A gas cooktop has one or more gas burners and one or more gas valves, each valve being connected to control gas flow to one of the gas burners. A touch-activated user interface is provided for user entry of burner heating level for each of the gas burners, and a controller is provided for controlling each of the gas valves proportionally in accordance with the user entry for the corresponding valve. A control system for the gas cooktop comprises: a) a microcontroller equipped with a bi-directional serial communication module, a pulse-width-modulation (PWM) module and optionally a modulating–valve fault–condition detector; b) an array of electronically calibrated gas modulating valves; c) an electronic capacitive keyboard interface capable of detecting human touch and optionally liquid spill; d) an optional electronic capacitive sensor capable of detecting pot presence on each burner; e) an optional array of capacitively activated pot sensors; f) an embedded down–draft control; g) a visual and auditory user interface; and h) software control instructions especially adapted to provide a smooth transition in gas flow level adjustment, thereby providing improved gas flame control.
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Title of Invention

GAS COOKTOP AND CONTROL SYSTEM

Technical Field

This invention relates generally to control of a gas appliance or hybrid gas/electric appliance and more particularly to a gas cooktop controlled proportionally with the aid of electronically controlled gas valves, a touch-activated human interface, and a microprocessor operating under software instructions. An exhaust fan and/or downdraft associated with the cooktop can also be controlled.

Background Art

Conventional gas cooktops are generally operated by using mechanical actuator knobs, operating associated gas valves. In those gas cooktops that have any electronic controls, the electronic controls are generally oven controls only, specifically timing functions such as time-of-day, timed-bake timers, and timed-oven-cleaner timers. Additionally, such controls have required mechanical presetting of the gas valve to predetermined levels.

Additionally, users of such actual gas cooking appliances have not benefited from having a burner capable of delivering very low heat, due to the difficulty of steadily maintaining a low flame. Most gas cooktops actually on the market do not have the ease of maintenance provided by some electric cooktops. Features such as capacitive touch control have not been available to the gas cooktop user. The control of a downdraft and/or exhaust fan commonly used with gas or electric cooktops has been accomplished mainly by using individual controls in the downdraft or exhaust unit itself. Other features such as pot detection have been accomplished heretofore either by a switch, or by infrared sensors, both of which can be affected by getting dirty from spillage or being covered with food residues and other contaminants.
U.S. Pat. No. 4,930,488 to Pearman et al. discloses a microprocessor-controlled gas appliance having a computer processor with a sensor interface, a valve assembly, and a human interface. The sensor interface is capable of passing the input from a series of sensors through the processor for subsequent use in controlling the operation of a burner valve in the valve assembly. Appropriate sensors are provided for connection to the sensor interface to measure, among other things, flame temperature, gas flow, carbon monoxide, combustibles, occupancy by an individual in the presence of the gas appliance, and gas composition. The valve controls the flow of natural gas through a line from a source of gas to a burner found in the appliance. The valve is controlled through a valve operator that responds to signals obtained from the computer processor via valve interface electronics. The valve, valve operator, and valve interface electronics together form the valve assembly. A visual display and a keypad-input device provide a way for the human user to interact with the gas appliance control system.

U.S. Pat. No. 5,458,294 to Zachary et al. discloses an apparatus for controlling gas fuel flow to a burner of a combustion device. A variable orifice solenoid-operated valve serves as a control element. The valve includes a poppet having a fixed control surface at an end received in an insert element having a variable control surface. The poppet has a plurality of positions within the insert element, including a full open position and a full closed position. Maximum fuel flow is measured in the full open position and minimum fuel flow is measured in the full closed position. Intermediate partially open positions are adjustable by a signal of an electronic controller connected to the solenoid valve operating as a function of actual and desired temperature of the combustion device.

U.S. Pat. No. 5,730,165 to Phillipp discloses a capacitive field sensor for the control of a water supply valve in a basin or fountain, employing a single coupling plate to detect a change in capacitance to ground. The apparatus comprises a circuit for charging a sensing electrode and a switching element acting to remove charge from the sensing electrode and to transfer it to a charge detection circuit. The time interval employed for the charging and discharging steps can vary widely. Usually at least
one of the charge or discharge pulses is on the order of a hundred nanoseconds, and is shorter in duration than a characteristic conduction time for a body of water disposed about the sensing plate. The sensor disclosed by Phillipp can also be used for control of a gas flame.

Thus, there is a need for a gas cooktop appliance capable of delivering very low heat and capable of fine control of heating level and thus providing the user with a more complete span of available and controllable temperatures. There is also a need for an electronic control capable of handling both gas and electric element at once, offering the user the choice over the power and high speed of a gas burner and the precision and low power control of the electric element, both built into the same embodiment.

Disclosure of Invention

Objects of the Invention

Thus, a major object of the invention is a gas cooktop appliance capable of delivering very low heat and capable of fine control of heating level. Another objective of the present invention is a gas cooktop appliance having an innovative electronic control featuring a capacitive touch user interface. Such a capacitive touch interface facilitates the maintenance of surfaces that are generally prone to become dirty and mostly difficult to reach. A capacitive touch interface offers the additional benefit of eliminating the wear and tear associated with mechanical devices.

Another objective is an electronic control capable of handling both gas and electric element at once, offering the user the choice over the power and high speed of a gas burner and the precision and low power control of the electric element, both built into the same embodiment. Yet another objective is a gas cooktop control having smooth control of gas flames at each burner, with smooth, steady flame control extending down to very low heating levels.

There is equally a need for having a gas/electric or electric cooktop featuring an embedded electronic controller capable of directly raising and lowering a remote down-draft as well as controlling its fan speed. There is also a need for a cooktop to
incorporate an electronic capacitive pot sensor featuring a flat surface, no mechanical part prone to wear and tear, and no opto-electronic device sensitive to interference due to dirt.

5 The present invention is intended to provide practical solutions to the existing art, thus globally fulfilling these needs.

SUMMARY OF THE INVENTION

10 The present invention relates to the field of gas and electric cooktop appliances in general and more specifically to a micro-controller-based electronic controller for gas / electric cooktop appliance and related remote down-draft. Although all of the features of the present invention are applicable to hybrid gas / electric cooktops, some of the features are also applicable to gas cooktops alone or to electric cooktops alone.

15 In its preferred embodiment, the present invention is presented as a gas / electric residential cooktop and controls, but it will be understood that the teachings of the present invention are also applicable to industrial and commercial gas and/or electric cooktop appliances.

20 Among features provided by this invention are: a capacitive touch keyboard interface, an entirely electronic control system controlling the gas flow through modulating valves, a directly embedded control with visual indication for a remote downdraft, the integration of gas burners and electric simmer heating element in a unique cooktop enclosure, and an innovative capacitively activated pot presence sensor.

25 The control is capable of detecting human touch to its keyboard interface through a dielectric material silk-screened at touch area, such as glass, ceramic, plastic etc. It is also capable of liquid (e.g., water) spill detection on the control surface area and of activation of safety features accordingly. It is capable of communicating keyboard information through a bi-directional serial-communication module. Through the use of a capacitive sensing module, each burner is capable of pot detection. Among other things, unattended burners can be de-activated and flame size can be automatically
adjusted to accommodate various pot sizes. A main solenoid valve, activated through a relay, permits the gas to enter the appliance from the main source. This provides a safety feature, as such a main valve is opened only according to whether one or more of the burners is activated through the touch control panel. Each in-line solenoid valve, also activated through relays, permits complete opening/closure of an individual-burner gas line and provides an additional and redundant safety feature, since each in-line solenoid valve is activated only if that particular burner is selected. Modulating valves activated through a pulse-width-modulation (PWM) port, control the flow of gas.

Natural or propane gas is selectively provided to each individual burner, thus eliminating the need for mechanical valves protruding through the user console and facilitating the maintenance of such surface. Each of the modulating valves is auto-calibrated under software control; calibration is electronically and permanently retained by an on-board electrically erasable programmable read-only memory (EEPROM). Each of the modulating valves is monitored for faulty operation and safety features such as visual and auditory alarms are generated. Ignition of the gas is also monitored and safety features such as in-line valve closure is supported in the event that a faulty condition occurs. Using sophisticated software control, the gas flame is gradually adjusted from level to level, offering smoothness of control similar to so-called “infinite” controls.

**Brief Description of the Drawings**

FIG. 1 is a block diagram of a cooktop system made in accordance with the invention.

FIGS. 2a and 2b together form a flowchart illustrating a control software process performed in accordance with the invention.

**Modes for Carrying Out the Invention**

FIG. 1 is a block diagram of a cooktop system made in accordance with the invention.

The cooktop of FIG. 1 has one or more gas burners, one or more gas valves (each of these valves being connected to control gas flow to one of the gas burners), a user
interface for user entry of burner heating level for each of the gas burners, and a
ccontroller operative to control each of the gas valves in accordance with the user’s
selection entered at the user interface, controlled by a suitably programmed
microcontroller. Among features provided by the cooktop system of FIG. 1 are: a
capacitive touch keyboard interface, an entirely electronic control system controlling
the gas flow through modulating valves, a directly embedded control with visual
indication for a remote downdraft, the integration of gas burners and electric simmer
heating element in a unique cooktop enclosure, and an innovative capacitively
activated pot presence sensor.

Central microcontroller 1 as used in the system is illustrated in the block diagram
FIG. 1. The microcontroller-based control for the gas cooktop preferably includes a
microcontroller integrated circuit having the following:
a) a gas pressure sensor input port for monitoring and calibration of modulating
valves;
b) a bidirectional serial communication port for interfacing with a capacitive keyboard
decoder integrated circuit;
c) a serial peripheral interface port for interfacing with display interface circuitry;
d) a pulse-width-modulation (PWM) port for controlling gas modulating valves;
e) a PWM fault detection port for monitoring gas modulating valves;
f) an input port for 60 Hz signal detection;
g) an output port for controlling a main gas solenoid valves and individual burner in
line gas solenoid valves;
h) an output port for interfacing with an audible annunciator;
i) an input analog-to-digital converter port for temperature monitoring;
j) an output port for controlling a gas igniter module; and
k) an input port for monitoring gas ignition.

The control system provides precise electronic control of gas flow through the use of
modulating valves, in order to provide precise electronic control of heating level in
this cooktop application.
Central microcontroller 1 may be any of the programmable microcontrollers conventionally used for controlling appliances, as are known to those skilled in the art of appliance control.

The control system for the gas cooktop preferably also includes a capacitive keyboard decoding interface module capable of detecting and analyzing a user touch condition. This capacitive keyboard decoding module preferably includes a capacitive matrix decoder integrated circuit with a serial or parallel communication interface; a user touch interface panel (preferably silk-screened); and a capacitive sensing keypad placed in registry with the user touch interface panel. Key sensitivity may be made individually trimmable for adaptation to key size, key shape, and key location on the user interface keyboard. Capacitive sensing for the keyboard interface may be done as described in U.S. Pat. No. 5,730,165 to Phillipp, the entire disclosure of which is hereby incorporated by reference. In U.S. Pat. No. 5,730,165, a capacitive field sensor employs a single coupling plate to detect a change in capacitance to ground. The apparatus comprises a circuit for charging a sensing electrode and a switching element acting to remove charge from the sensing electrode and to transfer it to a charge detection circuit. The time interval employed for the charging and discharging steps can vary widely. Usually, at least one of the charge or discharge pulses is on the order of a hundred nanoseconds, and is shorter in duration than a characteristic conduction time for matter disposed about the sensing plate. If desired, a short charge or discharge pulse duration may be used when the controlled valve is closed, and a longer duration may be used when the valve is open.

A suitable module for capacitive keyboard decoding interface 20 is the model QM1 available from Quantum Research Group Ltd. of Southampton, England and Pittsburgh, PA, or preferably the model QT60320 Matrix Scan IC available from that company.

Similarly, capacitive sensing can be used for pot presence sensing and pot size detection in the cooktop application. Such capacitive sensing can also use the charge pumping method of Phillipp described above. Pot sensors may be embedded in
ceramic grates disposed at each burner position. A cooktop made in accordance with
the invention may have two types of pot sensors: a discrete local sensor and a large
surface sensor. Such pot sensors may be made without connectors, by utilizing
capacitive coupling to the grates.

The user interface also includes a visual interface portion for displaying information
concerning the status of the cooktop to the user. This visual interface may include a
display using any of several display types, such as seven-segment LED displays,
discrete LED displays, bargraph LED displays, LCD displays, and vacuum
fluorescent displays.

The display elements are driven by a display power driver module preferably
comprising serial output shift registers (integrated circuits), multiple channels of
source driver integrated circuits, multiple channels of sink driver integrated circuits,
and may also include drivers using discrete transistors.

A valve portion of the system preferably includes an in-line gas valve assembly
having a main in-line safety solenoid valve; an in-line shut-off gas solenoid valves for
each burner; an in-line gas modulating valve for each burner; and a gas pressure
output port for calibration of the modulating valves. One suitable modulating valve is
disclosed in U.S. Pat. No. 5,458,294 to Zachary et al., in which a variable orifice
solenoid has a plurality of positions, and the positions are controlled by the
application of a voltage signal to the modulating valve. The entire disclosure of U.S.
Pat. No. 5,458,294 to Zachary et al. is incorporated herein by reference. As described
in more detail below, exceptionally smooth gas flow level transition is obtained in the
present invention by using multiple micro-controller steps between each pair of user-
selected gas-flow level steps. For example, 280 settings have been used between each
pair of adjacent settings of eleven control settings to control the movement of the
valve to make a perfectly smooth flame change. Calibration of the modulating valves
is preferably performed using thermocouple feedback.
A valve power driving module includes a power relay module for driving main and shut-off in line valves and a Darlington array integrated circuit for driving the modulating valves. A zero-crossing voltage detection circuit is provided for the microcontroller, for precise timing of the pulse-width-modulation (PWM) port.

Remote fan control and/or remote down-draft elevation control are optionally provided through the cooktop control, allowing the user to control either of these functions by touching suitable control keys of the cooktop control. The control of the cooktop is combined with the control of a down-draft unit by placing the controls of the down-draft unit in the cooktop area. Up and down arrows indicate raising or lowering the down-draft unit (which is typically located behind either a 30 in. or 36 in. deep cooktop) and indicate various fan speeds in between that can be selected by the user’s sliding a finger along the indicated speed levels. The invention can also control an overhead hood from the cooktop. The benefit of being able to control the hood and/or downdraft is that a user does not have to reach over the burners to adjust the fans. All controls for the cooking functions exist in one place.

FIGS. 2a and 2b together form a flowchart illustrating a control software process performed in accordance with the invention (Arrows at the lower edge of FIG. 2a continue into FIG. 2b at its upper edge). This flowchart illustrates a typical flow of control for a cooktop of the present invention, programmed for execution with a conventional microcontroller.

After initialization of the control program, the capacitive keyboard decoding interface (4 in FIG. 1) is polled by sending a letter “s” from central microcontroller 1 via a bidirectional serial communication (RS232) module. The central microcontroller waits for data (e.g. 8 bytes) from capacitive keyboard decoding interface 20, indicating which key(s) were touched. The remaining steps of the control process that occur after the microcontroller detects which key was touched are clearly described in the flowchart of FIGS. 2a – 2b.
An important feature of the control software is giving the valve poppet many more increments than it would have with conventional manual control. Thus, where the digit setting would have 11 settings, (L, 1-9, and H) normally the valve poppet would have the same number of increment settings. For some uses, control with those 11 increments (or even fewer) may be satisfactory. In the present invention, the valve poppet, through the software control, will preferably have many more gradations, to make flame changes occur more smoothly and less jumpy. Because the poppet moves in much shorter steps, it gains less momentum. This allows the readings to be more accurate and the flame to be less jerky. Thus, exceptionally smooth gas flow level transition is obtained in the present invention by using multiple micro-controller steps between each pair of user-selected gas-flow level steps. For example, 280 settings have been used between each pair of adjacent settings of eleven control settings to control the movement of the valve to make a perfectly smooth flame change.

Two types of valves may be combined: a modulating valve, such as that described in U.S. Pat. No. 5,458,294 to Zachary et al. mentioned above, may be combined with a solenoid valve to make one valve suitable for the cooktop of the present invention. Gas flow to a gas burner suitable for cooktops is controlled incrementally with a modulating gas valve and each burner may also have a solenoid valve as an on/off device. By merging the two valves into one, a valve is provided that is specifically adapted to perform in a cooktop application. The merged valve takes up less space, reduces production costs, and is safer.

Use of the Invention

To use the invention, a user touches desired control keys on a keyboard layout as illustrated in FIG. 1. For example, the user may touch the ON-OFF key to turn a gas burner on, corresponding to a position on the keyboard layout. The user may touch keys to raise (▲) or lower (▼) the gas flame heating level. Similarly, the user may turn an electric simmer element (if present) ON or OFF. If a “slider” control is provided on the keyboard layout, the user can move a finger along the slider control to control the heat level for the electric simmer element. The user may touch a POWER level number or “L” for low or “H” for high, or “up” (▲) or “down” (▼) keys to
change the power. The particular keyboard layout embodiment depicted in FIG. 1 is meant to be representative of a type of touch-sensitive keyboard layout suitable for a cooktop. Preferably, the keyboard layout should, by the use of numerals, symbols, and other indicia, convey to the user the various control functions available, in a manner that is as clear and intuitive as possible. The person of ordinary skill in the art of appliances will recognize that many variations of keyboard layouts with correspondingly programmed functions may be made that are suitable for various uses of gas or hybrid gas/electric cooktops.

Industrial applicability

The invention is useful in manufacture and use of gas or hybrid gas/electric cooking appliances.

Although specific embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing detailed description, it will be understood that the invention is not limited to the particular embodiments described herein, but is capable of numerous rearrangements, modifications, and substitutions without departing from the scope of the invention. From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. For example, an electronically controlled hybrid gas burner / electric simmer may be provided in a cooktop application. The electric simmer function may be triac driven and relay-controlled electric elements may be used in such a cooktop application. The control system may combine two control types: one set of electronic touch cooktop controls for an electric simmer burner (using a triac) and one or more gas burners controlled by modulating valves for controlling the power settings in combination with solenoid valves for the shutoff function. The solenoid valves are then controlled by relays, which are controlled by the microprocessor. Also preheat (i.e. initial on-time) may be provided and used only during the first selection of heat level.

What is claimed is:
1. A cooktop, comprising:
   a) one or more gas burners, and
   b) one or more gas valves, each of said valves being connected to control gas flow to one of said gas burners,
   said cooktop being characterized in that:
   i) a touch-activated user interface is provided for user entry of burner heating level for each of said one or more gas burners; and
   ii) a controller is provided, said controller being operative to control each of said one or more gas valves proportionally in accordance with said user entry entered for the corresponding one of said one or more gas valves.

2. A cooktop as in claim 1, wherein said user interface comprises one or more touch-sensitive pads.

3. A cooktop as in claim 1, wherein each of said gas valves comprises a proportionally controlled solenoid-operated modulating gas valve.

4. A cooktop as in claim 1, wherein said user interface comprises a multiplicity of touch-sensitive pads operable to select burner heating levels in a predetermined set of user-selectable steps.

5. A cooktop as in claim 4, wherein said each of said user-selectable steps corresponds to a flow setting of said gas valves.

6. A cooktop as in claim 4, wherein said each of said user-selectable steps corresponds to a multiplicity of flow-settings of said gas valves in a predetermined range of flow-settings.

7. A cooktop as in claim 4, wherein said user interface further comprises a visual interface including a display selected from the list consisting of:
   a) seven-segment LED displays,
   b) discrete LED displays,
   c) bargraph LED displays,
   d) LCD displays, and
e) vacuum fluorescent displays.
FIG. 2A

WAIT FOR 8 BYTES FROM KEYBOARD DECODING INTERFACE (KEYS TOUCHED AND UNTOUCHED)

WAIT-TIME LIMIT IS PASSED?

YES

KEY COMMUNICATION ERROR!
FLASH 'E' AS INDICATION AND
SHUT OFF ALL ACTIVE BURNERS

NO

DO THE OPERATION BASED ON WHICH KEY IS TOUCHED

DISPLAY CONTROL

ANY GAS BURNER SHOULD BE ACTIVE?

NO

TURN OFF MAIN SOLENOID VALVE AND ALL IN-LINE SOLENOID VALVES

YES

TURN ON MAIN SOLENOID VALVE AND CORRESPONDING IN-LINE SOLENOID VALVE

BURNER IS AT POWER LEVEL TRANSITION?

YES

INCREASE OR DECREASE PWM COUNT BY ONE EVERY 2 MILLISECONDS UNTIL THE RIGHT PWM COUNT NUMBER IS REACHED

NO

GET PWM COUNT ACCORDING TO ITS POWER LEVEL

POLL KEYBOARD DECODING INTERFACE BY RS232 BY SENDING LETTER "S"

INITIALIZATION
CONTROL MODULATION VALVES
DUTY CYCLES BY THEIR
CORRESPONDING PWM COUNT

SHOULD ELECTRIC
BURNER BE ACTIVE?

YES

NO

TURN ON THE CORRESPONDING RELAYS
AND CONTROL DUTY CYCLES OF TRIACS

TURN OFF CORRESPONDING
RELAYS AND TRIACS

RAISE OR LOWER
DOWNDRAFT?

YES

TURN ON DOWNDRAFT MOTOR
RELAY FOR 1 SECOND

NO

SHOULD
DOWNDRAFT FAN
BE ON?

YES

FAN PHASE CONTROL BASED ON
ITS SPEED SETTING

NO

CHECK TEMPERATURE

TEMPERATURE
TOO HIGH?

YES

TURN OFF ALL BURNERS AND
DISPLAYS FLASH 'F'S

NO

FIG. 2B

RECTIFIED SHEET (RULE 91)
ISA/EP
### INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

<table>
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<tr>
<th>IPC 7</th>
<th>F23N5/26</th>
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According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

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

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

**PAJ, EPO-Internal**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
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<td>EP 0 773 409 A (WIRLPOOL EUROPE) 14 May 1997 (1997-05-14) the whole document</td>
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<td>X</td>
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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier document but published on or after the international filing date
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"&" document member of the same patent family

Date of the actual completion of the international search: 13 July 2000

Date of mailing of the international search report: 20/07/2000

Name and mailing address of the ISA:
European Patent Office, P.B. 5816 Patentlaan 2 NL - 2280 HV Rijswijk
Tel: (+31-70) 340-2040, Tx: 31 651 epc nl, Fax: (+31-70) 340-5016

Authorized officer:
Kooijman, F
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<td>PATENT ABSTRACTS OF JAPAN vol. 014, no. 319 (M-0996), 9 July 1990 (1990-07-09) &amp; JP 02 107876 A (SANYO ELECTRIC CO LTD; OTHERS: 01), 19 April 1990 (1990-04-19) abstract; figure</td>
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