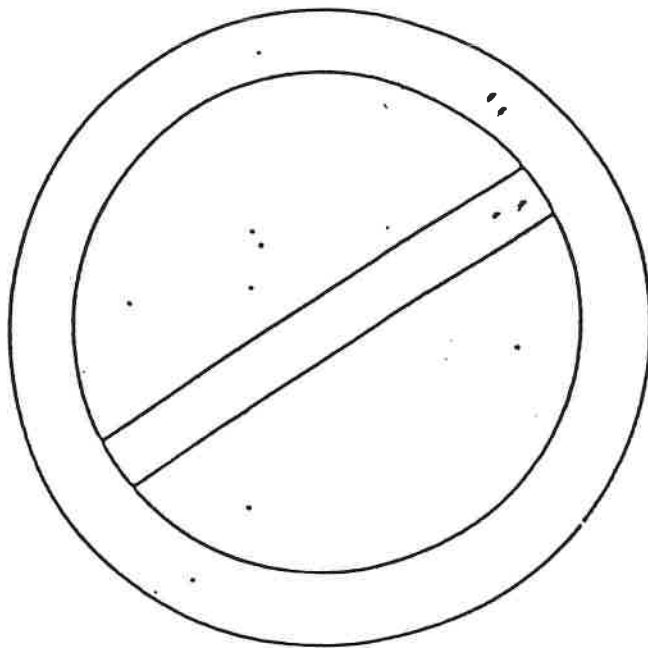
EP 80 10 8055.7

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	Patents Abstracts of Japan Vol. 3, No. 65, 6 June 1979, page 163M61 & JP - A - 54 - 43347 * complete document *	1,2	F 24 C 7/08 F 24 C 7/02 G 05 D 23/19 G 05 D 23/30
	Patents Abstracts of Japan Vol. 3, No. 116, 27 September 1979 page 13M74 & JP - A - 54 - 89345 * complete document *	1,2	
	Patents Abstracts of Japan Vol. 3, No. 97, 17 August 1979 page 53M69 & JP - A - 54 - 71445 * complete document *	1	
	DE - A1 - 2 622 308 (MATSUSHITA ELEC- TRIC INDUSTRIAL CO.) * fig. 2b and 5 *		
	& US - A - 4 097 707		
			TECHNICAL FIELDS SEARCHED (Int. Cl.)
			F 24 C 7/00 G 05 D 23/00
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Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
06/511,356	07/07/83	SMITH P	9DRG-16125

H. NEIL HOUSER
GENERAL ELECTRIC CO.
APPLIANCE PARK, BLDG. 1, RM. 230
LOUISVILLE, KY 40225

EXAMINER	
LEUNG, P	
ART UNIT	PAPER NUMBER
213	3

DATE MAILED: 05/21/84

This is a communication from the examiner in charge of your application.
COMMISSIONER OF PATENTS AND TRADEMARKS

☒ This application has been examined ☐ Responsive to communication filed on _____ ☐ This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

- | | |
|---|---|
| 1. ☒ Notice of References Cited by Examiner, PTO-892. | 2. ☐ Notice re Patent Drawing, PTO-948. |
| 3. ☒ Notice of Art Cited by Applicant, PTO-1449 | 4. ☐ Notice of Informal Patent Application, Form PTO-152 |
| 5. ☐ Information on How to Effect Drawing Changes, PTO-1474 | 6. ☐ _____ |

Part II SUMMARY OF ACTION

1. ☒ Claims 1-9 are pending in the application.
Of the above, claims _____ are withdrawn from consideration.
2. ☐ Claims _____ have been cancelled.
3. ☒ Claims 3-5 and 9 are allowed.
4. ☒ Claims 1 and 6 are rejected.
5. ☒ Claims 2, 7 and 8 are objected to.
6. ☐ Claims _____ are subject to restriction or election requirement.
7. ☐ This application has been filed with informal drawings which are acceptable for examination purposes until such time as allowable subject matter is indicated.
8. ☐ Allowable subject matter having been indicated, formal drawings are required in response to this Office action.
9. ☐ The corrected or substitute drawings have been received on _____. These drawings are ☐ acceptable;
☐ not acceptable (see explanation).
10. ☐ The ☐ proposed drawing correction and/or the ☐ proposed additional or substitute sheet(s) of drawings, filed on _____, has (have) been ☐ approved by the examiner. ☐ disapproved by the examiner (see explanation).
11. ☐ The proposed drawing correction, filed _____, has been ☐ approved. ☐ disapproved (see explanation). However, the Patent and Trademark Office no longer makes drawing changes. It is now applicant's responsibility to ensure that the drawings are corrected. Corrections **MUST** be effected in accordance with the instructions set forth on the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474.
12. ☐ Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has ☐ been received ☐ not been received
☐ been filed in parent application, serial no. _____; filed on _____.
13. ☐ Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. ☐ Other

15. The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

16. Claims 1 and 6 are rejected under 35 U.S.C. 103 as being unpatentable over Buck (995) in view of Okubo (Japanese Kokai no. 52-13150). Buck shows the basic method and arrangement of fire detection in a microwave oven. Buck uses a temperature sensor and a humidity sensor for monitoring the temperature change and the humidity change within a predetermined time period. Obviously, this change of temperature or humidity within a time period is the same as the rate of change characteristic of the temperature or the humidity respectively. It does not show explicitly "means for

circulating air through the cavity to remove therefrom gases emitted from the food load" although it mentions about "an air exchange control circuit" (col. 3, line 22). It monitors the "humidity" instead of the "gas concentration." Okubo shows that it is known in the art to circulate air through a microwave oven cavity to remove gases emitted from the food with the use of a blower (4) and the entry port (5) and monitor the gases passing through the exhaust guide (6) to control the power supply for fire prevention. It would have been obvious to one of ordinary skill in the art to modify Buck with a gas sensor for monitoring the gases emitted from the food and being circulated through the cavity for better fire prevention in view of the teaching of Okubo.

17. Claims 3-5 and 9 are allowed

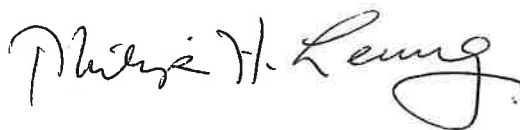
18. Claims 2, 7 and 8 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

19. Hitachi (Japanese 53-54839) is further cited to show a fire preventing arrangement in a microwave oven. Other references cited by the applicant have been considered and made of record.

Leung/dc

703/557/5050

5/17/84



P. H. LEUNG
PATENT EXAMINER
ART UNIT 213

1-1

FORM PTO-892 (REV. 3-78)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		SERIAL NO. 511556		GROUP/ART UNIT 213		ATTACHMENT TO PAPER NUMBER		3			
NOTICE OF REFERENCES CITED				APPLICANT(S) SMITH									
U.S. PATENT DOCUMENTS													
*		DOCUMENT NO.						DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE	
	A												
	B												
	C												
	D												
	E												
	F												
	G												
	H												
	I												
	J												
	K												
FOREIGN PATENT DOCUMENTS													
*		DOCUMENT NO.						DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG. PP. SPEC.
	L	52-13150						2-77	JAPAN	OKUBO	219	10.5B	
	M	53-64839						6-78	JAPAN	HITACHI	219	10.5B	
	N												
	O												
	P												
	Q												
OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)													
	R												
	S												
	T												
	U												
EXAMINER								DATE					
PHILIP H. LEUNG								5-10-84					
ACTION ①													
* A copy of this reference is not being furnished with this office action. (See Manual of Patent Examining Procedure, section 707.05 (a).)													



Docket No. 9D-RG-16129

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AUG 28 1984

Applicant: PETER H. SMITH

Serial No. 511,556

Group Art Unit: 213 GROUP 210

Filing Date: July 7, 1983

Examiner:

Title: AUTOMATIC FIRE DETECTION FOR A
MICROWAVE OVEN

STATEMENT OF RELEVANCE OF PRIOR ART CITED BY APPLICANT

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

SIR:

The following statement of relevance is submitted with the accompanying Form PTO-1449 (Rev. 7-80).

Document
Designation

Relevance

Page 1

AA

Discloses an arrangement for controlling the heating power applied to the object being heated in a microwave oven as a function of the humidity of the air exiting the cooking cavity.

AB

Discloses apparatus for controlling heating time in a microwave oven as a function of sensed humidity in the cooking cavity.

Discloses a method of detecting a fire in the cooking cavity of a microwave oven by sensing the time dependent humidity and temperature conditions in the cavity; a fire is indicated when the humidity decreases and the temperature increases within a predetermined time interval. Upon detection, the oven is turned OFF.

AD

Discloses a method of controlling cooking in a microwave oven as a function of the sensed humidity and temperature in the cooking cavity.

Document
Designation

Relevance

AE

Discloses a microwave oven sensing system which incorporates a temperature sensor and a humidity sensor for cooking control.

AF

Discloses a method of determining the optimum time to turn meats heated in a microwave oven as a function of the sensed temperature and humidity in the oven.

AG

Discloses a method of detecting the degree of doneness for meats heated in a microwave oven as a function of sensed humidity and temperature in the oven.

AH

Discloses an arrangement for detecting microwave oven cooking cavity temperatures approaching abnormal levels and suppressing microwave generation upon such detection, which employs a heat sensitive film to detect the abnormal condition.

AI

Discloses a method of cooking thin meats in a microwave oven as a function of sensed temperature and humidity in the oven.

AJ

Discloses the auxiliary use in a microwave oven of a Figaro gas sensor as an ambient leak detector when the oven is not in use for cooking.

AK

Discloses use of a Figaro gas sensor for food doneness sensing in a combination microwave and thermal oven.

Page 2

AA

Discloses use of a Figaro gas sensor and a temperature sensor for food doneness sensing in a combination microwave and thermal oven.

AB

Discloses a malfunction detection arrangement for a Figaro gas sensor employed in a microwave oven.

AC

Discloses a control arrangement for a combination microwave and thermal oven providing for user selection of the reference level against which the Figaro gas sensor output is to be compared for doneness sensing.

Document
Designation

Relevance

AD

Discloses a building alarm system employing a gas sensor, which system is responsive to a predetermined concentration of gaseous hydrocarbon in an area.

AL

Discloses an arrangement for controlling doneness in a combination microwave and thermal or browner oven, which employs a gas sensor selectively operative in two modes, a humidity sensing mode for microwave control and soot sensing mode for "grille menus."

Full text copies of the art listed above are enclosed. It is respectfully requested that this art be considered by the examiner in the above-entitled application and made of record therein.

Respectfully submitted,



H. Neil Houser
Attorney
Reg. No. 28,859

August 9, 1983

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AUG 28 1984

GROUP 210

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of :

PETER H. SMITH :

Examiner: P. Leung

Serial No. 511,556 :

Group Art Unit: 213

Filed July 7, 1983 :

AUTOMATIC FIRE DETECTION FOR A
MICROWAVE OVENAMENDMENTHonorable Commissioner of Patents and Trademarks,
Washington, D.C.

SIR:

In response to the Office Action of May 21, 1984, from
Examiner Leung, please amend the subject patent application as follows.

In the Claims:

Cancel Claim 1.

2.1 (Amended) [The method of Claim 1 wherein the step of
detecting the characteristic rate of change includes] A method of
anticipating a fire condition in the cooking cavity of a microwave oven
of the type having means for continuously circulating air through the
cavity to remove gaseous emissions from the food being heated in the
cavity and sensor means for sensing the concentration of such gases in
the circulating air, said method comprising the steps of:

circulating air through the cavity to remove therefrom
gases emitted from the food load being heated in the cavity;

sensing the concentration level of such gases in the
circulating air;

periodically determining the rate of change of
concentration level;

monitoring the rate of change to detect a rate of change
characteristic of the temperature of the food load in the cavity
closely approaching its combustion temperature including the steps of
detecting a first relatively slow rate of change indicative of the load

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having been cooked to its drying out stage and thereafter detecting a second relatively rapid rate of change, detection of said second rate following said first rate being indicative of closely approaching the combustion temperature of the load; and having detected said second rate of change, turning off power to the oven.

Cancel Claim 6.

1.5 (Amended) [A control arrangement in accordance with Claim 6 wherein] A control arrangement for a microwave oven comprising:

means for generating microwave energy for heating foods received in the cooking cavity;

means for continuously circulating air through the cooking cavity to remove therefrom gases emitted by the food load being heated in the cavity;

sensing means for sensing the concentration level of such gases in the circulating air and generating a first signal having a magnitude representative of the sensed concentration level;

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sensor monitoring means responsive to said first signal and including means operative to periodically determine the rate of change of concentration level as a function of time, and means operative to detect a rate of change indicative of closely approaching the combustion point of the load being heated in the oven, said [means for] detecting means [said characteristic rate includes] including means for detecting the occurrence of the second of two periods of relatively rapidly increasing concentration level separated by a period of relatively slowly increasing concentration level, and generating [said] a second signal upon detection of said second period; and

means for terminating operation of said microwave energy generating means and said air circulating means in response to said second signal.

8.6 (Amended) [The control arrangement of Claim 6 wherein said sensor monitoring means comprises] A control arrangement for a microwave oven comprising:

means for generating microwave energy for heating foods received in the cooking cavity;

means for continuously circulating air through the cooking cavity to remove therefrom gases emitted by the food load being heated in the cavity;

sensing means for sensing the concentration level of such gases in the circulating air and generating a first signal having a magnitude representative of the sensed concentration level;

sensor monitoring means responsive to said first signal and including means operative to periodically determine the rate of change of concentration level as a function of time, and means operative to detect a rate of change indicative of closely approaching the combustion point of the load being heated in the oven including means for detecting a relatively slow rate of increase in concentration level indicative of the food load being heated to its drying out stage and thereafter detecting a relatively rapid increase in concentration level indicative of closely approaching the combustion point of the food load and [wherein said] generating a second signal [is generated] upon detection of said relatively rapid increase; and

means for terminating operation of said microwave energy generating means and said air circulating means in response to said second signal.

REMARKS

Claim 1 has been cancelled, the substance thereof having been incorporated in amended Claim 2. Claim 2 has been amended to independent form including all of the limitations of Claim 1. Claim 6 has been cancelled, the substance thereof having been incorporated in amended Claims 7 and 8. Claims 7 and 8 have been amended to independent form, each including all of the limitations of base Claim 6.

Claims 3-5 and 9 are allowed. Claims 2, 7 and 8 are objected to as being dependent upon a rejected base claim but deemed allowable if rewritten in independent form including all of the limitations of

the base claim. Claims 2, 7 and 8 having been so amended, it is believed that the application is in condition for allowance. Reconsideration and allowance are requested.

It is noted that in the Office Action of May 21, 1984, only Sheet 2 of the "List of Prior Art Cited by Applicant" form was attached. It is assumed that the references listed on Sheet 1 of the form submitted by applicant have been fully considered by the Examiner and the failure to attach this sheet to the Office Action was merely an administrative oversight. However, to ensure that all of the references cited by the applicant are considered by the Examiner and made of record, a complete copy of the Form PTO-1449 originally submitted by applicant, together with its associated Statement of Relevance, is attached. It is requested that all of the references listed therein be considered and made of record.

Please charge the required \$30 fee for the additional independent claim, and any additional fee required by this response to Account No. 07-0844. A Deposit Account form is enclosed herewith for this purpose.

Respectfully submitted,


H. Neil Houser
Reg. No. 28,859

Louisville, Kentucky 40225

August 20, 1984

(502) 452-4653

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Commissioner of Patents and Trademarks Washington, D.C. 20231, on Aug 20, 1984

H Neil Houser Date
Name of applicant, assignee, or
Registered Representative
H Neil Houser Signature
Aug 20, 1984 Date

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Account No. **07-0844** Order No. **H00 - RG**

Name and Address of Depositor:
Patent Operation
General Electric Company
Appliance Park
Louisville, Kentucky 40225

DESCRIPTION OF ARTICLES OR SERVICES TO BE FURNISHED

AMENDMENT ADDING ONE ADDITIONAL DEPENDENT CLAIM

PETER H. SMITH

Serial No. 511,556

Filed July 7, 1983

AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

additional space is needed attach separate sheet.

Joseph M. Miller Patent Clerk
(Signature)

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MR. JOSEPH M. MILLER
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3. Please insert your own order number in the space provided on both the order form and the mailing label. The use of the order number is very important as it will serve as the means for identifying your order with the work performed.

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**UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office**

 Address : COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

**NOTICE OF ALLOWANCE
AND ISSUE FEE DUE**

 H. NEIL HOUSER
GENERAL ELECTRIC CO.
APPLIANCE PARK, BLDG. 1, RM. 230
LOUISVILLE, KY 40225

All communications regarding this application should give the serial number, date of filing, name of applicant, and batch number.

Please direct all communications to the Attention of "OFFICE OF PUBLICATIONS" unless advised to the contrary.

 The application identified below has been examined and found allowable for issuance of Letters Patent. **PROSECUTION ON THE MERITS IS CLOSED.**

SC/SERIAL NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT	DATE MAILED
06/511,556	07/07/83	007	LEUNG, P	213 09/06/84
First Named Applicant	SMITH,	PETER H.		

 TITLE OF INVENTION **AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN.**

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
9DRG-16129	219-010.55M	C62	UTILITY	NO	\$500.00	12/06/84

The amount of the issue fee is specified by 37 C.F.R. 1.18 as follows: for an original or reissue patent, except for a design or plant patent, \$500; for a design patent, \$175; and for a plant patent, \$250. If the applicant qualifies for and has filed a verified statement of small entity status in accordance with 37 C.F.R. 1.27, the issue fee is one-half the respective amount aforementioned. The issue fee due printed above reflects applicant's status as of the time of mailing this notice. A verified statement of small entity status may be filed prior to or with payment of the issue fee. However, in accordance with 37 C.F.R. 1.28, failure to establish status as a small entity prior to or with payment of the issue fee precludes payment of the issue fee in the amount so established for small entities and precludes a refund of any portion thereof paid prior to establishing status as a small entity.

THE ISSUE FEE MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE as indicated above. The application shall otherwise be regarded as ABANDONED. The issue fee will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the Patent and Trademark Office. Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of the notice of allowance, the issue fee is charged to the deposit account at the time of mailing of this notice in accordance with 37 C.F.R. 1.311. If the issue fee has been so charged, it is indicated above.

In order to minimize delays in the issuance of a patent based on this application, this Notice may have been mailed prior to completion of final processing. The nature and/or extent of the remaining revision or processing requirements may cause slight delays of the patent. In addition, if prosecution is to be reopened, this Notice of Allowance will be vacated and the appropriate Office action will follow in due course. If the issue fee has already been paid and prosecution is reopened, the applicant may request a refund or request that the fee be credited to a Deposit Account. However, applicant may wait until the application is either found allowable or held abandoned. If allowed, upon receipt of a new Notice of Allowance, applicant may request that the previously submitted issue fee be applied. If abandoned, applicant may request refund or credit to a Deposit Account.

In the case of each patent issuing without an assignment, the complete post office address of the inventor(s) will be printed in the patent heading and in the Official Gazette. If the inventor's address is now different from the address which appears in the application, please fill in the information in the spaces provided on PTOL-85b enclosed. If there are address changes for more than two inventors, enter the additional addresses on the reverse side of the PTOL-85b.

The appropriate spaces in the ASSIGNMENT DATA section of PTOL-85b must be completed in all cases. If it is desired to have the patent issue to an assignee, an assignment must have been previously submitted to the Patent and Trademark Office or must be submitted not later than the date of payment of the issue fee as required by 37 C.F.R. 1.334. Where there is an assignment, the assignee's name and address must be provided on the PTOL-85b to ensure its inclusion in the printed patent.

Advance orders for 10 or more printed copies of the prospective patent can be made by completing the information in Section 4 of PTOL-85b and submitting payment therewith. If use of a Deposit Account is being authorized for payment, PTOL-85c should also be forwarded. The order must be for at least 10 copies and must accompany the issue fee. The copies ordered will be sent only to the address specified in section 1 or 1A of PTOL-85b.

☐ Note attached communication from Examiner.

☐ This notice is issued in view of

applicant's communication filed _____

IMPORTANT

ATTENTION IS DIRECTED TO 37 C.F.R. 1.334

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ITEM 3 ON FORM PTOL-85b, ATTACHED



UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office

Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
06/511,556	07/07/83	SMITH	P 9DRG-16129

H. NEIL HOUSER
GENERAL ELECTRIC CO.
APPLIANCE PARK, BLDG. 1, RM. 230
LOUISVILLE, KY 40225

EXAMINER	
LEUNG, P	
ART UNIT	PAPER NUMBER
213	6

DATE MAILED: 09/06/84

This is a communication from the examiner in charge of your application

COMMISSIONER OF PATENTS AND TRADEMARKS

1. ☒ THIS IS AN ATTACHMENT TO THE NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE, PTOL 85.
2. ☒ All the claims being allowable, PROSECUTION ON THE MERITS IS CLOSED in this application. If not attached hereto, a Notice of Allowance or other appropriate communication will be sent in due course.
 - A. ☐ Note the attached PTO-152, Notice of Informality, which indicates that the declaration (or oath) is deficient and that a substitute is required. The substitute declaration (or oath) MUST BE SUBMITTED WITHIN THE THREE MONTH STATUTORY PERIOD SET FOR PAYMENT OF THE BASE ISSUE FEE IN THE "NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE" (PTOL-85), preferably with and attached to the base issue fee. Note that the statute does not permit extension of the three month period set for payment of the base issue fee. Failure to timely file the substitute declaration (or oath) will result in ABANDONMENT of the application. The transmittal letter accompanying the declaration (or oath) should indicate the following in the upper right hand corner:
Issue Batch Number; Date of the Notice of Allowance, and Serial Number.
 - B. ☐ Formal drawings are now required and MUST BE SUBMITTED WITHIN THE THREE MONTH STATUTORY PERIOD SET FOR PAYMENT OF THE BASE ISSUE FEE IN THE "NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE" (PTOL-85). Note that the statute does not permit extension of the three month period set to pay the base issue fee. Failure to timely submit the drawings will result in ABANDONMENT of the application. The drawings should be submitted as a separate paper with a transmittal letter which is addressed to the Official Draftsman and which indicates the following in the upper right hand corner:
Issue Batch Number; Date of the Notice of Allowance, and Serial Number.
 - C. ☒ The claims are allowed in view of:
 - a. ☒ Applicant's communication filed 8-23-84.
 - b. ☐ The interview summarized on the attached EXAMINER INTERVIEW SUMMARY RECORD, PTOL-413.
 - c. ☐ The attached Examiner's Amendment.
 - d. ☐ An Examiner's Amendment which will follow in due course.
 - D. ☒ The allowed claims are 2-5 and 7-9
3. ☐ Note the attached Examiner's Statement of Reasons for Allowance.
4. ☐ Note attached NOTICE OF REFERENCES CITED, PTO-892, which is part of this communication. The listed references are considered to be pertinent to the claimed invention, but the claims are deemed to be patentable thereover.
5. ☐ Note attached LIST OF ART CITED BY APPLICANT, PTO-1449.
☒ Note the first sheet of PTO-1449 which was inadvertently omitted in the last office action.
6. ☐ The drawings filed on _____ are acceptable as filed. ☐ are acceptable subject to correction as indicated on the attached Notice re Drawings, PTO-948. In order to avoid ABANDONMENT of this application, correction is required. Corrections can only be made in accordance with the instructions set forth in the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474.
7. ☐ The ☐ proposed drawing correction and/or the ☐ proposed additional or substitute sheet(s) of drawings filed on _____ has (have) been approved by the examiner. Applicant is reminded that in order to avoid abandonment of this applicant, execution of the proposed changes or submission of additional or substitute drawings MUST be made in accordance with the instructions set forth in the letter, "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474, attached to Paper No. _____.
8. ☐ The proposed drawing correction, filed _____, has been approved. However, the Patent and Trademark Office no longer makes drawing changes. It is now applicant's responsibility to ensure that the drawings are corrected. Corrections are required and MUST be effected in accordance with the instructions set forth on the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474.
9. ☐ In order to avoid ABANDONMENT, the drawing informalities noted on the Notice re Drawing, PTO-948, attached to Paper No. _____, must now be corrected. Applicant is reminded that the corrections can only be made in accordance with the instructions set forth in the letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474, attached to the PTO-948.
10. ☐ Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has; ☐ been received. ☐ not been received.
☐ been filed in parent application, Serial No. _____ filed on _____

Philip H. Leung

P. H. LEUNG
PATENT EXAMINER
ART UNIT 213



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

Peter Harold Smith :

Serial No. 511,556 :

Filed July 7, 1983 :

Allowed September 6, 1984 :

756

9-18-84

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1984 SEP 20 AM 11:53

B27 CC2 GROUP 210

Examiner: P.H. Leung

Group: 213

#8

SUPPLEMENTAL DECLARATION

Peter Harold Smith, whose application for Letters Patent for an improvement in Automatic Fire Detection for a Microwave Oven Serial No. 511,556, was filed in the U. S. Patent and Trademark Office on or about the 7th day of July, 1983, declares that the subject matter of the claims of said application as they now stand amended was part of his invention, was invented by him before he filed said application, and has not been abandoned; that he does not know and does not believe that the same was ever known, or used in the United States before his invention or discovery thereof, or patented or described in any printed publication in any country before his invention or discovery thereof or more than one year prior to said application, or in public use or on sale in the United States more than one year prior to said application; and that the invention has not been patented or made the subject of an inventor's certificate in any foreign country on an application filed by himself or his legal representatives or assigns more than twelve months prior to said application.

The undersigned petitioner declares further that all statements made herein of his own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Peter Harold Smith

Date September 13 1984

ISSUE FEE TRANSMITTAL

U.S. Department of Commerce
Patent and Trademark Office

This form is provided in lieu of a formal transmittal and should be used for transmitting the Issue Fee. Sections 1A through 4 must be completed as appropriate.

INVENTOR(S) ADDRESS CHANGE | SC/SERIAL NO.

INVENTOR'S NAME

Street Address

City, State and Zip Code

CO-INVENTOR'S NAME

Street Address

City, State and Zip Code

☐ Check if additional changes are on reverse side.

MAILING INSTRUCTIONS

All further correspondence including the Issue Fee Receipt, the Patent, and advanced orders will be mailed to the addressee entered in section 1 on PTOL-85c, unless you direct otherwise by specifying the appropriate name and address in 1A below.

2A. The COMMISSIONER OF PATENTS AND TRADE-MARKS is requested to apply the Issue Fee to the application identified below.

9D-RG-16129, S.N. 511,556

(Signature of party in interest of record)

(Date)

11/7/84

Note: The Issue Fee will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the Patent and Trademark Office.

	SC/SERIAL NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT	DATE MAILED
	06/511,556	07/07/83	007	LEUNG, P	09/06/83
First Named Applicant	SMITH, PETER H.				

TITLE OF INVENTION
AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
9DRG-16129	219-010.55M	062	UTILITY	NO	\$500.00	12/06/84

1A. Further correspondence to be mailed to the following:

2B. For printing on the patent front page, list the names of not more than 3 registered patent attorneys or agents OR, alternatively, the name of a firm having as a member a registered attorney or agent. If no name is listed, no name will be printed.

1 H. Neil Houser

2 Radford M. Reams

3

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11/28/84 511556
11/28/84 5115562 142
2 501500.00 CK
10.00 CK

3. ASSIGNMENT DATA (print or type)

- A. (1) ☐ This application is NOT assigned.
(2) ☒ Assignment previously submitted to the Patent and Trademark Office.
(3) ☒ Assignment submitted herewith.

B. For Printing On The Patent: (Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data below is only appropriate when an assignment has been previously submitted to the PTO or is submitted herewith. Completion of this form is NOT a substitute for filing of an assignment as required by 37 C.F.R. 1.334).

(1) NAME OF ASSIGNEE:

GENERAL ELECTRIC COMPANY

(2) ADDRESS: (City & State or Country)

Louisville, KY

(3) STATE OF INCORPORATION, IF ASSIGNEE IS A CORPORATION:

New York

The following fees are enclose:

☒ Issue fee ☒ Advanced order ☐ Assignment recording

The following fees should be charged to deposit acc. no.

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3 201
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11\56\84 211222
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ISSUE FEE TRANSMITTAL



2A. The COMMISSIONER OF PATENTS AND TRADE-MARKS is requested to apply the Issue Fee to the application identified below.

9D-RG-76129, S.N. 511,556

(Signature of party in interest of record)

(Date)

H. Neil Houser

11/7/84

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H. NEIL HOUSER
GENERAL ELECTRIC CO.
APPL. TOWN PARK, INDC 1-PM. 730
LOUISVILLE, KY 40205

SC/SERIAL NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT	DATE MAILED
9D-RG-76129	07/07/82	907	11980- P	09/05/84
First Named Applicant	PETER H.			

TITLE OF INVENTION: AUTOMATIC FIRE DETECTION FOR A MICROHAIR GUN

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
9D-RG-76129	710-010 556	622	UTILITY	NO	1500.00	11/06/84

1A. Further correspondence to be mailed to the following:

2B. For printing on the patent front page, list the names of not more than 3 registered patent attorneys or agents OR, alternatively, the name of a firm having as a member a registered attorney or agent. If no name is listed, no name will be printed.

1 H. Neil Houser

2 Radford M. Reams

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DO NOT USE THIS SPACE

3. ASSIGNMENT DATA (print or type)

- A. (1) ☐ This application is NOT assigned.
(2) ☒ Assignment previously submitted to the Patent and Trademark Office.
(3) ☐ Assignment submitted herewith.

B. For Printing On The Patent: (Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data below is only appropriate when an assignment has been previously submitted to the PTO or is submitted herewith. Completion of this form is NOT a substitute for filing of an assignment as required by 37 C.F.R. 1.334).

(1) NAME OF ASSIGNEE:
GENERAL ELECTRIC COMPANY

(2) ADDRESS: (City & State or Country)
Louisville, KY

(3) STATE OF INCORPORATION, IF ASSIGNEE IS A CORPORATION:
New York

4.

The following fees are enclose:

☒ Issue fee ☒ Advanced order ☐ Assignment recording

The following fees should be charged to

deposit acc. no. (PTOL-85c must be enclosed)

☐ Issue fee
☐ Advanced order
☐ Assignment recording

Number of advanced order copies requested, 10
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TRANSMIT THIS FORM WITH PTOL-85b WHEN AUTHORIZING USE OF A DEPOSIT ACCOUNT

Handwritten signature or scribble



Handwritten text, possibly a date or initials



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: PETER H. SMITH Batch No. C62
Serial No.: 511,556
Filed: 7/7/83
For: AUTOMATIC FIRE DETECTION FOR
 A MICROWAVE OVEN

Commissioner of Patents
Box M Fee
Washington, D.C. 20231

DESIGNATION OF FEE ADDRESS

Dear Sir:

Kindly enter the "fee address" for the above identified application, as follows:

General Electric Company
Washington Patent Operation
2001 Jefferson Davis Highway
Arlington, Virginia 22202

Respectfully submitted,

Signature

Name H. Neil Houser

Reg. No. 28,859

Address Appliance Park, AP1-230

Louisville, KY 40225

Telephone (502) 452-4653

Date November 7, 1984

[54] **AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN**

[75] **Inventor:** Peter H. Smith, Anchorage, Ky.

[73] **Assignee:** General Electric Company,
Louisville, Ky.

[21] **Appl. No.:** 511,556

[22] **Filed:** Jul. 7, 1983

[51] **Int. Cl.³** H05B 6/68

[52] **U.S. Cl.** 219/10.55 M; 219/10.55 B;
219/10.55 R; 340/578; 340/579; 236/44 C

[58] **Field of Search** 219/10.55 B, 10.55 R,
219/10.55 M, 10.55 E, 510, 494, 497; 340/577,
578, 579, 588, 589, 628, 629; 236/44 C;
426/234, 241, 243, 242; 99/325, DIG. 14

[56] **References Cited**

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3,839,616	10/1974	Risman	219/10.55
4,097,707	6/1978	Kobayashi et al.	219/10.55 B
4,133,995	1/1979	Buck	219/10.55 M
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31156	1/1981	European Pat. Off.	
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53-64839	6/1978	Japan	219/10.55 B

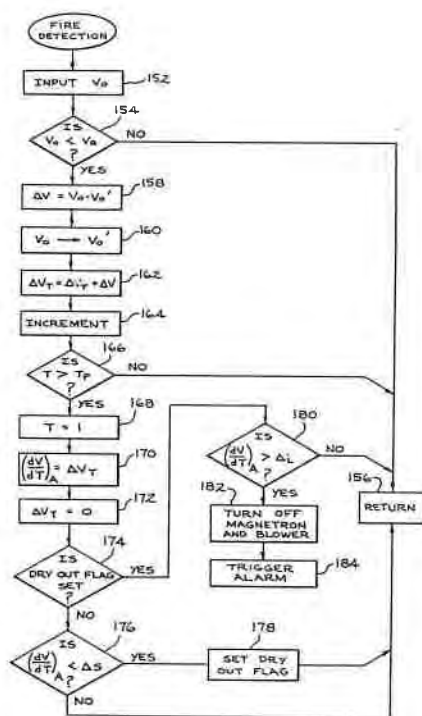
Primary Examiner—P. H. Leung

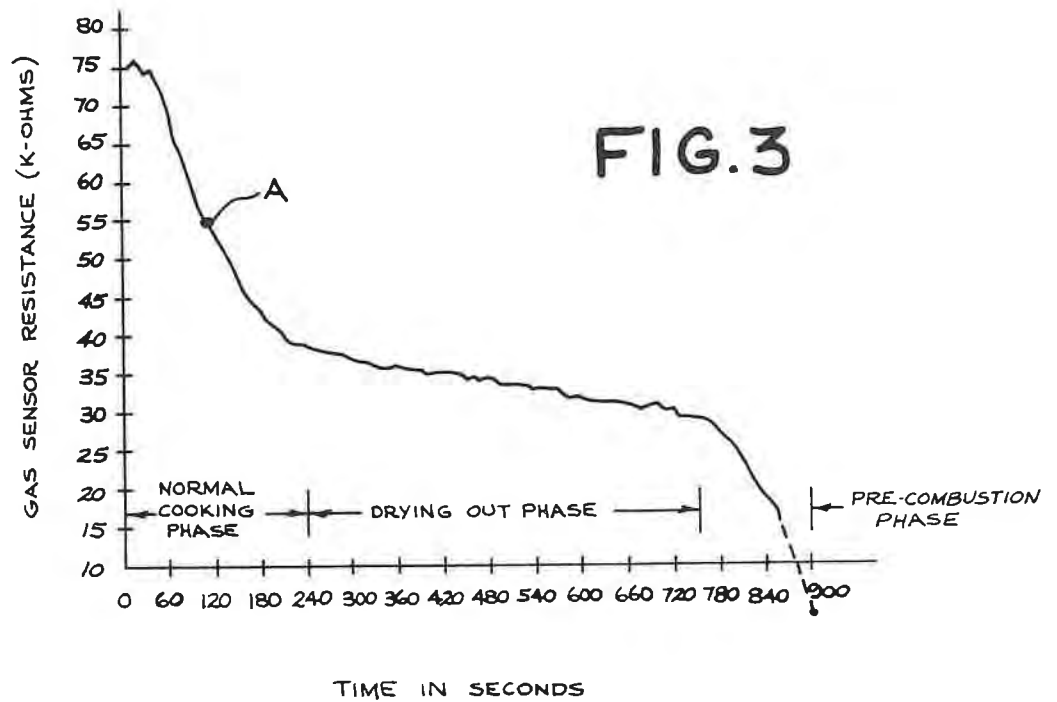
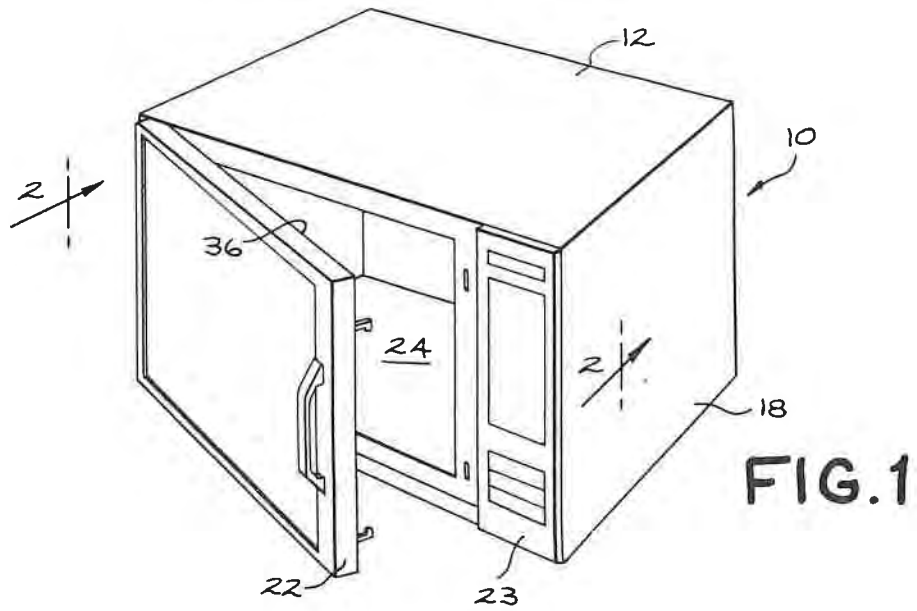
Attorney, Agent, or Firm—H. Neil Houser; Radford M. Reams

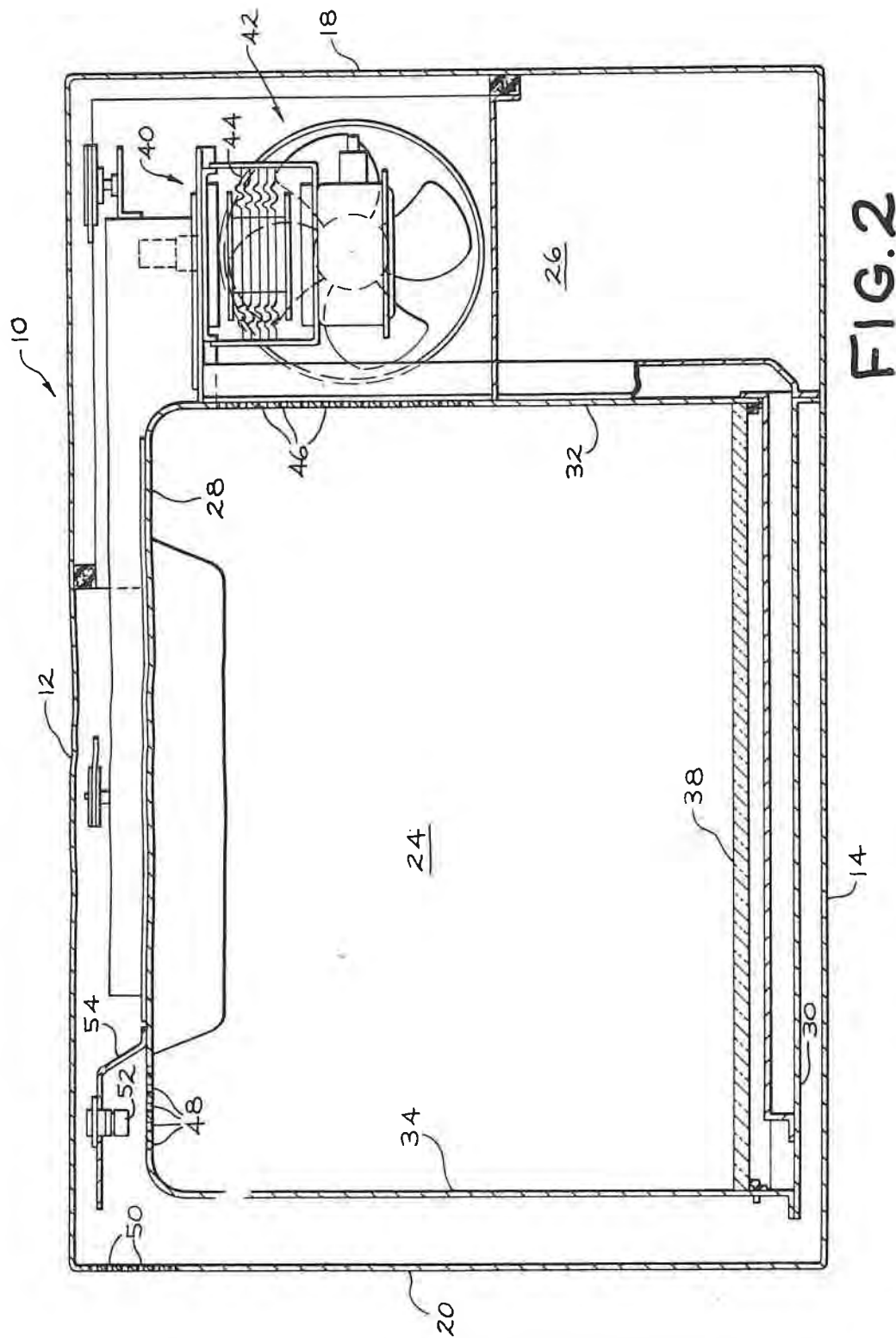
[57] **ABSTRACT**

A method and apparatus for anticipating the occurrence of a fire in the cooking cavity of a microwave oven. The oven is provided with a blower for continuously circulating outside air through the cooking cavity to carry away gases by food loads being heated therein. A sensor responsive to the concentration of gases in the circulating air monitors the gas concentration level and generates an output signal representative thereof. Sensor monitoring circuitry responsive to the sensor output signal is operative to determine the rate of change of the gas concentration level, and a detect a characteristic rate of change indicative of the load being heated closely approaching its combustion point. Upon detection of the characteristic rate of change, power to the oven is turned off and indication is provided to the user that a combustion condition in the oven cavity is imminent.

7 Claims, 5 Drawing Figures







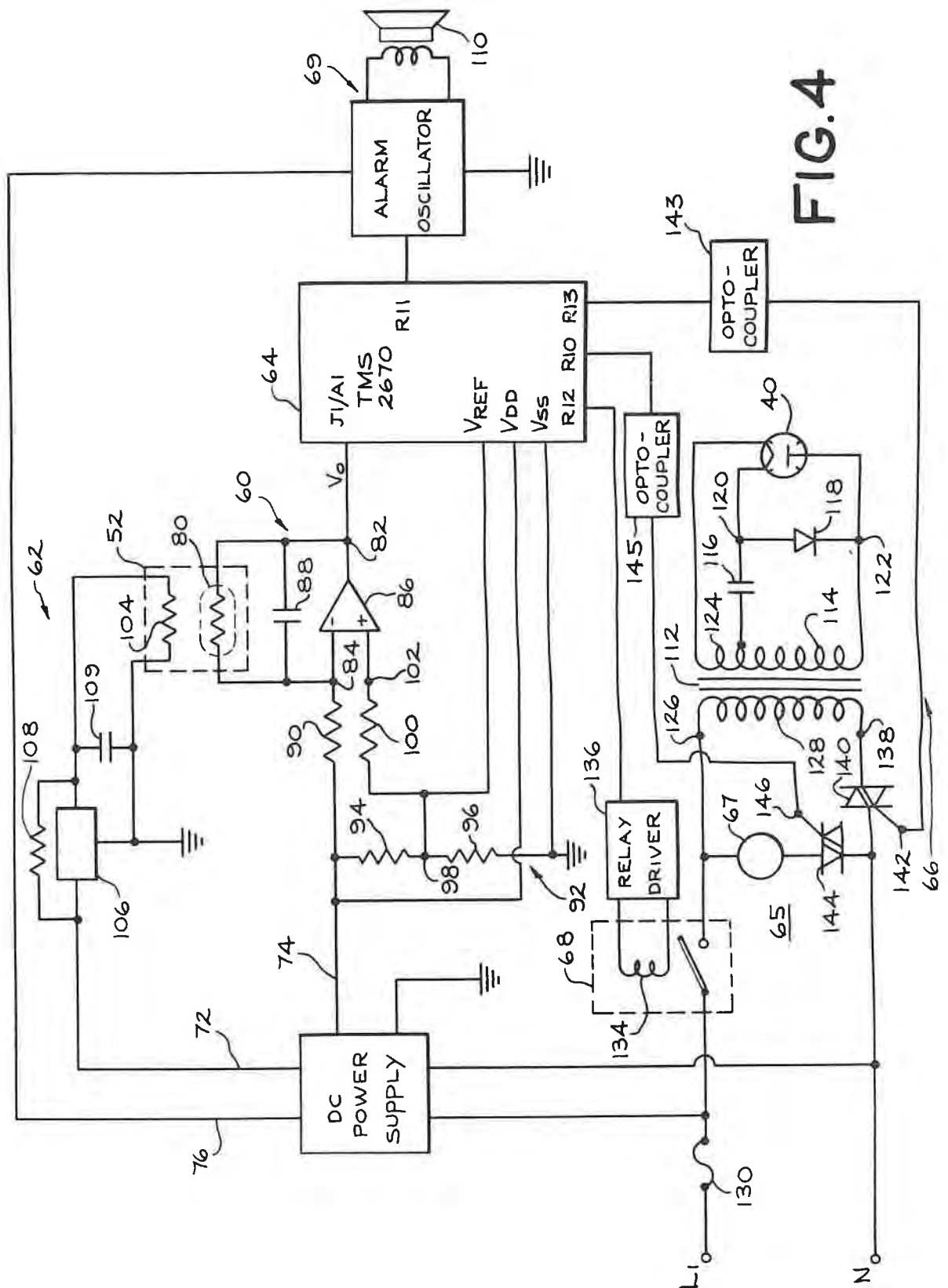
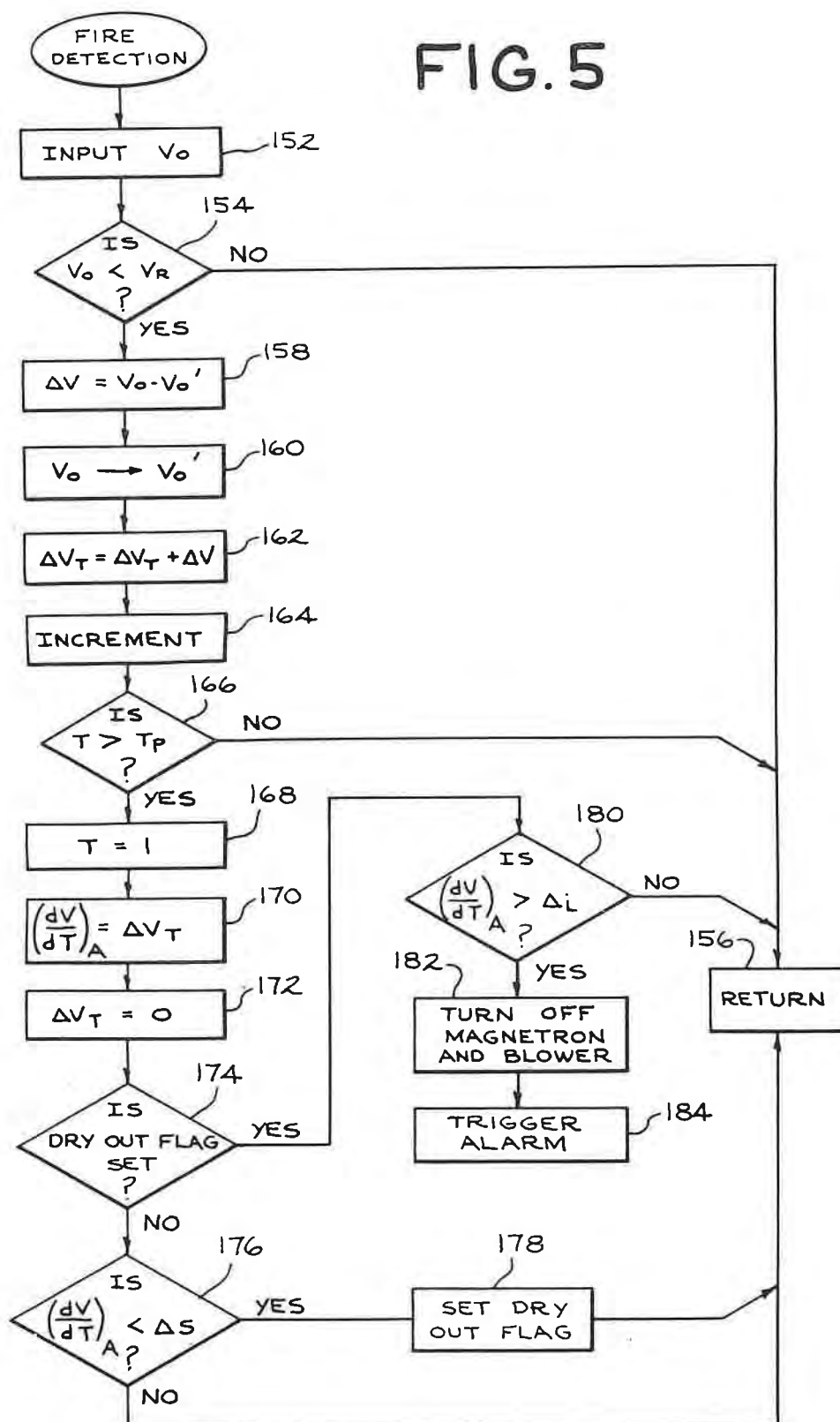


FIG. 4

FIG. 5



AUTOMATIC FIRE DETECTION FOR A MICROWAVE OVEN

BACKGROUND OF THE INVENTION

The present invention relates generally to improvements in a microwave oven and more particularly to an arrangement for anticipating the occurrence of combustion in the cooking cavity of a microwave oven.

When heating a food load in a microwave oven, if the food load is allowed to heat substantially longer than required for proper cooking, the food itself or the container for the food may become heated to the combustion point, resulting in a fire in the oven cavity. The overcooking of whole potatoes, fats raised to the combustion temperature due to excessive overcooking of meats, and oven shelf hot spots due to imperfections in the pyroceramic shelf when heated over a prolonged period, are three primary sources of such cavity fires. The potato is particularly vulnerable to fire since it dries out non-linearly with the core of the potato getting hot before the outer portions. The heat from the core is not readily dissipated. As a result the core of the potato can be heated to its ignition point relatively quickly.

One commonly used approach to the cavity fire detection problem is to provide a thermal cutout switch on the oven cavity ceiling which cuts off the magnetron when the oven cavity ceiling temperature exceeds a predetermined level. This arrangement works satisfactorily but is relatively costly and has a relatively slow response time. An alternative approach is disclosed in U.S. Pat. No. 4,133,995 to Buck. In the Buck arrangement a humidity sensor and a temperature sensor are employed to monitor the relative humidity and temperature in the cavity. A microprocessor is programmed to detect a fire condition when both the temperature rises and the humidity falls by predetermined amounts within a prescribed time period, on the order of 10-30 seconds, and to de-energize the oven upon detecting such a condition.

The present invention improves over both of the foregoing approaches to fire detection in the microwave oven by providing an arrangement which anticipates fire conditions developing in the cooking cavity before actual ignition employing a single sensor normally used for cooking control which is responsive to the concentration of gases in the circulating air exiting the cooking cavity. In addition to providing an anticipatory warning of an imminent fire condition, this arrangement eliminates the need for the relatively costly thermal cutout switch and also eliminates the need for the "in situ" temperature sensor of the Buck method.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for anticipating the occurrence of a fire in the cooking cavity of a microwave oven. The oven is provided with means for continuously circulating outside air through the cooking cavity to carry away gases emitted by food loads being heated therein. A sensor responsive to the concentration of gases in the circulating air monitors the gas concentration level and generates an output signal representative thereof. Sensor monitoring means responsive to the sensor output signal is operative to determine the rate of change of the gas concentration level, and detect a characteristic rate of change indicative of the load being heated closely approaching its combustion point. Upon detection of the characteristic

rate of change, means responsive to the sensor monitoring means de-energizes the oven and provides an indication to the user that a combustion condition in the oven cavity is imminent.

In accordance with one form of the invention, the sensor monitoring means detects the characteristic rate of change by first detecting a relatively slow rate of change indicative of the food load drying out and thereafter detecting a relatively rapid rate of change indicative of the load being heated to a temperature closely approaching its combustion temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

While the novel features of the invention are set forth with particularity in the appended claims, the invention both as to organization and content will be better understood and appreciated from the following detailed description taken in conjunction with the drawings, in which:

FIG. 1 is a perspective view of a microwave oven embodying the present invention;

FIG. 2 is a schematic sectional view of the oven of FIG. 1 taken along lines 2-2;

FIG. 3 depicts a curve representative of the gas emission characteristics of a baked potato heated in the microwave oven of FIG. 1;

FIG. 4 is a simplified schematic circuit diagram of that portion of the microprocessor-based control system of the oven of FIG. 1 illustratively embodying the present invention; and

FIG. 5 is a flow diagram illustratively embodying a fire detection control algorithm implemented by the microprocessor in the circuit of FIG. 4 in accordance with the present invention.

DETAILED DESCRIPTION

Referring now to FIGS. 1 and 2, there is shown a microwave oven designated generally 10. The outer cabinet comprises six cabinet walls including upper and lower walls 12 and 14, a rear wall (not shown), two side walls 18 and 20, and a front wall partly formed by a hingedly supported door 22 and partly by control panel 23. The space inside the outer cabinet is divided generally into a cooking cavity 24 and a controls compartment 26. Cooking cavity 24 is formed by a top wall 28, a bottom wall 30, side walls 32 and 34, the rear cavity wall being a cabinet wall and the front cavity wall being defined by the inner face 36 of door 22. A shelf 38 of pyroceramic material or other suitable material pervious to microwave energy is provided in the lower region of cavity 24 to support food loads to be heated in cavity 24.

A magnetron 40 adapted to produce microwave energy is mounted in controls compartment 26. Means for circulating air through the cavity 24 includes a blower designated generally 42 which draws cooling air into the controls compartment 26 through louvered openings (not shown) formed in the back cabinet wall. This air passes over cooling fins 44 of magnetron 40. A portion of the air drawn in by blower 42 enters cavity 24 via perforations 46 formed in cavity side wall 32. This air circulates past the food load (not shown) being heated in cavity 24 and exits cavity 24 through perforations 48 formed in upper cavity wall 28 near the upper left corner of cavity 24. Vent holes 50 formed in side cabinet wall 20 near the upper left corner of the oven

cabinet permit air exiting cavity 24 via perforations 48 to exit the oven cabinet to the exterior.

Foods heated in the microwave oven tend to emit water vapor and other gases as the food heats. Such gases mix with the air circulating in the cavity and are removed from the cavity by the circulating air. Means for sensing the concentration level of such gases in the air leaving the cavity is provided in the form of a gas sensor 52 disposed in the air flow path between perforations 48 in cavity wall 28 and vent openings 50 in cabinet wall 20. Sensor 52 is supported proximate perforations 48 by mounting bracket 54 which is suitably secured to cavity wall 28. Sensor 52 in the illustrative embodiment of FIG. 2 is a gas sensor readily commercially available from Figaro Engineering, Inc., identifiable as Model TGS No. 186. This sensor is responsive to the cumulative concentration of water vapor and various organic gases. Use of such a sensor in a microwave oven for automatic cooking control is known in the art. One example of such a control arrangement is described in U.S. Pat. No. 4,311,895.

In accordance with the present invention, information regarding the concentration level of gases in the circulating air exiting cavity 24 provided by sensor 52 is used to anticipate the occurrence of combustion conditions in the cavity.

It has been empirically determined that for foods likely to ignite in the oven cavity when overcooked, the concentration of gases emitted by the food load into the air circulating through the cavity changes during heating in a predictable fashion. At the beginning of the cooking cycle, the food load is normally not sufficiently heated to cause significant gaseous emissions from the food. Consequently, the sensed gas concentration level remains relatively low and constant. As the food continues to heat, it reaches sufficient temperature to begin emitting water vapor and organic gases. There ensues a period of relatively rapidly increasing gas concentration level which continues until the food load is heated to a point of near maximum gaseous emissions. The recommended cooking time for most foods is such that the cooking cycle is normally terminated prior to reaching this point. However, if the food continues to be heated beyond this point such as may inadvertently occur due to the miscalculation of appropriate cooking time or simply forgetfulness, the temperature of the food continues to rise but the gas concentration level increases relatively slowly during what can be a relatively long period, hereinafter referred to as the "drying out" period. Eventually, the temperature of the food closely approaches its combustion temperature. However, before actually reaching the ignition point, the food begins to char, smoke or smolder, resulting in a second period of relatively rapidly increasing gas concentration in the circulating air, comparable to that rate of increase which characterizes the normal cooking period. This second period of rapidly increasing concentration level, referred to hereinafter as the "pre-combustion" period, typically begins a matter of minutes before actual combustion in the cavity. Thus, detection of the transition from the drying out phase to the pre-combustion phase provides an advance warning that a combustion condition in the cavity is imminent. Hence, according to the present invention, a fire condition in the cavity of a microwave oven may be anticipated by monitoring the gas concentration level of the air circulated through the cavity during the cooking cycle, periodically determining the rate of change of the sensed concentration level

during heating, and detecting a rate of change characteristic of the food load closely approaching its combustion temperature.

The sensor resistance versus time curve of FIG. 3 shows the change in resistance of the sensing element of sensor 52 during the cooling cycle for a whole potato heated in cooking cavity 24 of oven 10 in response to the changing gas concentration level in the air exiting the cooking cavity as the potato is heated to its combustion point. The potato was chosen for purposes of illustration because, as described briefly in the Background discussion, it is one of the foods most easily overcooked to the point of combustion. Also, the basic shape of the response curve is fairly representative of all food loads of the type conducive to ignition when overcooked.

The resistance R_s of the TGS 186 sensor varies with gas concentration level in the air to which it is exposed in accordance with the formula

$$R_s = A \times C^{-\alpha}$$

where A and α are constants and C is the gas concentration. Hence, the changing resistance as the potato cooks reflects the aforementioned predictable variation in concentration level.

Referring particularly to FIG. 3, as the cooking cycle begins, the resistance is relatively high and constant indicative of the relatively low and essentially constant concentration level at this point. There next ensues a period in which the resistance decreases relatively rapidly indicative of the concentration level increase, characteristic of the normal cooking phase for the potato. The change from a relatively rapidly decreasing resistance to a relatively slowly decreasing resistance is indicative of the change from a relatively rapidly increasing concentration level to a period of relatively slowly increasing concentration level which marks the transition from the normal cooking phase to the drying out phase for the potato. Continued heating of the potato continues to raise its temperature but the resistance continues to decrease at a relatively slow rate indicating that during the relatively long drying out phase for the potato, which is roughly twice the duration of the normal cooking period, the gas concentration level is increasing at a relatively slow rate. As the temperature of the potato sufficiently closely approaches its combustion point, the resistance begins to decrease at a relatively rapid rate indicative of a relatively rapidly increasing gas concentration level. The transition from relatively slow to relatively rapid increase in concentration level marks the transition from the drying out phase to the pre-combustion phase. For a potato cooked in oven 10, this transition typically occurs at least 2-3 minutes prior to reaching the combustion temperature of the potato. Thus, by detecting the rate of change of the gas concentration level characteristic of the pre-combustion phase early in this phase, it is possible to anticipate a combustion condition in the cavity at least 2 to 3 minutes in advance. By turning off the power to the magnetron and blower at this point, fire in the cavity may be prevented.

Referring now to the simplified schematic circuit diagram of FIG. 4, gas sensor 52 is incorporated in a microprocessor based control arrangement which illustratively embodies the apparatus and performs the method of the present invention. The circuit of FIG. 4 includes a gas sensing circuit 60 for sensing the concentration level of gases in the circulating air as it exits

cooking cavity 24, and generating a voltage signal having a magnitude representative of the sensed gas concentration level; a sensor heater circuit 62 for maintaining the sensing element of gas sensor 52 at its proper operating temperature; a microprocessor 64 for monitoring the voltage signal from sensing circuit 60; a power circuit 65 for oven 10 including a magnetron power circuit 66, an air circulating blower motor 67 and a power control relay 68 for controlling energization of magnetron power circuit 66 and air circulating blower 67 in response to a control signal from microprocessor 64; and an alarm circuit 69 responsive to a control signal from microprocessor 64 for providing an audible signal to the user of an imminent fire condition in the cooking cavity. Power for the circuit of FIG. 4 is provided by a conventional DC power supply circuit 70 which converts a standard 120 volt, 60 Hz AC signal input on lines L1 and N to dc output power signals of -9 volts, -9 volts and -16 volts on lines 72, 74, and 76, respectively.

Gas sensor circuit 60 includes a gas sensing element 80. Element 80 is the gas sensing element of sensor 52 (FIG. 2), which is exposed to the circulating air exiting cooking cavity 24. The resistance R_s of sensor element 80 varies with gas concentration level in the circulating air exiting cavity 24 (FIG. 2) as hereinbefore described with reference to FIG. 3. Sensing element 80 is connected between the output terminal 82 and the inverting input terminal 84 of conventional operational amplifier 86. Capacitor 88 connected in parallel with sensor element 80 serves as a high pass filter for noise reduction. Input resistor 90 connects inverting input terminal 84 of amplifier 86 to DC supply line 74. Reference voltage divider 92 comprising resistors 94 and 96, serially connected between dc input line 74 and said system ground, provides the reference input signal for amplifier 86 at terminal 98. This signal is coupled to amplifier 80 by reference input resistor 100 connected between divider terminal 98 and the non-inverting input terminal 102 of amplifier 86.

The output voltage V_o appearing at amplifier output terminal 82 is proportional to the ratio of the resistance of sensor element 80 to the resistance of input resistor 90. Hence, voltage V_o varies linearly with the resistance of sensor element 80. Output terminal 82 of amplifier 86 is connected to input port J1/A1 of microprocessor 64 to couple the sensor output voltage V_o to the microprocessor. As shown in FIG. 3, the approximate dynamic range for sensor element resistance R_s of the illustrative embodiment during the cooking cycle is from 75K ohms at the beginning of the cooking cycle to less than 5K ohms at the combustion point. The magnitude of input resistor 90 and the magnitude of reference voltage from divider 92 are selected to scale and position the output voltage V_o to fall within the desired input range for the internal analog to digital converter of microprocessor 64 over the dynamic range of sensor element 80.

TGS 186 gas sensor 52 includes heater element 104 as an integral component of the sensor package to maintain sensing element 80 at an appropriate temperature for satisfactory operation. For stable sensor operation, the voltage applied to sensor heater element 104 should be closely regulated. To this end, heater circuit 62 includes, in addition to sensor heater element 104, a voltage regulator integrated circuit 106. Heater element 104 is serially connected between the output of voltage regulator 106 and system ground. Voltage regulator 106 regulates the -9 volt dc signal from line 72 of power

supply 70 to provide a regulated -5 volt signal to heater 104. Regulator circuit 106 in the circuit is a standard 7905 integrated circuit readily commercially available from National Semiconductor. Bypass resistor 108 connected in parallel with integrated circuit 106 and capacitor 109 in parallel with heater 98 reduce power dissipation in voltage regulator 106.

Sensor monitoring means responsive to the voltage signal V_o generated by the sensor circuit 60 at terminal 82 is provided in the circuit of FIG. 4 by microprocessor 64 which is appropriately programmed to provide means for detecting a magnitude of V_o indicative of a gas concentration level greater than a reference level, means for determining the rate of change of the magnitude of V_o , and means for first detecting a relatively small rate of change of magnitude indicative of the drying out phase for the food being heated following detection of concentration level greater than said reference level and thereafter detecting a relatively large rate of change of magnitude indicative of the transition to the pre-combustion phase. Microprocessor 64 is further programmed to generate a signal at output ports R11 and R12 upon detection of the large rate of change. The signal at R11 is operative to energize alarm oscillator circuit 69. Oscillator circuit 69 may comprise any one of a number of conventional multivibrator circuits known in the art to drive load speaker 110 at a frequency discernible by the user to indicate that a fire condition in cavity is imminent. The signal at R12 is operative to open power control relay 68, de-energizing power circuit 65, thereby de-energizing magnetron 40 and blower motor 67.

Microprocessor 64 is a standard TMS 2670 series 4K microprocessor of the type readily commercially available from Texas Instruments. The ROM of microprocessor 64 has been customized to perform the desired control functions for microwave oven 10.

Power circuit 65 is connected between power input lines L1 and N to provide power to magnetron 40 and blower motor 69 of blower 42 (FIG. 2). The power circuit 66 for magnetron 40 includes power transformer 112 having a high voltage secondary 114 connected to energize magnetron 40 through a half-wave voltage doubler comprising series capacitor 116 and rectifying diode 118 connected across the magnetron anode and cathode terminals 120 and 122, respectively, and oppositely poled with respect thereto. Secondary winding portion 124 of transformer 112 is connected as a filament winding to heat the cathode of magnetron 40. Power line L1 is coupled to terminal 126 of primary winding 128 of transformer 112 through a fuse 130 and main power relay switch 68. Main power relay 68 is controlled by a signal from microprocessor 64 coupled to the relay coil 134 of relay 68 from output port R12 via conventional relay driver circuit 136. The other terminal 138 of primary winding 128 is coupled to power line N via triac 140 having a gate terminal 142. Triac 140 is operated in a duty cycle control mode by suitable control signals from output port R13 of microprocessor 64 which are coupled to triac gate terminal 142 via conventional opto-coupler circuit 143.

Energization of fan motor 67 is controlled by triac 144 serially connected to motor 67 across power lines L1 and N. Triac 144 is controlled by signals from output port R10 of microprocessor 64 connected to triac gate terminal 146 of triac 144 via conventional opto-coupler 145.

The following component values have been found suitable for use in the circuit of FIG. 4. These values are exemplary only and are not intended to limit the scope of the claimed invention.

FIXED RESISTORS	
90	107K ohms
94	732 ohms
96	511 ohms
100	22K ohms
108	56 ohms
CAPACITORS	
88	.01 μ f
108	10 μ f
116	.91 μ f

Operation of the circuit of FIG. 4 will now be described with reference to the flow diagram of FIG. 5. This flow diagram illustrates an algorithm which is implemented in the ROM of microprocessor 64. From this diagram, one of ordinary skill in the programming art can readily prepare a set of instructions for permanent storage in the ROM of microprocessor 64. It is of course to be understood that other portions of the microprocessor ROM may be utilized to implement additional oven control algorithms. Since the details of such additional algorithms add nothing to the understanding of the present invention such details have been omitted for brevity and simplicity.

The method of anticipating a fire condition in the cooking cavity implemented by the algorithm illustrated in the flow diagram of FIG. 5 includes the following steps. First, in order to distinguish the initial period of relatively constant gas concentration which normally occurs at the beginning of the normal cooking phase (FIG. 3), from the later occurring "drying out" phase, the sensor output voltage V_o is monitored to detect a voltage magnitude corresponding to a concentration level indicative of having progressed in the cooking cycle to a point beyond the initial plateau. Having detected a concentration level in excess of the reference level, the rate of change of V_o corresponding to the rate of change of sensed concentration level is periodically determined. The rate of change of voltage magnitude is then monitored, first to detect a rate of change corresponding to a rate of change of concentration level less than a predetermined rate signifying transition from the normal cooking phase to the drying out phase. Having detected such a lesser rate, the rate of change of V_o is thereafter monitored to detect a rate of change corresponding to a rate of change of concentration level greater than a predetermined rate, signifying the transition from the drying out phase to the pre-combustion phase. Upon detection of the greater rate, the magnetron and the blower motor are de-energized and an indication is provided to the user such as an audible signal signifying that a combustion condition in the cavity is imminent.

Referring now to FIG. 5, the FIRE DETECTION routine is periodically entered from the master or executive program for microprocessor 64 throughout the cooking cycle. Such periodic entry may be satisfactorily made with a time between entries on the order of 2-5 seconds. However, time between entries need not be limited to this range for satisfactory performance. Upon entering the routine, the sensor output voltage V_o at input port J1/A1 is sampled (Block 152). Inquiry 154 compares the sampled voltage V_o with a predetermined reference value V_R representative of the food

being heated having reached that portion of the normal cooking phase characterized by a relatively rapidly increasing concentration level. In the illustrative example, a reference voltage level V_R corresponding to the sensor resistance at point A (FIG. 3) was somewhat arbitrarily selected as being about the midpoint of this portion of the normal cooking phase for a potato. The precise reference value is not critical provided it represents a point between the initial constant portion of the normal cooking phase and the transition into the drying out phase. A No response to Inquiry 154 results in a return (Block 156) to the master program. As the food continues to heat, at some point prior to the end of the normal cooking phase the sensor output voltage V_o will drop below the reference value V_R , resulting in a YES to Inquiry 154. On this and each subsequent pass through the FIRE DETECTION routine during the same cooking cycle, the response to Inquiry 154 will be Yes and Blocks 158-164 and Inquiry 166 will determine the rate of change of the magnitude of output voltage V_o . As shown by the resistance curve in FIG. 3, the change in resistance as the cooking cycle progresses is not a smooth curve but, rather, is characterized by irregular small oscillations. For proper operation the system must respond to the average rate of change computed over a sufficiently long period to smooth out the oscillations. The average rate of change is periodically determined as follows. First, the current incremental change ΔV in the output voltage V_o is computed by subtracting V_o from the previously sampled voltage signal stored as V_o' (Block 158). V_o is then placed in memory as V_o' (Block 160). The cumulative or total change ΔV_T in voltage over the averaging period T_P is updated by adding the just computed ΔV to the old ΔV_T (Block 162). Next, the timer T is incremented (Block 164). The duration of the averaging period is controlled by Inquiry 166 which detects T greater than T_P where T_P is the desired duration of the averaging period. The duration of the averaging period is not critical and may fall in a wide range of values provided only that it be of sufficient duration for adequate smoothing and yet sufficiently short to provide a satisfactory response time for the system. A period on the order of 30 seconds duration is thought to provide satisfactory smoothing. Until completion of the period T_P , a NO to Inquiry 166 causes a return (Block 156) to the main program. At the completion of each averaging period signified by a YES to Inquiry 166, the timer is reset (Block 168). The average rate of change $(dv/dt)_A$ for the just completed averaging period is set equal to the cumulative change for that period ΔV_T (Block 170). This value is directly proportional to the true average since the time period T_P is constant. ΔV_T is then reset for the next averaging period (Block 172). Having updated the average rate, Inquiry 174 checks the status of a Drying Out Flag, which is set upon detection of an average rate of change characteristic of the cooking operation having progressed to the drying out phase. Thus, initially, this Flag is not set and the response to Inquiry 174 is No. Inquiry 176 then compares $(dv/dt)_A$ with a predetermined reference ΔS . ΔS corresponds to an average rate of change sufficiently small as to be characteristic of the cooking cycle having entered the drying out phase. Hence, Inquiry 176 detects the small rate of change characteristic of the drying out phase. During the balance of the normal cooking phase, the answer to Inquiry 176 is No and the program returns to

the master program at this point (Block 156). As the food continues to be heated beyond the normal cooking phase, it enters its drying out phase. During this phase, as hereinbefore described, the rate of change of the concentration level drops off significantly. When a $(dv/dt)_A$ less than ΔS (Yes to Inquiry 176) is first detected indicative that the transition into the drying out phase has occurred, the Drying Out Flag is set (Block 178) and the program returns (Block 156). Thereafter, for the balance of the cooking cycle, Inquiry 174 indicates that the Drying Out Flag is set and the program will proceed to Inquiry 180 to detect a rate of change greater than a predetermined reference rate of change ΔL characteristic of entering the pre-combustion phase. For the balance of the drying out phase, Inquiry 180 will be No and the program will return to the master program at this point (Block 156). Upon detection of a rate of change greater than reference ΔL , (Yes to Inquiry 180) a signal is provided at output port R12 causing power control relay 68 to open, thereby de-energizing magnetron 40 and the blower motor 67 (Block 182). It will be appreciated that fan motor 67 and magnetron 40 could alternatively be de-energized by inhibiting trigger signals to triac gate terminals 146 and 142, respectively, rather than by opening relay 68. The de-energizing of both the magnetron and the blower motor using either technique in effect turns off power to the oven. Also following a Yes to Inquiry 180, a signal is provided at R11 triggering the alarm oscillator circuit 69 into oscillation to provide an audible signal to the user that a fire condition in the cavity is imminent (Block 184).

By detecting the occurrence of a rapid increase in the rate of change of concentration level by the hereinbefore described method, magnetron 40 is de-energized prior to the load being heated in the oven reaching its actual combustion temperature, thereby anticipating a potential fire condition and preventing the load from reaching its combustion point.

While a specific embodiment of the method and apparatus of the present invention has been illustrated and described herein, it is realized that modifications and changes will occur to those skilled in the art to which the invention pertains. For example, to distinguish the drying out phase from the initial relatively constant portion of the normal cooking phase, rather than detecting a concentration level greater than a predetermined reference level to initiate looking for the relatively small rate of change marking the transition into the drying out phase, the reference level may be computed as a percentage of the initial value for each cycle. Alternatively, the elapsed time since initiation of the cooking cycle might be monitored to determine a starting point for detecting the small rate of change. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit and scope of the invention.

What is claimed is:

1. A method of anticipating a fire condition in the cooking cavity of a microwave oven of the type having means for continuously circulating air through the cavity to remove gaseous emissions from the food being heated in the cavity and sensor means for sensing the concentration of such gases in the circulating air, said method comprising the steps of:

circulating air through the cavity to remove therefrom gases emitted from the food load being heated in the cavity;

sensing the concentration level of such gases in the circulating air;
periodically determining the rate of change of concentration level;

monitoring the rate of change to detect a rate of change characteristic of the temperature of the food load in the cavity closely approaching its combustion temperature including the steps of detecting a first relatively slow rate of change indicative of the load having been cooked to its drying out stage and thereafter detecting a second relatively rapid rate of change, detection of said second rate following said first rate being indicative of closely approaching the combustion temperature of the load; and having detected said second rate of change, turning off power to the oven.

2. A method of anticipating a fire condition in the cooking cavity of a microwave oven of the type having means for continuously circulating air through the cavity to remove gaseous emissions from the food being heated in the cavity and sensor means for sensing the concentration of such gases in the circulating air, said method comprising the steps of:

continuously circulating air through the cooking cavity;
sensing the concentration level of gases emitted by the food in the circulating air;
detecting a concentration level above a predetermined reference level indicative of having heated the food sufficiently to cause the food to emit gases into the circulating air;
having detected a concentration level greater than the reference level, thereafter periodically determining the rate of change of the concentration level as a function of time;
monitoring the rate of change of the concentration level to detect a relatively small rate of change characteristic of the drying out of the food load;
having detected the small rate of change, thereafter monitoring the rate of change to detect a relatively large rate of change; and
upon detection of the relatively large rate of change, turning off power to the oven and providing an indication to the user that a combustion condition in the oven is imminent.

3. A method of anticipating and preventing a fire condition in the cooking cavity of a microwave oven of the type having means for circulating air through the cavity and sensor means for sensing the concentration of gases in the circulating air emitted from food loads being heated in the cavity, said method comprising the steps of:

(a) continuously circulating air through the cooking cavity of the oven during the cooking cycle;
(b) periodically sensing the concentration level in the circulating air of gases emitted from the food during cooking and generating a voltage signal representative of the sensed concentration level;
(c) monitoring the voltage signal to detect a voltage level indicative of having completed an initial portion of the normal cooking cycle;
(d) having detected an indicative voltage, thereafter periodically computing the rate of change of voltage with time;
(e) monitoring the rate of change of voltage to detect a small rate of change of voltage characteristic of the drying out of the food load;

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- (f) having detected the small rate of change, thereafter monitoring the rate of change to detect a large rate of change characteristic of a relatively rapid increase in the concentration of gases in the circulating air; and
- (g) upon detection of the large rate turning off the power to the oven and providing an indication to the user that a combustion condition in the oven is imminent.
4. A method for anticipating the occurrence of a fire in the cooking cavity of a microwave oven of the type having means for circulating air through the cavity during the cooking process and a sensor for determining the concentration of gases in the circulating air emitted by foods being cooked in the cavity, which concentration level as a function of time is divided into three phases: a normal cooking phase characterized by an initial brief period of relatively constant concentration level followed by a period of relatively rapidly increasing concentration level; a drying out phase characterized by a relatively slowly increasing concentration level, and a pre-combustion phase, characterized by a relatively rapidly increasing concentration level, said method comprising the steps of:
- circulating air through the cooking cavity of the oven;
 - detecting a concentration level of gases in the circulating air indicative of the cooking cycle having progressed beyond the initial period of the normal cooking phase for the food being heated;
 - thereafter periodically determining the rate of change of concentration level as a function of time;
 - detecting a first rate of change characteristic of the drying out phase;
 - having detected said first rate of change, thereafter detecting a second rate of change indicative of the pre-combustion phase; and
 - upon detection of said second rate of change, turning off power to the oven and providing an indication to the user that a fire condition in the cavity is imminent.
5. A control arrangement for a microwave oven comprising:
- means for generating microwave energy for heating foods received in the cooking cavity;
 - means for continuously circulating air through the cooking cavity to remove therefrom gases emitted by the food load being heated in the cavity;
 - sensing means for sensing the concentration level of such gases in the circulating air and generating a first signal having a magnitude representative of the sensed concentration level;
 - sensor monitoring means responsive to said first signal and including means operative to periodically determine the rate of change of concentration level as a function of time, and means operative to detect a rate of change indicative of closely approaching the combustion point of the load being heated in the oven, said detecting means including means for detecting the occurrence of the second of two periods of relatively rapidly increasing concentration level separated by a period of relatively slowly increasing concentration level, and generating a

12

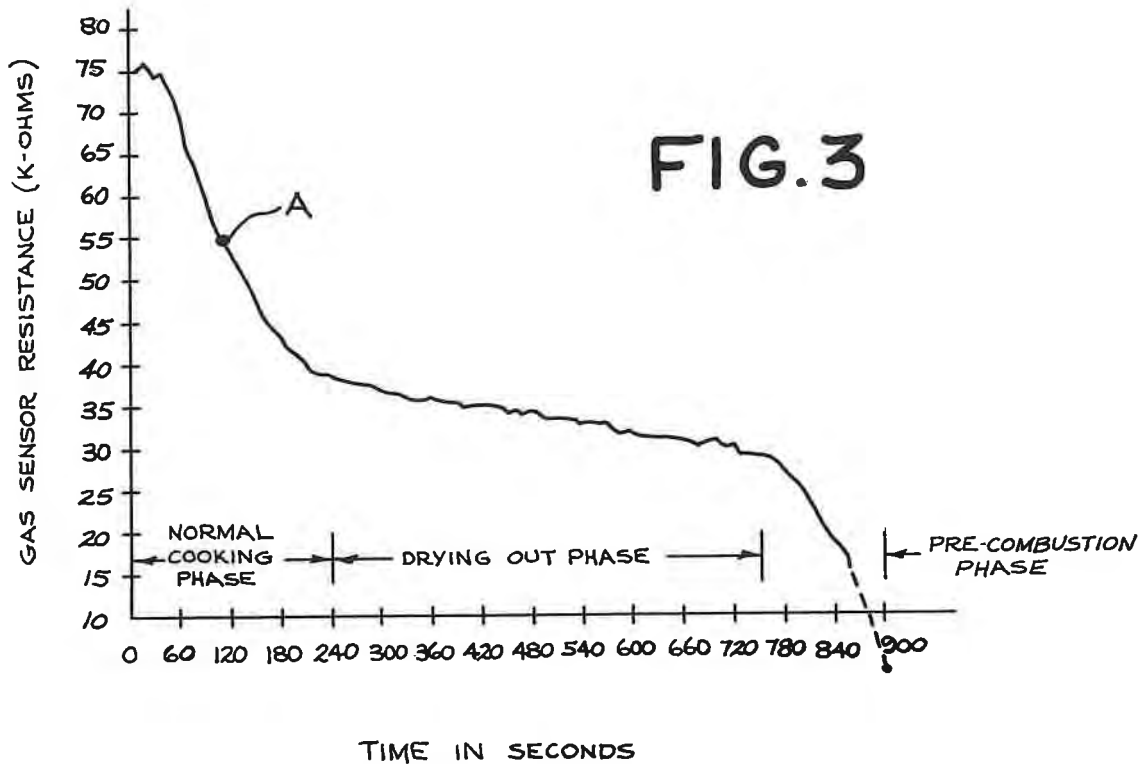
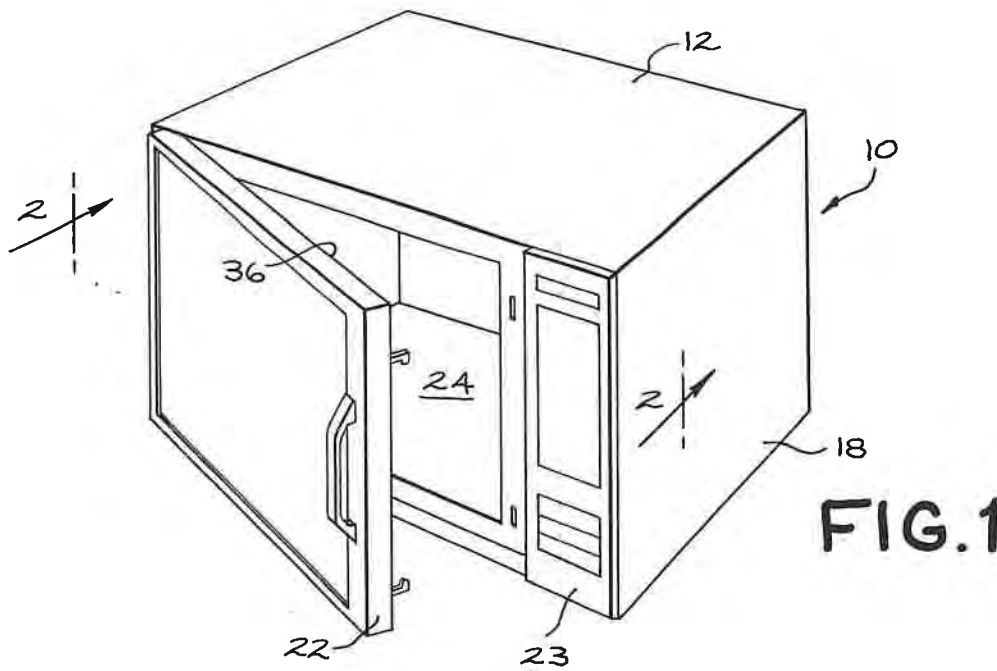
- second signal upon detection of said second period; and
- means for terminating operation of said microwave energy generating means and said air circulating means in response to said second signal.
6. A control arrangement for a microwave oven comprising:
- means for generating microwave energy for heating foods received in the cooking cavity;
 - means for continuously circulating air through the cooking cavity to remove therefrom gases emitted by the food load being heated in the cavity;
 - sensing means for sensing the concentration level of such gases in the circulating air and generating a first signal having a magnitude representative of the sensed concentration level;
 - sensor monitoring means responsive to said first signal and including means operative to periodically determine the rate of change of concentration level as a function of time, and means operative to detect a rate of change indicative of closely approaching the combustion point of the load being heated in the oven including means for detecting a relatively slow rate of increase in concentration level indicative of the food load being heated to its drying out stage and thereafter detecting a relatively rapid increase in concentration level indicative of closely approaching the combustion point of the food load and generating a second signal upon detection of said relatively rapid increase; and
 - means for terminating operation of said microwave energy generating means and said air circulating means in response to said second signal.
7. A control arrangement for a microwave oven which anticipates a fire condition in the cooking cavity of the oven, said control arrangement comprising:
- means for generating microwave energy for heating foods received in the cooking cavity;
 - means for continuously circulating air through the cooking cavity to remove therefrom gases emitted from the food load being heated in the cavity;
 - sensing means for sensing the gas concentration level of the circulating air and generating a first signal having a magnitude representative of the sensed gas concentration level;
 - sensor monitoring means responsive to said first signal including: means for detecting a signal magnitude indicative of a gas concentration level greater than a reference level; means for determining the rate of change of said signal magnitude; means for first detecting a relatively slow rate of change following detection of said concentration level greater than said reference level and thereafter detecting a relatively rapid rate of change;
 - means responsive to said sensor monitoring means operative to de-energize said microwave energy source and to terminate operation of said air circulating means following detection of said rapid rate of change; and
 - means responsive to said sensor monitoring means operative to provide an indication to the user that a fire condition in the cavity is imminent following detection of said rapid rate of change.

* * * * *

U.S. Patent Jan. 29, 1985

Sheet 1 of 4

4,496,817



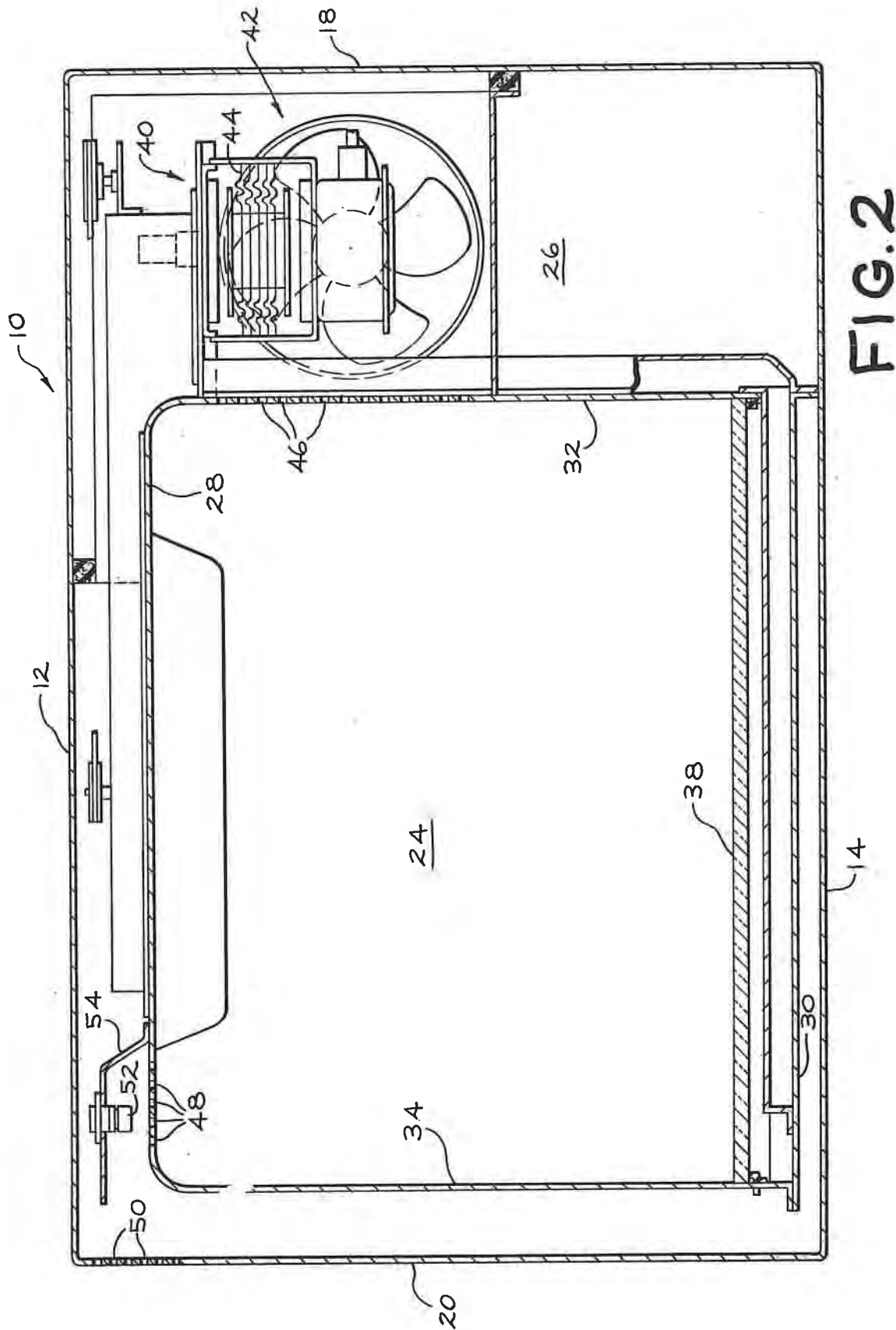


U.S. Patent

Jan. 29, 1985

Sheet 2 of 4

4,496,817







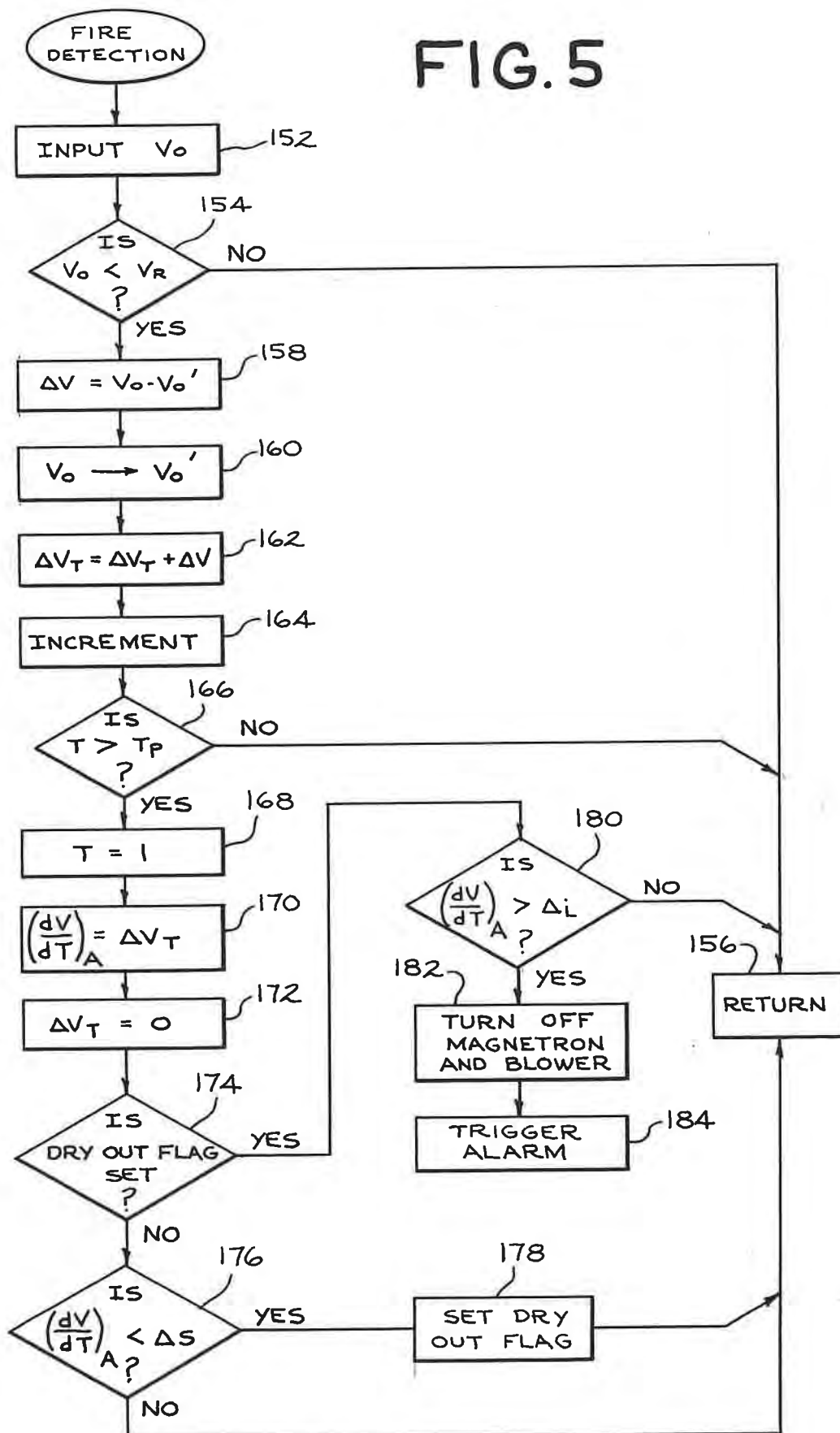


U.S. Patent Jan. 29, 1985

Sheet 4 of 4

4,496,817

FIG. 5





M PTO-875 (3-83)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	SERIAL NO. 511556	FILING DATE 7/07/83
PATENT APPLICATION FEE DETERMINATION RECORD		APPLICANT (FIRST NAMED) Smith	

CLAIMS AS FILED - PART I

	NO. FILED	NO. EXTRA
IC FEE		
AL CLAIMS	9	-20=
EP. CLAIMS	6	-3=
MULTIPLE DEPENDENT CLAIM PRESENT		

If the difference in col. 1 is less than zero, enter "0" in col. 2

SMALL ENTITY

RATE	FEE
	\$150
x5=	\$
x15=	\$
+50=	\$
TOTAL	\$

OTHER THAN A SMALL ENTITY

RATE	FEE
	\$300
x10=	\$
x30=	\$ 90
+100=	\$
TOTAL	\$ 390

CLAIMS AS AMENDED - PART II

(1)	(2)	(3)
CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA
TOTAL	9	MINUS 20 = 0
INDEP.	7	MINUS 6 = 1
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM		

SMALL ENTITY

RATE	ADDIT. FEE
x5=	\$
x15=	\$
+50=	\$
TOTAL ADDIT. FEE	\$

OTHER THAN A SMALL ENTITY

RATE	ADDIT. FEE
x10=	\$
x30=	\$ 300
+100=	\$
TOTAL	\$ 300 Paid

CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA
TOTAL		MINUS ** =
INDEP.		MINUS *** =
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM		

RATE	ADDIT. FEE
x5=	\$
x15=	\$
+50=	\$
TOTAL ADDIT. FEE	\$

RATE	ADDIT. FEE
x10=	\$
x30=	\$
+100=	\$
TOTAL	\$

CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA
TOTAL		MINUS ** =
INDEP.		MINUS *** =
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM		

RATE	ADDIT. FEE
x5=	\$
x15=	\$
+50=	\$
TOTAL ADDIT. FEE	\$

RATE	ADDIT. FEE
x10=	\$
x30=	\$
+100=	\$
TOTAL	\$

* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.
 If the "Highest No. Previously Paid For" IN THIS SPACE is less than 20, enter "20".
 If the "Highest No. Previously Paid For" IN THIS SPACE is less than 3, enter "3".
 The "Highest No. Previously Paid For" (Total or Indep.) is the highest number found in the appropriate box in Col. 1

PATENT NUMBER

ORIGINAL CLASSIFICATION

CLASS

SUBCLASS

219

10.55M

APPLICATION SERIAL NUMBER

06/511,556

CROSS REFERENCE(S)

CLASS

SUBCLASS
(ONE SUBCLASS PER BLOCK)

219

10.55B

10.55R

340

578

579

236

44C

APPLICANT'S NAME (PLEASE PRINT)

SMITH

IF REISSUE, ORIGINAL PATENT NUMBER

INTERNATIONAL CLASSIFICATION (INT. CL.³)

H05B

6/68

GROUP
ART UNIT

213

ASSISTANT EXAMINER (PLEASE STAMP OR PRINT FULL NAME)

PRIMARY EXAMINER (PLEASE STAMP OR PRINT FULL NAME)

PHILIP

H. LEUNG

PTO 270
(10/80)U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

ISSUE CLASSIFICATION SLIP

Dionice 3/23/03



2

APPROVED FOR LICENSE ☐

INITIALS 010



REQ808282318

WNR-01-04-040-1-020-05-005

Transfer#: W241-97-0253 Box:56 CC:NP

ARR1-4834050212

Asset#: AAC1-22872871

Whole Container: N

C/F:06/511556 | 4496817

Created: 08/28/2023

General Reference

Temporary Loan of Records

Emergency Customer Pick-up N/A

TO: WILLIAM THOMPSON
600 DULANY STREET
ALEXANDRIA VA 22314
P: (571)272-5082 F:

REGUL

Form PTO-436
(Rev. 8/78)

SERIAL NUMBER
(series of 1979)
511556

SERIAL NUMBER
06/511,556

APPLICANTS
PETE'

SEARCHED

Class	Sub	Date	Ex'r
219	10.55B 10.55R 10.55M 10.55E 510,444 497	5/10/84	mp
340	577,578 579,588 589,628 629		
236	44,C		
426	234 241,243 242		
99	325 DLG,14		
Updated 9/5/84 me			

PRINT CLAIM(S):

INDEX OF CLAIMS

Claim	Date	Claim	Date
Final	Original	Final	Original
1	5/10/84	26	
2	5/10/84	27	
3	5/10/84	28	
4	5/10/84	29	
5	5/10/84	30	
6	5/10/84	31	
7	5/10/84	32	
8	5/10/84	33	
9	5/10/84	34	
10	5/10/84	35	
11	5/10/84	36	
12	5/10/84	37	
13	5/10/84	38	
14	5/10/84	39	
15	5/10/84	40	
16	5/10/84	41	
17	5/10/84	42	
18	5/10/84	43	
19	5/10/84	44	
20	5/10/84	45	
21	5/10/84	46	
22	5/10/84	47	
23	5/10/84	48	
24	5/10/84	49	
25	5/10/84	50	

INTERFERENCE SEARCHED

Class	Sub	Date	Ex'r
as above		9/5/84	me

SYMBOLS

STATUS

- V Rejected
- = ... Allowed
- (Through numeral) Canceled
- + ... Restriction requirement
- N Nonelected invention or species
- I Interference
- A Appeal
- O Objected

511556



Entered

CONTENTS

1. Application Pts papers2. Prior Cut3. By (3)4. Threat Cut5. Cost A6. Notice of allowance September 6, 19847. Notice of allowability September 6, 19848. Appl Declaration Sept. 17, 1984

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