

CLAIMS

[0177] The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Heater control apparatus for controlling power to a heater that has an AC powered heating element which produces heat when connected to an AC power source, said heater control apparatus comprising:
 - A. A first temperature sensor and a second temperature sensor positioned in close enough proximity to the heating element to sense heat produced by the heating element;
 - B. A heater controller comprising:
 - (i) an AC power circuit extending between an inlet connector in the heater controller and an outlet connector in the heater controller, wherein said inlet connector is connectable electrically to an AC power source and said outlet connector is connectable electrically to the heating element to provide AC power to the heating element via the AC power circuit;
 - (ii) a high-limit power switch in the AC power circuit between the inlet connector and the outlet connector of the heater controller that is capable of opening and closing the AC power circuit;
 - (iii) a high-limit control circuit that is connected to the high-limit power switch in a manner that causes the high-limit power switch to open the AC power circuit in response to a temperature sensed by the first temperature sensor exceeding a high-limit temperature parameter and that causes the high-limit power switch to close in response to the temperature sensed by the first

temperature sensor not exceeding the high-limit temperature parameter and a power sequence condition;

(iv) a controllable process power switch in the AC power circuit between the inlet connector and the outlet connector of the heater controller that is capable of opening and closing the AC power circuit to control the AC power provided at said outlet; and

(v) a process control circuit that is connected to the process power switch in a manner that causes the process power switch to open and close the AC power circuit in response to comparison of the temperature sensed by the second temperature sensor with a preset desired set point temperature.

2. The heater control apparatus of claim 1, wherein the controllable power process switch is positioned in series electrically with the high-limit power switch.

3. The heater control apparatus of claim 2, wherein the controllable power process switch is positioned electrically in series between the high-limit switch and the outlet of the heater controller.

4. The heater control apparatus of claim 1, wherein the power sequence condition includes opening a drain circuit that, when closed, prevents the high-limit power switch from closing.

5. The heater controller apparatus of claim 1, wherein the power sequence condition includes a sequence comprising power to the process control circuit being terminated and then reestablished.

6. The heater controller apparatus of claim 5, wherein the high-limit control circuit is programmed to cause the high-limit power switch to open and thereby turn off AC power to the outlet connector if the temperature sensed by the first temperature sensor is higher than the high-limit temperature parameter.

7. The heater control apparatus of claim 6, wherein the high-limit control circuit is programmed to cause the high-limit power switch to close if the temperature sensed by the first temperature sensor is not higher than the high-limit temperature parameter and the power sequence condition has occurred.

8. The heater control apparatus of claim 1, wherein the process control circuit is programmed to cause the process power switch to open the AC power circuit if the temperature sensed by the second temperature sensor exceeds a preset hysteresis upper value in relation to a preset desired set point temperature and to close the AC power circuit if the temperature sensed by the second temperature sensor is below the preset hysteresis lower value in relation to the preset desired set point temperature.

9. The heater control apparatus of claim 7, wherein the heater controller also has a DC power supply connected electrically to the AC power circuit between the inlet connector of the heater controller and the high-limit power switch for converting AC power to DC power and providing the DC power to the high-limit control circuit, and wherein the power sequence condition includes the DC power to the high-limit control circuit being terminated and then reestablished.

10. The heater control apparatus of claim 1, wherein the high-limit power switch comprises a mechanical relay switch that opens and closes in response to signal input from the high-limit control circuit.

11. The heater control apparatus of claim 1, wherein the process power switch comprises a solid state power switch that turns off and on to open and close the AC power circuit in response to signal input from the process control circuit.

12. The heater control apparatus of claim 11, wherein the solid state power switch includes a triac.

13. The heater control apparatus of claim 1, including:

(i) a temperature range signal circuit in the heater controller connected to the inlet connector for connection to a remote temperature range signal circuit; and

(ii) a temperature range signal switch in the heater controller that opens and closes the temperature range signal circuit in response to temperature range signal input from the process control circuit.

14. The heater control apparatus of claim 13, wherein the process control circuit is programmed to compare the temperature sensed by the second temperature sensor to a preset desired operating temperature range and to generate the temperature range signal input to the temperature range signal switch to cause the temperature range signal switch to open the temperature range signal switch if the temperature sensed by the second temperature sensor is not within the preset desired operating temperature range and to close the temperature range signal switch if the temperature sensed by the second temperature sensor is within the preset desired operating temperature range.

15. The heater control apparatus of claim 1, wherein:

(i) the high-limit control circuit is capable of being programmed with the high-limit temperature parameter and of receiving program signals for adjusting the high-limit temperature parameter; and

(ii) the process control circuit is capable of being programmed with the desired set point temperature and the hysteresis and of receiving program signals for adjusting the set point temperature and the hysteresis.

16. The heater control apparatus of claim 15, including a base control module housing that contains the AC power circuit, the high-limit switch, the high-limit control circuit, the process power switch, the process control circuit, the inlet connector, and the outlet connector.

17. The heater control apparatus of claim 16, including an expansion module housing that contains a tactile data input interface connected electronically to an adjust/display microprocessor for inputting adjustment data for adjusting the high-limit temperature parameter, the desired set point temperature, the hysteresis, and the desired operating temperature range to the adjust/display microprocessor, a visual alpha-numeric display connected electronically to the adjust/display microprocessor for receiving electronic data signals from the adjust/display microprocessor for visual display, and an electronic data port with contacts for interfacing the adjust/display microprocessor electronically to the base module, and wherein the expansion module housing is physically attachable to the base module housing in a detachable manner with the contacts of the electronic data port of the expansion module in mating alignment with complementary contacts of a corresponding electronic data port on the base module housing, said adjust/display microprocessor being programmed to process input data signals from the tactile data input interface for delivery of queries and adjustments to the high-limit control circuit and to the process control circuit and for receiving and processing data from the high-limit control circuit and from the process control circuit for display, whereby attachment of the expansion module housing to the base module housing enables user input of adjustments of the preset high-limit temperature parameter, set point temperature, hysteresis, and desired operating temperature range as well as display of the preset high-limit temperature parameter, set point temperature, hysteresis, and desired operating temperature range.

18. The heater control apparatus of claim 1758, wherein the expansion module also includes a communications port for receiving adjustment data from an external data generating device for adjusting the high-temperature parameter and the operating temperature set point, and a communications microprocessor with electronic connections to the communications port and to the adjust/display microprocessor, said communications

microprocessor being programmed for feeding the received data to the adjust/display microprocessor, which is programmed for processing and sending the received data to the high-limit control circuit and the process control circuit.

19. The heater control apparatus of claim 18, wherein the communications microprocessor is also programmed for receiving and processing data from the high-limit temperature parameter data and the operating temperature set point, which are processed by the adjust/display microprocessor for transmission via the communications port to an external display.

20. The heater control apparatus of claim 17, wherein the process control circuit is also programmed to compare the temperature sensed by the second temperature sensor to a preset desired temperature operating range and to generate one or more of a plurality of status signals that indicate:

(i) that the process control circuit has the AC power circuit turned on, i.e., in "output" mode;

(ii) that the temperature sensed by the second temperature sensor is within the desired operating temperature range, i.e., "in range"; and

(iii) that the temperature sensed by the second temperature sensor is not within the desired operating temperature range, i.e., "alert/alarm".

21. The heater control apparatus of claim 20, including a LED display in the base module that comprises a plurality of LEDs, individual ones of which light in response to respective ones of the status signals.

22. The heater control apparatus of claim 21, wherein the expansion module housing includes a front panel, a rear panel, and a plurality of light conductors that extend from the back panel to the front panel and that align with respective ones of the LEDs when the expansion module is attached onto the base module so that the light conductors conduct

light from respective ones of the LEDs to the front panel of the expansion module for visual displays of the “output”, “in range”, and “alert/alarm” status.

23. Heater control apparatus, comprising a set of components that are configured for assembly in a variety of desired combinations of daisy chain connected heater control systems for a plurality of heaters, including:

A. A plurality of heater controller base modules, each of which includes a base module housing containing (i) an AC power circuit extending between an inlet connector and an outlet connector in the base module housing, (ii) a controllable high-limit power switch and a process power switch in the AC power circuit, (iii) a high-limit control circuit that controls the high-limit power switch to turn the AC power circuit on and off to the outlet connector in response to a comparison of a temperature measurement from a first temperature sensor to a preset high-temperature parameter and a power sequence that includes a power off and on sequence, and (iv) a process control circuit that controls the process power switch to turn the AC power circuit on and off to the outlet connector in response to a comparison of a temperature measurement from a second temperature sensor to a preset operating set point temperature;

B. A plurality of controller expansion modules, each of which includes an expansion module housing that is physically attachable to the base module and contains (i) a tactile data input interface, (ii) a visual alpha-numeric display, (iii) an adjust/display microprocessor, and (iv) a data connection interface with the base module for user input of adjustments of the high-limit parameter and the operating temperature set point and for display of the high-limit parameter and the operating temperature set point;

C. A plurality of heaters, each of which comprises (i) an AC powered heating element for producing heat, (ii) a first temperature sensor positioned in close enough proximity to the heating element to sense heat produced by the heating element, (iii) a second temperature sensor positioned in close enough proximity to the heating element to sense heat produced by the heating element, and (iv) a heater inlet connector that is connected electrically to the heating element and to the first and second temperature sensors and which is physically and electrically for mating connection to the outlet connector of the heater controller for routing controlled AC power from the AC power circuit in the heater controller to the heating element of the heater and for routing sensed temperature signals from the first and second temperature sensors to the heater controller;

D. A plurality of T-type source power cables, each of which comprises (i) a trunk section and a branch section, (ii) a trunk inlet connector and a trunk outlet connector on opposite ends of the trunk section, (iii) a branch outlet connector on the branch section that is configured physically and electrically for mating connection to the inlet connector of the heater controller for routing AC source power into the heater controller, and (iv) a pair of trunk AC power conductors that extend between and connect the trunk inlet connector electrically to the trunk outlet connector, and wherein said branch outlet connector being connected electrically in parallel to the trunk AC power conductors, wherein the trunk inlet connector and the trunk outlet connector are configured physically and electrically for mating connection with each other so that the trunk sections of the plurality of T-type source power cables can be daisy chain connected together in order to provide AC source power from an AC power source to the plurality of heater controllers;

E. At least one linear-type terminating source power cable with an inlet connector and a terminal outlet connector on opposite ends of the linear-type terminating source power cable and a pair of AC power conductors extending between and electrically connecting the inlet connector and the terminal outlet connector, wherein the inlet connector of the linear-type terminating source power cable is configured physically and electrically for mating connection to the trunk outlet connector of the T-type source power cable and the terminal outlet connector of the linear-type terminating source power cable is configured physically and electrically for mating connection with the inlet connector of the heater controller for routing the AC source power to the heater controller,

F. A slave adapter comprising (i) a master segment that includes a master inlet connector, which is configured physically and electrically for mating connection with the outlet connector of the heater controller for routing controlled AC power from the heater controller to the slave adapter and for routing temperature signals from the first and second temperature sensors to the heater controller, a master outlet connector, which is configured physically and electrically for mating connection with the heater inlet connector for routing controlled AC power from the slave adapter to a master heater and for routing temperature signals from the first and temperature sensors to the slave adapter, a pair of master AC power conductors that extend between and electrically connect the master inlet connector to the master outlet connector to conduct controlled AC power from the master inlet connector to the master outlet connector, two pairs of low voltage signal conductors that extend between and electrically connect the master inlet connector and the master outlet connector for routing temperature signals from the first and second temperature sensors from the master outlet connector to the master inlet connector, and (ii) a slave

segment that includes a slave outlet connector and a pair of slave AC power conductors that connect the slave outlet connector electrically in parallel to the master AC power conductors; and

G. A plurality of T-type slave power cables, each of which includes:

(i) slave trunk section, (ii) a slave branch section, (iii) a slave trunk inlet connector on one end of the slave trunk section that is configured physically and electrically to mate with the slave outlet connector of the slave adapter, (iv) a slave trunk outlet connector on the other end of the slave trunk section that is configured physically and electrically the same as the slave outlet connector of the slave adapter to accommodate daisy chain connection of a plurality of T-type slave power cables, (v) a pair of slave trunk AC power conductors that extend between and electrically connect the slave trunk inlet connector to the slave trunk outlet connector to route controlled AC power from the slave trunk inlet connector to the slave trunk outlet connector, and (vi) a slave branch outlet connector that is connected electrically in parallel to the slave trunk AC power conductors and is configured physically and electrically to mate with the heater inlet connectors to route controlled AC power to the slave heaters.

24. The heater control apparatus of claim 23, wherein the base controller module includes a controllable signal switch and the process control circuit is programmed to open the signal switch if the temperature sensed by the second temperature sensor is not within a preset desired operating temperature range.

25. The heater control apparatus of claim 24, wherein:

(i) the signal switch is connected in series to the inlet connector of the heater controller,

(ii) the T-type source power cables also include signal wires that connect the branch outlet connectors in series to a signal circuit at a remote monitoring station so that connection of the branch outlet connector to the inlet connector of the heater controller connects the signal switch in the heater controller in series with the signal circuit; and

(iii) the linear-type terminating source power cable also has signal wires that connect the terminal outlet connector in series to the signal circuit so that connection of the inlet connector of one of the heater controllers to the terminal outlet connector of the linear-type terminating source power cable also connects the signal switch of that heater controller in series with the signal circuit.

26. A method of providing a high-limit thermal safety shutdown for a heater that is powered by AC power via an AC power circuit, comprising:

positioning a high-limit switch in the AC power circuit that is capable of turning the AC power to the heater on and off; and

controlling the high-limit switch with a high-limit control circuit that is powered by low voltage DC power from a DC power source and that is programmed to (i) compare a temperature sensed by a temperature sensor that is positioned in close enough proximity to the heater to sense heat produced by the heater to a preset high temperature limit parameter, (ii) cause the high-limit switch to turn off the AC power to the heater if the temperature sensed by the temperature sensor exceeds the preset high temperature limit, and (iii) cause the high-limit switch to turn on the AC power to the heater if the low voltage DC power to the high-limit control circuit has been stopped and then started again and if the temperature sensed by the temperature sensor does not exceed the preset temperature limit.

27. A method of providing a high-limit thermal safety shutdown for a heater that is powered by AC power via an AC power circuit, comprising:

positioning a high-limit switch in the AC power circuit that is capable of turning the AC power to the heater on and off, said high-limit switch including a normally open relay switch that is powered by a coil to close and thereby to turn the AC power on and that opens when the coil is not powered; and

positioning a PTC thermistor in the heater, directing electric current to flow through the PTC resistor in series with a coil power circuit so that the coil is powered from current that flows through the PTC thermistor, providing a drain circuit that closes when current stops flowing through the PTC thermistor and that remains closed to drain current away from the coil when current starts flowing again through the PTC resistor.

28. A method of controlling a plurality of heaters that are powered by AC power from an AC power source to produce heat, comprising:

positioning a heater controller adjacent each of the plurality of heaters, with each heater controller having means for turning AC power in an AC power circuit on and off based on comparison of a sensed heater temperature to an operating temperature set point to create AC controlled power, wherein each heater has an inlet connector for receiving AC source power into the AC power circuit and an outlet connector for delivering controlled AC power to the heaters;

connecting the heaters electrically to the respective heater controllers via the outlet connectors of the heater controllers so that the heaters are powered by the controlled AC power; and

connecting the AC power from the AC power source to the plurality of heater controllers via a series of T-type source power cable sections, each of which has a

trunk segment that is daisy chain connected to the trunk segment of another one of the T-type source power cables and each of which has a branch segment that connects to one of the heater controllers via the inlet connector of the heater controller so that the heater controllers are connected electrically in parallel in relation to each other in the AC power circuit.

29. A method of controlling a plurality of heaters that are powered by AC power from an AC power source, comprising:

positioning a heater controller adjacent a plurality of heaters, each of which has a heating element and at least one temperature sensor adjacent the heating element and a heater inlet connector where power wires connected electrically to the heating element and signal wires connected electrically to the temperature sensor are terminated, wherein the heater controller includes an inlet connector for receiving AC power from the AC power source, an outlet connector for receiving temperature signals from the temperature sensor in the heater and for delivering controlled AC power to the heating element in the heater, and a process control circuit that compares the temperature signals to at least one temperature set point parameter and turning the AC power to the heater on and off based on the comparison of the temperature signal to the set point parameter;

operating one of the heaters as a master heater by connecting both the signal wires and the power wires at the heater inlet connector to the controller outlet connector via respective power and signal conductors in a slave adapter; and

operating at least one more of the plurality of heaters as a slave heater by connecting only the power wires at the heater inlet connector of that heater to the controller outlet connector via power conductors in the slave adapter that connect the heaters electrically in parallel to the AC power.

30. A method of controlling a heater that has an AC powered heating element and that has at least one temperature sensor, comprising:

connecting a heater controller base module electrically to an AC power source and connecting the heating element and the temperature sensor of the heater electrically to the heater controller base module;

comparing temperature signals from the temperature sensor to a temperature set point parameter in the base module and switching the AC power to the heater on and off in the base module to provide controlled AC power to the heater based on the comparison of the signals from the temperature sensor to the temperature set point parameter; and

displaying the sensed temperature and the set point parameter by attaching a detachable expansion module to the base module, wherein the expansion module has display apparatus and a microprocessor that is programmed to receive sensed temperature and set point data from the base module and to process said sensed temperature and set point data for display at the expansion module.

31. The method of claim 30, wherein the expansion module also has data input apparatus for inputting to the microprocessor instructions to adjust the set point, and wherein the microprocessor is programmed to receive and process the instructions and to send signals to the base module to adjust the temperature set point according to the instructions.

32. The method of claim 31, wherein the base module also uses adjustable hysteresis and temperature range parameters for turning AC power to the heater on and off, and wherein the expansion module also has capabilities of receiving and displaying those parameters and of receiving and processing adjustment inputs for those parameters and sending signals to adjust one or more of those parameters in the base module.

33. Wire connector apparatus for connecting an outlet connector on a first component to an inlet connector on a second component, comprising:

a latch protrusion on the inlet connector;

a pivotal latch lever on the outlet connector, said pivotal latch lever having a dog on a distal end of the latch lever that is sized, shaped, and positioned for engagement with the latch protrusion when the outlet connector is matingly connected to the inlet connector, and wherein the second component includes bias apparatus positioned to bear against the distal end of the latch lever in a manner that resists a pivotal movement of the latch lever that is required to disengage the dog on the latch lever from the latch protrusion in order to disconnect the outlet connector from the inlet connector.

34. The wire connector apparatus of claim 33, wherein the bias apparatus includes a cantilevered biasing tab molded as a part of a housing on the second component adjacent the inlet connector, said biasing tab being yieldably moveable against an elastic bias in response to a pivotal force applied to the latch lever.

35. The wire connector apparatus of claim 33, wherein the bias apparatus includes a spring positioned adjacent the inlet connector.

36. The wire connector apparatus of claim 35, wherein the spring is a leaf spring;

37. The wire connector apparatus of claim 35, wherein the spring is a coiled compression spring.

38. The wire connector apparatus of claim 33, wherein the bias apparatus includes a compressible material.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Heater control apparatus for controlling power to a heater that has an AC powered heating element which produces heat when connected to an AC power source, said heater control apparatus comprising:

A. A first temperature sensor and a second temperature sensor positioned in close enough proximity to the heating element to sense heat produced by the heating element;

B. A heater controller comprising:

(i) an AC power circuit extending between an inlet connector in the heater controller and an outlet connector in the heater controller, wherein said inlet connector is connectable electrically to an AC power source and said outlet connector is connectable electrically to the heating element to provide AC power to the heating element via the AC power circuit;

(ii) a high-limit power switch in the AC power circuit between the inlet connector and the outlet connector of the heater controller that is capable of opening and closing the AC power circuit;

(iii) a high-limit control circuit that is connected to the high-limit power switch in a manner that causes the high-limit power switch to open the AC power circuit in response to a temperature sensed by the first temperature sensor exceeding a high-limit temperature parameter and that causes the high-limit power switch to close in response to the temperature sensed by the first temperature sensor not exceeding the high-limit temperature parameter and a power sequence condition;

(iv) a controllable process power switch in the AC power circuit between the inlet connector and the outlet connector of the heater controller that is capable of opening and closing the AC power circuit to control the AC power provided at said outlet; and

(v) a process control circuit that is connected to the process power switch in a manner that causes the process power switch to open and close the AC power circuit in response to comparison of the temperature sensed by the second temperature sensor with a preset desired set point temperature.

2. The heater control apparatus of claim 1, wherein the controllable power process switch is positioned in series electrically with the high-limit power switch.

3. The heater control apparatus of claim 2, wherein the controllable power process switch is positioned electrically in series between the high-limit switch and the outlet of the heater controller.

4. The heater control apparatus of claim 1, wherein the power sequence condition includes opening a drain circuit that, when closed, prevents the high-limit power switch from closing.

5. The heater controller apparatus of claim 1, wherein the power sequence condition includes a sequence comprising power to the process control circuit being terminated and then reestablished.

6. The heater controller apparatus of claim 5, wherein the high-limit control circuit is programmed to cause the high-limit power switch to open and thereby turn off AC power to the outlet connector if the temperature sensed by the first temperature sensor is higher than the high-limit temperature parameter.

7. The heater control apparatus of claim 6, wherein the high-limit control circuit is programmed to cause the high-limit power switch to close if the temperature sensed by the first temperature sensor is not higher than the high-limit temperature parameter and the power sequence condition has occurred.

first temperature sensor is not higher than the high-limit temperature parameter and the power sequence condition has occurred.

8. The heater control apparatus of claim 1, wherein the process control circuit is programmed to cause the process power switch to open the AC power circuit if the temperature sensed by the second temperature sensor exceeds a preset hysteresis upper value in relation to a preset desired set point temperature and to close the AC power circuit if the temperature sensed by the second temperature sensor is below the preset hysteresis lower value in relation to the preset desired set point temperature.

9. The heater control apparatus of claim 7, wherein the heater controller also has a DC power supply connected electrically to the AC power circuit between the inlet connector of the heater controller and the high-limit power switch for converting AC power to DC power and providing the DC power to the high-limit control circuit, and wherein the power sequence condition includes the DC power to the high-limit control circuit being terminated and then reestablished.

10. The heater control apparatus of claim 1, wherein the high-limit power switch comprises a mechanical relay switch that opens and closes in response to signal input from the high-limit control circuit.

11. The heater control apparatus of claim 1, wherein the process power switch comprises a solid state power switch that turns off and on to open and close the AC power circuit in response to signal input from the process control circuit.

12. The heater control apparatus of claim 11, wherein the solid state power switch includes a triac.

13. The heater control apparatus of claim 1, including:

- (i) a temperature range signal circuit in the heater controller connected to the inlet connector for connection to a remote temperature range signal circuit; and
- (ii) a temperature range signal switch in the heater controller that opens and closes the temperature range signal circuit in response to temperature range signal input from the process control circuit.

14. The heater control apparatus of claim 13, wherein the process control circuit is programmed to compare the temperature sensed by the second temperature sensor to a preset desired operating temperature range and to generate the temperature range signal input to the temperature range signal switch to cause the temperature range signal switch to open the temperature range signal switch if the temperature sensed by the second temperature sensor is not within the preset desired operating temperature range and to close the temperature range signal switch if the temperature sensed by the second temperature sensor is within the preset desired operating temperature range.

15. The heater control apparatus of claim 1, wherein:

- (i) the high-limit control circuit is capable of being programmed with the high-limit temperature parameter and of receiving program signals for adjusting the high-limit temperature parameter; and
- (ii) the process control circuit is capable of being programmed with the desired set point temperature and the hysteresis and of receiving program signals for adjusting the set point temperature and the hysteresis.

16. The heater control apparatus of claim 15, including a base control module housing that contains the AC power circuit, the high-limit switch, the high-limit control circuit, the process power switch, the process control circuit, the inlet connector, and the outlet connector.

17. The heater control apparatus of claim 16, including an expansion module housing that contains a tactile data input interface connected electronically to an adjust/display microprocessor for inputting adjustment data for adjusting the high-limit temperature parameter, the desired set point temperature, the hysteresis, and the desired operating temperature range to the adjust/display microprocessor, a visual alpha-numeric display connected electronically to the adjust/display microprocessor for receiving electronic data signals from the adjust/display microprocessor for visual display, and an electronic data port with contacts for interfacing the adjust/display microprocessor electronically to the base module, and wherein the expansion module housing is physically attachable to the base module housing in a detachable manner with the contacts of the electronic data port of the expansion module in mating alignment with complementary contacts of a corresponding electronic data port on the base module housing, said adjust/display microprocessor being programmed to process input data signals from the tactile data input interface for delivery of queries and adjustments to the high-limit control circuit and to the process control circuit and for receiving and processing data from the high-limit control circuit and from the process control circuit for display, whereby attachment of the expansion module housing to the base module housing enables user input of adjustments of the preset high-limit temperature parameter, set point temperature, hysteresis, and desired operating temperature range as well as display of the preset high-limit temperature parameter, set point temperature, hysteresis, and desired operating temperature range.

18. The heater control apparatus of claim 17, wherein the expansion module also includes a communications port for receiving adjustment data from an external data generating device for adjusting the high-temperature parameter and the operating temperature set point, and a communications microprocessor with electronic connections to the communications port and to the adjust/display microprocessor, said communications microprocessor being programmed for feeding the received data to the adjust/display microprocessor, which is programmed for processing and sending the received data to the high-limit control circuit and the process control circuit.

19. The heater control apparatus of claim 18, wherein the communications microprocessor is also programmed for receiving and processing data from the high-limit temperature parameter data and the operating temperature set point, which are processed by the adjust/display microprocessor for transmission via the communications port to an external display.

20. The heater control apparatus of claim 17, wherein the process control circuit is also programmed to compare the temperature sensed by the second temperature sensor to a preset desired temperature operating range and to generate one or more of a plurality of status signals that indicate:

- (i) that the process control circuit has the AC power circuit turned on, i.e., in "output" mode;
- (ii) that the temperature sensed by the second temperature sensor is within the desired operating temperature range, i.e., "in range"; and
- (iii) that the temperature sensed by the second temperature sensor is not within the desired operating temperature range, i.e., "alert/alarm".

21. The heater control apparatus of claim 20, including a LED display in the base module that comprises a plurality of LEDs, individual ones of which light in response to respective ones of the status signals.

22. The heater control apparatus of claim 21, wherein the expansion module housing includes a front panel, a rear panel, and a plurality of light conductors that extend from the back panel to the front panel and that align with respective

ones of the LEDs when the expansion module is attached onto the base module so that the light conductors conduct light from respective ones of the LEDs to the front panel of the expansion module for visual displays of the "output", "in range", and "alert/alarm" status.

23. A method of providing a high-limit thermal safety shutdown for a heater that is powered by AC power via an AC power circuit, comprising:

- positioning a high-limit switch in the AC power circuit that is capable of turning the AC power to the heater on and off; and

- controlling the high-limit switch with a high-limit control circuit that is powered by low voltage DC power from a DC power source and that is programmed to (i) compare a temperature sensed by a temperature sensor that is positioned in close enough proximity to the heater to sense heat produced by the heater to a preset high temperature limit parameter, (ii) cause the high-limit switch to turn off the AC power to the heater if the temperature sensed by the temperature sensor exceeds the preset high temperature limit, and (iii) cause the high-limit switch to turn on the AC power to the heater if the low voltage DC power to the high-limit control circuit has been stopped and then started again and if the temperature sensed by the temperature sensor does not exceed the preset temperature limit.

24. A method of providing a high-limit thermal safety shutdown for a heater that is powered by AC power via an AC power circuit, comprising:

- positioning a high-limit switch in the AC power circuit that is capable of turning the AC power to the heater on and off, said high-limit switch including a normally open relay switch that is powered by a coil to close and thereby to turn the AC power on and that opens when the coil is not powered; and

- positioning a PTC thermistor in the heater, directing electric current to flow through the PTC thermistor in series with a coil power circuit so that the coil is powered from current that flows through the PTC thermistor; providing a drain circuit that closes when current stops flowing through the PTC thermistor and that remains closed to drain current away from the coil when current starts flowing again through the PTC resistor.

25. High-limit thermal safety shutdown apparatus for a heater that is powered by AC power via an AC power circuit, comprising:

- a high-limit switch in the AC power circuit that is capable of turning the AC power to the heater on and off; and
- a high-limit control circuit that is powered by low voltage DC power from a DC power source and that is programmed to (i) compare a temperature sensed by a temperature sensor that is positioned in close enough proximity to the heater to sense heat produced by the heater to a preset high temperature limit parameter, (ii) cause the high-limit switch to turn off the AC power to the heater if the temperature sensed by the temperature sensor exceeds the preset high temperature limit, and (iii) cause the high-limit switch to turn on the AC power to the heater if the low voltage DC power to the high-limit control circuit has been stopped and then started again and if the temperature sensed by the temperature sensor does not exceed the preset temperature limit.

26. High-limit thermal safety shutdown apparatus for a heater that is powered by AC power via an AC power circuit, comprising:

- a high-limit switch in the AC power circuit that is capable of turning the AC power to the heater on and off, said high-limit switch including a normally open relay switch that is powered by a coil to close and thereby to turn the AC power on and that opens when the coil is not powered;
- a PTC thermistor positioned in the heater and connected electrically in series with the coil by a PCT thermistor circuit;
- a closable and openable drain circuit connected to the PTC thermistor circuit electrically in parallel with the coil in a manner that drains current away from the coil in a closed mode, said drain circuit including a drain circuit control that closes the drain circuit automatically in response to a no current condition in the PTC thermistor circuit and that opens the drain circuit in response to a manual input.