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(54) **MODULATION CONTROL OF A HYDRONIC HEATING SYSTEM**

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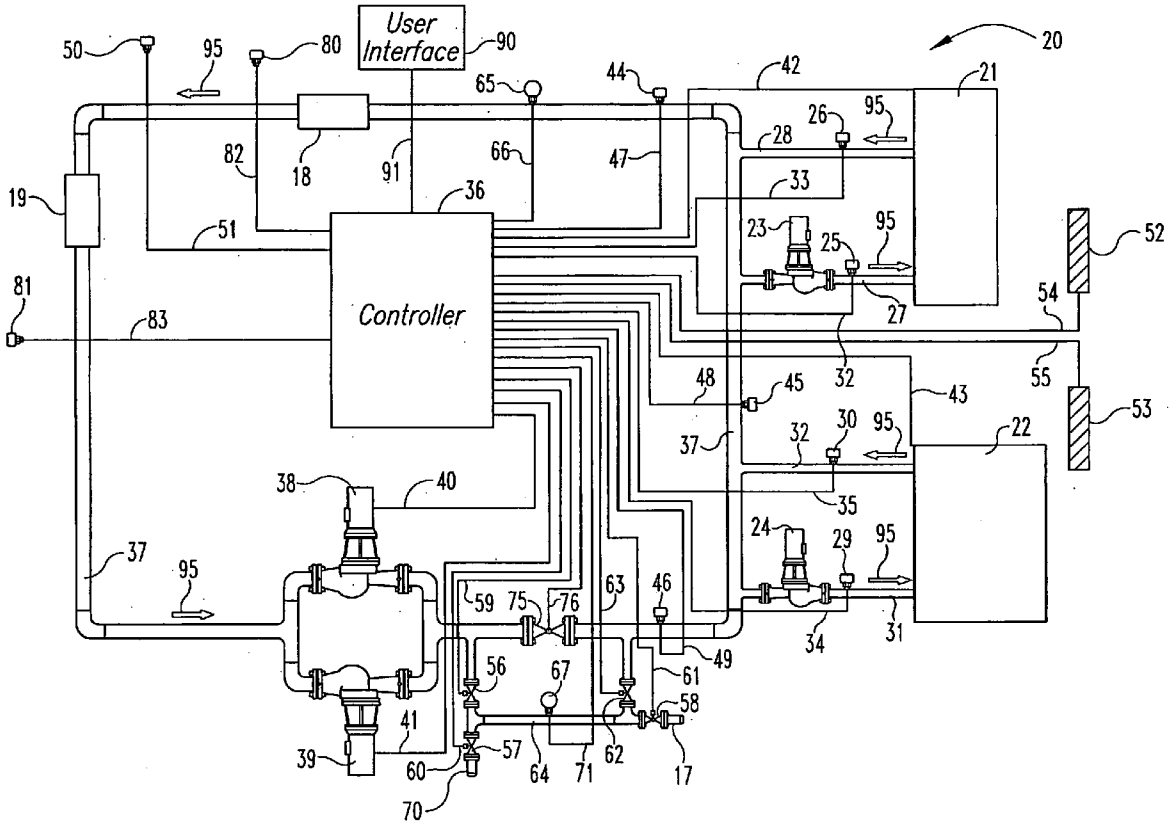
(52) **U.S. Cl.** ..... **237/8 A**

(57) **ABSTRACT**

A hydronic heating system for a building includes condensing and non-condensing boilers in a hybrid arrangement. A control apparatus receives information from one or more condition sensors, such as air temperature or water flow, and calculates heating load requirements. The control apparatus then independently selects and operates the various boilers of the system to optimize boiler efficiency and operating characteristics. The independent operation of said first and second boilers is modulated as a function a comparison of a heat load assignment for the and second boilers to a heat output of the first and second boilers.



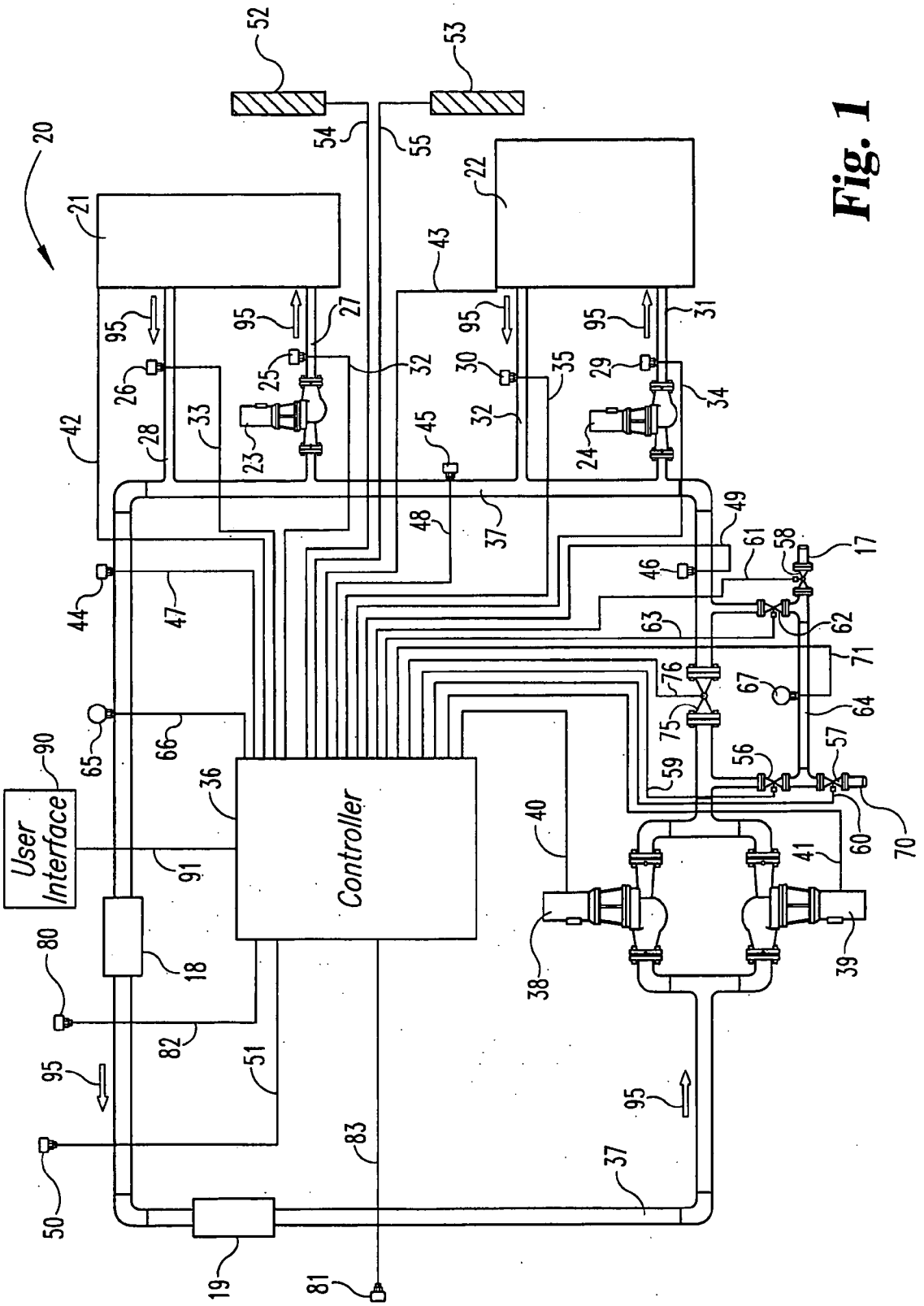


Fig. 1

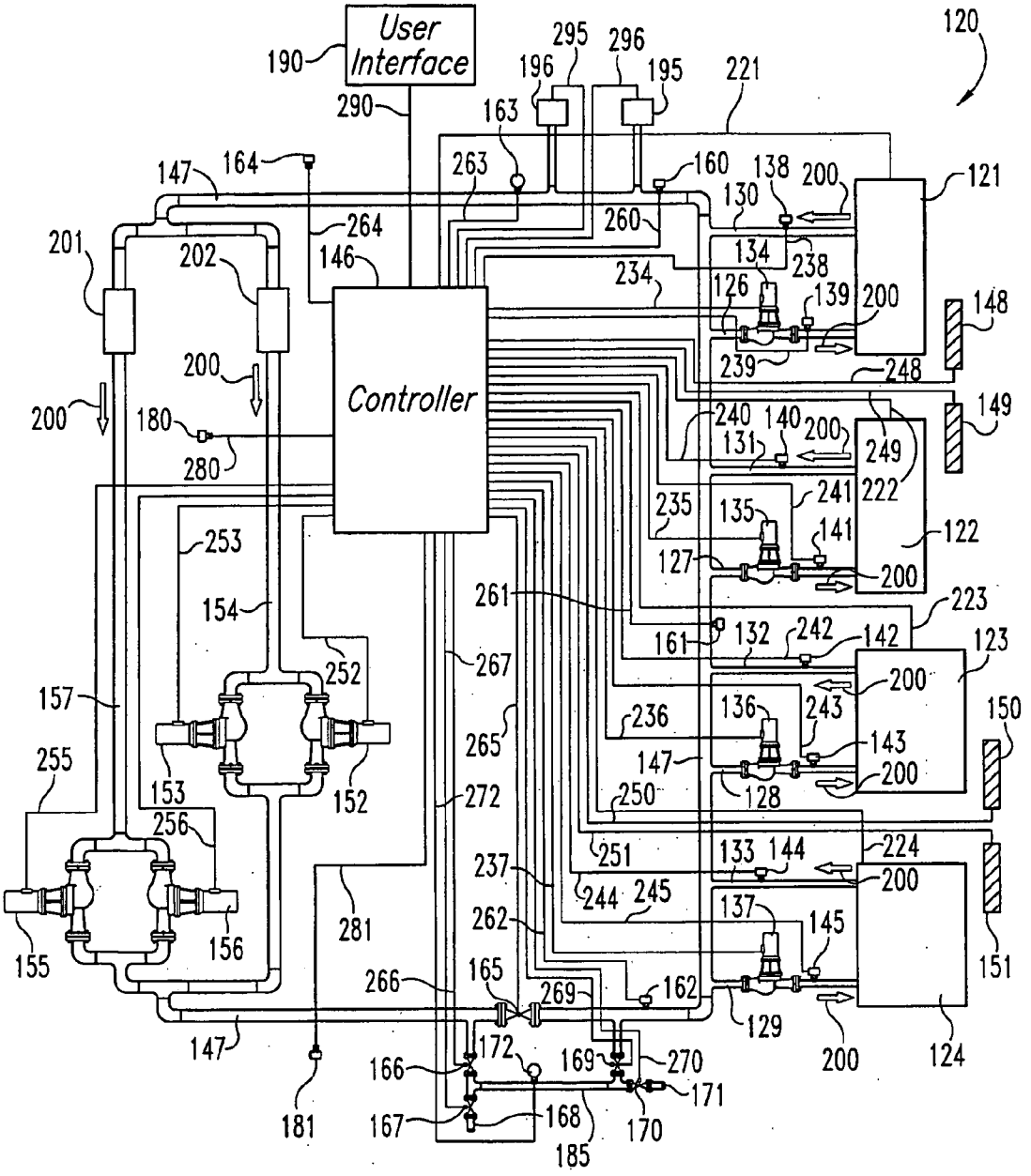

User Interface
Controller
120
121
122
123
124
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
160
161
162
163
164
165
166
167
168
169
170
171
172
180
181
185
190
195
196
200
201
202
221
222
223
224
234
235
236
237
238
239
240
241
242
243
244
245
248
249
250
251
252
253
255
256
260
261
262
263
264
265
266
267
269
270
272
280
281
290
295
296

Fig. 2

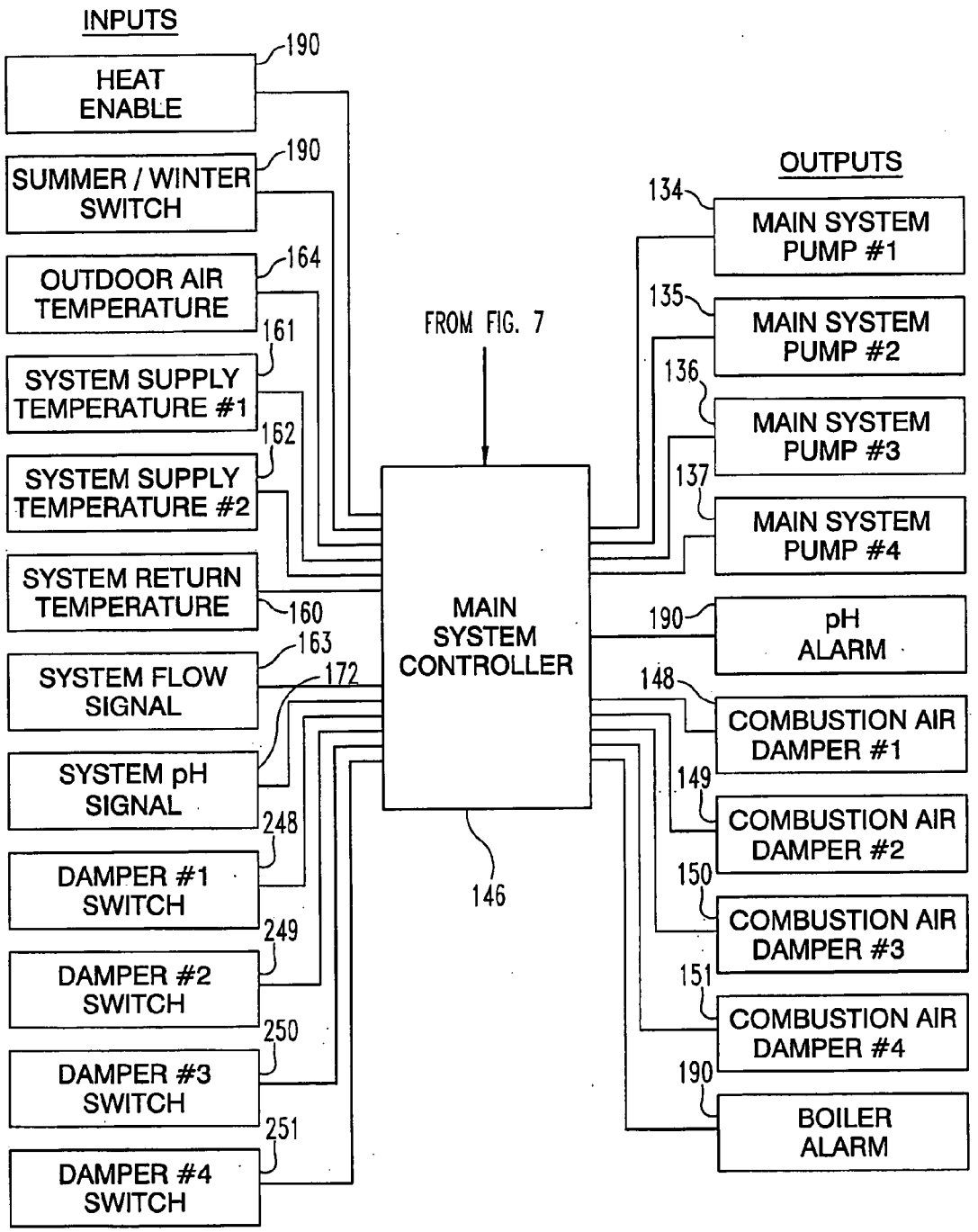

INPUTS
HEAT ENABLE
190
SUMMER / WINTER SWITCH
190
OUTDOOR AIR TEMPERATURE
164
SYSTEM SUPPLY TEMPERATURE #1
161
SYSTEM SUPPLY TEMPERATURE #2
162
SYSTEM RETURN TEMPERATURE
160
SYSTEM FLOW SIGNAL
163
SYSTEM pH SIGNAL
172
DAMPER #1 SWITCH
248
DAMPER #2 SWITCH
249
DAMPER #3 SWITCH
250
DAMPER #4 SWITCH
251
FROM FIG. 7
MAIN SYSTEM CONTROLLER
146
OUTPUTS
MAIN SYSTEM PUMP #1
134
MAIN SYSTEM PUMP #2
135
MAIN SYSTEM PUMP #3
136
MAIN SYSTEM PUMP #4
137
pH ALARM
190
COMBUSTION AIR DAMPER #1
148
COMBUSTION AIR DAMPER #2
149
COMBUSTION AIR DAMPER #3
150
COMBUSTION AIR DAMPER #4
151
BOILER ALARM
190

Fig. 3

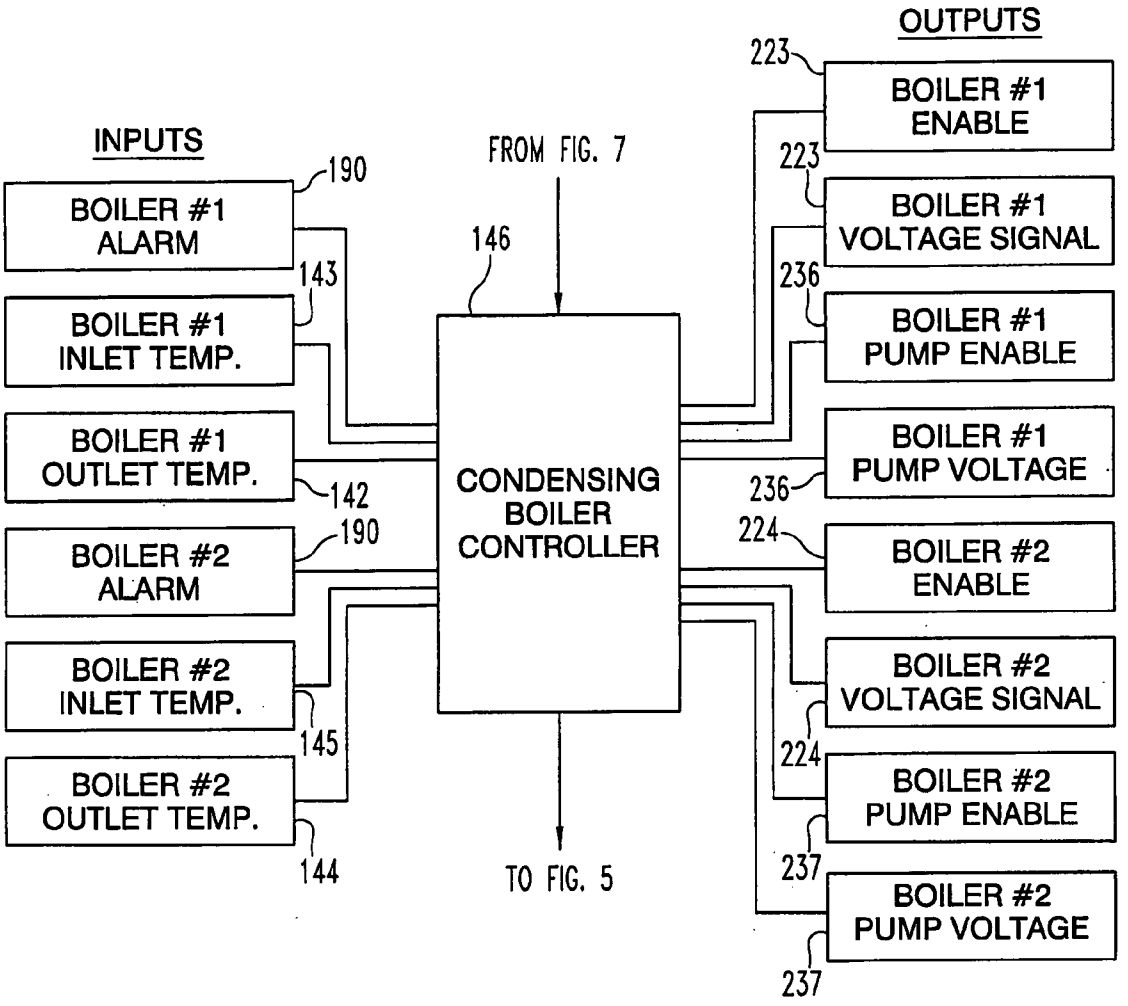

INPUTS
BOILER #1 ALARM
190
BOILER #1 INLET TEMP.
143
BOILER #1 OUTLET TEMP.
142
BOILER #2 ALARM
190
BOILER #2 INLET TEMP.
145
BOILER #2 OUTLET TEMP.
144
FROM FIG. 7
146
CONDENSING BOILER CONTROLLER
TO FIG. 5
OUTPUTS
223
BOILER #1 ENABLE
223
BOILER #1 VOLTAGE SIGNAL
236
BOILER #1 PUMP ENABLE
236
BOILER #1 PUMP VOLTAGE
224
BOILER #2 ENABLE
224
BOILER #2 VOLTAGE SIGNAL
237
BOILER #2 PUMP ENABLE
237
BOILER #2 PUMP VOLTAGE

Fig. 4

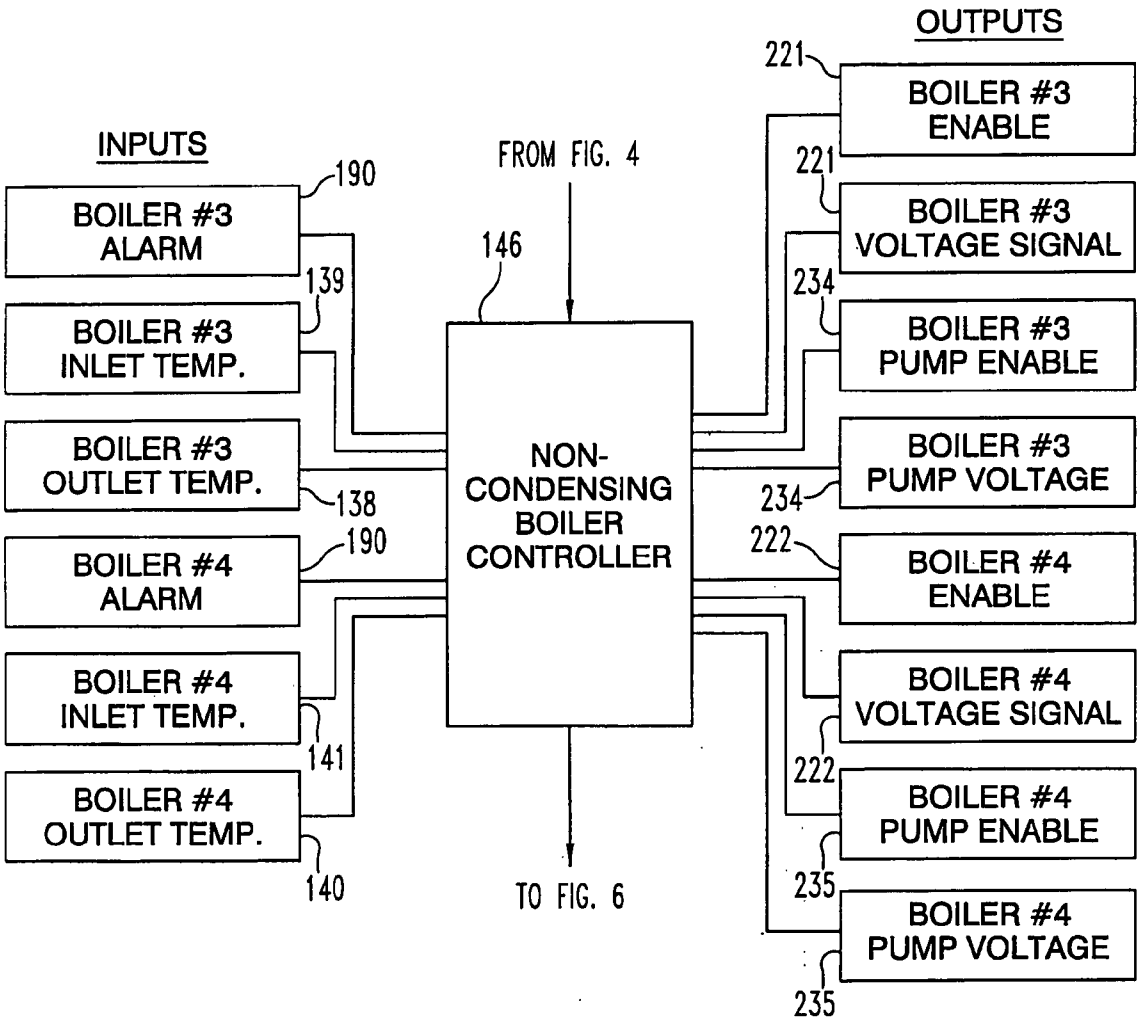

INPUTS
BOILER #3 ALARM
190
BOILER #3 INLET TEMP.
139
BOILER #3 OUTLET TEMP.
138
BOILER #4 ALARM
190
BOILER #4 INLET TEMP.
141
BOILER #4 OUTLET TEMP.
140
FROM FIG. 4
146
NON-CONDENSING BOILER CONTROLLER
TO FIG. 6
OUTPUTS
221
BOILER #3 ENABLE
221
BOILER #3 VOLTAGE SIGNAL
234
BOILER #3 PUMP ENABLE
234
BOILER #3 PUMP VOLTAGE
222
BOILER #4 ENABLE
222
BOILER #4 VOLTAGE SIGNAL
235
BOILER #4 PUMP ENABLE
235
BOILER #4 PUMP VOLTAGE

Fig. 5

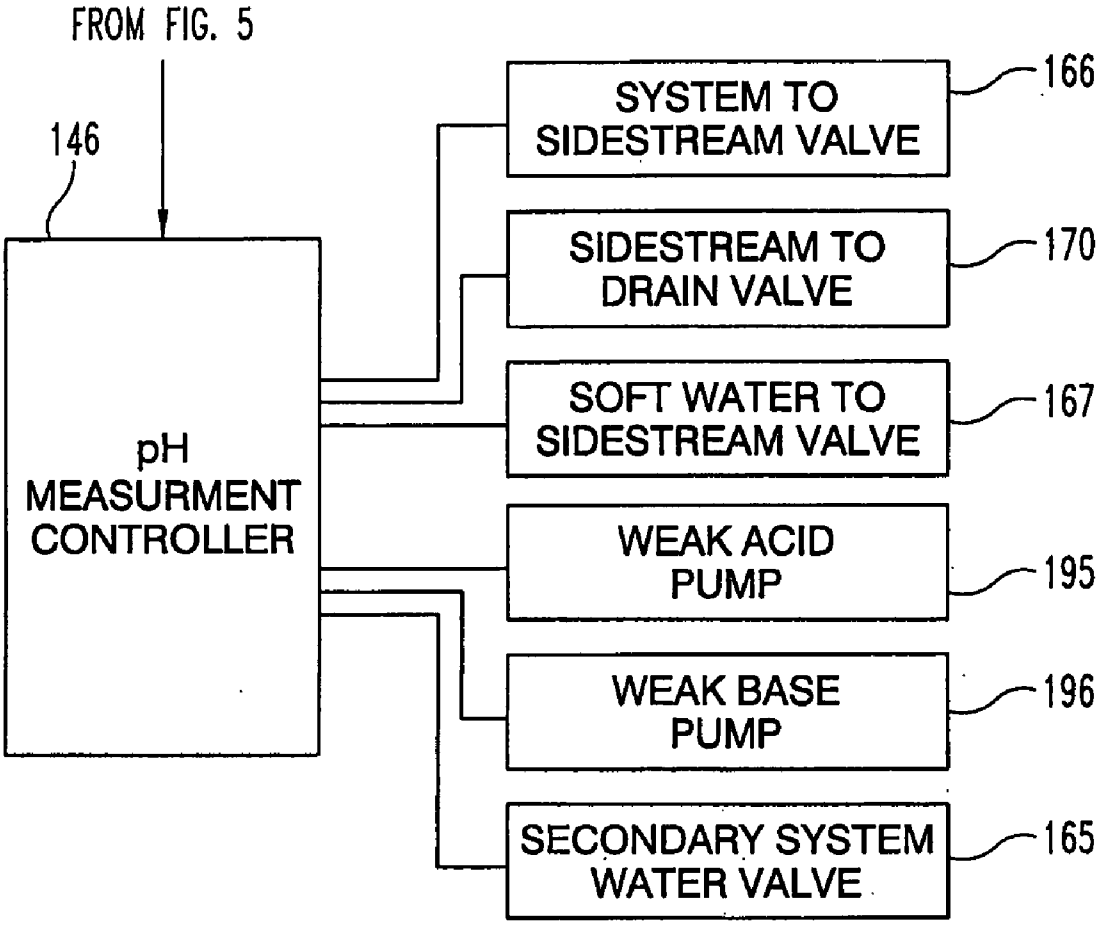

FROM FIG. 5
146
pH MEASURMENT CONTROLLER
SYSTEM TO SIDESTREAM VALVE
166
SIDESTREAM TO DRAIN VALVE
170
SOFT WATER TO SIDESTREAM VALVE
167
WEAK ACID PUMP
195
WEAK BASE PUMP
196
SECONDARY SYSTEM WATER VALVE
165

Fig. 6

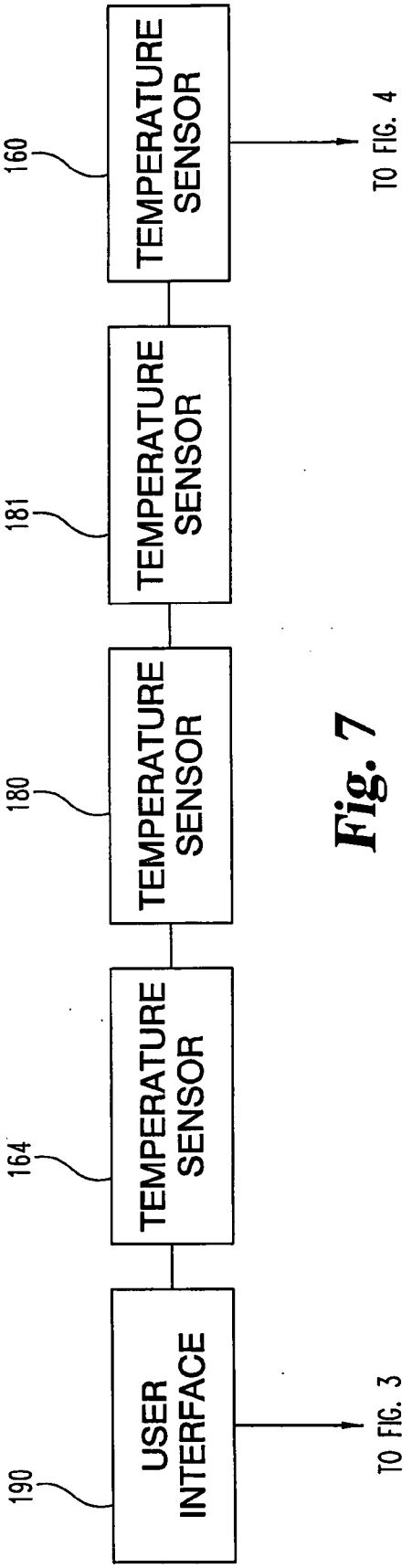

USER INTERFACE
190
TO FIG. 3
TEMPERATURE SENSOR
164
TEMPERATURE SENSOR
180
TEMPERATURE SENSOR
181
TEMPERATURE SENSOR
160
TO FIG. 4

Fig. 7

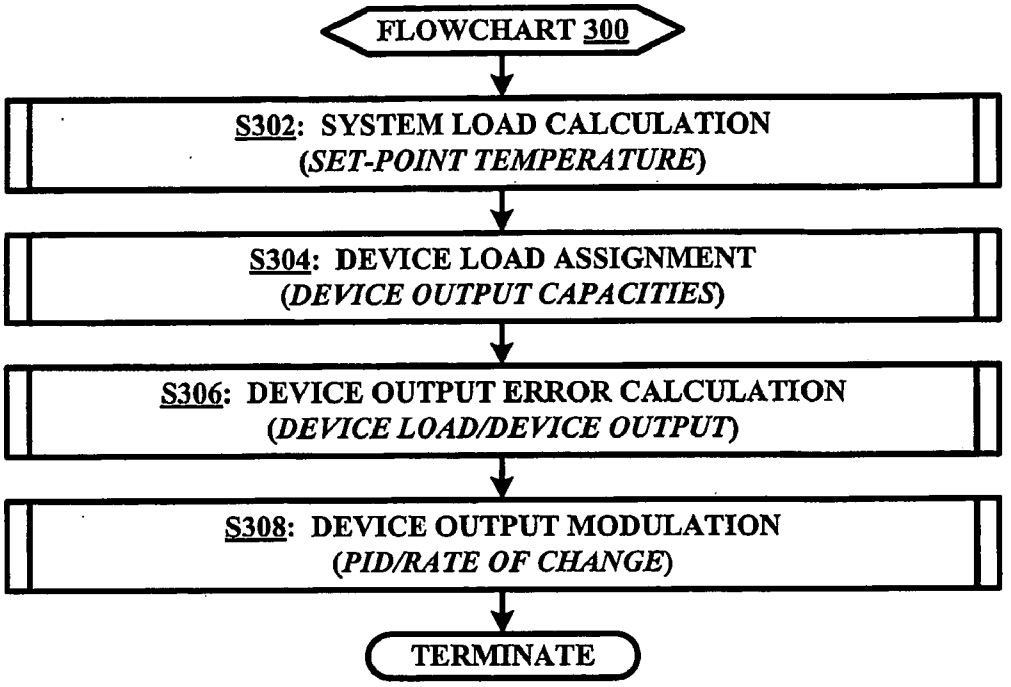

FLOWCHART 300
S302: SYSTEM LOAD CALCULATION
(SET-POINT TEMPERATURE)
S304: DEVICE LOAD ASSIGNMENT
(DEVICE OUTPUT CAPACITIES)
S306: DEVICE OUTPUT ERROR CALCULATION
(DEVICE LOAD/DEVICE OUTPUT)
S308: DEVICE OUTPUT MODULATION
(PID/RATE OF CHANGE)
TERMINATE

Fig. 8

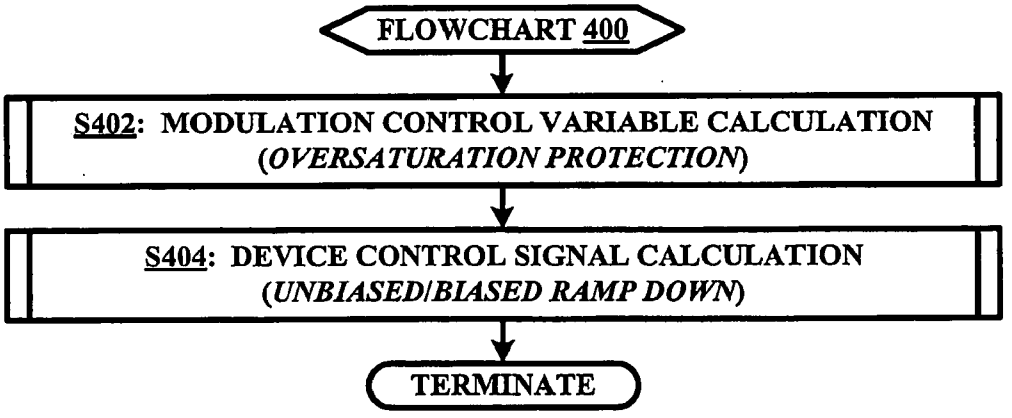

FLOWCHART 400
S402: MODULATION CONTROL VARIABLE CALCULATION
(OVERSATURATION PROTECTION)
S404: DEVICE CONTROL SIGNAL CALCULATION
(UNBIASED/BIASED RAMP DOWN)
TERMINATE

Fig. 9

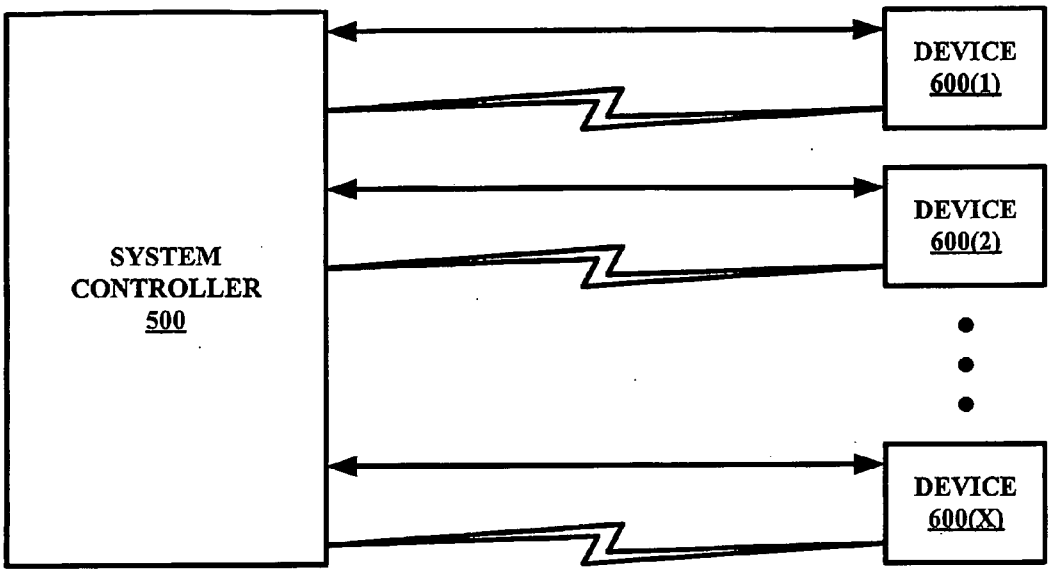

SYSTEM
CONTROLLER
500
DEVICE
600(1)
DEVICE
600(2)
DEVICE
600(X)

Fig. 10

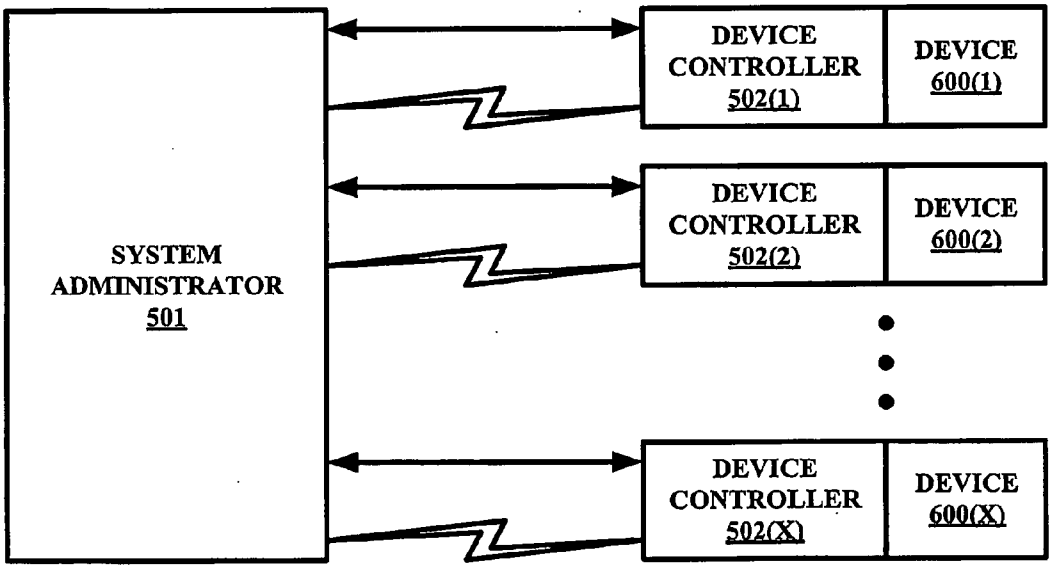

SYSTEM
ADMINISTRATOR
501
DEVICE
CONTROLLER
502(1)
DEVICE
600(1)
DEVICE
CONTROLLER
502(2)
DEVICE
600(2)
DEVICE
CONTROLLER
502(X)
DEVICE
600(X)

Fig. 11

MODULATION CONTROL OF A HYDRONIC HEATING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 11/627,739, entitled "Hydronic Heating System" and filed Jan. 26, 2007, and priority and the benefit of U.S. patent application Ser. No. 11/627,739 are claimed in the present application to the extent the subject matter of this application is found in the previously filed application. The content of that application is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to modulation control of various systems utilizing one or more energy sources for a particular purposes, such as, for example, systems utilizing natural gas, oil, coal, gasoline, steam, water and/or electricity for purposes of providing heating, cooling, pumping, current output and/or mechanical energy. The present invention specifically relates to a load based modulation control of such systems.

BACKGROUND

[0003] Commercial hydronic heating systems are used in buildings to supply heat via hot water that is circulated by a pump. One type of traditionally common heating system utilizes non-condensing boilers in which a portion of the input heat is lost via the boiler flue. A more modern type of heating system increases overall efficiency by employing condensing boilers. A condensing boiler recovers a large amount of heat from exhaust gases that would otherwise be lost via the flue. Through the use of heat exchangers, the temperature of the gases exiting the flue may be reduced from a range of 300° F.-450° F. to a range of 90° F.-130° F.

[0004] Although it is becoming more of a standard practice to employ hydronic heating systems that utilize high-efficiency condensing boilers, many existing heating systems employ one or more non-condensing boilers of an age or condition that does not justify replacement of those boilers from an economic standpoint, as associated radiators, heat exchangers, or other end user heat transfer or transmission devices would require replacement as well. The result is that many buildings may have both non-condensing as well as condensing boilers, thereby forming what is known as hybrid heating systems. Although the overall efficiency of a condensing boiler system is higher than a non-condensing system, each type of boiler has certain advantages over the other depending upon factors such as outside air temperature and the heat load on the boiler. The present disclosure is directed to an arrangement for controlling a hybrid heating system in which each type of boiler can be realized to its particular advantage.

SUMMARY

[0005] It is therefore an object of the present disclosure to provide a hybrid hydronic heating system in which the operation of condensing and non-condensing boilers is controlled to optimize the efficiency and life of each boiler based on heating load requirements.

[0006] It is a further object of this disclosure to control the operation of each boiler independently based on a variety of factors, including the type, size, cycle time, efficiency, and use history of the boiler.

[0007] Further objects, embodiments, forms, benefits, aspects, features and advantages of the present disclosure may be obtained from the description, drawings, and claims provided herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic and block diagram of an embodiment of the present disclosure, illustrating a hybrid heating system having two boilers.

[0009] FIG. **2** is a schematic and block diagram of an embodiment of the present disclosure, illustrating a hybrid heating system having four boilers.

[0010] FIG. **3** is a schematic and block diagram of the main control circuit used in a heating system constructed in accordance with an embodiment of this disclosure.

[0011] FIG. **4** is a schematic and block diagram of condensing boiler control circuitry used in a heating system constructed in accordance with an embodiment of this disclosure.

[0012] FIG. **5** is a schematic and block diagram of non-condensing boiler control circuitry used in a heating system constructed in accordance with an embodiment of this disclosure.

[0013] FIG. **6** is a schematic and block diagram of a pH measurement control circuit used in a heating system constructed in accordance with an embodiment of this disclosure.

[0014] FIG. **7** is a schematic and block diagram illustrating a number of temperature sensor circuits, as well as a user interface circuit used in a heating system constructed in accordance with an embodiment of this disclosure.

[0015] FIG. **8** is a flowchart representative of a process modulation algorithm in accordance with an embodiment of this disclosure.

[0016] FIG. **9** is a flowchart representative of a rate-of-change modulation scheme in accordance with an embodiment of this disclosure.

[0017] FIG. **10** is a schematic and block diagram of a single system controller for a plurality of devices constructed in accordance with an embodiment of this disclosure.

[0018] FIG. **11** is a schematic and block diagram of a system administrator and corresponding device controllers for a plurality of devices constructed in accordance with an embodiment of this disclosure.

DETAILED DESCRIPTION

[0019] For the purposes of promoting an understanding of the principles of the disclosure, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended, and alterations and modifications in the illustrated examples, and further applications of the principles of the disclosure as illustrated therein are herein contemplated as would normally occur to one skilled in the art to which the disclosure relates.

[0020] Referring to FIG. **1**, there is shown a hydronic (i.e., hot water) heating system **20** that includes boilers **21** and **22** for heating water that is circulated in order to heat a building. Boilers **21** and **22** may both be condensing or non-condensing boilers, or one boiler may be a condensing boiler while the other is a non-condensing boiler. Boilers **21** and **22** are respectively associated with pumps **23** and **24** that act to provide circulation of the heated water throughout the building. Controller **36** is operably connected to boilers **21** and **22** via connectors **42** and **43** respectively. Connectors **42** and **43**

are illustratively shown as being a cable or wire, but connectors **42** and **43**, as well as other connectors described and shown herein, may take the form of an apparatus or functionality consistent with any technology known to those skilled in the art and appropriate for the purpose and application described (e.g., wireless transmission technology). Controller **36** provides signals that control the operation of boilers **21** and **22**, including the operation of their respective boiler pumps **23** and **24**. A temperature sensor **25** is located to measure the water temperature in boiler inlet or return water line **27** of boiler **21**. Temperature sensor **25** is operably connected to controller **36** via connector **32**. Temperature sensor **26** is located to measure the water temperature in outlet or system supply water line **28** of boiler **21** and is operably connected to controller **36** via connector **33**. Similarly, a temperature sensor **29** is located to measure the water temperature in inlet or return water line **31** of boiler **22**. Temperature sensor **29** is operably connected to controller **36** via connector **34**. Temperature sensor **30** is located to measure the water temperature in outlet or system supply water line **32** of boiler **22** and is operably connected to controller **36** via connector **35**.

[0021] Water lines **27**, **28**, **31** and **32** are connected to the main circulating water line **37** that circulates heated water through heat transmission devices **18** and **19** (e.g., heat exchangers, radiators, or air handlers) located at various points throughout the building to heat the building. Auxiliary pumps **38** and **39** are connected to main water line **37** to assist the water flow. Pumps **38** and **39** are connected via connectors **40** and **41**, respectively, to controller **36** to provide control of pumps **38** and **39**. Water flow direction in heating system **20** is indicated by arrows **95** in FIG. **1**.

[0022] Additional temperature sensors **44**, **45**, and **46** are located along main water line **37** to measure the temperature of the water at that location, and return the temperature data via data lines **47**, **48**, and **49**, respectively, to controller **36**, although it is understood that temperature data may be returned in a non-wired manner, e.g., wireless transmission, as would be known to those skilled in the art. Sensor **44** is illustratively shown as being located in the vicinity of the outgoing heated water from boilers **21** and **22**, respectively. Sensor **45** is illustratively shown as being located in between boilers **21** and **22** to measure water temperature in the return portion of main water line **37**. Sensor **46** is illustratively shown as being located in the return water flow from heat transmission devices **18** and **19** to boilers **21** and **22**. An outside air temperature sensor **50** is connected to controller **36** via data line **51** to provide measurements of outside air temperature to controller **36** of heating system **20**.

[0023] Air temperature sensors **80** and **81** are illustratively shown as being connected to controller **36** via connectors **82** and **83**, respectively. Air temperature sensors **80** and **81** are illustratively located in rooms or areas of the building to be heated, and provide data to controller **36** regarding the ambient temperature of those rooms or areas.

[0024] Dampers **52** and **53** are illustratively shown as being controlled via connectors **54** and **55**, respectively, by controller **36** for controlling outside air flow to boilers **21** and **22**, respectively, in order to provide free air make-up to boilers **21** and **22**. Flow valves **56**, **57**, **58**, and **62** are illustratively shown as being connected to and controlled by controller **36** via connectors **59**, **60**, **61**, and **63**, respectively. The rate and quantity of soft or conditioned water supplied to flush by-pass or sidestream water line **64** via incoming water line **70**, in order to maintain calibration of pH meter **67** located in sidestream water line **64**, is controlled by way of flow valves **57** and **58**. Water is drained from main water line **37** via drain line **17** by way of flow valves **56** and **58**. pH meter **67** measures the pH of the water within main water line **37**. Main valve **75** is located within main water line **37** and is illustratively shown as being connected to controller **36** by connector **76** to force water flow through sidestream water line **64**. Connector **71** connects pH meter **67** to controller **36**. Flow measuring device **65** is mounted to main water line **37** and provides flow data via connector **66** to controller **36**. A user interface **90**, e.g., computer input screen, is illustratively shown as being connected to controller **36** by way of connector **91**.

[0025] It will be understood that the system of FIG. **1** is illustrative in nature and is not limited to any specific number of boilers, any particular piping arrangement of the various water lines, valves, sensors or controls shown in the drawings, which will in operation depend upon particular building requirements.

[0026] To further illustrate the non-limiting nature of the present disclosure, reference is now made to FIG. **2** which illustrates a heating system **120**. Heating system **120** illustratively includes non-condensing boilers **121** and **122** and condensing boilers **123** and **124** connected to a main water circulation line **147** by inlet or boiler return water lines **126**, **127**, **128**, and **129**, respectively and outlet or system supply water lines **130**, **131**, **132**, and **133**, respectively. Boilers **121**, **122**, **123**, and **124** are respectively associated with pumps **134**, **135**, **136**, and **137** which are mounted on the boiler return water lines **126**, **127**, **128**, and **129**, respectively. Pumps **134**, **135**, **136**, and **137** are preferably enabled with variable frequency drive circuitry that allows the pumps to be operated at variable speeds, i.e., pumping rates. Similar to heating system **20** of FIG. **1**, heating system **120** of FIG. **2** includes temperature sensors **138**, **140**, **142**, and **144** mounted on the outlet or system supply water lines **130**, **131**, **132**, and **133**, respectively, and temperature sensors **139**, **141**, **143**, and **145** mounted on the inlet or return water lines **126**, **127**, **128**, and **129**, respectively. Boilers **121**, **122**, **123**, and **124** are operably connected to controller **146** via connectors **221**, **222**, **223**, and **224**, respectively. Pumps **134**, **135**, **136**, and **137** are operably connected to controller **146** via connectors **234**, **235**, **236**, and **237**, respectively. Temperature sensors **138**, **139**, **140**, **141**, **142**, **143**, **144**, and **145** are operably connected to a controller **146** via connectors **238**, **239**, **240**, **241**, **242**, **243**, **244**, and **245**, respectively. While FIG. **2** shows controller **146** connected to the various components herein described via hard wired control or connection lines or wires, it will be understood that various wireless connections are envisioned including, but not limited to, IR, RF, and optical links. In addition, control and sensor data may be communicated via various network interfaces and protocols including parallel or serial data buses, Ethernet, Bluetooth, IEEE standard control interfaces, or other computer or data networks that are known to those of ordinary skill in the art both now and as may be developed in the future.

[0027] Boilers **121**, **122**, **123**, and **124** include air dampers **148**, **149**, **150**, and **151**, which are also operably connected to controller **146** via connectors **248**, **249**, **250**, and **251**, respectively. Controller **146** may independently control the operation of air dampers **148**, **149**, **150**, and **151** via switching or control signals, e.g., digital signals, sent to dampers **148**, **149**, **150**, and **151** via connectors **248**, **249**, **250**, and **251** to control the outside or free air make-up to boilers **121**, **122**, **123**, and

124, respectively. Auxiliary pumps 152 and 153 pump or circulate water through secondary water line 154 of main water line 147 and are operated by controller 146 via connectors 252 and 253, respectively. Auxiliary pumps 155 and 156 pump or circulate water through secondary water line 157 and are operated by controller 146 via connectors 255 and 256, respectively. Water flow direction through system 120 is illustratively shown by arrows 200.

[0028] Valves 167 and 170 are connected to and controlled by controller 146 via connectors 267 and 270, respectively, to provide soft or conditioned water via inlet line 168 to flush sidestream 185 as necessary to maintain the calibration of pH meter 172. Controller 146 is also operably connected to sidestream valves 166 and 169 via connectors 266 and 269, respectively, to control the flow of water from main water line 147 to a pH measurement sidestream water line 185. A pH meter 172 is provided to measure the pH of the water circulating throughout system 120. pH meter 172 is shown as being mounted in pH measurement sidestream 185 and operably connected to controller 146 via connector 272. Main valve 165 is mounted within main water line 147 and is also operably connected to controller 146 via connector 265. Controller 146 operates main valve 165 to force the flow of water through pH measurement sidestream 185. A weak acid pump 195 and a weak base pump 196 are illustratively shown as being coupled into main water line 147. Acid pump 195 and base pump 196 are shown as being operably connected to controller 146 via connectors 295 and 296, respectively. Controlling the pH of the water circulating through main water line 147 is important to prevent premature failure or wear with respect to the components of heating system 120 due to overly acidic or basic water. Through the operation of valves 165, 166, 167, 169, and 170 by controller 146 by signals via connectors 265, 266, 267, 269, and 270, respectively, periodic checks of the pH of the water in main water line 147 can be made by diverting some water into sidestream 185 and measuring its pH by pH measurement sensor 172 and returning that data to controller 146 via connector 272. If the water requires an adjustment of its pH, controller 146 can initiate the operation of weak acid pump 195 or weak base pump 196 by signals sent via connectors 295 or 296, respectively, as needed to restore the pH of the water in main water line 147 to a satisfactory level.

[0029] Temperature sensors 160, 161, and 162 are mounted to main water line 147 to measure the temperature of the circulating water at various locations along main water line 147. Sensors 160, 161, and 162 are shown as being operably connected to controller 146 via connectors 260, 261, and 262, respectively. A flow measuring device 163 is shown as being mounted on main water line 147 to provide water flow information to controller 146 via connector 263. An outdoor air temperature sensor 164 is mounted outside the building and is operably connected to controller 146 via connector 264. Air temperature sensors 180 and 181 are located in rooms or areas of the building and are also operably connected to controller 146 via connectors 280 and 281, respectively, to provide information with respect to the ambient temperature of the rooms or areas in which the sensors are located. FIG. 2 illustratively shows heat transmission devices 201 and 202 located within system 120. Devices 120 may be end user heat distribution apparatus, such as radiators, heat exchangers, or air handlers, for only a few examples. A user interface device 190 is also operably connected to controller 146 via connector 290 to allow a user of heating system 120 to select or change various input criteria, e.g., desired room temperature, or the manner in which heating system 120 is operated. User interface device 190 also provides a means for information regarding the status or condition of the components of system 120 to be communicated to the user.

[0030] The piping configuration of main water line 37 shown in FIG. 1 and main water line 147 shown in FIG. 2 locates the condensing boilers 123 and 124 upstream from the non-condensing boilers 121 and 122 such that during the time the condensing boilers are enabled, their operation will preheat the water flowing to the non-condensing boilers, thereby increasing the efficiency of the non-condensing boilers and acting to prevent the non-condensing boilers from condensing, thereby protecting the non-condensing boilers from the detrimental effects of condensation.

[0031] As previously described, the present disclosure does not limit the number or types of boilers that can be used within a heating system. For purposes of explaining the operation of a heating system constructed in accordance with the present disclosure, reference will be made to FIGS. 3-7 which, for example only, illustrate elements of a hydronic heating system that includes two condensing and two non-condensing boilers in an arrangement such as that shown in FIG. 2. Reference will therefore be made primarily to FIG. 2, although it is understood that the principles of operation to be described apply equally to heating systems having different numbers of boilers, including but not limited to the system of FIG. 1.

[0032] FIG. 3 illustrates the presence of a main system controller and its associated input and output signals and functions. FIG. 4 illustrates the presence of a condensing boiler controller and its associated input and output signals and functions. FIG. 5 illustrates a non-condensing boiler controller with its associated input and output signals and functions, and FIG. 6 illustrates a pH measurement controller and its associated input and output signals and functions. It is understood that While separate or individual controllers can of course be used, a unitary controller, such as controller 36 or 146, may comprise the functionality of each of the controller elements shown in FIGS. 3-6 in the physical embodiment of a single device. Therefore, for purposes of simplifying the following explanation, each of the controller devices in FIGS. 3-6 will be identified by reference number 146. Additionally, while FIGS. 3-7 may illustrate elements that contain language that suggests a function or type of information, that element may be identified by a reference number that corresponds to the physical device shown in FIG. 2 that performs such function or provides such information. FIG. 7 illustrates a representation of the functionality within heating system 120 of user interface 190 as well as a number of representative temperature sensors, e.g., sensors 160, 164, 180, and 181.

[0033] Through the use of user interface device 190, the type of each boiler 121-124 (e.g., condensing or non-condensing) will be inputted by the user. Minimum and maximum return and supply temperatures for each of boilers 121-124, as defined by the boiler manufacturer, will be inputted by the user as well. The outdoor air temperature switch point, i.e., the temperature above which a condensing-type boiler is initially selected, may also be provided to system 120 via user interface device 190. Using data provided by interface device 190, and the outdoor air temperature provided by sensor 164 via connector 264, controller 146 will enable at least one of pumps 134-137 via their respective connectors 234-237. After a user defined delay (e.g., 1 to 10 minutes), a flow

reading using flow sensor **163** in the main water line **147** will be taken. Using this flow data provided via connector **263**, as well as other initializing data, controller **146** calculates an initial building heating load for system **120**. Based on this calculated load and the outdoor air temperature switch point, controller **146** will determine which type of boiler (e.g., condensing or non-condensing) to initially enable. For example, if the outdoor air temperature calls for a condensing boiler and there is more than one condensing boiler available in system **120**, then the first boiler selected can be based on which one has accumulated the least hours of operation. This may be done by comparing timers linked with each boiler's respective output enable circuits, unless a particular boiler in the system has been designated a dedicated lead boiler, in which case it will always be enabled or fired first. Since controller **146** also knows the output capability of each boiler on the system, controller **146** may also select for operation the boiler having an output that is most closely matched to the building load. If the condition should exist that a particular boiler is in an alarm state (i.e., the boiler is not working properly), controller **146** will not enable that boiler until the condition causing the alarm is remedied. For purposes of this example, condensing boiler **124** is initially enabled by controller **146** via connector **224**. After an initial period of low fire output of boiler **124**, the building heating load will be recalculated to obtain a real-time heating load. This low fire time delay, e.g., 30 minutes, is used to ensure that the initial calculated heating load is accurate so as to avoid overshooting the desired building temperature by overfiring the initially enabled or fired boiler or boilers. If the recalculated heating load indicates that heat is still required, the initially enabled boiler **124** will thereafter by operated in its normal or real-time mode, e.g., via proportional-integral-derivative (PID) control, by controller **146** via connector **224**.

[0034] The operation of the PID mode of controller **146** will be constantly monitored. If controller **146** causes the output of boiler **124** to remain above a user defined output percentage (e.g., 25%-100%) for a given user defined time period (e.g., 5-60 minutes), then a second boiler, e.g., condensing boiler **123**, will be enabled via connector **223** and controller **146** will split the real time heating load between the two enabled boilers **124** and **123** in a manner that operates both boilers as efficiently as possible. The heating load distribution between boilers **124** and **123** is monitored often (e.g., once per second) to ensure boilers **124** and **123** continue to be operated as efficiently as possible. If the heating load increases, this pattern of sequencing will continue until all boilers of a particular type (e.g., condensing or non-condensing) that exist in a given heating system have been enabled or fired. Should the outdoor air temperature remain above the condensing/non-condensing switch point and all condensing boilers, in this case boilers **124** and **123**, have been operating at a user defined maximum output for a user defined period of time and a user defined heating load percentage (e.g., 1-10%) has not been reached, a non-condensing boiler, e.g., boiler **122** will then be enabled by an enabling signal via connector **222**. Once non-condensing boiler **122** has been enabled, condensing boilers **124** and **123**, that are still enabled, will be reset to cover that portion of the heating load that still allows non-condensing boiler **122** to maintain its minimum recommended return water temperature. Non-condensing boiler **122** will operate under PID control to cover the balance of the heating load. Should the heating load increase, the non-condensing boilers will follow the same sequencing control described above to enable and control additional non-condensing boilers, e.g., boiler **121**, and boiler pumps, e.g., pump **134**. During the run cycles of both condensing and non-condensing boiler reset loops, building zone temperatures will be polled by network temperature devices, e.g., sensors **180** and **181**, to determine if the output (i.e., supply temperature) of system **120** is meeting the heating load. Based on this information, boiler reset temperatures will be increased to supply more heat if needed, decreased to increase efficiency of boiler operation, or left the same. This polling enables controller **146** to know how much energy has been used to heat the building and, based on the calculated heating load, enable only the boiler or boilers needed to most efficiently meet the remaining heating load.

[0035] Once the heating load covered by condensing boilers **124** and **123** has been satisfied, condensing boilers **124** and **123** will be shut down by controller **146** by signals provided via connectors **224** and **223**, respectively. Condensing boilers **124** and **123** will be enabled again only if the return water temperature of non-condensing boilers **121** and **122** (if enabled) falls below a user defined limit (e.g., 130° F.) and remains there for more than a user defined period of time (e.g., 5-30 minutes), or if the outdoor air temperature rises above the condensing/non-condensing switch point, or if all the non-condensing boilers, in this case boilers **121** and **122**, are operating at a user defined maximum output for a user defined period of time (e.g., 15-60 minutes) and have failed to adequately satisfy the heating load. As the heating load is satisfied or reduced, a non-condensing boiler will be shut down by controller **146**. The boiler selected for shut down is chosen based on hours of operation. As the heating load continues to decrease, additional boilers will be shut down.

[0036] Boiler operating regulations require that a boiler must be shut down at least once every 24 hours. In order to comply with this requirement and to even wear across boilers, system **120** operates such that each boiler **121-124** is shut down at least once every six hours. This process allows controller **146** to regularly compare hours of accumulated operation and enable or fire the boiler of a given type with the least operating hours first. If the heating load of the building is determined to be less than the minimum operating range of all the available boilers **121-124** on system **120**, controller **146** will select and enable the boiler having the lowest operating range. This functionality of controller **146** will help to eliminate as much as possible the efficiency losses and significant wear effects of short cycling on boilers **121-124**.

[0037] When the switch to non-condensing boilers occurs because outdoor air temperature has dropped below the switch point, all of the heating load will be assigned to non-condensing boilers **121** and **122**. Once a non-condensing boiler has been enabled or fired as described above and the return water temperature is equal to or greater than a user defined limit (e.g., 130° F.), any condensing boilers (e.g., boiler **123** or **124**) that is enabled will be shut down, although its main pump will continue to operate for a period of time that is calculated as a percentage of the boiler's just-concluded run time in order to extract additional heat from that boiler and reduce the effects of boiler precipitation on scaling of the boiler tubes. The total load will then be assigned to the running non-condensing boiler and the reset of the supply or output temperature will be defined by an equation having a slope which is designated for non-condensing boilers.

[0038] The inlet and outlet temperature difference, i.e., ΔT, is a user defined value (e.g., 10° F.-45° F. or within the boiler

manufacturer's limits) that can be selected via user interface device **190**. This ΔT, measured by temperature sensors **144** and **145** for boiler **124**, for example, is maintained to the extent possible via operation of controller **146** by providing control signals to the variable frequency drives of the boiler's respective pump, e.g., pump **137** in the above example. Pump **137**, for example, will then be modulated or operated to increase or decrease water flow so as to maintain the measured ΔT with the user selected value. By modulating or controlling the flow rate of the boiler pumps, the pumps can put out less water at higher temperatures, thereby increasing boiler efficiency.

[0039] It can be seen from the previous explanation with reference to the drawings that system **120** provides microprocessor control of differing types of boilers in a heating system through the use of a variety of sensor inputs to optimally sequence and operate each boiler in the heating system to maximize efficiency of the boilers. The system is suitable for controlling multiple boilers of different sizes and of different types within the same heating system. By calculating real time heating load and using that information to select and operate boilers, efficiency losses and detrimental effects on equipment life due to short-cycling of boilers are prevented or eliminated. The system disclosed herein effectively prevents non-condensing boilers from condensing while condensing boilers are allowed to condense. The system offers the ability to reset and control both condensing and non-condensing boilers on the same system. With two unique and user definable reset temperature slopes, both types of boilers can be utilized seamlessly.

[0040] The controllers shown in FIGS. **3-6** were described in the context of implementing a PID version of a process modulation algorithm of the present invention for purposes of controlling a hybrid boiler system. In practice, the process modulation algorithm is applicable to many types of systems including, but not limited too, systems employing devices using energy sources (e.g., natural gas, oil, coal, gasoline, steam, water and electricity) for any purpose (e.g., heating, cooling, pumping, current output and mechanical energy). To facilitate further understanding of the process modulation algorithm of the present invention in the context of any system and to introduce a rate-of-change modulation version of the process modulation algorithm, a description will now be provided herein of a flowchart **300** representative of the process modulation algorithm as shown in FIG. **8** and a description of a flowchart **400** representative of the rate-of-change modulation version of the process modulation algorithm as shown in FIG. **9**.

[0041] Referring to FIG. **8**, a stage S**302** of flowchart **300** encompasses a system load calculation that is dependent upon one or more operational conditions (e.g., temperature, pressure, power consumption, motion, etc.) of an applicable system (e.g., heating, cooling, pumping, current output and mechanical energy). For example, in the context of a hybrid heating system including one or more condensing boilers and one or more non-condensing boilers, the following equations [1] and [2] can be utilized for purposes of calculating a system load for the hybrid heating system that is dependent upon a set-point temperature of the hybrid heating system:

$$L=((T_{SP}-T_R)+(T_{SP}-T_S))*(\text{GPM}*\text{WLG}*\text{MPH}) \quad [1]$$

$$L=((T_{SP}-T_R)+(T_{SP}-T_S)+(\text{CTL}-T_R))*(\text{GPM}*\text{WLG}*\text{MPH}) \quad [2]$$

[0042] where (1) L is a calculated system load (BTU/H) for the hybrid heating system,

[0043] (2) T_{SP} is the set-point temperature (° F.) of the hybrid heating system,

[0044] (3) T_S is the supply water temperature (° F.) of the hybrid heating system,

[0045] (4) T_R is the return water temperature (° F.) of the hybrid heating system,

[0046] (5) GPM is the number of gallons per minute flowing through the hybrid heating system past a flow sense point,

[0047] (6) WLG is the pounds of water per gallon within the hybrid heating system,

[0048] (7) MPH is the minutes per hour the hybrid heating system is expected to be operational for an hour time period, and

[0049] (8) CTL is a condensing temperature limit (° F.) of the hybrid heating system.

[0050] Equation [1] is utilized for fall condensing operations and for non-condensing operations whereby the return water temperature T_R is equal to or greater than the condensing temperature limit CTL. Conversely, equation [2] is utilized for non-condensing operations whereby the return water temperature T_R is less than the condensing temperature limit CTL. As previously described herein, a hybrid heating system can be switched between condensing operations and non-condensing operations based on a comparison of the outdoor air temperature to a switch temperature point whereby condensing operations primarily occur above the switch temperature point and non-condensing operations primarily occur below the switch temperature point.

[0051] A determination of the set-point temperature is also dependent upon whether the hybrid heating system is in condensing operations or non-condensing operations. For example, a condensing reset temperature slope is derived from a graph of a water temperature range and output air temperature range for the condensing boiler(s). For this slope, one endpoint is plotted as the maximum water temperature/minimum outdoor air temperature and the other endpoint is plotted as the minimum water temperature/maximum outdoor air temperature whereby the set-point temperature is the water temperature on the slope corresponding to a sensed outdoor air temperature. Similarly, a non-condensing reset temperature slope is derived from a graph of a water temperature range and output air temperature range for the non-condensing boiler(s). Again, for this slope, one endpoint is plotted as the maximum water temperature/minimum outdoor air temperature and the other endpoint is plotted as the minimum water temperature/maximum outdoor air temperature whereby the set-point temperature is the water temperature on the slope corresponding to a sensed outdoor air temperature.

[0052] Still referring to FIG. **8**, a stage S**304** of flowchart **300** encompasses a device load assignment that is dependent upon the output capacities of the device(s) (e.g., boilers, chillers, pumps, dampers, etc.) of the applicable system (e.g., heating, cooling, pumping, current output and mechanical energy). For example, in the context of a hybrid heating system including one or more condensing boilers and one or more non-condensing boilers, the following equations [3] and [4] can be utilized for purposes of assigning a device load for each boiler Y of a total of X enabled boilers of the hybrid heating system:

$$BY_{IL}=(OY_{MAX}/\Sigma OX_{MAX}))*(L) \quad [3]$$

$$BY_{IL}=(OY_{MIN}/\Sigma OX_{MIN}))*(L) \quad [4]$$

[0053] where (1) BY_{IL} is a load assignment (BTU/H) for a particular boiler Y,

[0054] (2) OY_{MAX} is the maximum output (BTU/H) for a particular boiler Y,

[0055] (3) ΣOX_{MAX} is a summation of all maximum outputs (BTU/H) for the enabled boilers X,

[0056] (4) OY_{MIN} is the minimum output (BTU/H) for a particular boiler Y,

[0057] (5) ΣOX_{MIN} is a summation of all minimum outputs (BTU/H) for the enabled boilers X, and

[0058] (6) L is the previously calculated system load (BTU/H) for the hybrid heating system.

[0059] Equation [3] is utilized whenever all of the control signal(s) (e.g., analog or digital, voltage or current) of the enabled boiler(s) X are to be modulated as subsequently described herein. Conversely, equation [4] is utilized whenever less than all of the control signal(s) (e.g., analog or digital, voltage or current) of the enabled boiler(s) X are to be modulated as subsequently described herein. As previously described herein, the determination of which boiler(s) to enable at any given moment is a function of the operational state of the system (i.e., condensing or non-condensing) as well as the operational state of each boiler in terms of at least an online/offline status of the boiler, and an operational time status of the boiler.

[0060] Stages S**302** and S**304** are initially executed prior to the conclusion of the low fire time delay of the hybrid heating system and thereafter are continually executed on a periodic basis to maintain a dynamic efficient control of the hybrid heating system.

[0061] Still referring to FIG. **8**, a stage S**306** of flowchart **300** encompasses a device output error calculation that is based on a comparison of an assigned device load and a device output for each enabled device (e.g., boiler, chiller, pump, damper, etc.) of the applicable system (e.g., heating, cooling, pumping, current output and mechanical energy). For example, in the context of a hybrid heating system including one or more condensing boilers and one or more non-condensing boilers, the following equations [5]-[10] can be utilized for purposes of calculating a device output error for each enabled boiler of the hybrid heating system:

$$BY_{SP} \approx BY_{IL} \quad [5]$$

$$BY_{HL} = OY_{MAX} + DB \quad [6]$$

$$BY_{LL} = OY_{MIN} - DB \quad [7]$$

$$DB = OF * (OY_{MAX}/100) \quad [8]$$

$$O_{BY} = (V_{CON} - V_{MIN}) * ((OY_{MAX} - OY_{MIN})/(V_{MAX} - V_{MIN})) + OY_{MIN} \quad [9]$$

$$E_Y = BY_{SP} - O_{BY} \quad [10]$$

[0062] where (1) BY_{SP} is the boiler output set-point temperature (BTU/H) for a particular boiler Y,

[0063] (2) BY_{IL} is the previously calculated load assignment (BTU/H) for a particular boiler Y,

[0064] (3) BY_{HL} is a high limit for the boiler output set-point temperature BY_{SP},

[0065] (4) BY_{LL} is a low limit for the boiler output set-point temperature BY_{SP},

[0066] (5) OY_{MAX} is the maximum output (BTU/H) for a particular boiler Y,

[0067] (6) OY_{MIN} is the minimum output (BTU/H) for a particular boiler Y,

[0068] (7) DB is a deadband based on an output percentage factor OPF of a particular boiler Y whereby the output percentage factor OPF can be designed to range from 1 to 100,

[0069] (8) O_{BY} is a calculated heat output (BTU/H) for a particular boiler Y,

[0070] (9) V_{CON} is an analog control voltage signal for a particular boiler Y that controls the fire level of that boiler Y,

[0071] (10) V_{MAX} is a maximum of the analog control voltage signal V_{CON} (e.g., 10 volts),

[0072] (11) V_{MIN} is a minimum of the analog control voltage signal V_{CON} (e.g., 0 volts), and

[0073] (12) E_Y is the calculated error for a particular boiler Y.

[0074] While equations [5]-[10] can be executed during the low fire time delay of the hybrid heating system, it is only essential for equations [5]-[8] to be executed or processed during the flow fire time delay and all of the equations [5]-[10] to be executed continually on a periodic basis upon completion of the low fire time delay.

[0075] Also note that the boiler output set-point temperature BY_{SP} is a function of the calculated load assignment BY_{IL} that can dynamically vary between the low limit BY_{LL} and the high limit BY_{HL}. As such, those having ordinary skill in the art will appreciate the purpose of utilizing the deadband DB to establish the low limit BY_{LL} and the high limit BY_{HL} is to limit the dynamic variable nature of the calculated load assignment BY_{IL}. For a hybrid heating system, the output percentage factor OPF is preferably 1 for stage S**306**.

[0076] Furthermore, during the low fire period, it is best to ramp the analog control voltage signal V_{CON} at a fixed rate in the appropriate up or down direction based on the calculated error E_Y in an attempt to reach the boiler output set-point temperature BY_{SP} during the low fire period in a controlled manner. Thereafter, the control voltage signal V_{CON} is modulated in the appropriate positive or negative direction based on the calculated error E_Y in accordance with stage S**308** of flowchart **300**.

[0077] Specifically, stage S**308** encompasses a modulation of an output of a device (e.g., boiler, chiller, pump, damper, etc.) based on the calculated device output error in accordance with a modulation scheme chosen for an applicable system (e.g., heating, cooling, pumping, current output and mechanical energy). For example, in the context of a hybrid heating system including one or more condensing boilers and one or more non-condensing boilers, a modulation of an output of an enabled boiler based on a calculated device output error of that enabled boiler is in accordance with PID modulation scheme previously described herein. In another exemplary embodiment, the chose modulation scheme is a rate-of-change modulation scheme as represented by the flowchart **400** shown in FIG. **9**.

[0078] Referring to FIG. **9**, a stage S**402** of flowchart **400** encompasses a calculation of a modulation control variable. For example, in the context of a hybrid heating system including one or more condensing boilers and one or more non-condensing boilers, the following equations [11]-[17] can be utilized for purposes of calculating the modulation control variable:

$$\text{IF } E_Y\uparrow \text{ and } E_Y > +DB, \text{ THEN } CV_Y = CV_Y + 2 \quad [11]$$

$$\text{IF } E^Y\uparrow \text{ and } E_Y < -DB, \text{ THEN } CV_Y = CV_Y - 2 \quad [12]$$

IF $E_Y\downarrow$ and $E_Y>+DB$, THEN $CV_Y=CV_Y+1$ [13]

IF $E_Y\downarrow$ and $E_Y<-DB$, THEN $CV_Y=CV_Y-1$ [14]

IF E_Y<DB and $E_Y>-DB$, THEN $CV_Y=CV_Y+0$ [15]

$CV_{LL}=(ADCF)*V_{MIN}$ [16]

$CV_{HL}=(ADCF)*V_{MAX}$ [17]

[0079] where (1) CV_Y is the modulation control variable for a particular boiler Y that varies between a low limit CV_{LL} and a high limit CV_{HL} (initially equal to low limit CV_{LL} upon the enablement of the boiler),

[0080] (2) E_Y is the calculated error for a particular boiler Y, and

[0081] (3) ADCF is an analog-to-digital conversion factor corresponding to a number bit states of a digital analog voltage signal AN_Y divided by the maximum voltage V_{MAX} for the analog control voltage signal V_{CON}.

[0082] Again, those having ordinary skill in the art will appreciate the purpose of utilizing the deadband DB to control the calculation for the modulation control variable CV_Y is to limit the dynamic variable nature of the calculated error E_Y, which is a function of the dynamic variable nature of calculated load assignment BY_{IL}. For a hybrid heating system, the output percentage factor OPF is preferably 1 for stage S**402**.

[0083] Furthermore, the following equation [18] can be utilized to prevent an oversaturation of the modulation control variable CV_Y:

IF E_Y<DB, THEN $CV_Y=AN_Y$ [18]

[0084] where AN_Y is the digital conversion of the analog control voltage signal V_{CON} that will be further explained subsequently herein. Preferably, the output percentage factor OPF for deadband DB is 50 for the oversaturation protection of the modulation control variable CV_Y.

[0085] A stage S**404** of flowchart **400** encompasses a calculation of a control signal for each enable device (e.g., boiler, chiller, pump, damper, etc.) of the applicable system (e.g., heating, cooling, pumping, current output and mechanical energy) as a function of the previously calculated modulation control variable CV_Y. For example, in the context of a hybrid heating system including one or more condensing boilers and one or more non-condensing boilers, the following equations [19]-[21] can be utilized for purposes of calculating an unbiased digital control voltage signal AN_Y of Z bits (e.g., 12 bits):

IF $CV_Y>AN_Y$, THEN $AN_Y=AN_Y+1$ [19]

IF $CV_Y<AN_Y$, THEN $AN_Y=AN_Y-1$ [20]

IF $CV_Y=AN_Y$, THEN $AN_Y=AN_Y-0$ [21]

The following equations [22]-[27] can be utilized for purposes of calculating a biased ramp down of digital control voltage signal AN_Y of Z bits (e.g., 12 bits):

$R_{PG1}=(V_G*10*B_E)/(OY_{MAX}/1000)/10$ [22]

$R_{PG2}=2R_{PG1}$ [23]

IF $CV_Y>AN_Y$, THEN $AN_Y=AN_Y+1$ [24]

IF $CV_Y<AN_Y$ AND $E_Y<-DB$, THEN $AN_Y=AN_Y-R_{PG1}$ [25]

IF $CV_Y<AN_Y$ AND $E_Y>-DB$, THEN $AN_Y=AN_Y-R_{PG2}$ [26]

IF $CV_Y=AN_Y$, THEN $AN_Y=AN_Y-0$ [27]

[0086] where (1) R_{PG1} is the base biased ramp down variable for a particular boiler Y,

[0087] (2) V_G is the water volume of a particular boiler Y in gallons,

[0088] (3) B_E is a maximum rated efficiency of a particular boiler Y,

[0089] (4) OY_{MAX} is the maximum output (BTU/H) for a particular boiler Y, and

[0090] (5) R_{PG2} is the amplified biased ramp down variable for a particular boiler Y.

[0091] Preferably, the output percentage factor OPF for deadband DB is 5 for the biased ramp down of digital control voltage signal AN_Y.

[0092] To modulate the rate-of-change of the unbiased or biased ramp down of digital control voltage signal AN_Y, the following equation [28] can be utilized to control a timer gate that counts up to allow a calculation of digital control voltage signal AN_Y and is thereafter reset to begin a new count up sequence for the next calculation of digital control voltage signal AN_Y:

IF $E_Y<+DB$ and $E_Y>-DB$, THEN $TGPV_Y=PA*TGF$ [28]

[0093] where (1) TPGVY is a timer gate preset value,

[0094] (2) PA is a process acceleration scale value, and

[0095] (3) TGF is a time gate factor inversely correlated to a chosen output percentage factor OPF for deadband DB.

[0096] The inverse correlation of the timer gate factor TGF and the output percentage factor OPF is a function of the timing specification of the timer gate and one or more designed output percentage factors OPF for deadband DB. For example, the following table illustrates an inverse correlation designed output percentage factors to a timer gate factor TGF in terms of the number times per second the timer gate should allow for a calculation of the digital control voltage signal AN_Y:

OUTPUT PERCENTAGE FACTOR OPF	TIMER GATE FACTOR TGF
1	8 (10 times/8 seconds)
2	7 (10 times/7 seconds)
5	6 (10 times/6 seconds)
10	5 (10 times/5 seconds)
20	4 (10 times/4 seconds)
30	3 (10 times/3 seconds)
40	2 (10 times/2 seconds)
50	1 (10 times/1 seconds)

[0097] The benefit of equation [28] is as the calculated error E_Y of stage **306** decreases, the rate-of-change of the modulation of the digital control voltage signal AN_Y is decelerated in view of a corresponding increase in the timer gate preset value TPGVY. Conversely, as the calculated error E_Y of stage **306** increases, the rate-of-change of the modulation of the digital control voltage signal AN_Y is accelerated in view of a corresponding decrease in the timer gate preset value TPGVY.

[0098] Please note flowchart **400** is designed to execute digital calculations of the modulation control variable and digital control voltage signal and thus the requirement for equations [16] and [17]. Those having ordinary skill in the art will appreciate that, in order to drive an analog circuit of a boiler, the digital control voltage signal has to be converted back into the analog control voltage signal.

[0099] Referring to FIGS. **8** and **9**, those having ordinary skill in the art will appreciate, the benefits of the process modulation algorithm and various modulation schemes of the

present invention. Those having ordinary skill in the art of the present invention will further appreciate how to apply equations [1]-[28] to various systems, in particular how to design the various variables of equations [1]-[28] in view of the particular type of devices to be controlled in accordance with the present invention. For example, FIG. **10** illustrates a system controller **500** for implementing flowcharts **300** (FIG. **8**) and **400** (FIG. **9**) via a wireline or wireless network with an X number of devices **600** of any type (e.g., boilers, chillers, pumps, dampers, etc.). By further example, FIG. **11** illustrates a system administrator **501** for executing stages S**302** and S**304** of flowchart **300** (FIG. **8**) via a wireline or wireless network to device controllers **502** for executing stages S**306** and S**308** of flowchart **300** as well as flowchart **400** (FIG. **9**) on behalf of devices **600** (e.g., boilers, chillers, pumps, dampers, etc.). Alternatively, administrator **501** can partially or entirely execute stage S**306**.

[0100] While the disclosure has been illustrated and described in detail in the drawings and <foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiments have been shown and described and that all changes, modifications and equivalents that come within the spirit of the disclosure provided herein are desired to be protected. The articles "a", "an", "said" and "the" are not limited to a singular element, and may include one or more such elements.

What is claimed is:

1. A hydronic heating system comprising:
- at least a first boiler having first operating characteristics;
- at least a second boiler having second operating characteristics;
- at least one sensor measuring a condition and providing an output indicative of said measured condition; and
- a controller, operably coupled to said first and second boilers, comprising:
  - a processor, responsive to said sensor output, for calculating a heating load; and
  - a control, responsive to said calculated heating load, for independently operating said first and second boilers in a manner that matches said heating load to said first and second operating characteristics, wherein the independent operating of said first and second boilers is modulated as a function a comparison of a heat load assignment for said first and second boilers to a heat output of said first and second boilers.

2. The hydronic heating system of claim **1**, wherein said first boiler comprises a condensing boiler.

3. The hydronic heating system of claim **1**, wherein said second boiler comprises a non-condensing boiler.

4. The hydronic heating system of claim **1**, wherein said first operating characteristics comprises at least a first temperature reset slope.

5. The hydronic heating system of claim **4**, wherein said at least said first temperature reset slope is selectable by a user of said system.

6. The hydronic heating system of claim **1**, wherein said second operating characteristics comprises at least a second temperature reset slope.

7. The hydronic heating system of claim **6**, wherein said at least said second temperature reset slope is selectable by a user of said system.

8. The hydronic heating system of claim **1**, wherein said condition comprises outdoor air temperature.

9. The hydronic heating system of claim **1**, wherein said condition comprises indoor air temperature.

10. The hydronic heating system of claim **1**, wherein said condition comprises the temperature of water circulating through said system for at least one location.

11. The hydronic heating system of claim **1**, wherein said processor calculates a real-time heating load.

12. The hydronic heating system of claim **1**, wherein said control operates at least one of said first and second boilers to maintain a predetermined difference between the temperature of water entering said at least one boiler and the temperature of water exiting said at least one boiler.

13. The hydronic heating system of claim **1**, wherein said control operates at least one of said first and second boilers to maintain water circulating through said at least one boiler for a period of time following a time of operation of said boiler, said period of time being calculated as a percentage of said time of operation.

14. The hydronic heating system of claim **1**, wherein said control provides sequencing of said first and second boilers.

15. The hydronic heating system of claim **14**, wherein said sequencing is in response to the accumulated operating time of each of said boilers.

16. The hydronic heating system of claim **14**, wherein said sequencing is in response to the output capacity of each of said boilers.

17. The hydronic heating system of claim **9**, wherein said sequencing is in response to said first and second operating characteristics.

18. The hydronic heating system of claim **1**, further comprising means for measuring and adjusting the pH of water circulating through said system.

19. A hydronic heating system comprising:
- a plurality of boilers having at least two different operating characteristics;
- at least one sensor for measuring a condition and providing an output indicative of said measured condition; and
- a control, operably coupled to said plurality of boilers, comprising:
  - a processor, responsive to said sensor output, for calculating a heating load; and
  - a control, responsive to said calculated heating load, for independently operating each of said plurality of boilers in a manner that matches said heating load to said different operating characteristics, wherein the independent operating of said first and second boilers is modulated as a function a comparison of a heat load assignment for said first and second boilers to a heat output of said first and second boilers.

20. A hydronic heating system comprising:
- a first boiler having first operating characteristics;
- a second boiler having second operating characteristics;
- a control, operably coupled to said first and second boilers, for determining a heating requirement in response to at least one condition and independently operating said first and second boilers to meet said heating requirement in accordance with said first and second operating characteristics, wherein the independent operating of said first and second boilers is modulated as a function a comparison of a heat load assignment for said first and second boilers to a heat output of said first and second boilers.

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