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Davis et al.

[11] **3,913,046**

[45] **Oct. 14, 1975**

[54] **CONDITION RESPONSIVE SYSTEMS**

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[22] Filed: **Oct. 9, 1973**

[21] Appl. No.: **404,688**

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[63] Continuation-in-part of Ser. No. 232,597, March 7, 1972.

[52] **U.S. Cl.** ..... **337/13;** 317/235 M; 337/3

[51] **Int. Cl.**[2] **H01H 31/00;** H01H 61/00

[58] **Field of Search** ..... 317/235 M, 144; 337/3, 337/13; 310/5, 6, 8.9

[56] **References Cited**

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3,020,423 2/1962 Gerber 310/8.9

Primary Examiner—L. T. Hix
Assistant Examiner—Fred E. Bell
Attorney, Agent, or Firm—Anthony A. O'Brien

[57] **ABSTRACT**

A plurality of condition responsive systems are disclosed which respond to one or more diverse conditions such as the insertion of a plug into a power receptacle and/or the signal from a thermally responsive device to control a switching device in response thereto.

35 Claims, 11 Drawing Figures

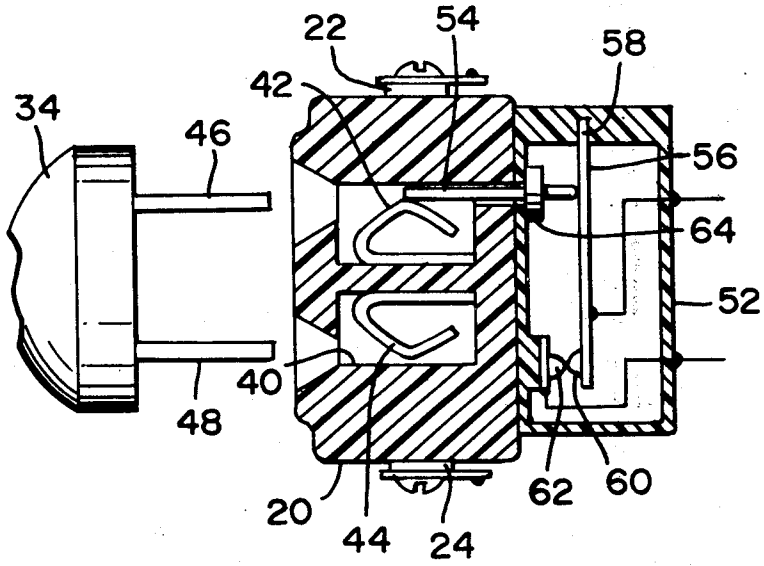


FIG. 1

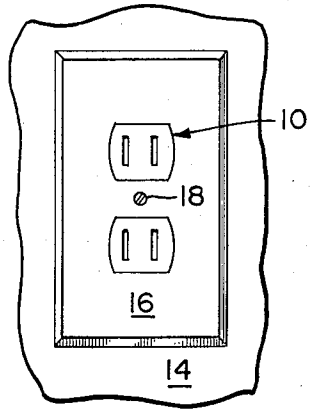


FIG. 2

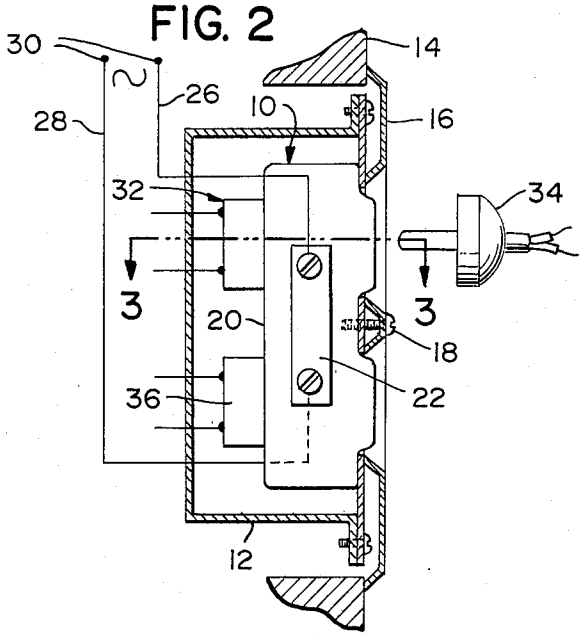


FIG. 3

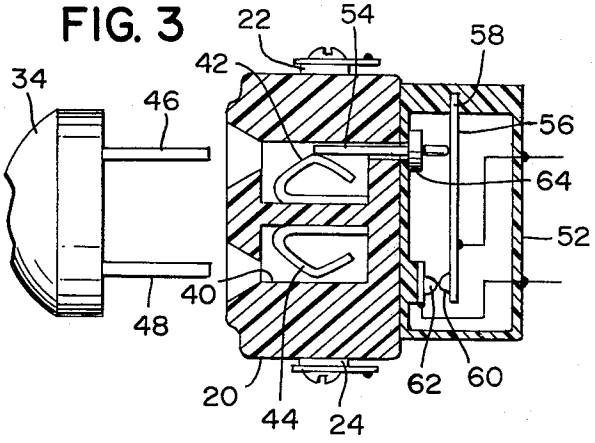


FIG. 4

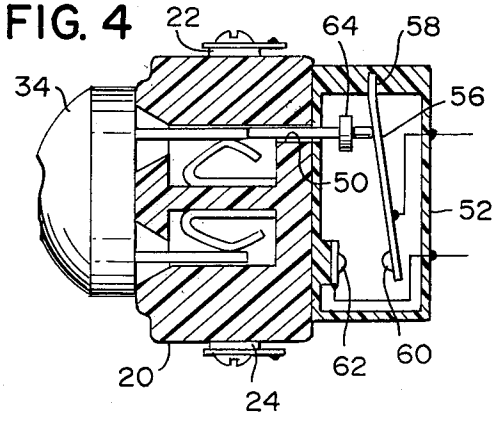


FIG. 5

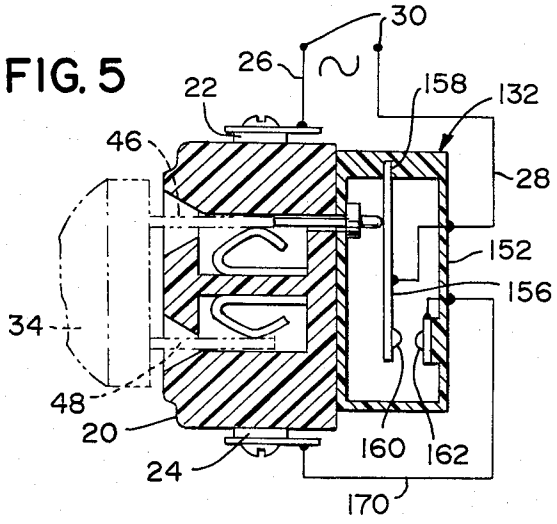
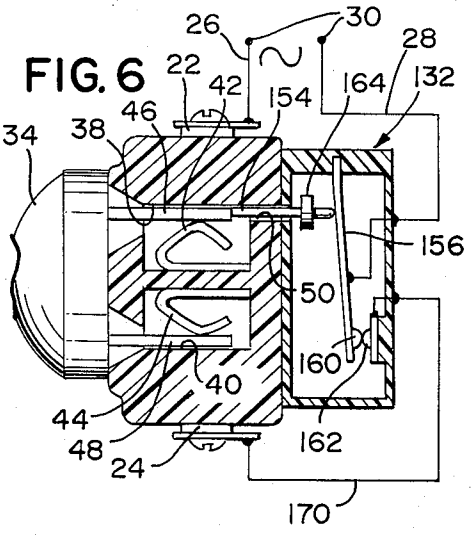


FIG. 6



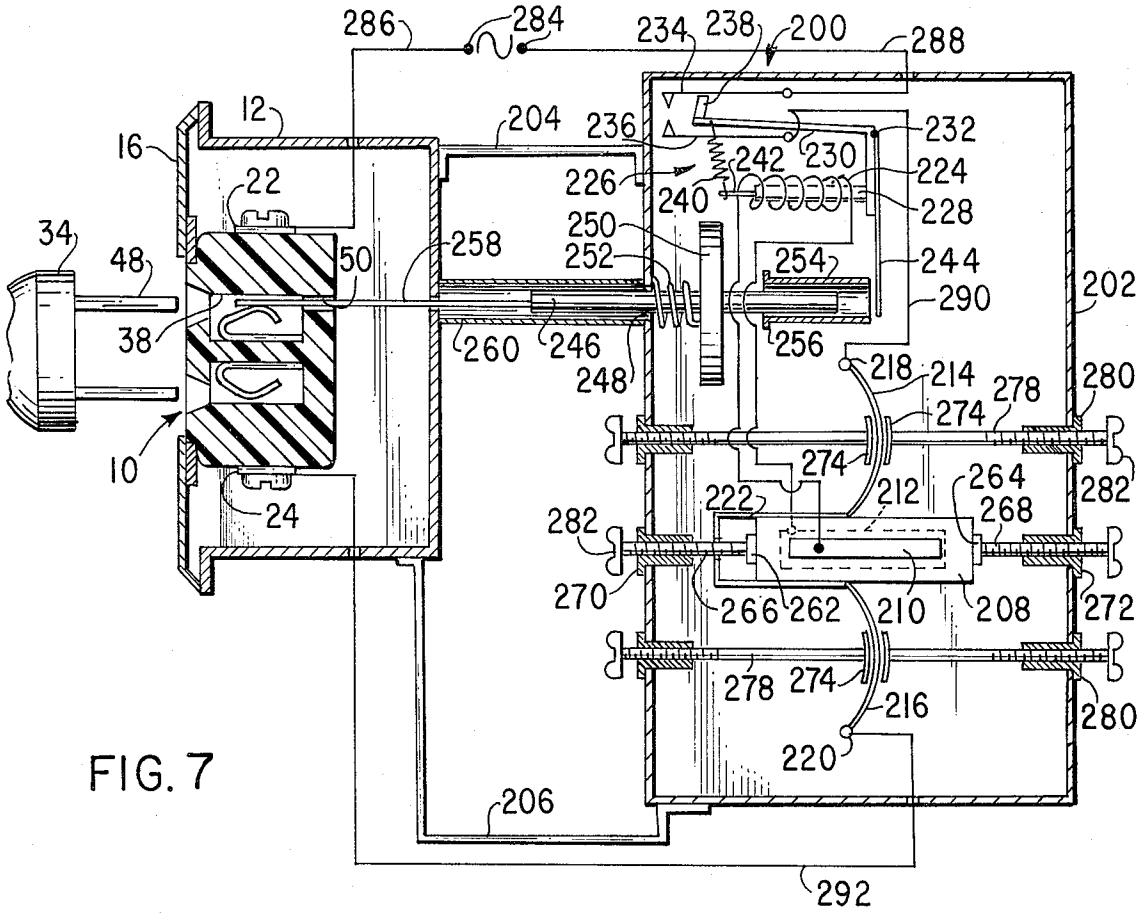

286
284
234
238
200
288
12
204
236
232
16
242
230
224
22
226
240
228
34
250
258
252
254
244
48
50
290
202
38
260
246
256
248
218
214
278
280
274
10
274
264
282
24
222
212
268
282
270
266
262
210
208
272
278
274
216
280
220
206
292

FIG. 7

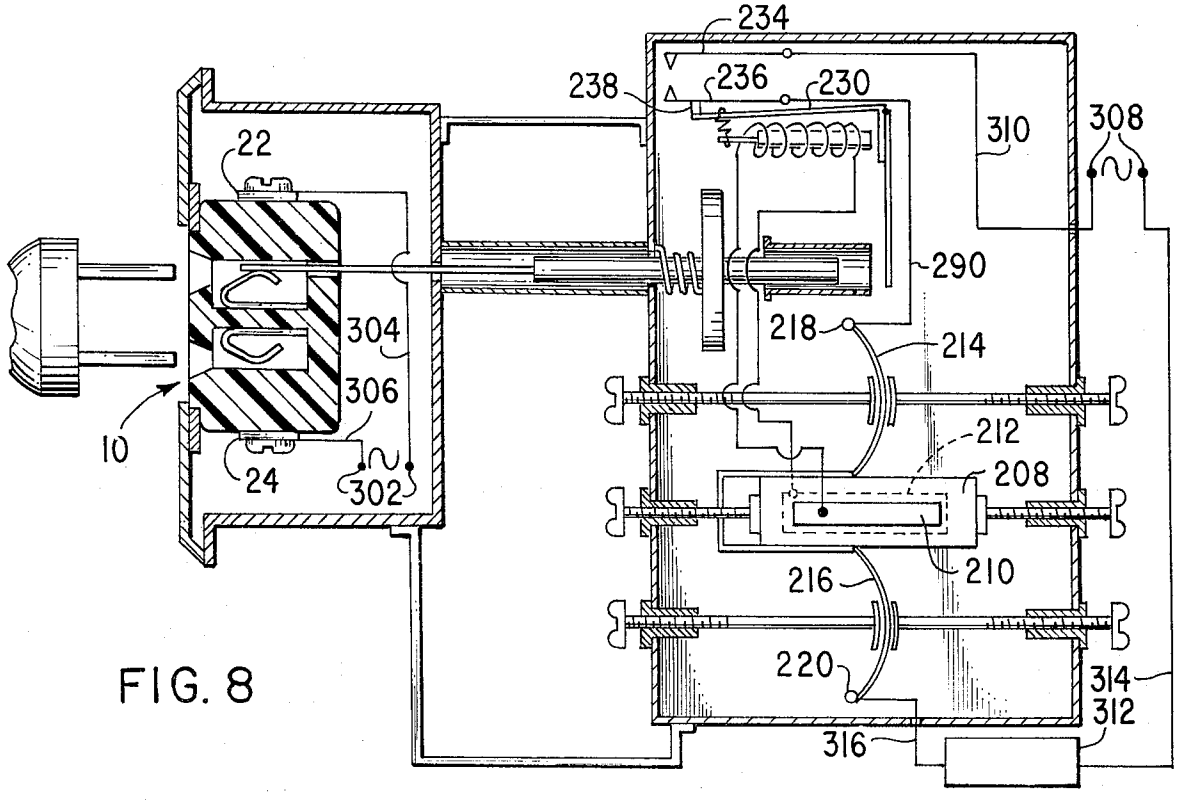

234
238
236
230
310
308
22
290
304
218
214
306
212
10
208
24
302
216
210
220
314
312
316

FIG. 8

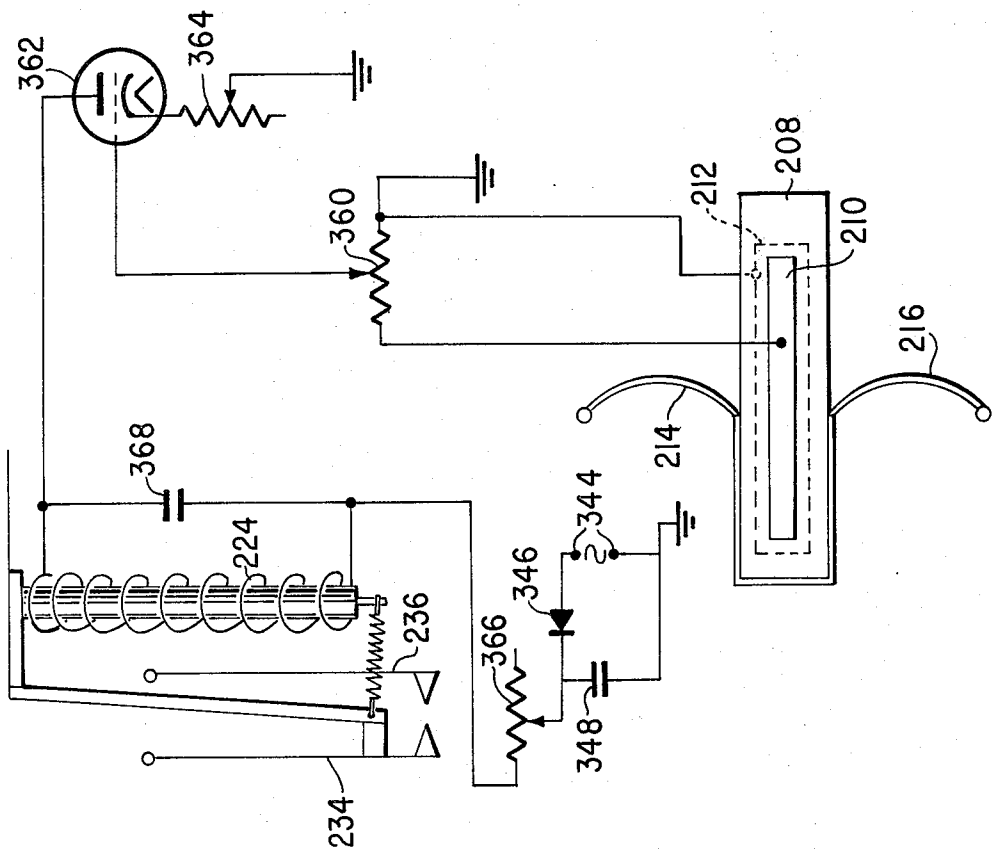

362
364
360
208
212
210
216
214
368
224
344
346
236
366
348
234

FIG. 10

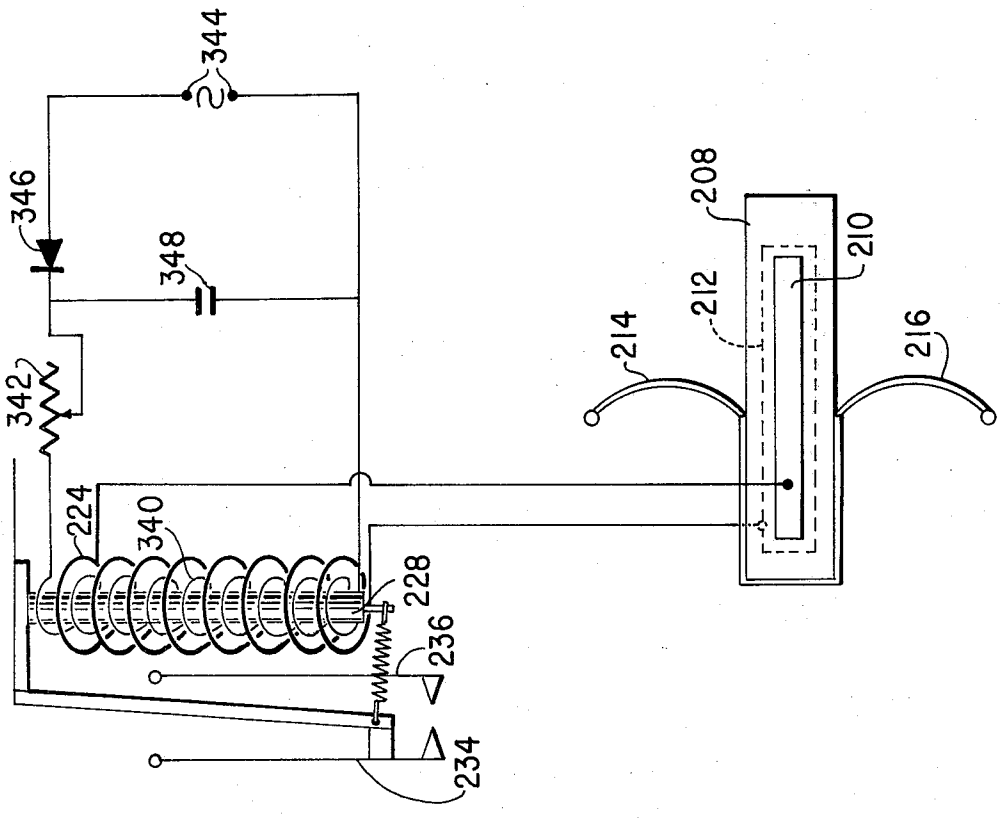

344
346
348
342
224
340
228
236
234
208
210
212
214
216

FIG. 9

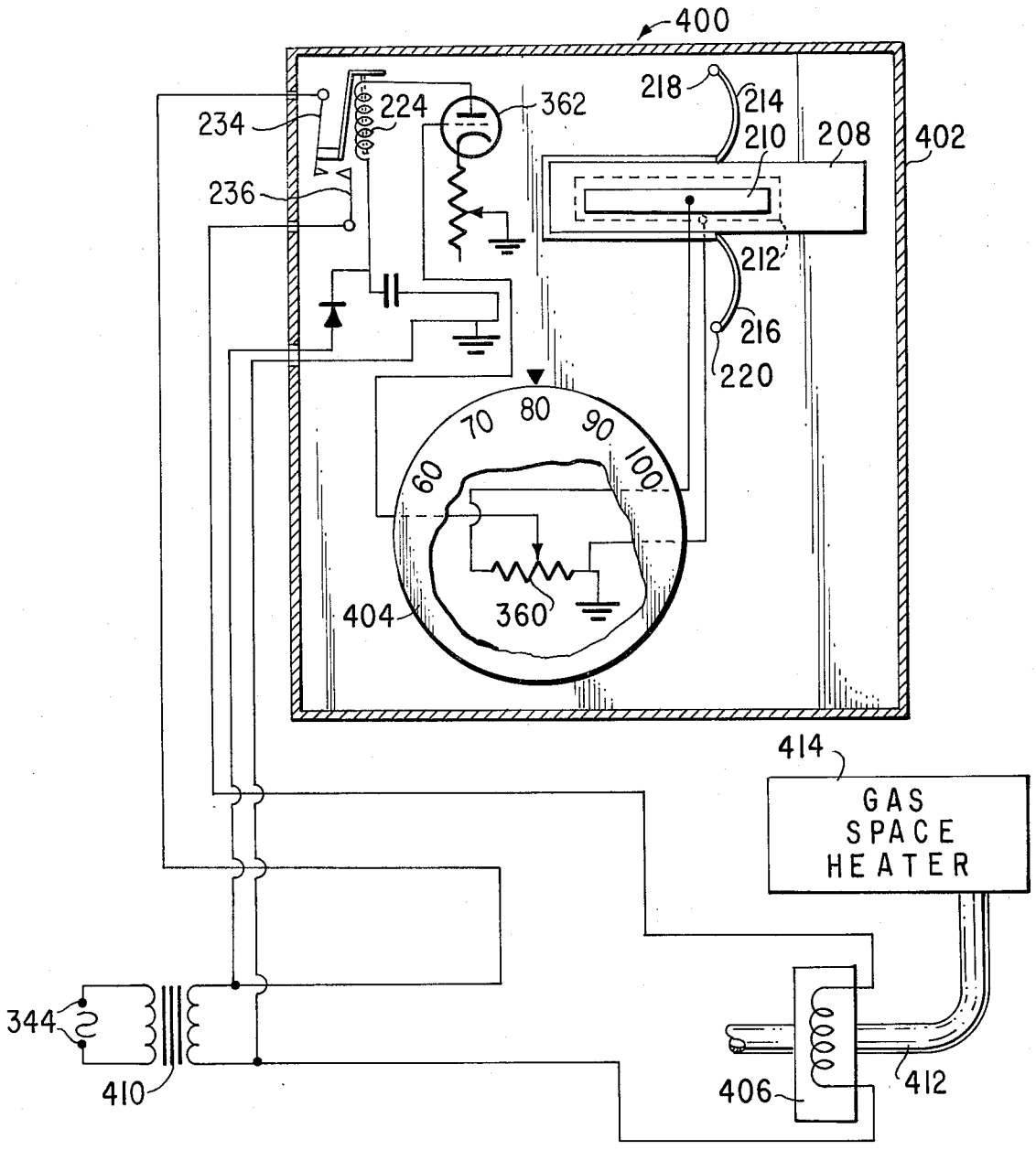

400
218
214
210
208
402
234
224
362
236
212
216
220
70
80
90
100
60
404
360
414
GAS
SPACE
HEATER
344
410
406
412

FIG. 11

CONDITION RESPONSIVE SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending application Ser. No. 232,597 filed Mar. 7, 1972.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to condition responsive systems, and more particularly, to condition responsive systems which control a switching device in response to a thermal condition and/or the insertion of a receptacle plug.

2. Description of the Prior Art

The prior art, as exemplified by U.S. Pat. Nos. 2,500,474; 2,531,625; 2,540,496; 2,735,906; 2,826,652; and 3,370,141, is generally cognizant of power receptacles which have a switch controlled in response to plug insertion and/or removal. However, all known prior art devices are constructed with the contact structure of the receptacle functioning as part of the switching device. This results in a complex and unique assembly in which important design criteria pertaining both to the power receptacle and the switch are comprises in order to obtain the desired composite structure.

The prior art, as exemplified by U.S. Pat. No. 3,320,601, is also aware of the use of thermally responsive devices, such as bimetals, to control the state of a switch and a utilization device which responds to the switch state to effect a control or alarm function. However, in the use of such systems, the switch contacts are usually positioned directly by the bimetal or through the intermediary of mechanical linkage, requiring a sizable movement of the bimetal and/or associated linkage to change the state of the switch and, accordingly, control the utilization device. Such prior art systems have not proven to be completely satisfactory in operation, exhibiting erratic switching with advancing age and a high failure rate.

SUMMARY OF THE INVENTION

The present invention is summarized in a thermally responsive system including thermal element means having a fixed portion and a portion movable in response to a thermal condition, and piezoelectric crystal means adjacent the movable portion of the thermal element means and capable of producing a signal in accordance with pressure applied thereto by the movable portion.

An object of the present invention is to construct a high sensitivity thermal sensor.

Another object of this invention is to produce a limited movement thermal sensor employing a pressure responder.

A further object of this invention is to accurately and reliably operate a control circuit in response to thermal stimulation.

Yet another object of the present invention is to provide a load current protection system employing the thermal sensor as a load current conductor.

Still another object of this invention is to construct an alarm system including a high sensitivity thermal sensor.

Another object of this invention is to actuate a switching device in response to plug insertion.

An advantage of the present invention over the prior art are that the mechanical movement which occurs in response to thermal variation can be considerably reduced, reduction in sensitivity.

Other objects and advantages of the present invention will be more fully apparent from the following description of the preferred embodiments when taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a partial elevational view of a receptacle according to the present invention;

FIG. **2** is a side elevational view, paritally in section, of the receptacle of FIG. **1**;

FIG. **3** is a sectional view taken along line **3—3** of FIG. **2** showing one embodiment of the receptacle of the present invention in one operative position;

FIG. **4** is a sectional view of the receptacle of FIG. **3** with parts shown in another operative position;

FIG. **5** is a sectional view similar to FIG. **3** showing another embodiment of the receptacle of the present invention in one operative position; and

FIG. **6** is a sectional view of the receptacle of FIG. **5** with parts shown in another operative position;

FIG. **7** is a side elevation view, partly in section and partly schematic circuit diagram, of a thermally responsive control system according to the present invention;

FIG. **8** is a side elevation view, partly in section and partly schematic, of another embodiment of a thermally responsive control system;

FIG. **9** is a schematic circuit diagram of a relay system which may be utilized in the embodiments of FIGS. **7** and **8**;

FIG. **10** is a schematic circuit diagram of another embodiment of a relay system which may be utilized in the embodiments of FIGS. **7** and **8**;

FIG. **11** is a side elevation view, partly in cross section and partly schematic circuit diagram, of a heating control system in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. **1** and **2**, a preferred embodiment of a connection responsive power receptacle according to the present invention is shown generally at **10** in its operative position within a conventional wall-box **12** mounted flush with the exposed surface of a wall **14**. A cover plate **16** is secured to the receptacle **10** by any suitable means such as a screw **18** to close the wall-box **12** and complete the installation.

Receptacle **10** includes a main body member **20** having a pair of contact terminals **22** and **24** which are connected by lines **26** and **28**, respectively, to a source of alternating current represented schematically by terminals **30**. Affixed to a rear surface of body member **20** is a single-pole, single-throw switch **32** which is responsive to insertion and removal of a conventional power plug **34** as will be described more fully below. A second switch **36** also may be affixed to the rear surface of body member **20**, as shown, if desired.

Referring to FIGS. **3** and **4**, body member **20** includes a pair of spaced, parallel plug-prong receiving slots **38** and **40** and a pair of contact blades **42** and **44** which are partially folded over upon themselves to estend laterally into slots **38** and **40**, respectively. Contact blades **42** and **44** are electrically interconnected internally of

body member **20** with terminals **22** and **24** to feed operating potential from source **30** to plug **34** through a set of plug-prongs **46** and **48.**

Slot **38** of body member **20** extends completely therethrough by means of an aperture **50** formed in a rear wall of the body member. As shown in FIGS. **3** and **4,** switch **32** has an electrically insulated housing **52** and is mounted onto body member **20** such that an actuating arm **54** of switch **32** extends through aperture **50** into slot **38.** Arm **54** is adapted to be engaged by prong **46** of plug **34** and moved linearly thereby along the elongate axis of slot **38.** A leaf-spring contact arm **56** is affixed at one end **58** to the switch housing **52** and carries a movable contact **60** at its distal end. A fixed contact **62** is attached to housing **52** for cooperation with movable contact **60.** As shown in the drawing, arm **54** engages contact arm **56** at a point near end **58** such that movement of arm **54** into housing **52** causes contact **60** to move away from its normal spring-biased position in engagement with fixed contact **62.** A collar **64** on arm **54** prevents the arm from inadvertently becoming dislodged from its operative position within switch housing **52.**

In operation, switches **32** and **36** may be connected to any suitable electrical apparatus to be controlled in response to plug insertion and/or removal, such as a burglar alarm (not shown). Also, the receptacle **10** preferably is supported within conventional wall-box **12** such that the exterior appearance thereof resembles that of an ordinary power receptacle as shown in FIG. **1.**

Referring to FIG. **3,** when a plug **34** is inserted into the slots **38** and **40** of housing **20,** arm **54** of switch **32** is engaged by prong **46** and moved linearly thereby such that contact **60** of bimetal **56** is moved away from fixed contact **62** (FIG. **4**). The switch thus becomes open to perform the desired control function. If plug **34** is subsequently removed, the withdrawal of prong **46** frees actuating arm **54,** and contact arm **56** springs back to its normally-biased position with contacts **60** and **62** engaged (FIG. **3**) If, for example, a burglar alarm is connected to switch **32** and the receptacle is used for the television receiver in a motel room, the removal of the television plug will result in the closure of switch **32** and the actuation of the burglar alarm. It can be appreciated, of course, that any number of diverse functions may be performed by the apparatus of the present invention, depending upon the particular application, and the above example is presented solely for purposes of explanation and clarity.

It is noted that receptacle **10** according to the present invention is particularly advantageous in that the switch **32** and the main body member **20** are structurally independent. By this is meant that failure of the switch does not necessitate replacement of the main body member, and vice versa. Also, by constructing the switch **32** separately from the main body member **20,** mass-produced standard receptacles may be used for main body member **20** with the minor modification of the forming of aperture **50** in a rear wall thereof. As a result, the receptacle of the present invention is extremely economical and reliable, has a conventional exterior appearance, and does not require complex, unusual contact-switch subassemblies which are inherently disadvantageous.

Referring now to FIGS. **5** and **6,** there is illustrated another embodiment of the power receptacle according to the present invention in which electrical power is only supplied to a plug after substantially complete plug insertion, thereby obviating a dangerous electrical shock hazard. For the sake of brevity, parts identical to parts described with respect to the embodiment of FIGS. **3** and **4** are identified with identical numbers and are not described again. Likewise, parts similar to parts in the embodiment of FIGS. **3** and **4** are identified with similar numbers having **100** added thereto.

As shown in FIG. **5,** affixed to a rear wall of main body member **20** is a switching device **132** which is connected to one terminal with line **28** from power supply **30** and at its other terminal with a line **170** feeding contact terminal **24** of the main body member **20.** Thus, switch **132** is connected in series with the contact blades **42** and **44.**

Switch **132** has an electrically insulated housing **152** affixed to a rear surface of body member **20** such that actuating arm **154** extends through aperture **50** for linear movement along the elongate axis of slot **38** by plug prong **46.** Actuating arm **154** is slightly shorter than arm **54** of the embodiment of FIG. **3** and, consequently, is not engaged by prong **46** until substantially complete insertion of plug **34** into slots **38** and **40,** as shown by the dashed lines in FIG. **5.**

A leaf-spring contact arm **156** is attached to housing **152** at one end and carries a movable contact **160** on its free end. A fixed contact **162** is mounted in housing **152** for cooperation with contact **160** to form a normally open, single-pole, single-throw switch. A collar **164** prevents actuating arm **154** from falling out of housing **152.** It is noted that actuating arm **154** is located adjacent the fixed end of contact arm **156** such that movement of actuating arm **154** into housing **152** closes contacts **160** and **162.**

In operation, switch **132** is normally biased to an open-circuit position such that no power is applied to contact blades **42** and **44** of the receptacle. The receptacle therefore is safe and will not cause electrical shock to children who, because of a lack of appreciation of the dangers involved, might inadvertently insert metal objects into slots **38** and **40.** However, upon insertion of plug **34** into the receptacle to the position shown by the dashed lines in FIG. **5,** prong **46** engages actuating arm **154** and after approximately the last one-quarter inch of insertion, switch contacts **160** and **162** become closed to apply from source **30** to both terminals **22** and **24** of the main body member **20** (FIG. **6**). Upon plug removal, actuating arm **154** will be freed by the withdrawal of prong **46** and contact arm **156** will spring back to its normally-open position as shown in FIG. **5.**

Thus, it can be appreciated that the receptacle of the present invention is extremely simple and effectively provides no-shock protection for use especially around small children. It should be understood, of course, that the teachings of this invention may be extended to construct switch **132** as a double-pole, single-throw switch to provide isolation of contact terminal **22** as well as contact terminal **24,** if so desired. The other advantages noted with respect to the embodiment of FIG. **3** are also provided by the receptacle of FIGS. **5** and **6** and thus will not be repeated for the sake of brevity.

Referring to FIG. **7,** power receptacle **10** is combined with a thermostat assembly, shown generally at **200,** including a housing **202** physically attached to wall box **12** by a pair of suitable brackets **204** and **206.**

A piezoelectric crystal **208**, having a pair of voltage-current pickup plates **210** and **212** thereon, is supported within the housing by any suitable means (not shown). Thermal elements **214** and **216**, such as bimetal strips, are fixedly supported at one end thereof by respective electrically conductive anchors **218** and **220** and have their other movable end contacting opposite sides of a conductive, U-shaped bracket member **222** disposed about and abutting opposite sides of the piezoelectric crystal **208**.

As shown, the thermal elements **214** and **216** have a curved or arcuate configuration, which configuration tends to change in accordance with changes in temperature, tending to either straighten or to assume a greater curvature configuration depending on the magnitude and direction of the temperature changes to which they are subjected. In the present instance, the thermal elements **214** and **216** utilized tend to straighten with increasing temperature, although it should be apparent that the opposite acting thermal elements may also be utilized with appropriate modifications without departing from the spirit of the invention.

The coil **224** of a relay **226** is electrically connected across the respective pickup plates **210** and **212**. Relay **226** additionally includes a core **228** of ferromagnetic material disposed within the relay coil **224** and a ferromagnetic armature **230** movable about a pivot **232** to control a pair of relay switch contacts **234** and **236** between open and closed positions by means of an actuator **238** carried by the armature **230**. A retract spring **240** is connected between an end of armature **230** and a support member **242** affixed to the ferromagnetic core **228**.

Affixed to armature **230** is a non-magnetic reed **244**, of slightly flexible construction, disposed in alignment with a movable plunger **246** which extends through an aperture **248** into the housing **202** and adapted to be contacted thereby. A collar **250** is fixedly supported on plunger **246** and a retract spring **252** is connected between the collar **250** and an inner wall of housing **202**. Plunger stop tube **254** is disposed about an end of plunger **246** and includes a flanged end **256** located proximate collar **250** which acts to limit the movement of the collar **250** and plunger **246** toward the reed **244**, thereby protecting same from damage due to an excessive application of force by plunger **246**. The plunger **246** includes a smaller diameter shaft **258** extending through the back of wall box **12** into slot **38** of power receptacle **10**. Shaft **258** is alignment with the path of prong **48** of plug **34** as it is inserted into power receptacle **10** and is adapted to be moved thereby. The portion of plunger **246** disposed between the wall box **12** and housing **202** is enclosed by a sleeve **260** attached at its ends to the wall box **12** and housing **202**, respectively.

A pair of pressure plates **262** and **264**, positioned adjacent opposite sides of piezoelectric crystal **208**, are movably supported on respective adjusting screws **266** and **268** which extend through threaded members **270** and **272** out of the housing **202**.

Each thermal element **214** and **216** has a pair of thermal load members **274**, of thermally conductive material such as metal, disposed adjacent respective sides thereof, which act to drain off some of the heat in the thermal elements **214** and **216** to thereby vary the range of operation and prevent excess pressure on the piezoelectric crystal **208**. Each thermal load member **274** is movably supported by a respective adjusting screw **278** which extends through respective threaded members **280** out of housing **202** in similar fashion to adjusting screws **266** and **268**. Each of the above adjusting screws **266**, **268** and **278** terminates outside the housing **202** in a manual control knob **282**.

The power receptacle **10** and thermostat assembly **200** are electrically interrelated to establish a continuous series power circuit therethrough. The power circuit includes a power supply **284** connected between contact terminal **22** of power receptacle **10** and switch contact **234** via conductors **286** and **288**, respectively. Switch contact **236** is electrically coupled to thermal element **214** at electrically conductive anchor **218** by a conductor **290**, and another conductor **292** connects thermal element **216** to contact terminal **24** of the power receptacle **10** through electrically conductive anchor **220** to complete the circuit.

In operation of FIG. 7 embodiment a load, such as a motor (not shown), to be protected from high current burnout, is connected to the contacts of plug **34**. The plug **34** is initially inserted in power receptacle **10** such that a series circuit is completed through power supply **284**, thermal elements **214** and **216** through anchors **218** and **220**, conductive member **222** and initially closed contacts **234** and **236** of relay **226** through conductors **286**, **288**, **290** and **292** to energize the motor load.

The pressure plates **262** and **264** have been adjusted to apply an initial pressure to the piezoelectric crystal **208** thereby establishing a residual signal at pickup plates **210** and **212** which may be set to overcome the residual magnetism effect of the relay **226**. In addition, the thermal load members **274** have also been adjusted to the proper spacing from the thermal elements **214** and **216** in aaccordance with the particular conditions to be encountered during operation.

The thermal elements **214** and **216** are initially relaxed in their curved position under low temperature and current conditions and, accordingly, under such conditions are applying little or no pressure to the surfaces of the piezoelectric cyrstal **208**. Consequently, the signal generated at the pickup plates **210** and **212** of the piezoelectric crystal **208** in response to the pressure applied by the thermal elements **214** and **216** and the pressure plates **262** and **264** is below the threshold level required to cause actuation of the relay armature **230**, and the contacts **234** and **236** maintain their initially closed condition.

In the event of an excessive current condition through the motor and, accordingly, through the thermal elements **214** and **216** in series therewith, the thermal elements **214** and **216** develop a tendency to straighten in response to heat produced by the high current flow therein. However, any straightening is substantially prevented due to the movable ends of the thermal elements being in contact with the sides of the U-shaped bracket member **222**, which sides are contacting, or positioned very close to, the surfaces of the piezoelectric crystal **208**. Therefore, the tendency of the thermal elements **214** and **216** to straighten will develop a commensurate increase in the pressure applied thereby to the piezoelectric cyrstal **208** through the opposite sides of U-shaped bracket member **222**. The increasing pressure causes the signal applied to relay coil **224** from the pickup plates **210** and **212** to increase toward the threshold level of the relay **226**. When the threshold level is reached, armature **230** will be at-

tracted to the ferromagnetic core **224** causing the actuator **238** carried thereby to operate on switch contact **236,** opening the switch contacts **234** and **236** and thereby terminating the power application to the motor load to protect same from burn-out.

Once the switch contacts **234** and **236** have opened, the lack of current flow through thermal elements **214** and **216** enables them to coll and gradually assume their initial relaxed state, thereby commensurately reducing the pressure applied to the piezolectric crystal and the level of the signal generated at pickup plates **210** and **212.** As the level of the signal from pickup plates **210** and **212** reduces, automatic reset may then occur when the combined pressure applied by thermal elements **214** and **216** and the pressure plates **262** and **264** carried by the respective adjusting screws **266** and **268** is reduced to a level below the holding level for the particular relay utilized. Upon the occurrence of reset, the motor will again be energized by the power supply **284.**

In the event that relay **226** fails to automatically reset, either because of malfunction of because the residual signal level from pickup plates **210** and **212** has been set to exceed the holding level of the relay **226,** a manual reset may be achieved by allowing the retract spring **252** to retract the plunger **246** away from reed **244** and thereafter extending the plunger **246** back into contact with the reed **244** to impulse same with a sufficient force, as limited by the flanged end **256** of plunger stop tube **254,** to retract the armature **230** from the relay core **228.** Such can be made to occur by merely removing plug **34** from the power receptacle **10** and thereafter fully reinserting same.

The above described system may also function control a heater load (not shown) with only slight adjustments. The heater load would be connected to the contacts of plug **34** like the motor load, and would be periodically energized and deenergized by the closing and opening, respectively, of the switch contacts **234** and **236** in response to the temperature of the surrounding medium as sensed by thermal elements **214** and **216.** When controlling a heater load in such manner, the system would be adjusted to insure automatic resetting such that upon cooling of the thermal elements **214** and **216** the switch contacts **234** and **236** would automatically close to restart a heating cycle by reestablishing current flow through the heater load.

Although the motor or heater load of FIG. **7** is shown to be serially connected to the power circuit through the intermediary of the plug **34** and power receptacle **10,** it should be understood that such load can also be connected directly to the power circuit without the use of the plug power receptacle intermediary. This may be accomplished for example, by connecting conductors **286** and **292** directly to the load rather than to contact terminals **22** and **24** of power receptacles **10.** Contact terminals **22** and **24** would then be connected directly to a pair of lines from a power supply to thereby energize power receptacle **10** in a conventional manner.

With slight modification the system of FIG. **7** can be converted from an overload responsive system into a heat or fire detecting system. As shown in FIG. **8** armature **230** has been relocated to a position outside of switch contacts **234** and **236** which now are normally opened. In addition, the series connected power circuit of FIG. **7** has been replaced by two separate series circuits which may be individually energized or may be connected in parallel for energization by a common power supply.

One of the circuits includes a power supply **302** coupled directly to contact terminals **22** and **24** of the power receptacle **10** by conductors **304** and **306,** respectively. The other circuit includes a power supply **308** connected to switch contact **234** by conductor **310** and to a control or utilization device **312,** such as an alarm, through conductor **314.** Anchors **218** and **220** are connected, respectively, to switch contact **236** via conductor **290** and to alarm **312** by conductor **316** to complete a series circuit through the thermal elements **214** and **216.** In this embodiment, thermal elements are selected which receive little or no heat due to current flow therethrough, such that they may be primarily responsive to ambient temperature conditions rather than current flow conditions.

In the operation of the FIG. **8** embodiment, initially assuming a normal ambient temperature, the thermal elements are initially relaxed and are applying little or no pressure to piezoelectric crystal **208** through bracket member **222** such that the pickup plates **210** and **212** of the piezoelectric crystal **208** initially produce a signal below the relay threshold level and the relay is initially deenergized, with switch contacts **234** and **236** in their normally open state. In the event of excessive ambient temperature sensed by the thermal elements **214** and **216** they develop a tendency to straighten, increasing the pressure applied to the piezoelectric crystal **208.** The signal from the pickup plates **210** and **212** then exceeds the relay threshold level and the contacts **234** and **236** are caused to close, thereby completing the series circuit through the power supply and the control or utilization circuit **312** to trigger an alarm and/or effect a control function in response to the excessive heat.

The resetting of switch contacts **234** and **236** may occur either automatically or manually as described above in the operation of the FIG. **7** embodiment.

FIGS. **9** and **10** show additional embodiments of relay systems which may be employed in place of the relay systems shown in FIGS. **7** and **8.** Although the switch contacts **234** and **236** are shown to be separable by the armature in response to actuation of the relay as in FIG. **7,** it should be apparent that the armature may be positioned, relative to the contacts, to be compatable in the embodiment of FIG. **8.**

In FIG. **9,** piezoelectric crystal **208** has its pickup plates **210** and **212** connected to the relay coil **224** wound about ferromagnetic core **228,** exactly as in FIGS. **7** and **8.** Another coil **340,** which is also wound around electromagnetic core **228** in the same direction as relay coil **224** such that the flux generated by the respective coils are additive is connected to a direct current power supply through a variable resistor **342.** The direct current power supply which is of a conventionally known type, includes an alternating current supply **344** in series with a rectifier diode **346,** and a ripple filter capacitor **348** thereacross.

In the operation of the FIG. **9** relay system, the alternating current signal from power supply **344** is rectified by diode **346** and filtered by capacitor **348** resulting in a direct current signal continuously applied to coil **340** having a magnitude which may be pre-set by adjustment of variable resistor **342.** Accordingly, an initial flux is generated in core **228** due to the direct current flow through coil **340** which is less than that required

to actuate the relay. Since the coil **224** coupled across pickup plates **210** and **212** may also be generating an intial flux aiding the flux from coil **340,** due to initial pressure applied by thermal elements **214** and **216** and-/or plates **262** and **264,** under normal initial conditions the sum of the fluxes must be less than the threshold flux value required to operate the relay, although it should be apparent that it may be adjusted to a level very close to the threshold flux value, such that only a slight additional pressure increase caused by the thermal elements in response to a change in current flow therethrough or ambient temperature thereabout will cause the relay to operate.

In FIG. **10,** piezelectric crystal **208** has its pickup plates **210** and **212** connected across the end terminals of a center tapped potentiometer **360,** one end of which is grounded. The center tap of potentiometer **360** is connected to the grid of an electron tube **362** which has its cathode grounded through a variable resistor **364.** The anode of electron tube is connected to the direct current power supply including alternating current power supply **344** rectifier diode **346** and ripple filter capacitor **348,** through a series circuit including relay coil **224** and variable resistor **366.** As an optional feature, a time delay capacitor **368** may be included in shunt with relay coil **224.**

In the operation of the FIG. **10** relay system, the signal from the pickup plates **210** and **212** of piezoelectric crystal **208** is applied to the grid of an electron tube **362** which initially is non-conducting or operating in a low conduction state. Accordingly, the initial current, if any, from the alternating current source **344,** as rectified by diode **346** and filter by capacitor **346,** which flows through the anode-cathode circuit of the electron tube **362** and the relay coil **224** in series therewith, is such that the flux in coil **224,** if any, is less than the flux threshold level of the relay. However, increased pressure from the thermal elements **214** and **216,** in response to increased current flow therethrough or increased ambient temperature, increases the signal to the grid of electron tube **362,** to thereby significantly increase the current flow through the anodecathode circuit thereof and the associated relay coil **224** to thereby actuate the relay armature and the contacts controlled thereby.

Referring to FIG. **11,** a thermostat, indicated generally at **400,** includes a housing **402** which may have approximate mounting means (not shown) to facilitiate disposition on a wall or the like.

Piezoelectric crystal **208** is mounted in the housing **402** between thermal elements **214** and **216** which are supported at their fixed ends by anchors **218** and **220,** and has its pickup plates **210** and **212** connected to the ends of a center tapped potentiometer **360** which is grounded at one end. A temperature control dial **404,** mounted on the housing **402,** is mechanically joined to the center tap of potentiometer **360** to facilitate adjustment thereof. The center tap of potentiometer **360** is coupled to the grid of electron tube **362** and the relay coil is connected in the anode-cathode circuit of the electron tube **362** as in FIG. **10.**

Switch contacts **234** and **236** are serially connected with a gas valve solenoid **406,** and the secondary of a transformer **410** energized by alternating current supply **344.** The solenoid **406** controls the flow of gas through a flow line **412** to a gas space heater **414.**

In the operation of the system of FIG. **11,** assuming the ambient temperature is below its normal level, the heater **414** is burning gas moving through gas line **412** due to the valve controlled by solenoid **406** being in its open position. The curved thermal elements, which were initially relaxed in response to the cool ambient temperature, tend to straighten and apply a gradually increasing pressure to the piezoelectric crystal **208** as the ambient temperature increases due to operation of the heater **414.** The voltage across potentiometer **360** likewise increases to bias the electron tube **362** from its initial low conduction state into its high conduction state, thereby energizing the relay coil **224** to open the contacts **234** and **236** and thereby cause the gas valve to close the gas line **412** to extinquish the heater **414.**

The ambient temperature will then start to drop in response to heater **414** being extinquished until a point is reached whereby the switch contacts **234** and **236** will automatically reset to their closed condition. At this time, the solenoid **406** will open the gas line **12** allowing the fuel to reach the heater **414** and be burned therein, thereby repeating the heating cycle.

Inasmuch as the present invention is subject to many variations, modifications and changes in detail, it is intended that all matter contained in the foregoing description or shown on the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate bimetal means having a curvature defined by one end fixed to said anchor means and a movable end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition; and
switch means responsive to changes in the output signal of said piezoelectric crystal means.

2. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate bimetal means having a curvature defined by one end fixed to said anchor means and a movable end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition; and
control means operable in response to the signal from said piezoelectric crystal means and comprising a relay including a pair of switch contacts and a coil energized by the signal from the piezoelectric crystal means for controlling the actuation of said contacts between opened and closed positions.

3. The invention of claim **2** including reset means for said relay.

4. The invention of claim **3** wherein the switch contacts are actuated by an armature controlled by the coil, and wherein the reset means includes reed means on the armature and plunger means movable into contact with the reed means to reset the switch contacts.

5. The invention of claim 4 including a power receptacle for receiving a plug therein, and said plunger extending into said receptacle for actuation by insertion of the plug into the receptacle to effect the reset.

6. The invention of claim 2 including another coil in flux aiding relationship with said relay coil; and means for providing energization to said another coil.

7. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate bimetal means haaving a curvature defined by one end fixed to said anchor means and a movalbe end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition;
means generating a voltage proportional to said signal from the piezoelectric crystal means, and
amplifier means providing an output signal in response to said proportional voltage.

8. The invention of claim 7 including pressure means operable on said piezoelectric crystal means for establishing an initial signal level from said piezoelectric signal means.

9. The invention of claim 8 including means adjustably positioning said pressure means relative to said piezoelectric crystal means.

10. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate bimetal means having a curvature defined by one end fixed to said anchor means and a movable end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition; and
thermal load means proximate said bimetal means.

11. The invention of claim 10 wherein said thermal load means comprise a pair of thermally conductive plate members.

12. The invention of claim 11 including means adjustably positioning said thermal load means relative to said bimetal means.

13. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate bimetal means having a curvature defined by one end fixed to said anchor means and a movable end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition; and
alarm means controlled by the signal from said piezoelectric crystal means providing an indication as to the occurrence of an excessive thermal condition.

14. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate bimetal means having a curvature defined by one end fixed to said anchor means and a movable end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition; and
means for transmitting pressure changes from said bimetal means to said piezoelectric crystal means comprising a somewhat flexible V-shaped bracket member.

15. A thermally responsive system comprising:
piezoelectric crystal means producing an output signal in accordance with pressure applied thereto;
anchor means disposed in spaced relation to said piezoelectric crystal means;
arcuate, electrically conductive bimetal means having a curvature defined by one end fixed to said anchor means and a movable end restrained by said piezoelectric crystal means for applying pressure thereto in accordance with a tendency to vary curvature in response to variations of a thermal condition; and
means establishing a current flow through said bimetal means whereby said bimetal means is responsive to heat generated therein by said current flow.

16. A system for protecting a load from excessive current therethrough comprising:
electrically conductive bimetal means in series with said load and having a portion movable in response to current flow therethrough;
piezoelectric crystal means contacting said movable portion of said bimetal means and capable of producing a signal in accordance with pressure applied thereto by said movable portion; and
means controlled by the signal from said piezoelectric crystal means for reducing the current through said load in response to the occurrence of excessive current therethrough.

17. The invention of claim 16 wherein the means for reducing load current includes a switch in series with said load which opens in response to the signal from said piezoelectric crystal achieving a particular value to terminate the flow of load current.

18. The invention of claim 17 including a coil energized by the signal from the piezoelectric crystal for opening said switch in response to the signal achieving said particular value.

19. The invention of claim 18 including an armature controlled by said coil for opening said switch, and reset means for reclosing said switch.

20. The invention of claim 19 wherein the reset means includes a reed attached to said armature and a plunger movable into contact with said reed for retracting the armature.

21. The invention of claim 20 including a power receptacle having a pair of contacts for energizing the load through a plug inserted therein, and means connecting said bimetal means in series with said contacts, said switch and the source of power for the load.

22. The invention of claim 21 wherein said reset plunger extends into said power receptacle and is operated by insertion of the plunger into the power receptacle to reset the switch and thereby complete the series circuit enabling current flow therein.

23. The invention of claim 16 including a thermal member located proximate said bimetal means, said

thermal member acting as a thermal load to said bimetal means.

24. The invention of claim **23** including means adjustably positioning said thermal member relative to said bimetal means to thereby vary the thermal loading.

25. The invention of claim **16** including pressure means applying a predetermined initial pressure to said piezoelectric crystal to thereby cause an initial signal to be produced thereby.

26. The invention of claim **25** wherein said pressure means comprises at least one pressure plate, and adjustable means supporting said at least one pressure plate against said piezoelectric crystal.

27. The invention of claim **16** wherein said bimetal means includes an arcuate element having a pair of ends, with one end abutting said piezoelectric crystal and the other end fixedly anchored.

28. The invention of claim **18** including flux generating means proximate said coil for establishing an initial flux level for enabling actuation of said contacts.

29. The invention of claim **28** wherein said flux generating means comprises another coil, and including means for providing energization to said coil.

30. The invention of claim **18** including amplifier means responsive to the signal from said piezoelectric crystal for controlling the energization of said coil.

31. A system for protecting a load from excess current flow therethrough comprising:

a power receptacle including a pair of contacts for energizing the load through a plug connected therein;

switch means;

bimetal means including a portion movable in response to current flow therethrough;

means for connecting said switch means, bimetal means and power receptacle contacts in series across a power supply for the load; and

piezoelectric crystal means contacting the movable portion of said bimetal means and generating a signal in accordance with pressure applied thereto by said bimetal means for controlling said switch means to thereby reduce current flow through the load.

32. The invention of claim **31** wherein said switch means comprises a relay including a pair of switch contacts, an armature controlling said switch contacts, and a coil energized by the signal from the piezoelectric crystal for actuating said armature.

33. The invention of claim **32** including a reset plunger and flexible reed means on said armature and operable by said plunger to retract said armature thereby closing said switch means.

34. The invention of claim **33** wherein said plunger extends into said power receptacle and is operable to reset the switch means by the insertion of said plug into said receptacle.

35. The invention of claim **31** wherein said bimetal means comprises an arcuate element having a pair of ends, one end of which is fixed and the other being movable against said piezoelectric crystal.

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