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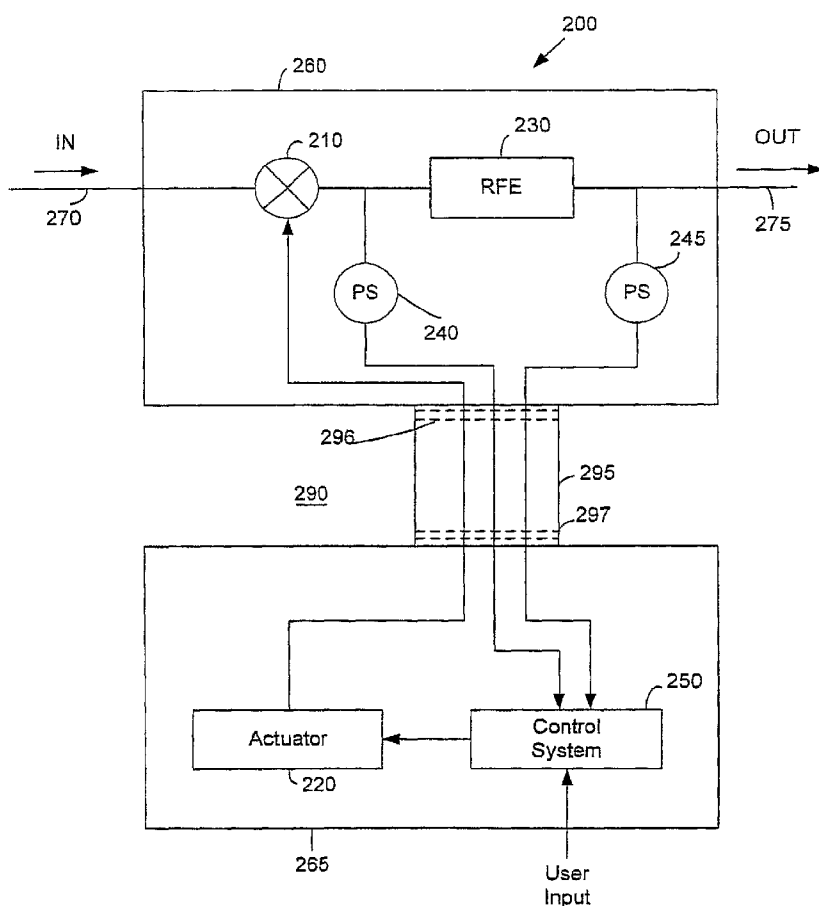
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(54) Title: SYSTEMS AND METHODS FOR MANAGING HEAT TRANSFER IN A FLUID HANDLING DEVICE



(57) Abstract: Systems and methods for reducing temperature variations induced by fluid handling equipment in process fluids by separating heat-producing portions of the control equipment from portions of the equipment which handle or are in close proximity to a fluid flow path. In one embodiment, the fluid handling components are contained in a first enclosure, while the heat-generating components are contained in a second enclosure. An air gap is maintained between the two enclosures to provide thermal isolation of the fluid handling components from the heat-generating components. In one embodiment, the air gap is maintained by connecting the two enclosures using insulating spacers. Interconnects between components in the two enclosures may be routed through an insulating tube that is sealed at each end to prevent heat transfer through the tube.



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SYSTEMS AND METHODS FOR MANAGING HEAT TRANSFER IN A FLUID HANDLING DEVICE

RELATED APPLICATIONS

- [0001] This application claims priority to U.S. Patent Application Serial No. 11/452,754 by inventors Marc Laverdiere, Iraj Gashgaree, Craig L. Brodeur, and Robert F. McLoughlin, entitled "Systems and Methods for Managing Heat Transfer in a Fluid Handling Device" filed on June 14, 2006, the entire contents of which are hereby expressly incorporated by reference for all purposes.

TECHNICAL FIELD OF THE INVENTION

- [0002] The invention relates generally to fluid handling, and more particularly to systems and methods for managing heat transfer in a fluid handling device such as a fluid flow controller of the type typically used in semiconductor processing.

BACKGROUND OF THE INVENTION

- [0003] There is an increasing demand for computers and other electronic devices that provide greater numbers of features and greater computing power, and that also consume less energy. In order to keep up with this demand, new designs for devices are continually being developed. Equally important are new techniques for manufacturing the devices which often are required to enable the new device designs.
- [0004] Because decreasing size and increasing precision is demanded by new device designs, the precision involved in manufacturing processes must increase as well. Both the environments in which the processes are carried out and the controls over specific aspects of the processes themselves must be tightly controlled in order to maintain the necessary precision. Extreme accuracy and precision is therefore required of the equipment that is used to implement the manufacturing processes. If this equipment cannot meet

these high standards, the processes cannot be properly carried out, and the new device designs cannot be implemented.

[0005] One type of manufacturing process parameter that must be tightly controlled concerns the delivery of fluids that are used in manufacturing processes. Systems have therefore been developed to control various aspects of fluid delivery in manufacturing equipment. For example, the amount or rate at which fluid which is provided in a process may significantly affect the results of the process. Mass flow controllers (or fluid flow controllers) have therefore been developed to enable the rate at which fluid is delivered in a process to be maintained within a very narrow operating range. Other factors, such as the temperature of the fluid, or the amount of particulate matter in the fluid may also impact the results of the process in which the fluid is used, so some flow controllers also incorporate features to control the temperature of the fluid, filter the fluid, and so on.

[0006] Even as improved process control equipment is developed, new manufacturing techniques, or new uses for existing equipment may lead to the discovery of shortcomings in process control equipment. In other words, while the equipment was sufficient for earlier manufacturing processes, it may not meet the needs of newer processes. For example, as noted above, fluid flow controllers have been developed to provide fluids in a manufacturing process at a precisely controlled rate. One of the applications for fluid flow controllers is the delivery of fluid under precisely controlled conditions to the surface of a glass panel, where the fluid is spread out across the face of the panel to form a coating. This process is used, for example, in the manufacture of large-screen flat-panel televisions or monitors. In this application, variations in the temperature of the fluid – even very minor ones – can result in variations in the thickness of the coating which is formed on the glass panel. Because variations in the thickness of the coating cause variations in picture quality across the panel, the initial variations in the temperature of the process fluid may ultimately result in a panel being discarded for poor quality.

[0007] Fluid flow controllers for manufacturing processes such as this typically incorporate all of the necessary components into a single enclosure. Because of clean-room constraints, it may be desirable to seal the enclosure. It has been found that the close proximity of the electronic portion of the control system to the fluid handling portion of the flow controller, the flow controller itself maintains temperature variations in the process fluid, particularly when the flow controller is experiencing transient conditions (e.g., when the heat generated in the flow controller increases at start-up.) Although some prior art flow controllers separate the electronics of the flow controller from the fluid handling mechanism and position the electronics at a substantial distance from the fluid handling mechanism to prevent heating of the process fluid, this results in other disadvantages. For example, since the flow sensors in the fluid handling portion of the flow controller now have to transmit their signals to the control electronics over a much larger distance, it is typically necessary to provide amplification of the signals at the sensor, which results in heating that was intended to be eliminated. Additionally, if the control valves in the fluid handling portion of the controller are pneumatically actuated, the increased distance between the fluid handling portion and control portion of the flow controller results in reduced responsiveness. In other words, the system may not be able to control the flow control valve quickly enough to meet the demands of the manufacturing process.

[0008] It would therefore be desirable to provide systems and methods for providing flow control in manufacturing processes that do not suffer from these drawbacks of prior art systems.

SUMMARY OF THE INVENTION

[0009] One or more of the problems outlined above may be solved by the various embodiments of the invention. Broadly speaking, the invention comprises systems and methods for reducing temperature variations induced by flow control equipment or other fluid handling equipment in process fluids by separating heat-producing portions of the control equipment from portions of

the equipment which handle or are in close proximity to a fluid flow path. In one embodiment, the fluid handling components are contained in a first sealed enclosure, while the heat-generating components are contained in a second sealed enclosure. An air gap is maintained between the two enclosures to provide thermal isolation of the fluid handling components from the heat-generating components.

[0010] Another embodiment comprises a fluid handling device having one or more fluid handling components that do not generate any significant heat, and one or more control components that do generate heat. The fluid handling components are contained in a first enclosure, while the heat generating components are contained in a second enclosure. An air gap is maintained between the two enclosures to thermally isolate the fluid handling components from the heat generating components. Interconnects between the two enclosures allow interaction between the fluid handling components and the heat generating components. The air gap may, for instance, be between about 0.75 and 1.25 inches. In one embodiment, the air gap is maintained by insulating spacers which are used to connect the two enclosures to each other. The spacers may, for example, be polypropylene or other material (e.g., Teflon or other suitable material) tubes. Another polypropylene tube may be coupled between the enclosures to form a conduit between them. The interconnects between the fluid handling and heat generating components can then be routed through the conduit. The ends of the conduit are sealed to prevent heat transfer through the conduit. In one embodiment, the enclosure containing the fluid handling components is made of an insulating material such as plastic, while the enclosure containing the heat generating components includes a thermally conductive material such as metal. The enclosure containing the heat generating components, for example, can be all metal or can have a metal inner housing and plastic outer housing.

[0011] Numerous additional embodiments are also possible.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0012] Other objects and advantages of the invention may become apparent upon reading the following detailed description and upon reference to the accompanying drawings.
- [0013] FIGURE 1, is a block diagram illustrating the structure of an exemplary fluid flow controller.
- [0014] FIGURE 2 is a simplified functional block diagram of a control system for use in a flow controller in accordance with the prior art.
- [0015] FIGURE 3 is a diagram illustrating the physical packaging of the components of an exemplary fluid flow controller in accordance with the prior art.
- [0016] FIGURE 4 is a block diagram illustrating the structure of an exemplary fluid flow controller in accordance with one embodiment of the invention.
- [0017] FIGURE 5 is a perspective view of a fluid flow controller in accordance with one embodiment of the invention.
- [0018] While the invention is subject to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and the accompanying detailed description. It should be understood, however, that the drawings and detailed description are not intended to limit the invention to the particular embodiments which are described. This disclosure is instead intended to cover all modifications, equivalents and alternatives falling within the scope of the present invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

- [0019] One or more embodiments of the invention are described below. It should be noted that these and any other embodiments described below are exemplary and are intended to be illustrative of the invention rather than limiting.
- [0020] As described herein, various embodiments of the invention comprise systems and methods for reducing temperature variations induced by flow

control equipment in process fluids by separating heat-producing portions of the control equipment from portions of the equipment which handle or are in close proximity to a fluid flow path.

[0021] In one embodiment, a fluid handling device (e.g., a flow controller, pump or other fluid handling device) is designed for use in manufacturing processes in which temperature control of the process fluid being handled by the flow controller is critical. Consequently, it is desirable to move components of the fluid handling device that may affect or the temperature of the process fluid away from the fluid flow path and to thermally isolate these components. The fluid handling components in this embodiment are therefore contained in a first enclosure, while the heat-generating components are contained in a second enclosure. Although the various components are interconnected (e.g., by wires or pneumatic lines) to allow them to interact and function in the same way as components of conventional fluid handling devices, an air gap is maintained between the two enclosures to provide the needed thermal isolation.

[0022] In this embodiment, the fluid handling components are contained in a plastic enclosure which is sealed. Heat-generating components such as the control electronics of the system are contained in another enclosure. This enclosure, according to one embodiment, can be a fully metal enclosure or can be an enclosure with a metal inner housing and a plastic outer housing. The control electronics enclosure does not have any vents, but is instead sealed, as is desirable in many manufacturing environments. The enclosures are positioned with an air gap of approximately 1.25 inches between them. This gap is maintained by spacers that are positioned between the enclosures, and which connect the enclosures to each other. The spacers are tubes made of an insulating material such as polypropylene or other suitable material (e.g., Teflon or other material) to prevent conduction of heat through the spacers. The control lines which interconnect the heat generating components with the fluid handling components are run through one of the spacer tubes which is sealed at both ends to prevent convective transfer of heat between the enclosures.

- [0023] For the sake explanation, embodiments of the present invention will be described in conjunction with a flow controller. Before describing the exemplary embodiments of the invention, it may be helpful to describe more conventional designs for flow controllers. Referring to FIGURE 1, a block diagram illustrating the structure of an exemplary fluid flow controller in accordance with the prior art is shown. Fluid flow controller 100 receives a process fluid, determines the rate at which fluid is flowing through the controller, and adjusts a control valve until the flow rate of the fluid is at a desired level. In this system, fluid flow controller 100 includes a flow control valve 110, an actuator 120, a restrictive flow element 130, pressure sensors 140 and 145 and a control system 150. All of these components are contained within an enclosure 160. Fluid flows into flow controller 100 through inlet 170, and flows out of the flow controller through outlet 175.
- [0024] After fluid enters flow controller 100, it flows through a flow path that consists of an inlet conduit 171, flow control valve 110, intermediate conduit 172, restrictive flow element 130, and outlet conduit 173. Restrictive flow element 130 may be any type of element that causes a pressure drop in the fluid flow path corresponding to the rate at which the fluid is flowing through the path, such as an orifice plate, a small diameter tube, a constriction in the fluid flow path, or the like. The purpose of restrictive flow element 130 is simply to create a pressure drop which can be measured by pressure sensors 140 and 145. Because the characteristic flow rate of the fluid through restrictive flow element 130 as a function of this pressure drop is known, the measured pressure drop can be used to calculate the rate at which the fluid is flowing through the restrictive flow element, hence through the fluid flow path. Restrictive flow element 130 does not control the fluid flow rate, but simply provides a pressure drop across the element corresponding to the current flow rate. The flow rate of the fluid is adjusted by adjusting the setting of fluid flow control valve 110. Flow control valve 110 may be any suitable type of valve, such as a throttling valve, a poppet valve, a butterfly valve, or the like. Flow control valve 110 may be driven by any appropriate means, including, but not limited to, pneumatic actuators, stepper motors and the

like. It should be noted that while in the embodiment of FIGURE 1, flow control valve is located upstream of the pressure sensors and flow restrictor, according to other embodiments, flow control valve 110 can be downstream of the pressure sensors and flow restrictor or otherwise located in the flow path.

[0025] As pointed out above, pressure sensors 140 and 145 are used to measure the pressure drop across restrictive flow element 130. Pressure sensors 140 and 145 may be any suitable type of sensors, including, for example, capacitance type sensors, piezoelectric sensors, transducer-type sensors, and the like. The portion of each sensor that is exposed to the process fluid should be inert with respect to the fluid. Pressure sensor 140 is positioned adjacent to and upstream from resistive flow element 130. Pressure sensor 145, the other hand, is positioned adjacent to, but downstream from restrictive flow element 130. Pressure sensors 140 and 145 do not, themselves, impede the flow of the fluid through flow controller 100, but simply measure the fluid pressure in the flow path immediately prior to and following restrictive flow element 130. Each of pressure sensors 140 and 145 generates a raw electrical signal corresponding to the sensed fluid pressure. Pressure sensor 140 provides its pressure measurement signal to control system 150 via sensor line (wire) 180, while pressure sensor 145 provides its pressure measurement to the control system via sensor line 185. Because control system 150 is positioned in close physical proximity to pressure sensors 140 and 145, it is not necessary to amplify the raw measurement signals from the pressure sensors before providing the signals to the control system.

[0026] Control system 150 calculates a pressure drop across restrictive flow element 130 based upon the signals received from pressure sensors 140 and 145. The pressure drop may be calculated by control system 150 in a variety of ways. As noted above, the signals received from pressure sensors 140 and 145 are raw signals, so control system 150 may convert each raw signal into a pressure measurement and then subtract the pressure corresponding to the signal of pressure sensor 145 from the pressure

corresponding to the signal of pressure sensor 140 to determine the pressure drop. Alternatively, control system 150 may simply take the difference between the raw signals received from pressure sensors 140 and 145 and determine the pressure drop across restrictive flow element 130 from this difference. Other alternatives may also be possible.

[0027] After control system 150 has determined the pressure drop across restrictive flow element 130, this pressure drop is compared to a target value. The target value is a desired pressure drop that corresponds to a desired flow rate through flow controller 100. If the sensed pressure drop is less than the target value, the fluid flow rate through flow controller 100 is too low, so the flow rate should be increased. If, on the other hand, the sensed pressure drop is greater than the target value, the flow rate through the flow controller is too high, so the flow rate should be decreased. Control system 150 may employ proportional-integral (PI,) proportional-integral-derivative (PID,) or any other suitable control scheme. Control system 150 increases or decreases the flow rate of the fluid through flow controller 100 by sending appropriate signals to control valve actuator 120. Upon receiving these control signals from control system 150, actuator 120 takes appropriate action to adjust flow control valve 110. For example, if actuator 120 uses a stepper motor to adjust to the flow control valve, the actuator will move the mechanical linkage between itself and the flow control valve by an appropriate number of steps.

[0028] Referring to FIGURE 2, a simplified functional block diagram of control system 150 is shown. The primary components of control system 150 include a data processor 151, a memory 152, an analog-to-digital (A/D) converter 153 and a digital-to-analog (D/A) converter 154. Data processor 151 may be a digital signal processor (DSP,) embedded microprocessor, or any other type of data processor suitable for performing the functions described herein. Data processor 151 is coupled to memory 152, which may be used by the data processor to store both data (e.g., user inputs, calibration data, sensor signal data, etc.) and program instructions to be executed by the data processor. Control system 150 may be configured to

receive both analog and digital input. The digital inputs may include such things as user input, remote-control data, diagnostic data and various other data, while the analog inputs may include such things as pressure sensor signals, temperature sensor signals, auxiliary analog inputs, etc. Digital input may be provided directly to data processor 151, while analog input is provided to A/D converter 153, which converts the analog data to digital data and then forwards the digital data to data processor 151. Control system 150 may also be configured to provide both analog and digital outputs. The digital outputs may include such things as user output, digital actuator data, diagnostic data, etc., while the analog outputs may include linear actuator signals, stepper motor driver signals, pulse width modulated signals and the like. The digital output data may be provided directly by data processor 151, while analog data is generated by D/A converter 154 based on digital data received by the D/A converter from the data processor.

- [0029] Referring to FIGURE 3, a diagram illustrating the physical packaging of the components of an exemplary fluid flow controller in accordance with the prior art is shown. As described above, all of the components of the flow controller are packaged within a single enclosure 160. It should be noted that one side of enclosure 160 is not shown in the figure so that the components of the flow controller can be seen. This is merely for purposes of illustration, and the components of the flow controller are normally completely sealed within enclosure 160. As depicted in the figure, the fluid handling portion of the flow controller (consisting of flow control valve 110, valve actuator 120, restrictive flow element 130, pressure sensors 140 and 145, and the conduits between them) is positioned immediately adjacent to the printed circuit board and associated electronic components of control system 150. The close physical proximity of control system 150 to the fluid handling portion of the flow controller allows the dissipation of heat from the control system to the fluid handling components.
- [0030] The components of fluid flow controller 100 which actually handle the fluid (i.e., flow control valve 110, restrictive flow element 130, pressure sensors 140, 145) do not generate a significant amount of heat which can be

transferred to the fluid. Control system 150, on the other hand, consumes electrical power as it processes the pressure sensor data, determines whether the fluid flow rate is too high or too low, and generates control signals to drive the flow control valve (via the control valve actuator.) As a result, control system 150 dissipates energy, heating its environment, including other components in flow controller 100. The heating of these components can affect the control of the process fluid in several ways. For example, the heat transferred to the components may then be transferred to the fluid itself. The heating of the fluid can cause the viscosity of the fluid to change. This is detrimental to flow control because flow controllers are often calibrated for a particular viscosity fluid. If the fluid heats and changes viscosity, the calibration curves used by the flow controller to correlate a pressure drop to flow rate may not longer be accurate. Additionally, heating of components can be detrimental as it may cause the components to behave differently than they would in the absence of this heating (e.g., heating of a temperature sensitive pressure sensor can cause the readings of the pressure sensor to drift.)

- [0031] The present systems and methods therefore isolate at least some of the heat-generating components of the flow controller from the fluid handling components in order to prevent the generated heat from adversely affecting the operation of the flow controller or from being conveyed to the process fluid itself. The isolation of these components is illustrated in FIGURE 4, which is a simplified block diagram of an exemplary embodiment.
- [0032] Referring to FIGURE 4, fluid flow controller 200 consists of the same primary components described above in connection with FIGURE 1, but the components are arranged in a different manner, and some of the components are housed in a separate enclosure. The process fluid is received at inlet 270, flows through control valve 210 and then to restrictive flow element 230. The fluid flows through restrictive flow element 230 and exits the flow controller through outlet 275. Again, however, control valve 210 can be placed at other locations in the flow path. The fluid pressure at the inlet of restrictive flow element 230 is measured by pressure sensor 240.

The fluid pressure at the outlet of restrictive flow element 230 is measured by pressure sensor 245. The signals generated by pressure sensors 240 and 245 are conveyed to control system 250. Control system 250 determines the pressure drop across restrictive flow element 230 based on the signals received from the pressure sensors and compares this pressure drop to a target value. Control system 250 then generates control signals that are conveyed to control valve actuator 220. If the pressure drop across restrictive flow element 230 is too low, the control signals generated by control system 250 cause actuator 220 to increase the fluid flow through control valve 210. If the pressure drop across restrictive flow element 230 is too high, control system 250 generates control signals that cause actuator 220 to decrease the fluid flow through control valve 210.

[0033] As depicted in the figure, the fluid handling portion of flow controller 200 is housed within a first enclosure 260, while the control portion of the components are housed in a second enclosure 265. As pointed out above, the fluid handling portion of the flow controller includes components that do not generate a significant amount of heat. Consequently, they do not significantly alter the temperature of the process fluid when the fluid flows through or near these components. Some of the control components of this system, however, such as control system 250 do generate a significant amount of heat which could be transferred to the process fluid if not for the separation of these components from the fluid handling components. Thus, the present system isolates the fluid handling portion of the flow controller from the heat generated by some of the components without causing the problems posed by remote location of the control components (e.g., the need to amplify sensor signals in the fluid handling enclosure.) It should be noted that control valve actuator 220 is depicted in FIGURE 4 as being contained in enclosure 265 with control system 250 because it is assumed that the actuator generates heat during its normal operation. If actuator 220 generates very little heat, it may alternatively be located with the fluid handling components in enclosure 260.

- [0034] As shown in FIGURE 4, enclosure 260 and enclosure 265 are separated by an air gap 290. While the use of separate enclosures provides some thermal isolation of the fluid handling components from the heat generating components, the generation of heat within enclosure 265 causes the temperature of the enclosure itself to increase, so the heat may still be communicated to the fluid handling components if this enclosure is in contact with, or in close proximity to enclosure 260. Air gap 290 provides additional thermal isolation. Air gap 290 is maintained by one or more spacers (e.g., 295) which are positioned between enclosures 260 and 265. The spacers are made of an insulating material such as polypropylene or other suitable material in order to prevent the conduction of heat through the spacers. It should also be noted that interconnections between the components in enclosure 260 and the components in enclosure 265 may conveniently be routed through a tubular spacer between the enclosures, as shown in the figure. Seals 296 and 297 are placed at the ends of tubular spacer 295 to prevent convective transfer of heat between the enclosures.
- [0035] Referring to FIGURE 5, a perspective view of a fluid flow controller in accordance with one embodiment is shown. In this figure, enclosures 260 and 265 are stacked vertically. Enclosure 260, which contains the fluid handling components of the flow controller, is the lower of the two enclosures and serves as the base of the physical package. Process fluid inlet 270 and outlet 275 can be seen at the front end of enclosure 260. Enclosure 265, which contains the heat-generating components of the flow controller, is the higher of the two enclosures. Various input and output connectors are shown on the front of enclosure 265. The specific connectors that are used may vary with different embodiments. Enclosure 265 is stacked on top of a set of cylindrical spacers 295. The spacers are rigidly connected to each of the enclosures so that they form a rigid assembly.
- [0036] In this embodiment, enclosure 260 is made of plastic. The plastic serves to provide some insulation between the fluid handling components in the sealed enclosure and the environment external to the enclosure. Enclosure

265, on the other hand, can be fully metal or can include, for example, a metal inner housing to house the electronics and a plastic outer housing that is exposed to the process environment. According to another embodiment, an all plastic enclosure can be used that is preferably coated to prevent RF transfer with an EMI coating or other coating. Because of the environments in which the flow controller is typically used, it is desirable for all of the components of the flow controller to be in sealed enclosures. Since the enclosures need to be sealed for some applications, enclosure 265, which contains the heat generating components, cannot be vented to allow cooling air flow through the enclosure. The metal construction of enclosure 265 (or the inner portion of enclosure 265) allows heat to be dissipated through the walls of the enclosure.

[0037] Spacers 295 between the enclosures consist of polypropylene or other material tubes. The polypropylene serves as an insulator, so that heat is not conducted from enclosure 265, through the spacers to enclosure 260. (It should be noted that the additional insulating material may also be used between the enclosures to augment the thermal isolation of the air gap.) In this embodiment, the spacers are approximately 1.25 inches long to maintain a corresponding air gap between the enclosures. Empirical testing with different sizes of air gaps indicated that, when using flow controller enclosures as described above, 1.25 inches is a sufficient air gap to prevent any significant heating of the fluid handling enclosure resulting from heating in the enclosure containing the heat generating components at start-up of the controller. (The temperature in the upper enclosure increased by approximately 30 degrees Fahrenheit during start-up.) By comparison, an air gap of 0.75 inches resulted in the temperature in the fluid handling enclosure increasing by about 1 degree Fahrenheit during start-up. It should be noted, of course, that the optimal size of the air gap may depend upon a number of factors, such as the amount of heat generated in the control system enclosure, the insulating properties of the spacers, the amount of airflow through the air gap, and so on.

- [0038] In this embodiment, a conduit 292 is placed between upper enclosure 265 and lower enclosure 260, and interconnects between components in the two enclosures are routed through the conduit. Conduit 292 is a polypropylene or other material tube similar to spacers 295. Each end of conduit 292 is connected to one of the enclosures at an opening through which the interconnects extend. Conduit 292 is sealed at each end (around the interconnects) so that each enclosure remains sealed. It should be noted that there are no openings in enclosures 260 or 265 where spacers 295 are connected to the enclosures.
- [0039] It should be noted that the particular structures described above are exemplary. While the various embodiments of the invention are distinctive in their isolation of heat generating components of the flow controller from the fluid handling components, the particular components and structures employed in the different embodiments may vary. For example, alternative embodiments may employ fluid flow measurement mechanisms other than that described above, in which pressure sensors are positioned upstream and downstream from a restrictive flow element to measure a pressure drop across the element so that a corresponding flow rate can be determined. Any suitable means can be used to measure fluid flow parameters, compute flow rates, generate control signals, and so on.
- [0040] It should be noted that various components of the foregoing embodiments have not been described in detail because these components are of essentially the same type and configuration as used in prior art systems. For example, the construction and configuration of flow control valves are also well known. Similarly, the general structure, configuration and operation of control systems for flow control valves are known. Despite the use of these known components, the particular arrangement of the components, as described above and claimed below, is believed to be distinctive of the prior art.
- [0041] Those of skill in the art will understand that information and signals may be represented using any of a variety of different technologies and techniques.

For example, data, instructions, commands, information, signals, bits, symbols, and the like that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof. The information and signals may be communicated between components of the disclosed systems using any suitable transport media, including wires, metallic traces, vias, optical fibers, and the like.

[0042] Those of skill will further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, software (including firmware,) or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Those of skill in the art may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[0043] The various illustrative logical blocks, modules, and circuits described in connection with the electronic circuits disclosed herein may be implemented or performed with application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), general purpose processors, digital signal processors (DSPs) or other logic devices, discrete gates or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be any conventional processor, controller, microcontroller, state machine or the like. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

- [0044] The steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in software (program instructions) executed by a processor, or in a combination of the two. Software may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. Such a storage medium containing program instructions that embody one of the present methods is itself an alternative embodiment of the invention. One exemplary storage medium may be coupled to a processor, such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside, for example, in an ASIC. The ASIC may reside in a user terminal.
- [0045] It should be further noted that embodiments of the present invention can be applied to other types of fluid handling devices, such as dispense pumps. In this example, the electronics for driving the pump(s) can be separated from the fluid handling portions of the pump by an air gap. Again, the electronics can be housed in a metal or metal and plastic enclosure spaced from the pump body through which fluid flows. The electronics can be connected to components of the pump via conduits as described above. The enclosure that encloses the fluid handling components can be the pump body itself.
- [0046] The benefits and advantages which may be provided by the present invention have been described above with regard to specific embodiments. These benefits and advantages, and any elements or limitations that may cause them to occur or to become more pronounced are not to be construed as critical, required, or essential features of any or all of the claims. As used herein, the terms "comprises," "comprising," or any other variations thereof, are intended to be interpreted as non-exclusively including the elements or limitations which follow those terms. Accordingly, a system, method, or other embodiment that comprises a set of elements is not limited to only

those elements, and may include other elements not expressly listed or inherent to the claimed embodiment.

[0047] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein and recited within the following claims.

WHAT IS CLAIMED IS:

1. A fluid handling device comprising:
one or more fluid handling components contained in a first enclosure;
one or more heat generating components contained in a second enclosure; and
one or more interconnects coupling one or more of the fluid handling components
to one or more of the heat generating components;
wherein the first and second enclosures are positioned to maintain an air gap
between the first and second enclosures.
2. The fluid handling device of Claim 1, further comprising one or more spacers
coupled between the first and second enclosures to maintain the air gap between the
first and second enclosures.
3. The fluid handling device of Claim 2, wherein the spacers comprise an insulating
material.
4. The fluid handling device of Claim 3, wherein the insulating material comprises
polypropylene.
5. The fluid handling device of Claim 3, wherein the spacers comprise tubes.
6. The fluid handling device of Claim 1, further comprising a conduit coupled
between the first and second enclosures, wherein one or more of the interconnects are
routed through the conduit.
7. The fluid handling device of Claim 6, wherein the conduit comprises an insulator.
8. The fluid handling device of Claim 6, wherein the conduit is sealed at a first end
coupled to the first enclosure and at a second end coupled to the second enclosure.
9. The fluid handling device of Claim 1, wherein the first enclosure is constructed of
a thermally insulating material.

10. The fluid handling device of Claim 9, wherein the thermally insulating material comprises plastic.
11. The fluid handling device of Claim 1, wherein the second enclosure is constructed of a thermally conductive material.
12. The fluid handling device of Claim 12, wherein the thermally conductive material comprises metal.
13. The fluid handling device of Claim 12, wherein the second enclosure includes an inner metal housing and a plastic outer housing.
14. The fluid handling device of Claim 1, wherein the first enclosure is sealed.
15. The fluid handling device of Claim 1, wherein the second enclosure is sealed.
16. The fluid handling device of Claim 1, wherein the fluid handling components contained in the first enclosure include one or more flow measurement sensors and a flow control valve.
17. The fluid handling device of Claim 16, wherein the fluid handling components contained in the first enclosure further include a restrictive flow element and wherein the flow measurement sensors are configured to measure a pressure drop across the restrictive flow element.
18. The fluid handling device of Claim 1, wherein the heat generating components contained in the second enclosure include an electronic control system.
19. The fluid handling device of Claim 1, wherein an insulating material is positioned in the air gap between the first and second enclosures.
20. The fluid handling device of Claim 1, wherein the air gap between the first and second enclosures is between about 0.75 inches and 1.25 inches.

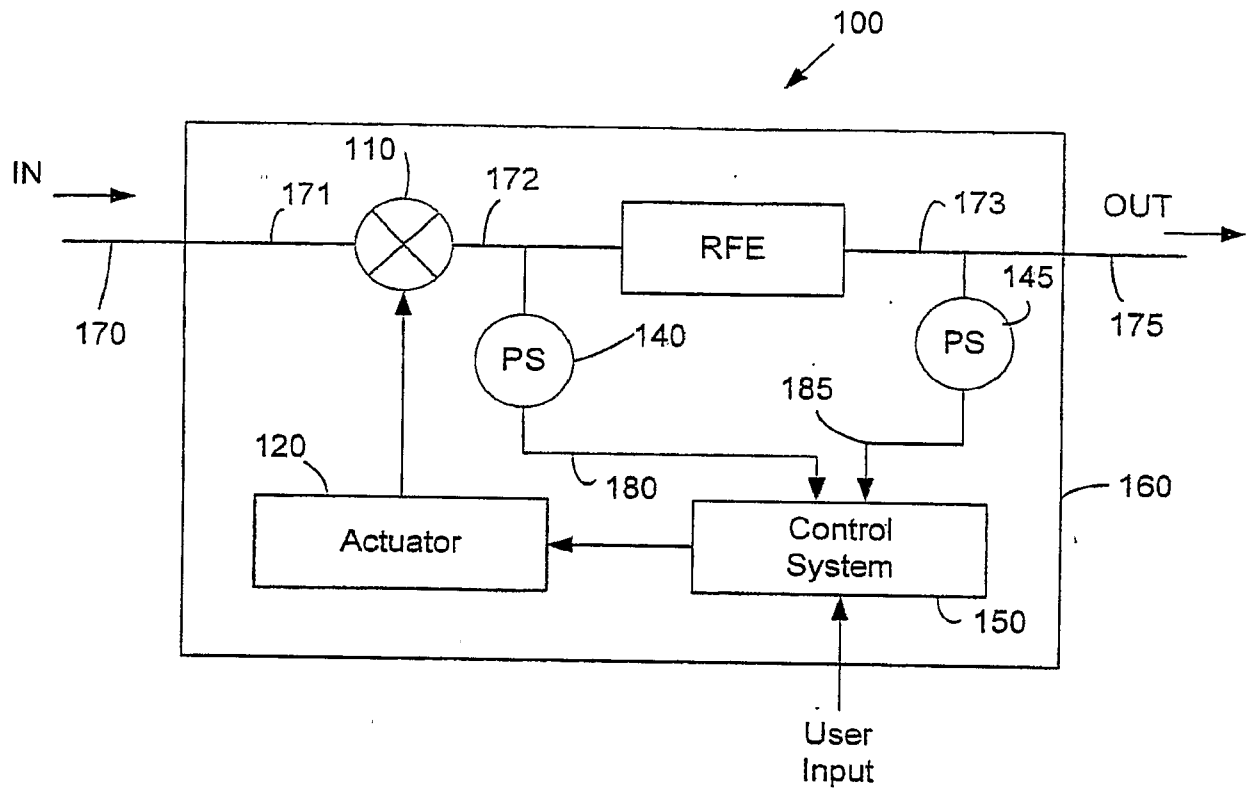


Fig. 1

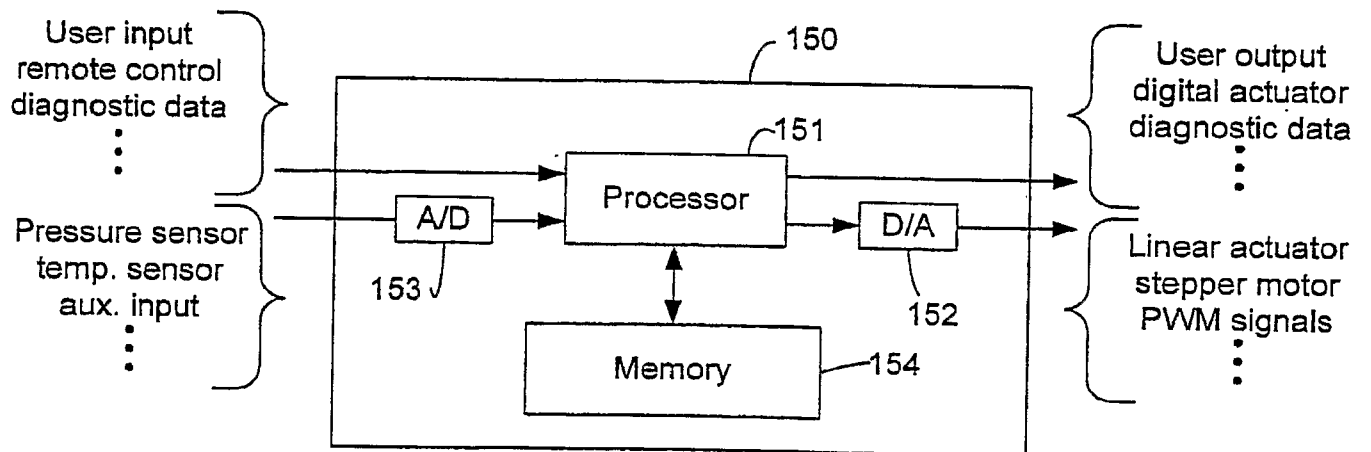


Fig. 2

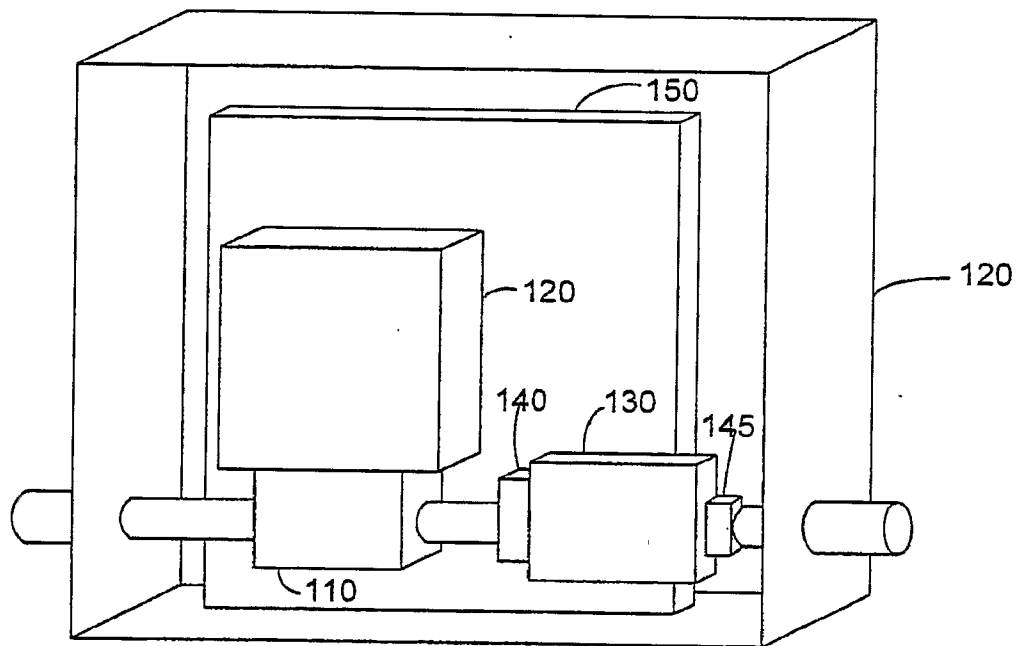


Fig. 3

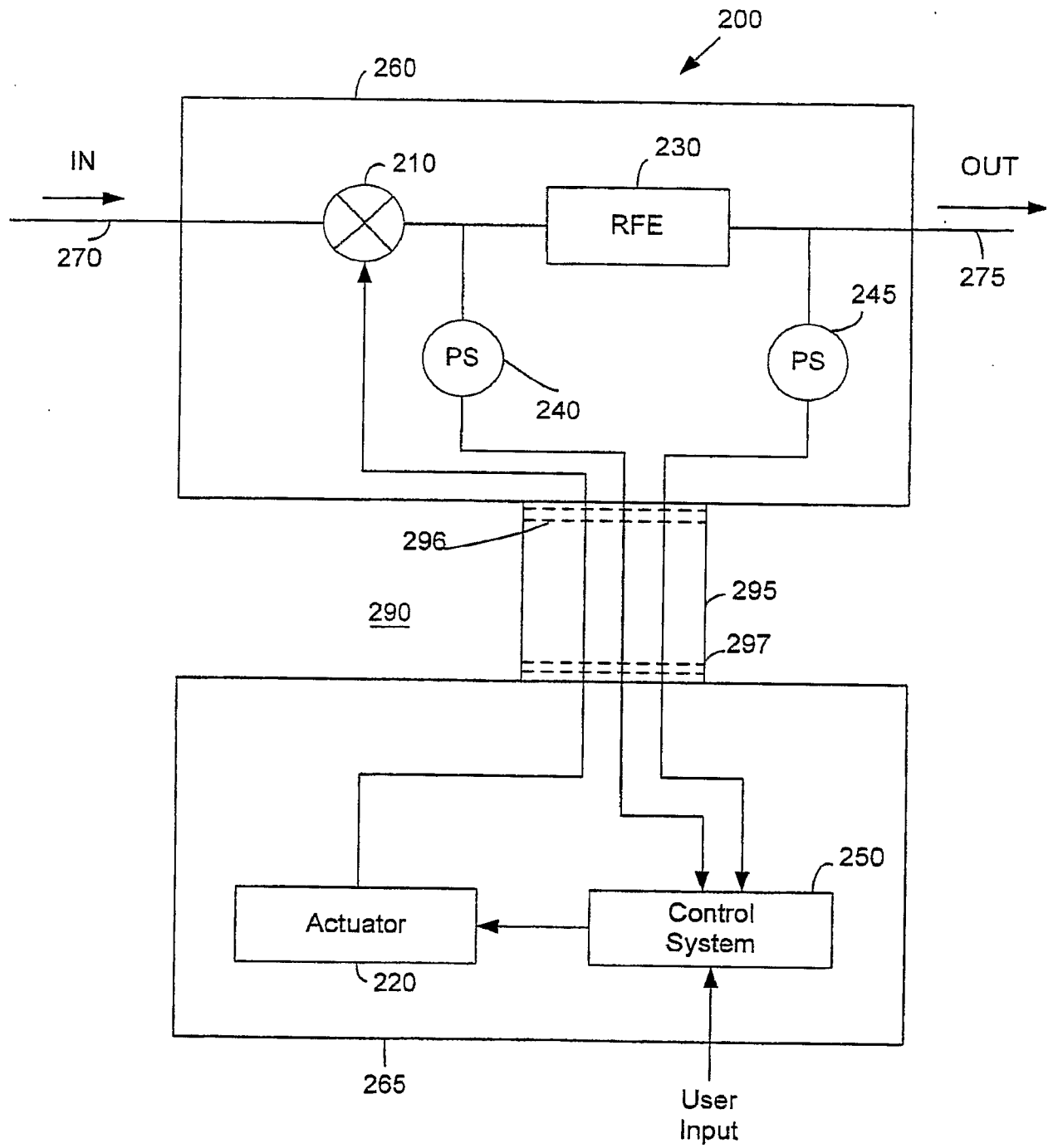


Fig. 4

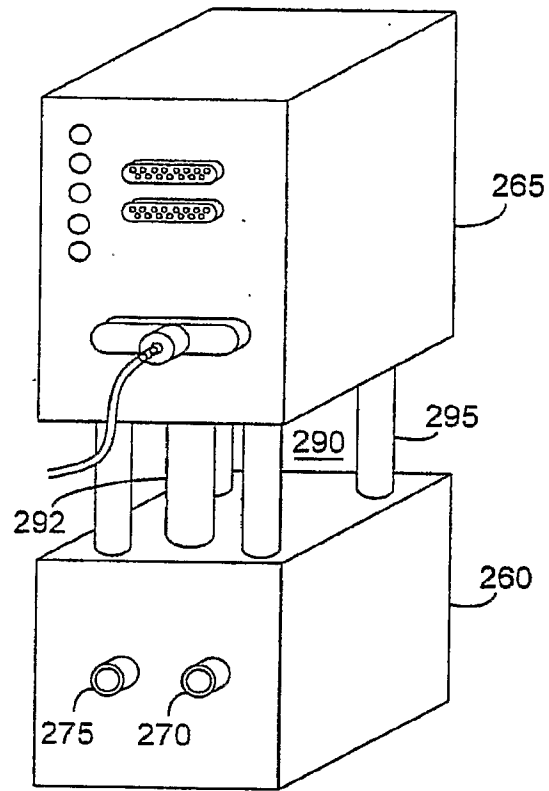


Fig. 5