VELOCITY CONTROL DEVICE FOR A BURNER USING THE CURIE EFFECT FOR PREHEATED FUEL AND OXIDIZER

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Abstract

Methods and systems for controlling jet velocity at a burner when using heated gases and standard temperature gases are described herein. Through the use of a temperature-sensitive magnetic valve, the flow of a gas can be redirected to reduce velocity based on temperature. The temperature-sensitive magnetic valve can redirect flow of the gas based on the magnetic state of a curie material. The curie material changes the state of the temperature-sensitive magnetic valve based on the temperature of the gas. Thus, heated gases and standard temperature gases can be delivered at approximately equal velocities thus maintaining flame size and shape.
FLOWING AN OXIDIZING GAS OR A FUEL GAS INTO A TEMPERATURE-SENSITIVE MAGNETIC VALVE AT A FIRST TEMPERATURE AND FIRST VELOCITY, THE TEMPERATURE-SENSITIVE BIMETALLIC VALVE COMPRISING A MAGNET, A CURIE MATERIAL, A BLOCKING DEVICE AND A FLOW CONTROL STRUCTURE

TRANSFERRING HEAT FROM THE OXIDIZING GAS OR THE FUEL GAS TO THE CURIE MATERIAL, WHEREIN THE CURIE MATERIAL CHANGES FROM A SECOND TEMPERATURE TO THE FIRST TEMPERATURE

CHANGING THE POSITION OF THE CURIE MATERIAL, AS MEASURED FROM THE FLOW CONTROL STRUCTURE OR THE MAGNET, IN RESPONSE TO THE CHANGE IN TEMPERATURE FROM THE SECOND TEMPERATURE TO THE FIRST TEMPERATURE

DELIVERING THE OXIDIZING GAS OR THE FUEL GAS FROM THE TEMPERATURE-SENSITIVE MAGNETIC VALVE TO A BURNER AT A SECOND VELOCITY, WHEREIN THE SECOND VELOCITY OF THE OXIDIZING GAS OR THE FUEL GAS CHANGES DEPENDANT ON THE POSITION OF THE CURIE MATERIAL

FIG. 9
VELOCITY CONTROL DEVICE FOR A BURNER USING THE CURIE EFFECT FOR PREHEATED FUEL AND OXIDIZER

BACKGROUND OF THE INVENTION

[0001] Field of the Invention

[0002] Embodiments described herein generally relate to control of jet velocity of a fuel gas or oxidizing gas. Specifically, embodiments described herein relate to maintaining proper jet velocity for gases delivered to a burner at non-standard temperatures.

[0003] Description of the Related Art

[0004] Many industrial operations employ furnaces within which fuel and oxidant are combusted, so that the heat of combustion can heat material that is in the furnace. Examples include furnaces that heat solid material to melt it, such as smelting furnaces, and furnaces that heat objects such as steel slabs to raise the material’s temperature (short of melting it) to facilitate shaping or other treatment of the material or object. The required high temperature is generally obtained by combustion of a hydrocarbon fuel such as natural gas. The combustion produces gaseous combustion products, also known as flue gas. Even in metal heating equipment that achieves a relatively high efficiency of heat transfer from the combustion to the solid materials to be melted, the flue gases released generally reach temperatures in excess of 1300 degrees Celsius (°C), and thus represent a considerable waste of energy that is generated in the high temperature operations, unless that heat energy can be at least partially recovered from the combustion products.

[0005] One mechanism to recover this lost energy is to preheat one or more of the combustion reactants (fuel or oxidant) using the flue gases. The combustion reactants can be heated to a critical temperature, thus increasing the heat delivered to the furnace during the combustion process. However, problems arise from the preheating of the combustion reactants. As the combustion reactants are heated, the gases expand leading to an increase in jet velocity. Jet velocity is the velocity with which the gases escape the burner. Increased jet velocity leads to a shorter residence time before the combustion reaction which can reduce flame luminosity. A larger jet can resolve this problem, but this solution is not applicable to both low temperature and high temperature combustion reactants.

[0006] Thus, there is a need in the art for control of jet velocity during burner operations based on temperature.

SUMMARY OF THE INVENTION

[0007] The embodiments of the invention described herein generally relate to systems and methods for controlling jet velocity. In one embodiment, a system for controlling jet velocity can include a source of oxidizing gas; a source of fuel gas; at least one temperature-sensitive magnetic valve in connection with one of the source of oxidizing gas or the source of fuel gas, the valve comprising a curie material, a magnet, a blocking device and a flow control structure and configured to receive an oxidizing gas or a fuel gas, wherein the oxidizing gas or the fuel gas is at a first temperature; change the temperature of at least the curie material from a second temperature to the first temperature; change position of the curie material, as measured from the flow control structure or the magnet, in response to the change in temperature from the second temperature to the first temperature; and change the velocity of the oxidizing gas or the fuel gas through the valve based on the position of the curie material; and a burner configured to receive an oxidizing gas or a fuel gas from the at least one temperature-sensitive magnetic valve, wherein the oxidizing gas or the fuel gas is at the first temperature; combine and combust the fuel gas with the oxidizing gas to create a jet; and deliver the jet to a target material.

[0008] In another embodiment, a method for controlling of gas velocity can include flowing an oxidizing gas or a fuel gas into a temperature-sensitive magnetic valve at a first temperature, the temperature-sensitive magnetic valve comprising a magnet, a curie material, a blocking device and a flow control structure; transferring heat from the oxidizing gas or the fuel gas to the curie material, wherein the curie material changes from a second temperature to the first temperature; changing the position of the curie material, as measured from the flow control structure or the magnet, in response to the change in temperature from the second temperature to the first temperature; and delivering the oxidizing gas or the fuel gas from the temperature-sensitive magnetic valve to a burner at a second velocity, wherein the second velocity of the oxidizing gas or fuel gas changes dependant on the position of the curie material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings.

[0010] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0011] FIGS. 1A-1C are a schematic view of a burner including a temperature-sensitive magnetic valve described herein.

[0012] FIGS. 2A-2B are representations of the temperature-sensitive magnetic valve according to one embodiment.

[0013] FIGS. 3A-3B are representations of the temperature-sensitive magnetic valve according to another embodiment.

[0014] FIGS. 4A-4B are representations of the temperature-sensitive magnetic valve according to another embodiment.

[0015] FIGS. 5A-5B are representations of the temperature-sensitive magnetic valve according to another embodiment.

[0016] FIGS. 6A-6B are representations of the temperature-sensitive magnetic valve according to another embodiment.

[0017] FIGS. 7A-7B are representations of the temperature-sensitive magnetic valve according to another embodiment.

[0018] FIGS. 8A-8B are representations of the temperature-sensitive magnetic valve according to another embodiment.

[0019] FIG. 9 is a flow diagram of a method for automated control of jet velocity, according to one embodiment.

[0020] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.
Methods, apparatus and systems for controlling gas flow are described herein. Significant energy is lost during the combustion process, specifically through heat that escapes to the atmosphere in flue gases. For example, in an o xo-fuel fired glass furnace where all the fuel is combusted with pure oxygen, and for which the temperature of the flue gas at the furnace exhaust is of the order of 1350°C, typically 30% to 40% of the energy released by the combustion of the fuel is lost in the flue gas.

The methods, apparatus and systems described herein propose heating the combustion reactants to recover a portion of the heat lost in the flue gases, which can then be redelivered to the site of combustion to reduce the reactor energy input required for the overall process. To maintain gas flow in the heated combustion reactants, a temperature-sensitive magnetic valve can be positioned between the gas source and the jet. The temperature-sensitive magnetic valve can control flow of the combustion reactants to the jet, thus allowing for an optimal gas flow rate for both heated and cooled gases, based on the temperature delivered to the valve. The embodiments of the invention disclosed herein are more clearly described with reference to the figures below.

The burner 104 can receive a fuel gas and an oxidizing gas as redirected through the temperature-sensitive magnetic valves 110a and 110b. In this embodiment, the oxidizing gas is delivered through the temperature-sensitive magnetic valve 110a to the first oxidizing gas pipe 112 and the fuel gas is delivered through the temperature-sensitive magnetic valve 110b to the second fuel gas pipe 118. The temperature-sensitive magnetic valves 110a and 110b have a first state and a second state. The temperature-sensitive magnetic valve 110a is depicted in the first state based on receiving a standard temperature oxidizing gas. The standard temperature oxidizing gas does not have significant thermal energy to transfer to the temperature-sensitive magnetic valve 110a, thus the temperature-sensitive magnetic valve 110a remains in the first state. The first state of the temperature-sensitive magnetic valve 110a prevents flow of the oxidizing gas through the second oxidizing gas pipe 114 while allowing flow through the first oxidizing gas pipe 112. The temperature-sensitive magnetic valve 110b is depicted in the second state based on receiving a heated fuel gas. The heated fuel gas heats the temperature-sensitive magnetic valve 110a as it flows in from the fuel gas line 108, thus the temperature-sensitive magnetic valve 110a switches to a second state when the magnet releases the cure material. The second state of the temperature-sensitive magnetic valve 110b prevents flow of the oxidizing gas through the first fuel gas pipe 114 while allowing flow through the second fuel gas pipe 112.

The burner 104 can receive a fuel gas and an oxidizing gas as redirected through the temperature-sensitive magnetic valves 110a and 110b. In this embodiment, the oxidizing gas is delivered through the temperature-sensitive magnetic valve 110a to the first oxidizing gas pipe 112 and the fuel gas is delivered through the temperature-sensitive magnetic valve 110b to the second fuel gas pipe 118. The temperature-sensitive magnetic valves 110a and 110b have a first state and a second state. The temperature-sensitive magnetic valve 110a is depicted in the first state based on receiving a standard temperature oxidizing gas. The standard temperature oxidizing gas does not have significant thermal energy to transfer to the temperature-sensitive magnetic valve 110a, thus the temperature-sensitive magnetic valve 110a remains in the first state. The first state of the temperature-sensitive magnetic valve 110a prevents flow of the oxidizing gas through the second oxidizing gas pipe 114 while allowing flow through the first oxidizing gas pipe 112. The temperature-sensitive magnetic valve 110b is depicted in the second state based on receiving a heated fuel gas. The heated fuel gas heats the temperature-sensitive magnetic valve 110a as it flows in from the fuel gas line 108, thus the temperature-sensitive magnetic valve 110a switches to a second state when the magnet releases the cure material. The second state of the temperature-sensitive magnetic valve 110b prevents flow of the oxidizing gas through the first fuel gas pipe 114 while allowing flow through the second fuel gas pipe 112.

The burner 104 can receive a fuel gas and an oxidizing gas as redirected through the temperature-sensitive magnetic valves 110a and 110b. In this embodiment, the oxidizing gas is delivered through the temperature-sensitive magnetic valve 110a to the first oxidizing gas pipe 112 and the fuel gas is delivered through the temperature-sensitive magnetic valve 110b to the second fuel gas pipe 118. The temperature-sensitive magnetic valves 110a and 110b have a first state and a second state. The temperature-sensitive magnetic valve 110a is depicted in the first state based on receiving a standard temperature oxidizing gas. The standard temperature oxidizing gas does not have significant thermal energy to transfer to the temperature-sensitive magnetic valve 110a, thus the temperature-sensitive magnetic valve 110a remains in the first state. The first state of the temperature-sensitive magnetic valve 110a prevents flow of the oxidizing gas through the second oxidizing gas pipe 114 while allowing flow through the first oxidizing gas pipe 112. The temperature-sensitive magnetic valve 110b is depicted in the second state based on receiving a heated fuel gas. The heated fuel gas heats the temperature-sensitive magnetic valve 110a as it flows in from the fuel gas line 108, thus the temperature-sensitive magnetic valve 110a switches to a second state when the magnet releases the cure material. The second state of the temperature-sensitive magnetic valve 110b prevents flow of the oxidizing gas through the first fuel gas pipe 114 while allowing flow through the second fuel gas pipe 112.

The temperature-sensitive magnetic valves 110a and 110b can be used to control the jet velocity of the jet 102 produced by the burner 104. In this embodiment, a first temperature-sensitive magnetic valve 110a is in fluid connection with the burner 104 through a first oxidizing gas pipe 112 and a second oxidizing gas pipe 114. A second temperature-sensitive magnetic valve 110b is in fluid connection with the burner 104 through a first fuel gas pipe 116 and a second fuel gas pipe 118. The fuel gas and the oxidizing gas can be heated prior to flowing into the temperature-sensitive magnetic valve 110a and 110b. The gases, either the fuel gas or the oxidizing gas, will equilibrate temperature with the temperature-sensitive magnetic valves 110a and 110b, thus increasing the temperature of the valve from a second temperature to the first temperature in the presence of the heated gases. The increase in temperature causes the temperature-sensitive magnetic valves 110a and 110b to shift from a first state to a second state based on reaching a threshold or cure temperature. When the temperature-sensitive magnetic valves 110a and 110b shifts from the first state to the second state, the velocity of either the fuel gas or the oxidizing gas is adjusted appropriate to the gas temperature.
Though shown here as permutations of a dual pipe embodiment, various designs may be employed to control velocity of gases delivered to the burner 104. In one embodiment, the oxidizing gas pipes 112 and 114 and the fuel gas pipes 116 and 118 may be a pipe-in-pipe design where a portion of the pipe is closed off for the standard temperature gas and the portion of the pipe is opened for heated gases. In general, the designs for both the valves and the pipes are only limited by the desire to maintain the same flame shape and size with flowing either heated or standard temperature gases at the same flow rate.

In one or more embodiments, the pipe used for the heated gases can be larger than the pipe used for the standard temperature gases. As the heated gases are delivered at a higher temperature, they are also at a higher pressure. The higher pressure can increase the velocity of the gas which reaches the burner, thus increasing the jet velocity. By effectively increasing the volume based on temperature, the jet velocity can be maintained between heated and standard temperature gases.

The fuel gas and the oxidizing gas can be any known fuel or oxidizer. In one embodiment, the fuel gas is natural gas and the oxidizing gas is oxygen. The fuel gas or the oxidizing gas may be heated. In order that the burners may use the heated oxidizing gas, such as preheated oxygen, with the fuel gas without serious safety problems, the difficulties in handling the preheated oxidizing gas should be considered. Therefore, the parts of the burners used in the apparatus and process of the invention in contact with the preheated oxidizing gas can be made of material compatible with preheated oxygen or other oxidant. These compatible materials can be refractory oxides such as silica, alumina, alumina-zirconia-silica, zirconia and the like. Alternatively, certain metallic alloys that do not combust in preheated oxygen use may be used. Coating metallic materials with ceramic materials on the surface exposed to the preheated oxidizing gas can also be employed for the construction of the burner. Components used in the temperature-sensitive magnetic valves 110a and 110b or the burner 104 may be coated with Alconel.

A flue gas can be thermally connected with the fuel gas, the oxidizing gas or downstream contacts to either container which are prior to the burner 104. When using natural gas as the fuel gas and oxygen (O₂) as the oxidizing gas, temperatures can be maintained below 450°C and 550°C, respectively. As the flue gas can reach temperatures of 1350°C or higher, the heat transfer from the flue gas can be delivered through a secondary device (not shown) to better maintain heat transfer to the fuel gas and the oxidizing gas.

There are various means by which the flow of the gases can be adjusted by the temperature-sensitive magnetic valves 110a and 110b as the temperature changes. In one embodiment, the fuel gas or the oxidizing gas is flowing through a pipe wherein the outlet of the pipe expands as the tube heats up, based on blocking devices connected to magnetic layers formed at the outlet. In another embodiment, the flow of the gas is redirected based on a pipe-in-pipe design, where a portion of the pipe is either blocked or open based on reaching a threshold temperature. This design would allow higher flow through the overall pipe when the threshold temperature is reached, thus allowing for a reduced jet velocity. In another embodiment, the flow of the gases is increased based on an “overlaying-leaf” design which increases in size as temperature increases. One skilled in the art will appreciate that there are numerous permutations of controlling velocity of a gas using a magnetic device as disclosed in the embodiments described herein.

Embodiments described herein relate to relevant portions of a typically burner useable with one or more embodiments of the invention. There can be other components that are not explicitly named which may be included or excluded based on the choice of design and other parameters. The components described herein may differ in shape, size or positioning from those used in practice. Further, the embodiments described herein are for exemplary purposes and should not be read as limiting the scope of the invention described herein, unless explicitly limited herein.

FIGS. 2-8 are representations of a temperature sensitive magnetic valve 200, according to one or more embodiments. The temperature sensitive magnetic valve 200 described herein can be used with the burner 104 described above, a burner which has not been disclosed herein or for another purpose where controlling the flow of a gas based on temperature is important. The disclosed embodiments are individual embodiments and are not intended to be limiting of the scope of the invention.

FIG. 2A depicts a pipe-in-pipe design for the temperature-sensitive magnetic valve 200 according to one embodiment. The temperature-sensitive magnetic valve 200 described herein can be used to maintain velocity of a gas as temperature of the gas changes. The gas described herein can be a fuel gas, an oxidizing gas or another gas. The gas can be preheated as previously described, such as by recovering lost heat from a flue gas as described above. The gas, whether preheated or not, can then be flowed through an aperture 202 of the valve 200. The aperture 202 can act as a connection to a gas source.

The aperture 202 can be formed in the valve chamber 203 of the temperature-sensitive magnetic valve 200. The valve chamber 203 can be fluidly sealed providing for the controlled flow of the gases, which flow through the aperture 202 from the gas container. The valve chamber 203 should be composed of a material which is resistant to at least the expected levels of heat from and the chemistry of the gases delivered. In one embodiment, the valve 200 is composed of ceramics or metals coated with a ceramic. Though the valve chamber 203 is shown as a square structure, this is not intended to be limiting of the possible embodiments. For example, the valve chamber 203 can be square, rectangular, cylindrical, circular, or combinations of those shapes.

The temperature-sensitive magnetic valve 200 can have a flow control structure 204. The flow control structure 204 can be fluidly connected to the aperture 202 to control flow of gas through the temperature-sensitive magnetic valve 200. The flow control structure 204 can include one or more walls which prevent flow in one or more directions, such as through ports 205a and 205b. The walls of the flow control structure 204 can be of any shape based on the shape of the valve chamber 203. The flow control structure 204 can be composed of various materials dependant on the needs of the user, the flow design and the gas being used. In one embodiment, the flow control structure 204 is composed of the same material as the valve chamber 203.

The temperature-sensitive magnetic valve 200 can further comprise a curie material 208. The curie material 208 is a ferromagnetic material which becomes paramagnetic at a specific temperature, known as the curie temperature. The curie temperature of a substance is dependent upon the com-
position of the substance. In one or more embodiments, the curie material 208 is primarily nickel, which has a curie temperature of 358° C. In one embodiment, the curie material 208 is a nickel alloy which contains more than 95% nickel, such as nickel alloy 200. The curie material 208 can be of any composition which has a curie temperature in the desired range. In embodiments of the present invention which use oxygen or natural gas, the desired curie temperature for the curie material 208 can be between 300° C. and 400° C. Further embodiments may include other temperatures, even temperatures below room temperature, for which a low curie temperature is desirable.

[0039] The temperature-sensitive magnetic valve 200 can further comprise a blocking device 206. The blocking device 206 can be in contact with an opening in the flow control structure 204, such as ports 205a and 205b, to prevent flow through the opening. The blocking device 206 can be of the same composition as the flow control structure 204 or valve chamber 203. The blocking device 206 may be made of the same material as the curie material 208 or a different material which is suitable for contact with the temperatures of the gases and the chemistry of the gases, which are flowed therein.

[0040] The temperature-sensitive magnetic valve 200 can further include a magnet 210. The magnet 210 can be positioned in proximity of the curie material 208. The magnet 210 can be of a standard composition for a high temperature magnet, such as an AlNiCo magnet. Though shown here as internal to the flow control structure 204, the magnet 210 can be positioned either internal, external or as part of the flow control structure 204. Further, the magnet 210 can be an electromagnet or a permanent magnet. In embodiments described here, the magnet 210 is shown as a permanent magnet.

[0041] In operation, as shown in FIG. 2A, the magnet 210 applies a magnetic force to, and thus is in connection with, the curie material 208 while the curie material 208 is below the curie temperature. In this embodiment, the curie material 208 is connected with the blocking device 206. Therefore, the magnetic force from the magnet 210 forces the curie material 208 and the blocking device 206 into a first state, which blocks the flow through port 205a. Stated another way, the blocking device 206 blocks port 205a so long as the curie material 208 is below the curie temperature. In this state, the gas delivered through the aperture 202 will flow through the temperature-sensitive magnetic valve 200 through port 205a when the gas is below the curie temperature.

[0042] The heated embodiment is shown in FIG. 2B. When the gas is delivered to the temperature-sensitive magnetic valve 200 at a temperature above the curie temperature, the components in the valve chamber 203, including the curie material 208, will heat up. Once the curie material 208 reaches the curie temperature, the curie material 208 will become paramagnetic and dissociates from the magnet 210. Stated another way, the curie material is not significantly attracted to the magnet 210 above the curie temperature. A second force, such as gravity, a spring (not shown) or other force will then force the blocking device 206 into a second state and block port 205a. Stated another way, the port 205a will be opened in the presence of a gas which is above the curie temperature of the curie material 208. In this embodiment, the blocking device 206 is connected with the curie material 208. However, in further embodiments, the blocking device 206 can be in connection with the magnet 210, can be the magnet 210 or can be the curie material 208.

[0043] Designs herein generally rely on one or more sources of force to actuate between the first state and the second state. When the curie material 208 reaches the curie temperature, the magnet 210, which acts as the first source of force, no longer holds it in place. The second source of force, in the absence of the first source of force, moves the curie material 208 and the blocking device 206 to a second state. Examples of the second source of force can include springs, gravity, pressure (such as dynamic or differential static pressures) or even additional magnets (such as magnets acting on a different section, a different material e.g. carbon steel, or with a different strength).

[0044] FIGS. 3A and 3B depict a portion of the temperature-sensitive magnetic valve 200 according to another embodiment. In the embodiment as shown in FIG. 3A, the magnet 218, the curie material 216, the flow control structure 214 and ports 215 are shown. In this embodiment, the magnet 218 is bound to the flow control structure 214. In the first graphic, the magnet 218 is applying a magnetic force to curie material 216 which shifts the curie material 216 into a first state. The curie material 216 as positioned with the flow control structure 214, creates a plurality of ports 215 for gas to flow through, shown here as twelve (12) open ports 215 of approximately equal size. Though a specific number and similar approximate size of the ports 215 is shown in this embodiment, it will be appreciated by one skilled in the art that the number and size of ports 215 available can be changed. In either state of the temperature-sensitive magnetic valve 200, the port size, number and organization can be altered and adjusted based on the needs or desires of the user. The ports 215 need not be positioned uniformly nor be of the same size.

[0045] As gas flows through the temperature-sensitive magnetic valve 200, the curie material equilibrates to the temperature of the gas, as shown in FIG. 3B. Once the curie material 216 has reached the curie temperature as related to the composition, the magnet 218 can no longer attract the curie material 216 by applying magnetic force. The spring 212, shown here as a leaf spring, then applies a second force to the curie material 216 which lifts the curie material to a second state. As shown here, four (4) ports 215 are aligned, and thus open, between the curie material 216 and the flow control structure 214.

[0046] Without intending to be bound by theory, most simple designs utilize actuation that moves a single component only a few millimeters due to the limited range of the magnetic field. As such, several magnets can be “cascaded” to increase the range of movement. Advantageously, it is believed to be possible to move the actuator a much greater distance using cascaded magnets. A curie material can only travel a certain distance relative to a fixed magnet. Thus by using more than one magnet with at least one intermediate magnet which is not stationary, the overall travel distance can be increased. Further, the valve could be gradually closed using a multiple magnet design. If oriented properly or composed of curie materials with separate curie temperatures, the individual curie materials used for actuation would reach the threshold temperature at different rates. This is believed to create a time delay between when the preheated gas is delivered and when the curie material actually heats up sufficiently. The time delay can be based on convective heat transfer which itself depends on material properties and flow.
dynamics/geometry (which can be altered between components to achieve different delays). One skilled in the art will understand that there are various permutations of the cascading design which can be employed without diverging from the invention described herein. Possible designs include any design which maintains the same flame shape and flame size using both standard temperature gases and heated gases for the jet produced by the burner.

[0047] FIGS. 4A and 4B depict the temperature-sensitive magnetic valve 200 in a tube-spring design according to another embodiment. In one embodiment, the gas can flow into apertures 228a and 228b formed in a valve chamber 224. Positioned inside of the temperature-sensitive magnetic valve 200 is a curie material 222 that is magnetically connected with a magnet 220. In this embodiment, the magnet 220 is stationary. In FIG. 4A, the curie material 222 is below the curie temperature. Thus, the curie material 222 is in contact with the magnet 220. This state redirects flow by preventing flow through one of the apertures 228a as well as preventing flow through one of the ports 225a.

[0048] In FIG. 4B, as the gas heats up based on the preheating process, the gas transfers heat to the curie material 222. The curie material 222, once it heats above the curie temperature, then is separated from the magnet 220 using a second force, shown here as delivered by a spring 226 or other combinations not specifically disclosed herein. Depending on the positioning of the temperature-sensitive magnetic valve 200 in this embodiment, the second force may also be gravity in combination with spring 226. The second force moves the curie material 222 into a second state. The curie material 222 in the second state blocks both the aperture 228b and the port 225b, thus redirecting flow through the previously closed aperture 228a and port 225a. In one or more embodiments, the port 225a can be larger than the port 225b, thus allowing a higher pressure gas, such as a heated gas, to be delivered to the burner (not shown) at the same velocity as a lower pressure gas, such as a standard temperature gas.

[0049] FIGS. 5A and 5B depict the temperature-sensitive magnetic valve 200 in a rotating latch design according to another embodiment. In this embodiment, the temperature-sensitive magnetic valve 200 includes a valve chamber 232, a curie material 234a, a blocking device 234b and a magnet 236. As shown in FIG. 5A, at temperatures below the curie temperature of the curie material 234a is in contact with the magnet 236. The magnet 236 can be a stationary high-temperature magnet, such as an AlNiCo magnet. While in contact with the magnet 236, the curie material 234a and the blocking device 234b can be considered to be in a first state and can prevent flow of a gas through a port 238a.

[0050] The heated state, or second state, is shown in FIG. 5B. When a preheated gas flows through an aperture 230 and into the valve chamber 232, the curie material 234a and the blocking device 234b can begin to heat up. Once the curie material 234a reaches the curie temperature, the curie material 234a is no longer attracted by the magnet 236 and a second force, shown here as gravity, forces the curie material 234a and the blocking device 234b to rotate on pivot 237 into a second state. The curie material 234a and the blocking device 234b in the second state block flow through port 238a and redirects flow through port 238b, as delivered through the aperture 230.

[0051] The curie material 234a and the blocking device 234b can be composed of the same material or separate materials. As only the curie material 234a needs to be composed of a temperature-sensitive substance, the composition of the blocking device 234b beyond pivot 237 can be different from the curie material 234a before pivot 237, as measured from the magnet 236. For example, the composition of blocking device 234b beyond an imaginary line 239 can be a material which is more or less dense than the composition of curie material 234a. The imaginary line 239 need not be positioned at the pivot 237 and the separation between the curie material 234a and the blocking device 234b can be at any point along the combination.

[0052] In the embodiments described above, rotating pieces are generally avoided for simplicity and to cut down on excess friction. However, one or more embodiments can employ rotating components or be adapted to use rotating components, as shown in the exemplary embodiment of FIGS. 5A and 5B. As the components of the temperature-sensitive magnetic valve 200 are designed to function largely without human intervention and at high temperatures, friction between components should be considered. Bearings or high temperature lubricants can be employed in one or more embodiments to reduce friction related issues.

[0053] FIGS. 6A and 6B depict the temperature-sensitive magnetic valve 200 in a rotating leaf/spring design according to another embodiment. In this embodiment, the temperature-sensitive magnetic valve 200 includes a valve chamber (not shown), a curie material 240, a blocking device 242, a flow control structure 243 and a magnet 244. As described previously, at temperatures below the curie temperature, the curie material 240 is in contact with the magnet 244. The magnet 244 is a stationary high-temperature magnet, such as an AlNiCo magnet. While in contact with the magnet 244, as shown in FIG. 6A, the curie material 240 and the blocking device 242 are considered to be in a first state and prevent flow of a gas through one or more ports 246. In this embodiment, two ports 246a and 246b are open in the first state with a total of four ports 246a, 246b, 246c, and 246d available, when considering both open and closed ports in the flow control structure 243. However, more or fewer ports may be used without diverging from the invention described herein.

[0054] When a preheated gas flows into the valve chamber, the curie material 240 can begin to heat up, described with reference to FIG. 6B. Once the curie material 240 reaches the curie temperature, the curie material 240 can be separated from the magnet 244. The blocking device 242 is then forced with the connected curie material 240 into a second state by a second force, shown here as a spring 247. The curie material 240 and the blocking device 242 rotate on a pivot 249 until the curie material 240 reaches a barrier 248 which prevents further rotation. The blocking device 242 in the second state blocks flow through the ports 246a and 246b and redirects flow of the gas through ports 246c and 246d.

[0055] FIGS. 7A and 7B depict the temperature-sensitive magnetic valve 200 with a lifting blocking device design according to another embodiment. The temperature-sensitive magnetic valve 200 includes a valve chamber 250, magnets 252a and 252b, curie materials 254a and 254b, a blocking device 256 and flow control structure 257. The curie materials 254a and 254b can be in contact with the magnets 252a and 252b under standard temperatures. A gas can be delivered through aperture 251 and into the valve chamber 250, shown in FIG. 7A. As the curie materials 254a and 254b are attached to the blocking device 256 and in the first state, the gas delivered through the aperture 251 can be directed through port 258a formed by the flow control structure 257. In this
embodiment, the blocking device 256 is positioned between the magnets 252a and 252b. The magnets 252a and 252b can serve as a guide for the temperature-sensitive actuation of the curie materials 254a and 254b and the blocking device 256.

[0056] When a preheated gas flows into the valve chamber 250, shown in FIG. 7B, the curie materials 254a and 254b can begin to heat up. Once the curie materials 254a and 254b reach the curie temperature, the curie materials 254a and 254b are separated from the magnets 252a and 252b. The blocking device 256 is then positioned with the connected curie materials 254a and 254b into a second state by a second force, shown here as springs 259. The curie materials 254a and 254b and the blocking device 256 slide into position until the curie materials 254a and 254b and the blocking device 256 reach a wall of the valve chamber 250 which prevents further movement. The blocking device 256 in the second state blocks flow through the ports 246a and 246b and redirects flow through port 258b.

[0057] As stated with reference to other embodiments, curie materials 254a and 254b may be of the same composition as one another, the same composition as the blocking device 256 or of different compositions based on the needs of the user. The imaginary lines 255a and 255b are positioned for exemplary purposes and the imaginary lines 255a and 255b between the curie materials 254a and 254b and the blocking device 256 may be more or fewer than two, may be in different positions than shown or may not exist, in one or more embodiments.

[0058] FIGS. 8A and 8B depict the temperature-sensitive magnetic valve 200 with a pipe-in-pipe design according to another embodiment. In this embodiment, the temperature-sensitive magnetic valve 200 can have a valve chamber 260, an aperture 261, a flow control structure 262a, a blocking device 263, a magnet 264, a protective cover 265, a curie material 266, a pivot 267 and ports 268a and 268b. The curie material 266, shown as a horseshoe shape, can be connected to the blocking device 263, shown as a half orb or ball design with reference to FIG. 8A. At temperatures below the curie temperature, the curie material 266 is in contact with the protective cover 265. The magnet 264 is positioned in connection with the protective cover 265 and delivers a magnetic force through the protective cover 265 to position the curie material 266 and the blocking device 263 in the first state. The blocking device 263 prevents flow through the port 268b while not affecting port 268a.

[0059] When a preheated gas flows into the valve chamber 260 described with reference to FIG. 8B, the curie material 266 can begin to heat up. Once the curie material 266 reaches the curie temperature, the curie material 266 is separated from the protective cover 265 and the magnet 264. The blocking device 263 is then forced with the connected curie material 266 into a second state by a second force, such as through gravity and pressure. The curie material 266 and the blocking device 263 rotate on the pivot 267 until the curie material 266 is position to block the port 268a. As shown here, curie material 266 is partially resting on a portion of the flow control structure 262a. The blocking device 263 in the second state allows flow through the port 268a.

[0060] The protective cover 265 is positioned to allow the magnetic field of the magnet 264 to be delivered to the curie material 266, while protecting the magnet 264 from the gas delivered to the valve chamber 261. The protective cover 265 can be formed of a ferromagnetic material which does not degrade in the operative environment, such as nickel or Inconel. Further, the protective cover may be a magnet itself, such as an AlNiCo magnet. The protective cover can allow stronger magnets which are not optimal for the conditions of the tube, for example magnets which are sensitive to temperatures or gases, to be used in the temperature-sensitive magnetic valve 200.

[0061] Insulation may also be used to isolate the magnet 264, in one or more embodiments described above, from the high temperatures or certain chemistries. For example, a very thin vacuum insulated housing may protect the magnet 264 from excess heat. Passive or active convective/conductive cooling may be utilized to keep the magnet cool, relying on other cooler process flows in the vicinity of the magnet 264. Of note, most magnets of useful size only have a field that will attract objects within a few millimeters. Thus, the amount and type of insulation used should take account of the limited range for these magnets. The insulation used to isolate the magnet 264 can be less than 10 mm.

[0062] Most designs are depicted with one magnet for simplicity purposes only. Other designs may include one or more magnets, in one or more positioning and orientations based on the needs of the user and the design of the valve, without diverging from the scope of the invention described herein. In one embodiment, additional magnets 264 could be employed for increasing the overall field strength, such as magnets oriented to create a field in the same direction, whether in series or in parallel. In another embodiment, additional magnets can be employed to achieve a more complex motion of the actuated pieces, such as magnets aligned perpendicularly to allow for a two-step series of motion below the curie temperature. In another embodiment, additional magnets can be “staged” in such a way that they actuate at slightly different times due to different heating rates. In another embodiment, additional magnets and additional curie materials can be staged so as to increase the distance travelled.

[0063] FIG. 9 is a flow diagram of a method 300 for automated control of jet velocity, according to one embodiment. In embodiments described herein, an oxidizing gas or a fuel gas can be heated prior to flowing to a burner. Positioned between the gas container and the burner is a temperature-sensitive magnetic valve. Initially, the temperature-sensitive magnetic valve, in a first state, allows the gas to flow to a velocity which is standard for a gas delivered at a standard temperature, such as room temperature. As the preheated gas flows through the valve, the curie material heats up. Once the curie material heats to a temperature which is at or above the curie temperature, the curie material will release from the magnet. A second force will then shift the curie material into a second state to redirect the gas flow. This shift in the gas flow maintains a constant velocity of the gas at an equal flow rate between the heated gas and the standard temperature gas.

[0064] The method 300 begins at step 302 by flowing an oxidizing gas or a fuel gas into a temperature-sensitive magnetic valve at a first temperature and a first velocity, the temperature-sensitive magnetic valve comprising a magnetic strip, a blocking device and a flow control structure. In one or more embodiment, the fuel gas can be heated by using a flue gas. As described above, thermal energy is wasted from the furnace in the form of heat in the flue gas. One mechanism to recover this lost heat, is to heat the oxidizing gas and/or the fuel gas prior to delivering to the burner. In one or more embodiments, either the oxidizing gas or the fuel gas is heated, while the other gas is maintained at standard temperature. After one or more of the gases are heated, the gases are
then flowed to the temperature-sensitive magnetic valve. In standard embodiments, the gas will enter at one velocity and exit at a predetermined velocity based on a change in port size between the first state and the second state. The velocity of entry and the velocity of exit may be equal based on the size of the port and the initial flow velocity from the gas container. Preheated gases will enter the temperature-sensitive magnetic valve at a faster velocity than comparatively colder gas, given other conditions such as flow rate remain constant between the preheated gas and cold gas.

At step 304, the oxidizing gas and the fuel gas can transfer heat with the magnetic strip in the temperature-sensitive magnetic valve. As the gases flow into the temperature-sensitive magnetic valve, the components which are in thermal contact with the gas equilibrate based on the starting temperature of the gas and the starting temperature of the components of the temperature-sensitive magnetic valve. The temperature-sensitive magnetic valve is expected to start at a second temperature, which can be an ambient temperature, such as room temperature. However, this can be altered by preheating the valve to assure quick transition from one state to another. The oxidizing gas and the fuel gas will be delivered at a first temperature which is the temperature each was heated to in the previous step. When the fuel gas is natural gas, the first temperature should be less than or equal to about 450° C. When the oxidizing gas is oxygen (O₂), the first temperature should be less than or equal to about 550° C. As the gases are delivered to the temperature-sensitive magnetic valve, the components of the temperature-sensitive magnetic valve including the curie material will change from the second temperature to the first temperature.

At step 306, the position of the curie material can change as measured from the flow control structure or the magnet, in response to the change in temperature from the second temperature to the first temperature. As the curie material changes from the second temperature to the first temperature, the curie material can lose magnetic properties and no longer be attracted to the magnet. At this point a second force, such as a spring or gravity can overcome the magnetic attraction between the magnet and the curie material thus shifting the temperature sensitive magnetic valve from a first state to a second state. Based on the change in the curie material, the size of the port or the port itself for delivery of the gas through the temperature-sensitive magnetic valve to the burner can change. The goal of either the size change or the port change is to maintain the velocity of the gas between the standard temperature gas and the heated gas as they exit the temperature-sensitive magnetic valve. Using the magnetic strip, the gas can be flowed into a second port or into a larger port to maintain the final velocity of the gas.

At step 308, the oxidizing gas or the fuel gas can be delivered from the temperature-sensitive magnetic valve to the burner at a second velocity. In this embodiment, the temperature of the gas affects the position of the curie material in the temperature-sensitive magnetic valve. By changing the curie material position in the temperature-sensitive magnetic valve, the port is changed or the port size is increased by one or more of the above described means, which increases the volume and changes the velocity of the gas. The change in velocity of the gas creates a second velocity which is approximately equal between the standard temperature gas and the heated gas. In one or more embodiments, the temperature-sensitive magnetic valve shifts based on the curie temperature between a first state and a second state, with the second state providing a larger port for the preheated gas to flow through after changing from the standard temperature gas to the preheated gas. It is important to note that, although the second velocity can be different from the first velocity, this is not required.

The transfer of heat to the curie material does not need to be a direct transfer. In one or more embodiments, an insulated heat pipe could sample and "transmit" heat from the area where process flow temperature is seen, to the curie material positioned proximate, but thermally isolated from, the gas, such that the curie material is not directly subject to the heat or chemistry of the gas. The curie material loses magnetic attraction based on the temperature change. A mechanical connection can then transmit the action of the curie material back to the blocking device and the flow control structure to redirect the process flow.

**CONCLUSION**

Embodiments described herein relate to automated control of the jet velocity of a gas based on temperature. Recovery of lost thermal energy is becoming more important as fuel costs rise. One important source of lost thermal energy in standard furnaces is through flue gas. One means to recapture this lost thermal energy is through heating of the combustion gases, one or more of the fuel gas or the oxidizing gas, prior to combustion. As gases heat up, they expand which changes the pressure and the subsequent velocity of the gas flow to the burner. This change can affect the flame size and shape as delivered through the burner to the furnace.

Embodiments described herein teach methods and systems for controlling jet velocity using a temperature-sensitive magnetic valve. By redirecting the flow based on a threshold temperature, flame size and shape can be maintained using high temperature gases and standard temperature gases without the inherent dangers of manual manipulation of a valve.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A system for controlling jet velocity of a gas, comprising:
   - a source of oxidizing gas;
   - a source of fuel gas;
   - at least one temperature-sensitive magnetic valve in connection with one of the source of oxidizing gas or the source of fuel gas, the valve comprising a curie material, a magnet, a blocking device and a flow control structure and configured to:
     - receive an oxidizing gas or a fuel gas, wherein the oxidizing gas or the fuel gas is at a first temperature;
     - change the temperature of at least the curie material from a second temperature to the first temperature;
     - change position of the curie material, as measured from the flow control structure or the magnet, in response to the change in temperature from the second temperature to the first temperature;
     - change the velocity of the oxidizing gas or the fuel gas through the valve based on the position of the curie material; and
a burner configured to:
receive an oxidizing gas or a fuel gas from the at least one temperature-sensitive magnetic valve, wherein the oxidizing gas or the fuel gas is at the first temperature;
combine and combust the fuel gas with the oxidizing gas to create a jet; and
direct the jet to a target material.
2. The system of claim 1, wherein the temperature sensitive magnetic valve is configured to maintain the velocity of the oxidizing gas or the fuel gas delivered to the burner over the temperature range determined by the first temperature and the second temperature.
3. The system of claim 1, wherein the temperature-sensitive magnetic structure further comprises the blocking device configured to:
change position with the curie material; and
change the velocity of the oxidizing gas and/or the fuel gas based on the position of the curie material in conjunction with the flow control structure.
4. The system of claim 1, wherein the curie material is configured to act as the blocking device.
5. The system of claim 1, wherein the curie material is configured to be in magnetic connection with the magnet at a temperature between the first temperature and the second temperature.
6. The system of claim 1, wherein the temperature-sensitive magnetic valve is configured to receive the fuel gas, the fuel gas is natural gas and the first temperature is less than or equal to 450 degrees Celsius.
7. The system of claim 1, wherein the temperature-sensitive magnetic valve is configured to receive the oxidizing gas, the oxidizing gas is oxygen (O₂) and the first temperature is less than or equal to 550 degrees Celsius.
8. The system of claim 1, wherein the source of oxidizing gas or the source of fuel gas is configured to receive and transmit heat from a flue gas.
9. The system of claim 1, wherein the burner comprises a first oxidizing gas pipe and a first fuel gas pipe.
10. The system of claim 9, wherein the temperature-sensitive magnetic valve is configured to change the velocity of the oxidizing gas or the fuel gas through the valve by redirecting at least a portion of the oxidizing gas or the fuel gas through one or more second oxidizing gas pipes or one or more second fuel gas pipes.
11. The system of claim 9, wherein the temperature-sensitive magnetic valve is configured to change the velocity of the oxidizing gas or the fuel gas through the valve by increasing the volume of the first oxidizing gas pipe or the first fuel gas pipe.
12. The system of claim 1, wherein the curie material comprises nickel.
13. The system of claim 1, wherein the magnet is an aluminum-nickel-cobalt (AlNiCo) magnet.
14. The system of claim 1, further comprising a protective cover configured to:
isolate the curie material or the magnet from the oxidizing gas or the fuel gas; and
transmit heat to at least the curie material.
15. The system of claim 1, wherein the temperature-sensitive magnetic valve is configured to change position of the curie material using a second force.
16. The system of claim 15, wherein the second force comprises a spring.
17. A method for controlling of gas velocity comprising:
flowing an oxidizing gas or a fuel gas into a temperature-sensitive magnetic valve at a first temperature, the temperature-sensitive magnetic valve comprising a magnet, a curie material, a blocking device and a flow control structure;
transferring heat from the oxidizing gas or the fuel gas to the curie material, wherein the curie material changes from a second temperature to the first temperature;
changing the position of the curie material, as measured from the flow control structure or the magnet, in response to the change in temperature from the second temperature to the first temperature; and
delivering the oxidizing gas or the fuel gas from the temperature-sensitive magnetic valve to a burner at a second velocity, wherein the second velocity of the oxidizing gas or fuel gas changes dependant on the position of the curie material.
18. The method of claim 17, wherein the oxidizing gas or the fuel gas are heated to a temperature below a critical temperature of the gas.
19. The method of claim 17, wherein the first temperature is a temperature which is less than a critical temperature of the oxidizing gas or the fuel gas.
20. The method of claim 17, wherein the oxidizing gas or the fuel gas indirectly exchanges heat with the magnetic strip.
21. The method of claim 17, wherein the oxidizing gas and/or the fuel gas is preheated using a flue gas.
22. The method of claim 17, wherein the second velocity is less than the first velocity.
23. The method of claim 17, wherein the oxidizing gas or the fuel gas is heated to the first temperature by a flue gas prior to flowing into the temperature-sensitive magnetic valve.
24. The method of claim 17, wherein the oxidizing gas or the fuel gas is delivered from the temperature-sensitive magnetic valve to the burner through one or more first pipes.
25. The method of claim 24, wherein the oxidizing gas or the fuel gas is delivered at the second velocity by changing the available volume of the one or more first pipes.
26. The method of claim 24, wherein the oxidizing gas or the fuel gas is delivered at the second velocity by using the one or more first pipes in conjunction with one or more second pipes.
27. The method of claim 17, wherein the fuel gas is natural gas and the first temperature is less than or equal to 450 degrees Celsius.
28. The method of claim 15, wherein the oxidizing gas is oxygen (O₂) and the first temperature is less than or equal to 550 degrees Celsius.

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