



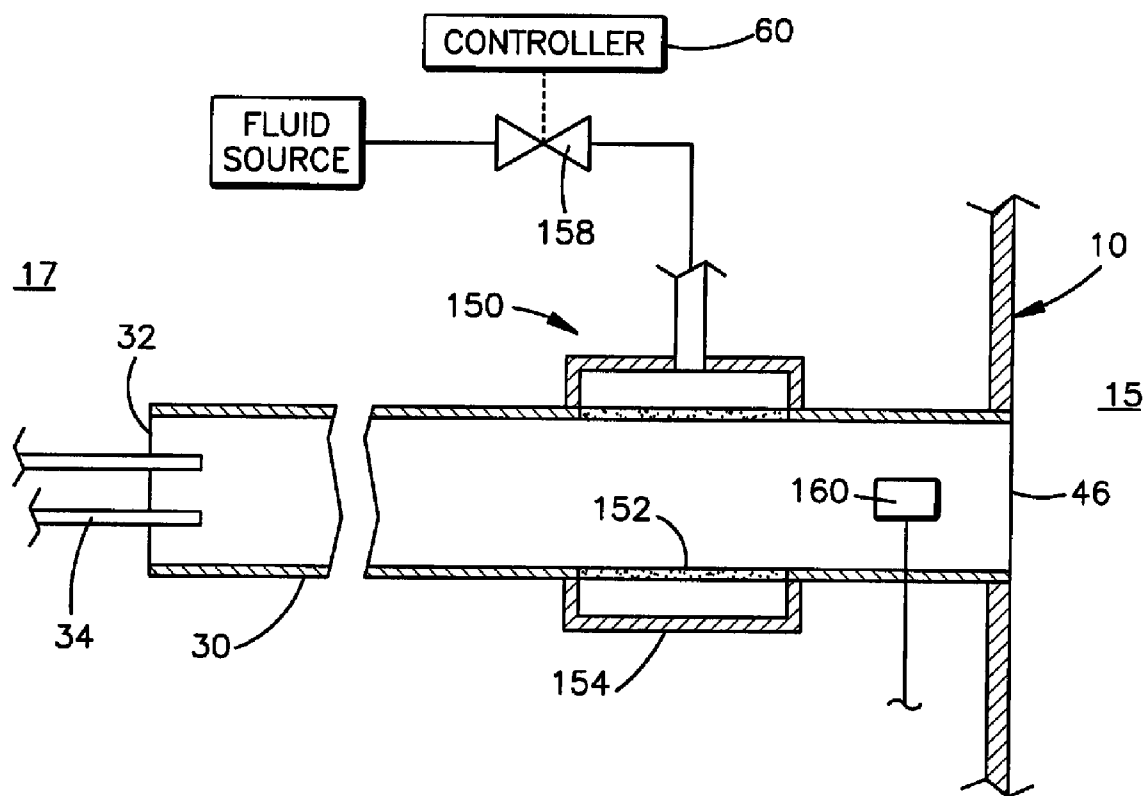
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(19) **United States**(12) **Patent Application Publication**
Hannum et al.(10) **Pub. No.: US 2012/0135360 A1**(43) **Pub. Date: May 31, 2012**(54) **PREMIX FLASHBACK CONTROL****Publication Classification**(75) Inventors: **Mark C. Hannum**, Hudson, OH (US); **John J. Nowakowski**, Valley View, OH (US); **Thomas F. Robertson**, Medina Township, OH (US)(51) **Int. Cl.**
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F23D 14/02 (2006.01)(73) Assignee: **Fives North American Combustion, Inc.**, Cleveland, OH (US)(52) **U.S. Cl. 431/350; 431/181; 239/132.3; 431/22**(21) Appl. No.: **13/307,570**(22) Filed: **Nov. 30, 2011****Related U.S. Application Data**

(60) Provisional application No. 61/418,096, filed on Nov. 30, 2010.

(57) **ABSTRACT**

An apparatus includes a furnace structure defining a combustion zone, and a tube that discharges fuel-oxidant premix into the combustion zone through an outlet from the tube. A reactant supply system provides the tube with unmixed fuel and oxidant for forming the premix. A flashback control means inhibits or extinguishes flashback in the tube.



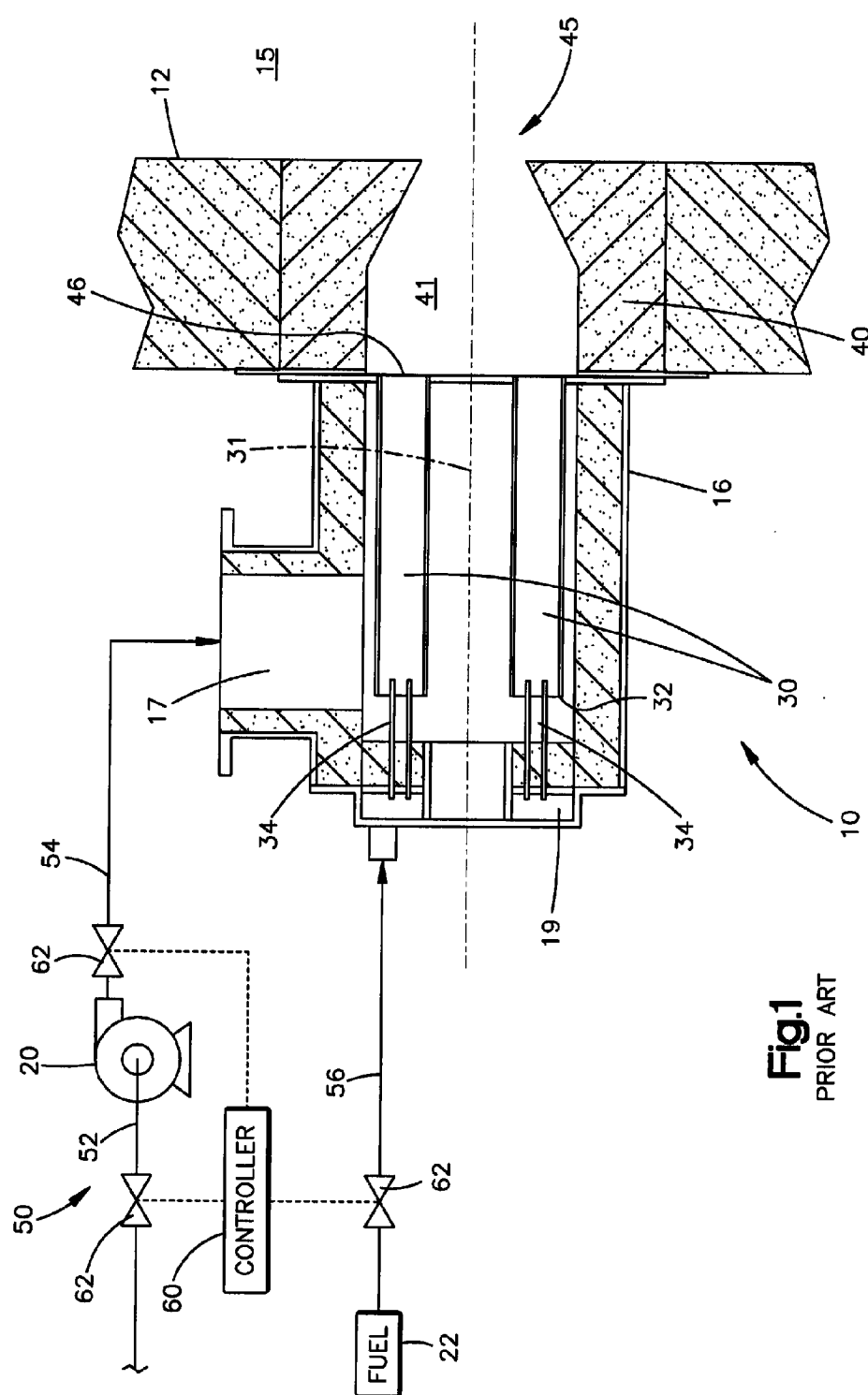
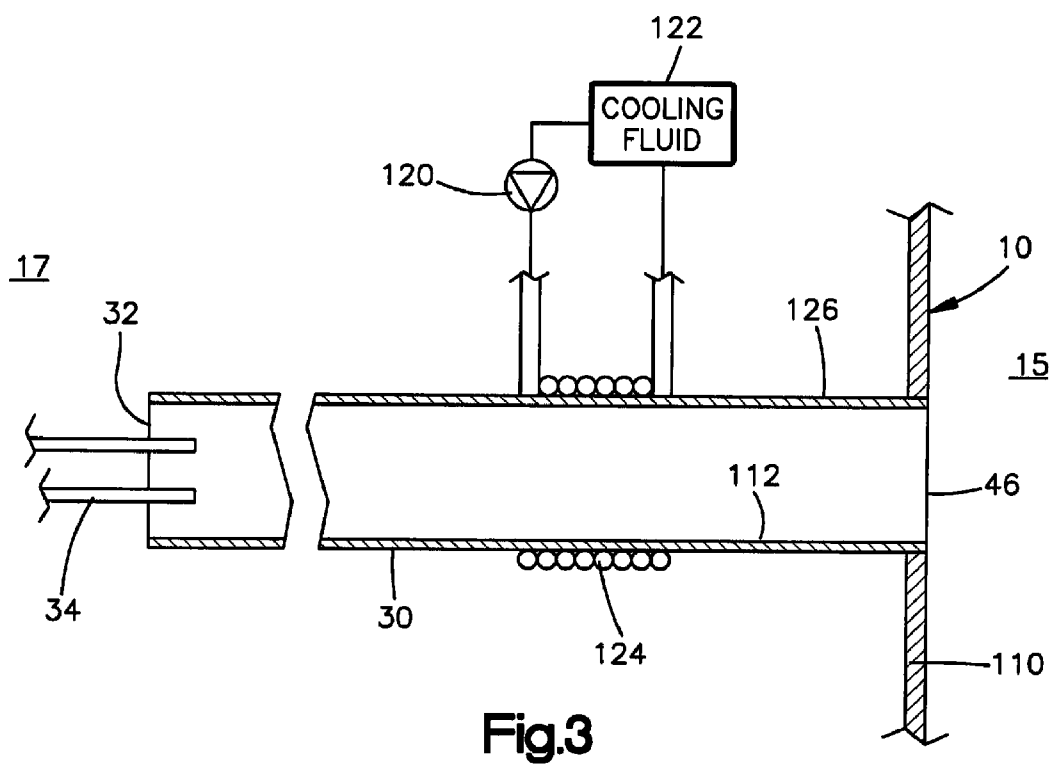
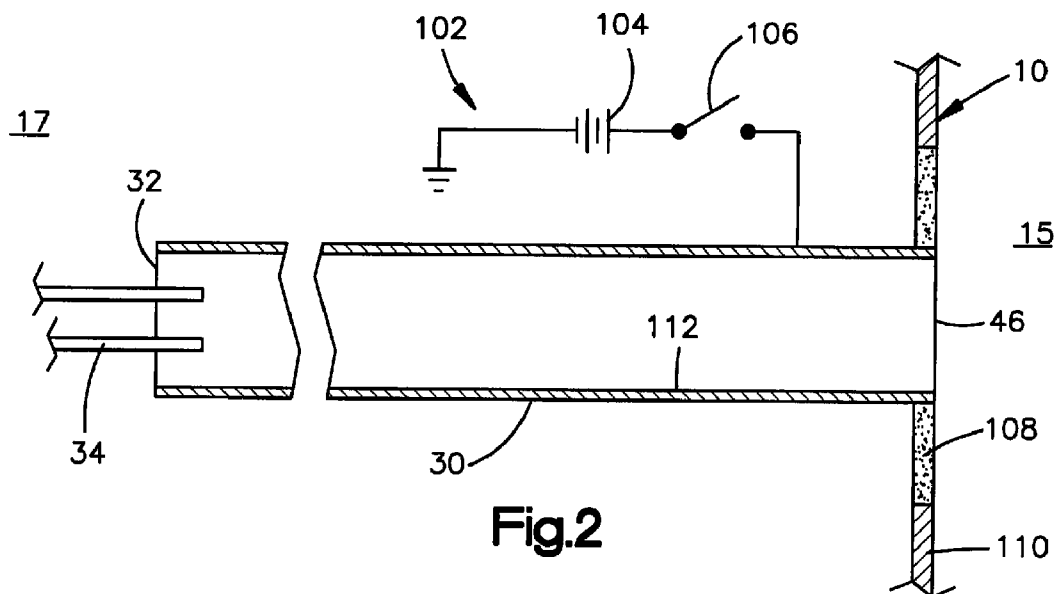
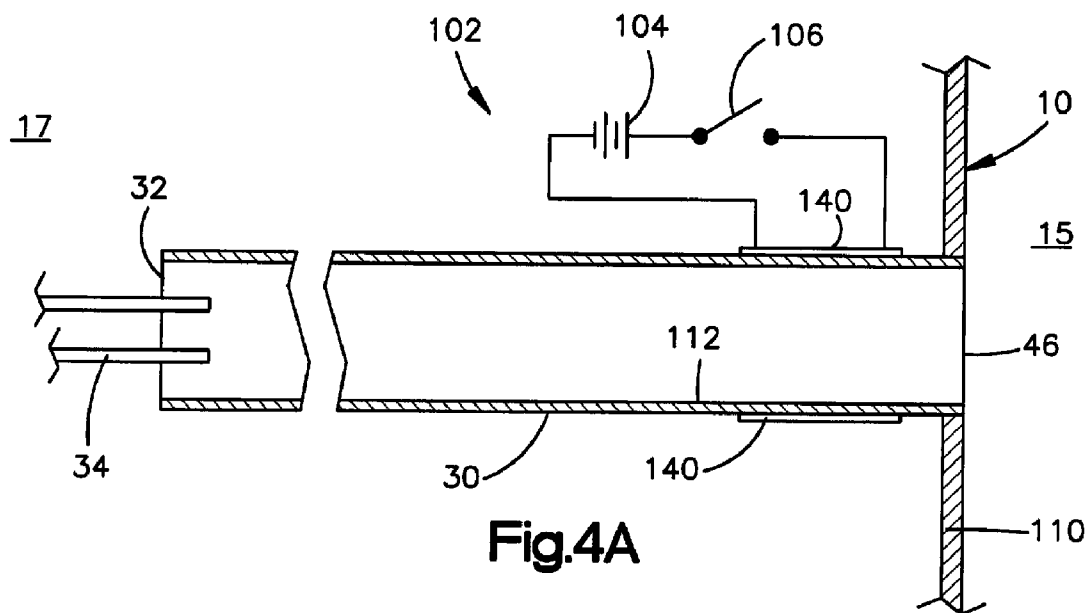
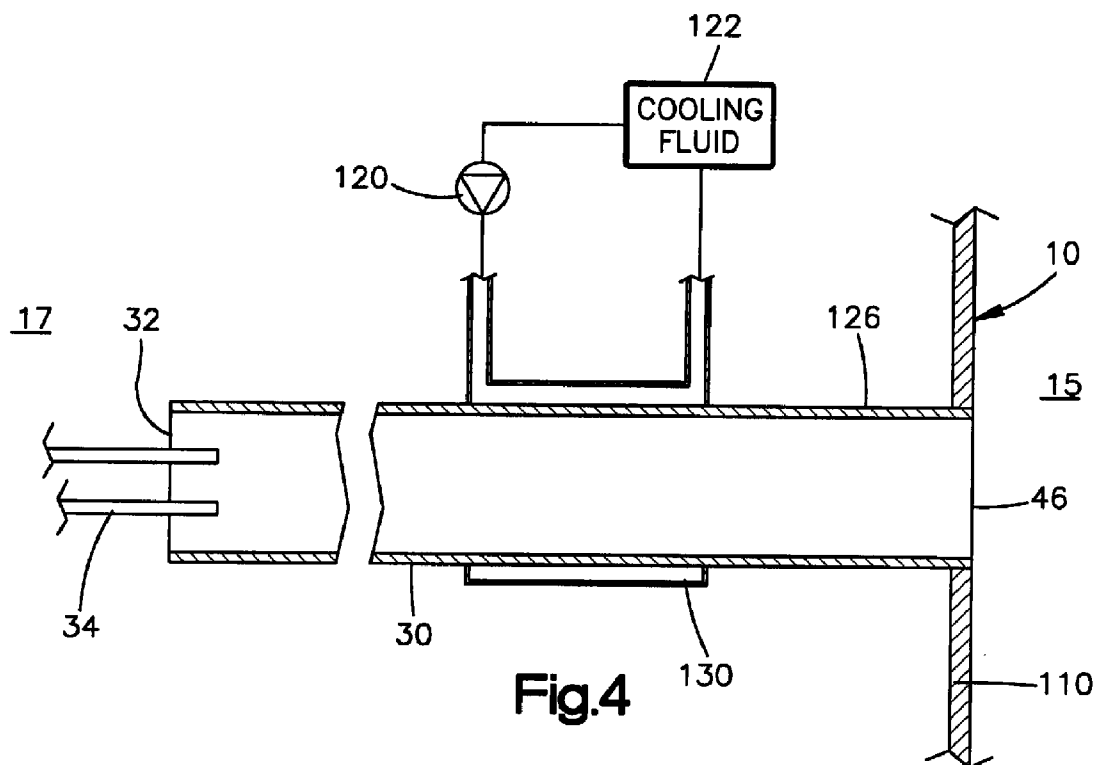


Fig.1
PRIOR ART





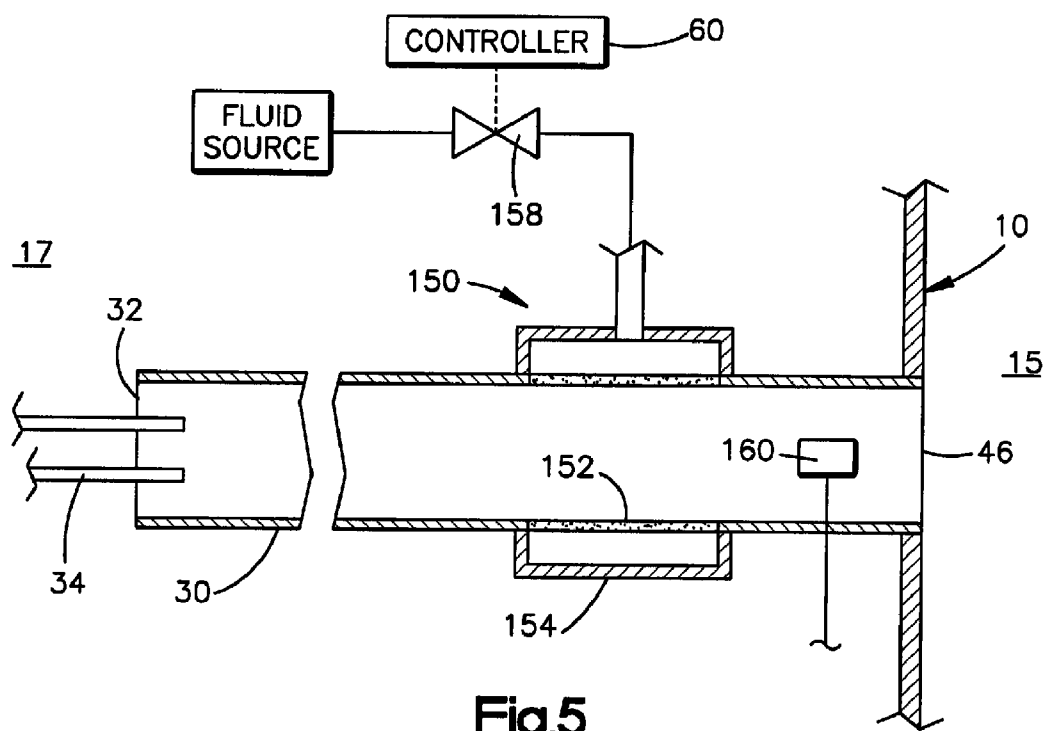


Fig.5

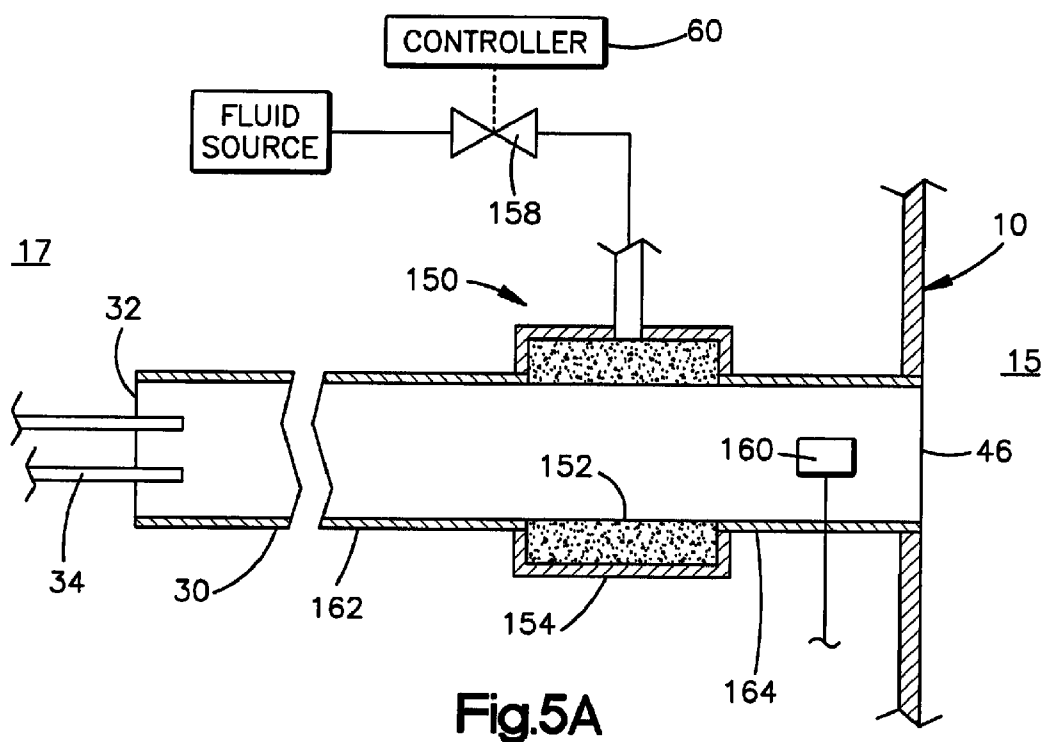


Fig.5A

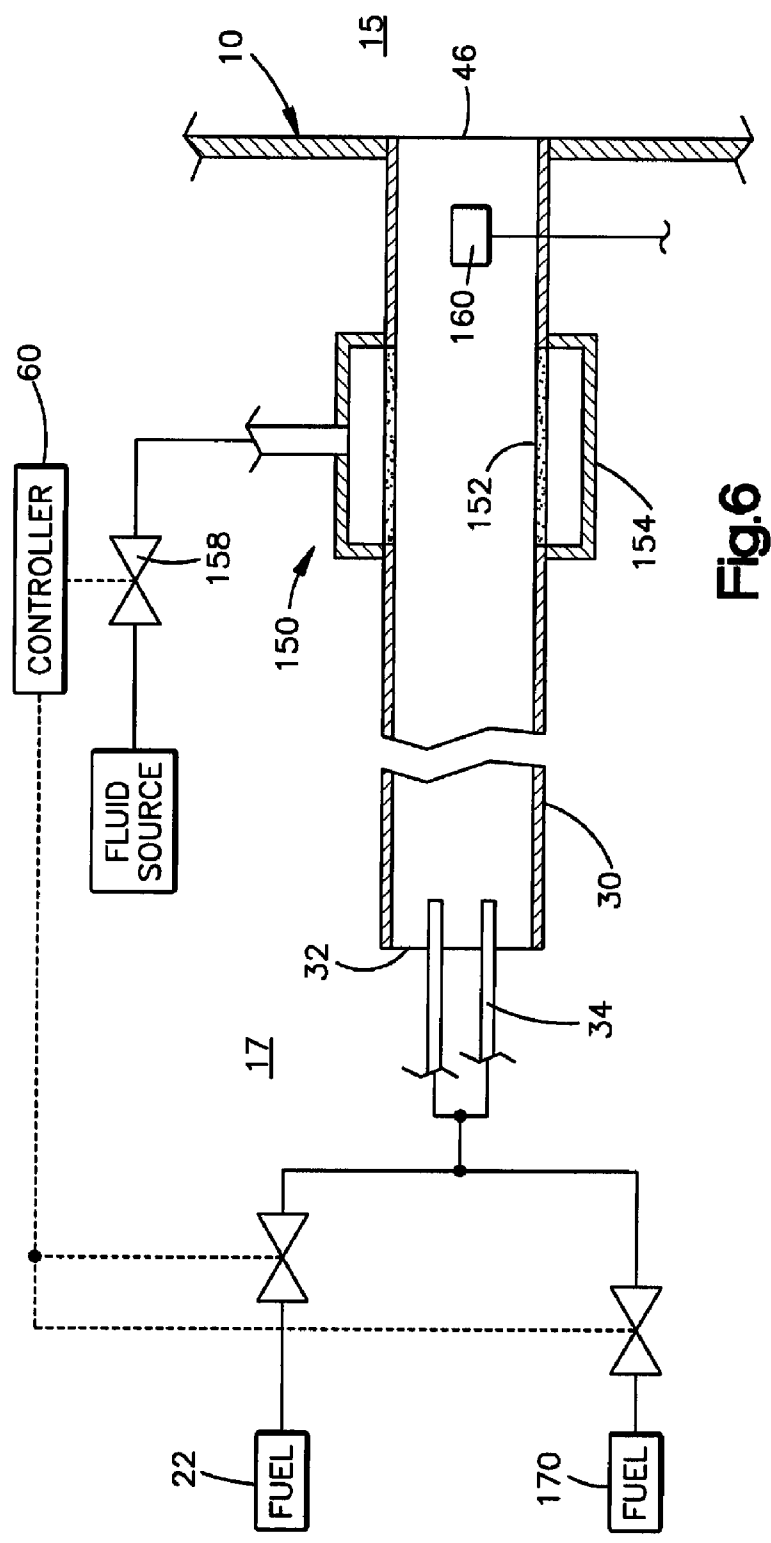
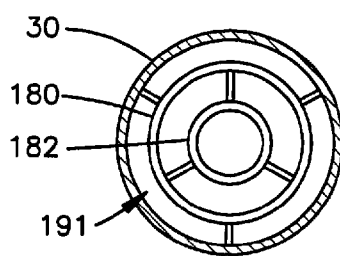
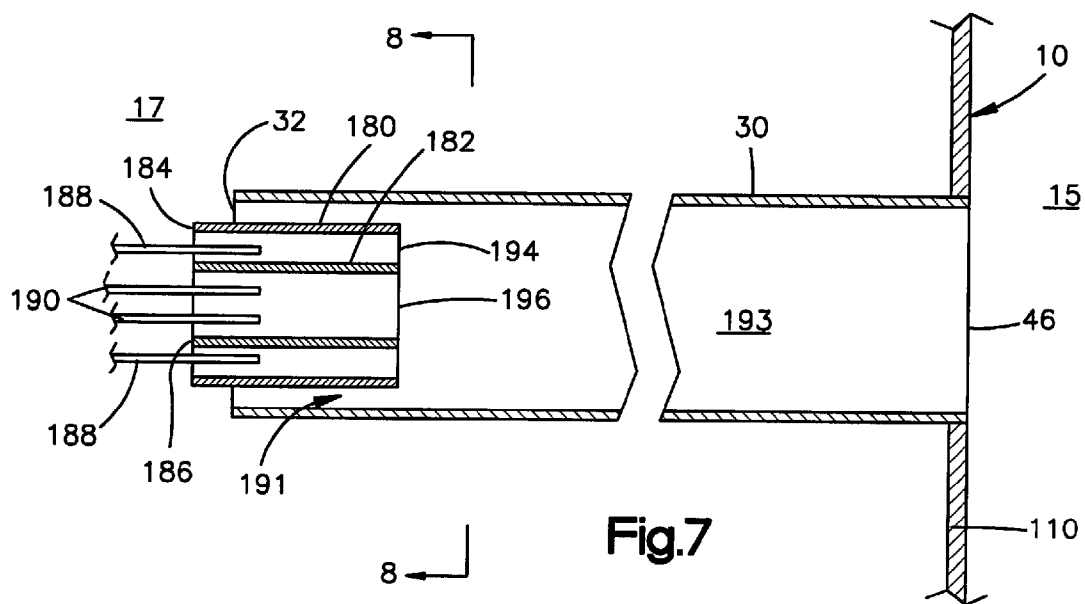
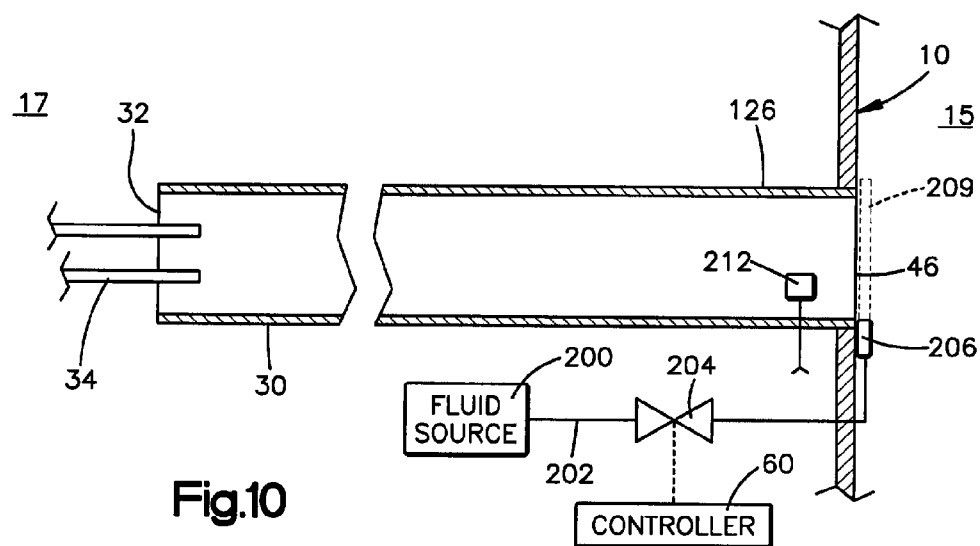
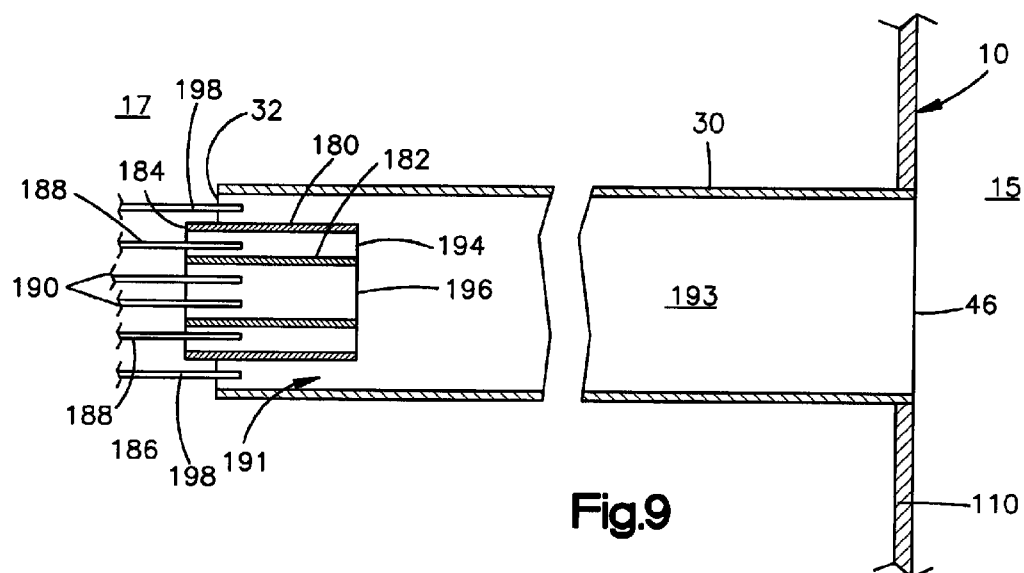


Fig.6





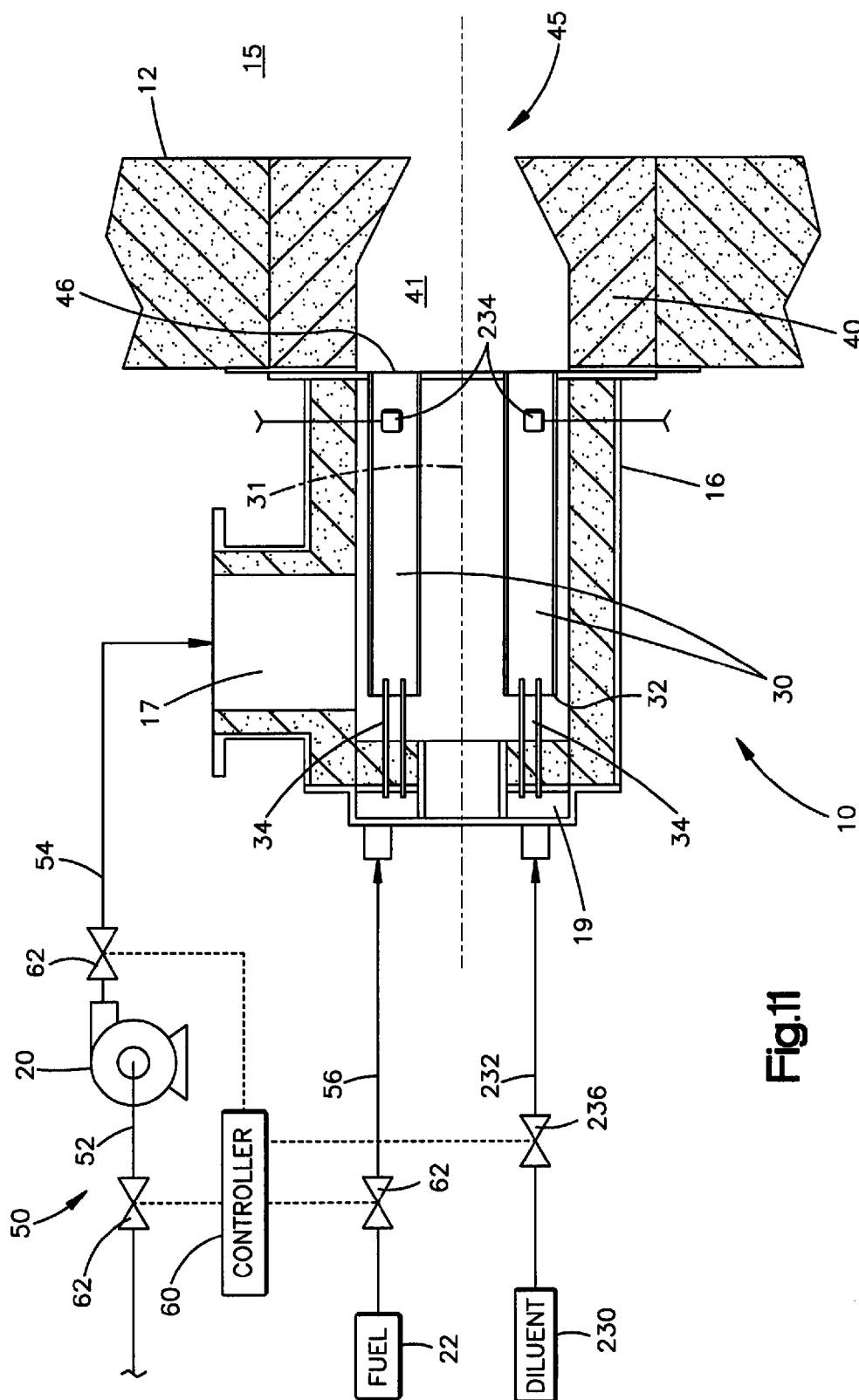


Fig.11

PREMIX FLASHBACK CONTROL

RELATED APPLICATIONS

[0001] This application claims the priority benefit of provisional U.S. Patent Application No. 61/418,096, filed Nov. 30, 2010, which is incorporated by reference.

TECHNICAL FIELD

[0002] This technology relates to a furnace with a premix burner in which flashback may occur.

BACKGROUND

[0003] As shown in FIG. 1, a prior art furnace includes a premix burner 10 mounted on a furnace wall 12 in a position to fire into an adjacent process chamber 15. The burner 10 has a rear portion 16 defining an oxidant plenum 17 and a fuel plenum 19. The oxidant plenum 17 receives a stream of combustion air from a blower system 20. The fuel plenum 19 receives a stream of fuel from a fuel source 22.

[0004] Mixer tubes 30 are located within the oxidant plenum 17. The mixer tubes 30 are preferably arranged in a circular array centered on a longitudinal axis 31. Each mixer tube 30 has an open inner end 32 that receives a stream of combustion air directly from within the oxidant plenum 17. Each mixer tube 30 also receives streams of fuel from fuel injector conduits 34 that extend from the fuel plenum 19 into the open inner end 32. These streams of fuel and combustion air flow through the mixer tubes 30 to form a combustible mixture known as premix.

[0005] An outer portion 40 of the burner 10 defines a stabilized combustion chamber 41 with an outlet port 45. The premix is ignited in the combustion chamber 41 upon emerging from open outer ends 46 of the mixer tubes 30. Ignition is initially accomplished by use of an igniter before the combustion chamber 41 reaches the auto-ignition temperature of the premix. Combustion continues as the premix is injected from the outlet port 45 into the furnace process chamber 15.

[0006] As further shown in FIG. 1, the burner 10 is coupled with a reactant supply system 50. This includes the blower system 20 and a duct 52 through which the blower system 20 draws air from the ambient atmosphere. Another duct 54 extends from the blower system 20 to the oxidant plenum 17 at the burner 10. A fuel line 56 communicates the fuel source 22 with the fuel plenum 19 at the burner 10. Other parts of the reactant supply system 50 include a controller 60 and valves 62 that are operated by the controller 60.

[0007] The controller 60 has hardware and/or software that is configured for operation of the burner 10, and may comprise any suitable programmable logic controller or other control device, or combination of control devices, that is programmed or otherwise configured to perform as described and claimed. As the controller 60 carries out those instructions, it operates the valves 62 to initiate, regulate, and terminate flows of reactant streams that provide the premix at the outlets 46 of the mixer tubes 30. The controller 60 is preferably configured to operate the valves 62 such that the fuel and combustion air are delivered to the burner 10 in amounts that form premix having a lean fuel-to-oxidant ratio. The fuel-lean composition of the premix helps to avoid the production of NO_x .

[0008] Flashback can occur in a premix of fuel and oxidant when the flame speed exceeds the velocity of the reactants. Specifically, flashback can occur in a boundary layer of pre-

mix at the inner wall surface of a mixer tube 30. It is believed that a flame propagates/ashes back upstream through the premix in the lower velocity portions of the boundary layer that are spaced away from the wall at a distance greater than the quenching distance for the given fuel/oxidant mixture. The quenching distance is the distance from a wall where combustion is prevented by heat loss and chemical radical absorption by the wall. Accordingly, the likelihood of flashback is increased when the thickness of the boundary layer is greater than the quenching distance.

SUMMARY

[0009] An apparatus includes a furnace structure defining a combustion zone, and a tube that discharges fuel-oxidant premix into the combustion zone through an outlet from the tube. A reactant supply system provides the tube with unmixed fuel and oxidant for forming the premix. A flashback control means inhibits or extinguishes flashback in the tube. In one embodiment, the flashback control means includes means for electrically charging the tube. In another embodiment, the flashback control means includes means for cooling the tube.

[0010] In other embodiments, the flashback control means responds to flashback in the tube by changing the flame speed of the fuel provided to the tube to form premix. Some embodiments include one or more inner tubes within an outer tube. Those embodiments provide stratified flammability that increases radially inward of the outer tube.

[0011] In another embodiment, the flashback control means injects non-flammable fluid across the tube to form a curtain that blocks flashback of the premix. An additional embodiment controls flashback by adding diluent fluid to the premix fuel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a partial view of a prior art furnace equipped with a premix burner and a reactant supply and control system.

[0013] Each of FIGS. 2-11 is a partial view of a modified version of the furnace of FIG. 1, showing a respective embodiment of means for controlling premix flashback.

DETAILED DESCRIPTION

[0014] The embodiments shown in FIGS. 2-11 are illustrated with reference to mixer tubes and other parts of furnaces which, in addition to having the premix burner 10 and the parts described above with reference to FIG. 1, are further equipped with flashback control means. All or part of each of the multiple flashback control means can be used in combination with all or part of any one or more of the others.

[0015] In the example of FIG. 2, flashback control is accomplished by electrically charging the mixer tube 30. Specifically, the mixer tube 30 is included in an electrical circuit 102 with a voltage source 104 and a switch 106. A refractory or other electrically insulating material 108 is interposed where needed between the mixer tube 30 and the other structural parts 110 of the premix burner 10. The controller 60 (FIG. 1) operates the switch 106 to apply a voltage to the mixer tube 30 to create an electric field. This inhibits flashback by increasing the boundary layer quenching distance through which combustion is prevented by chemical radical absorption in the metal material at the inner surface 112 of the mixer tube 30.

[0016] In the example of FIG. 3, flashback control is accomplished by cooling the mixer tube 30 to increase the boundary layer quenching distance through which combustion is prevented by heat loss at the inner surface 112 of the mixer tube 30. In this embodiment, the controller 60 operates a pump 120 to drive a flow of cooling fluid from a source 122 through a coil 124 of heat exchange tubing on the outer surface 126 of the mixer tube 30. The alternative embodiment of FIG. 4 includes a sleeve 130 through which the cooling fluid flows in contact with the outer surface 126 of the mixer tube 30. The alternative embodiment of FIG. 4A cools the mixer tube 30 with thermoelectric elements 140 in a modification of the circuit 102 of FIG. 2.

[0017] In the example of FIG. 5, the flashback control means introduces non-flammable fluid into the mixer tube 30 at an intermediate inlet location 150. The intermediate inlet location 150 is between the outlet 46 and the open inner end 32 at which the mixer tube 30 receives unmixed fuel and oxidant, but is preferably closer to the outlet 46 than to the inner end 32. In this embodiment, the mixer tube 30 has a porous media fluid inlet structure 152 through which the non-flammable fluid enters the mixer tube 30. The non-flammable fluid inhibits flashback from the outlet 46 by forming a non-flammable boundary layer along the inner surface of the mixer tube 30 between the outlet 46 and the intermediate location 150.

[0018] The inlet structure 152 receives the non-flammable fluid from a surrounding annular duct 154. As shown schematically in FIG. 5, the controller 60 operates a valve 158 to provide the duct 154 with the non-flammable fluid, which can comprise liquid water, water in the form of vapor or steam, air from the blower system 20, recirculated flue gas, an inert gas, carbon dioxide, or any other suitable non-flammable fluids or mixtures of such fluids.

[0019] The porous inlet structure 152 is formed of solid material that is permeable to fluids and, although sintered metal is preferred, may comprise any such material or materials that can withstand the high temperatures of combustion in the burner 10. It has a skeletal structure called the matrix or frame that has voids. A porous medium has distinct advantages over a solid with manufactured holes, which are known as through holes. A porous medium can have a pore size and density that is not attainable through machining or fabrication techniques. Introducing a flow along the inner wall surface of the mixer tube 30 is effective through the use of a porous medium because the permeability of the porous section will allow the non-flammable fluid to gradually displace the bulk mixer flow radially inward from the wall surface to form a more uniform boundary layer composition that is more resistant to flashback. With proper porous medium selection the flow passing through the medium will have a low exit velocity at the wall of the mixer tube 30 which reduces its interaction with the bulk mixer flow.

[0020] The embodiment of FIG. 5 further includes a sensor 160 to detect flashback. The sensor 160 may comprise any suitable device known in the art, such as a flame detector, a UV sensor, an acoustic sensor, a temperature sensor, and the like, as described in the provisional application. The controller 60 can respond to the sensor 160 by operating the valve 158 to initiate a flow of the non-flammable fluid into the mixer tube when flashback has been detected, to regulate the flow as needed to control flashback, and to terminate the flow when flashback has been extinguished.

[0021] In the embodiment of FIG. 5, the porous medium inlet structure 152 is formed of sintered metal. It is shaped as a cylinder, and is welded in place at its opposite ends to form a longitudinal section of the mixer tube 30 at the intermediate location 150. In the embodiment of FIG. 5A, the porous medium inlet structure 152 is formed of ceramic material. The ceramic material fills the annular duct 154, which is welded between adjacent sections 162 and 164 of the mixer tube 30 to provide the structural strength needed to support the tube 30 at the intermediate location 150.

[0022] As shown in FIG. 6, the furnace can be further equipped with multiple sources of differing fuels for forming the premix in the mixer tube 30. The controller 60 in this example is configured to respond to flashback by combining or switching between the fuel source 22 and one or more additional sources 170 of fuels, each of which has a different flame speed. Specifically, under given conditions of temperature, pressure, and fuel-to-oxidant ratio, most fuels have respective flame speeds that differ from each other. High flame speed fuels include hydrogen at 170 cm/sec, and acetylene at 144 cm/sec, in fuel-air premix at 25 degrees C., 1 atm pressure, and an equivalence ratio of 1.0. Others include ethylene, propylene, and ethylene oxide with flame speeds of 68 cm/sec, 70.2 cm/sec, and 88.8 cm/sec, respectively, in fuel-air premix under the same conditions of 25 degrees C., 1 atm pressure, and an equivalence ratio of 1.0. Low flame speed fuels under that set of conditions include methane at 43.4 cm/sec, ethane at 44.5 cm/sec, propane at 45.6 cm/sec, and butane at 44.8 cm/sec. When flashback is detected, the controller 60 can respond by shifting from one or a combination of high speed fuels to one or a combination of lower speed fuels, or by varying a combination of high and/or low speed fuels, to reduce the overall flame speed of the premix fuel. The use of a premix fuel with a lower overall flame speed would preferably occur only momentarily, with a resumption of the original premix fuel when flashback has been extinguished.

[0023] FIGS. 7 and 8 show an alternative structural arrangement for one or more mixer tubes and the accompanying fuel injector conduits at the open inner ends 32 of the mixer tubes 30. This arrangement includes a pair of inner mixer tubes 180 and 182 nested concentrically within an outer mixer tube 30. The open inner ends 184 and 186 of the first and second inner tubes 180 and 182 have respective fuel injector conduits 188 and 190. The open inner end 32 of the outer tube 30 does not have a respective fuel injector conduit. The burner 10 in this embodiment is thus configured for the outer tube 30 to receive only oxidant in the form of combustion air from the oxidant plenum 17 (FIG. 1).

[0024] In operation of the embodiment of FIGS. 7 and 8, combustion air flows from the plenum 17 into the outer tube 30, through an annular flow space 191 radially between the outer tube 30 and the first inner tube 180, and into a cylindrical mixing section 193 of the outer tube 30. The mixing section 193 reaches longitudinally from the outlets 194 and 196 of the inner tubes 180 and 182 to the outlet 46 of the outer tube 30.

[0025] The controller 60 is configured for the inner tubes 180 and 182 to receive combustion air from the plenum 17 and fuel from the injector conduits 188 and 190 at respective ratios that differ from each other. Specifically, the first inner tube 180 receives unmixed fuel and oxidant at a first ratio, and the second inner tube 182 receives unmixed fuel and oxidant at a second ratio that is more fuel rich than the first ratio.

Premix then flows from the first inner tube **180** into the mixing section **193** at the first ratio, and from the second inner tube **182** into the mixing section **193** at the second, relatively fuel rich ratio. This inhibits flashback upstream from the outlet **46** by providing stratified ratios of fuel-to-oxidant that increase radially inward of the outer tube **30**.

[0026] In a variation of the embodiment of FIGS. 7 and 8, the outer tube **30** has fuel injector conduits **198** as shown in FIG. 9. The controller **60** in this embodiment is configured for the outer tube **30** to receive combustion air from the plenum **17** and fuel from the conduits **198** at a third ratio. The third ratio is more fuel lean than the first ratio at the first inner tube **180**, and the premix formed in the annular flow space **191** is preferably non-flammable. The controller **60** may also be configured to provide the tubes **30**, **180** and **182** with fuels having differing flame speeds for flashback control, as described above, as an alternative to differing ratios for flashback control, or in combination with differing ratios.

[0027] The embodiment of FIG. 10 includes a nonflammable fluid source **200**, a fluid line **202**, a valve **204** in the fluid line **202**, and an injector **206** configured to inject a curtain **209** of the non-flammable fluid across the outlet **46** of a mixer tube **30**. The non-flammable fluid of FIG. 10 may be the same as the non-flammable fluid described above with reference to FIG. 5, and the controller **60** may operate the valve **204** in response to a flashback sensor **212** in the same manner as described above with reference to FIG. 5.

[0028] FIG. 11 is a view similar to FIG. 1, but shows a flashback control means comprising a source **230** of diluent fluid and a diluent fluid line **232** communicating the source **230** with the fuel plenum **19** at the burner **10**. The diluent fluid may comprise any of the non-flammable fluids described above.

[0029] Each mixer tube **30** in the embodiment of FIG. 11 is equipped with a flashback sensor **234**. The controller **60** can respond to one or more of the sensors **234** by operating a valve **236** to initiate a flow of the diluent fluid into the fuel plenum **19** when flashback has been detected. This dilutes the premix to a fuel-to-oxidant ratio at which the flashback will be extinguished. The controller **60** can further regulate the flow of diluent through the valve **236** as needed to control flashback with reference to the sensors **234**, and to terminate the flow of diluent through the valve **236** when flashback has been extinguished. The controller **60** can also interrupt the flow of fuel through the valve **62** until the detected flashback is extinguished.

[0030] This written description sets forth the best mode of carrying out the invention, and describes the invention so as to enable a person of ordinary skill in the art to make and use the invention, by presenting examples of the elements recited in the claims. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those of ordinary skill in the art. Such other examples are intended to be within the scope of the claims if they have elements that do not differ from the literal language of the claims, or if they have elements with insubstantial differences from the literal language of the claims.

1. An apparatus comprising:

- a furnace structure defining a combustion zone;
- a tube that discharges fuel-oxidant premix into the combustion zone through an outlet from the tube;
- a reactant supply system that provides the tube with unmixed fuel and oxidant for forming the premix; and

means for inhibiting or extinguishing flashback in a boundary layer of fluid that extends along the length of the tube upstream from the outlet, including means for electrically charging the tube.

2. An apparatus comprising:

- a furnace structure defining a combustion zone;
- a tube that discharges fuel-oxidant premix into the combustion zone through an outlet from the tube;
- a reactant supply system that provides the tube with unmixed fuel and oxidant for forming the premix; and
- means for inhibiting or extinguishing flashback in a boundary layer of fluid that extends along the length of the tube upstream from the outlet, including means for cooling the tube.

3. An apparatus as defined in claim 2 wherein the cooling means is configured to apply a cooling medium to a surface of the tube.

4. An apparatus as defined in claim 2 wherein the cooling means includes a thermoelectric element coupled to the tube.

5. An apparatus comprising:

- a furnace structure defining a combustion zone;
- a tube configured to form premix from fuel and oxidant flowing along the length of the tube, having an open inner end configured to receive unmixed fuel and oxidant, and having an outlet configured to discharge the premix into the combustion zone;

an injector configured to inject fuel into the open inner end of the tube; and

a reactant supply system that provides the injector with fuel, including flashback control means for responding to flashback in the tube by changing the overall flame speed of the fuel provided to the injector.

6. An apparatus as defined in claim 5 wherein the reactant supply system is configured to provide the injector with a first fuel from a first source, and the flashback control means responds to flashback in the tube by providing the injector with a second fuel from a second source, with the first fuel having a first overall flame speed in fuel-air premix under a given set of conditions of temperature, pressure and fuel-to-air ratio, and the second fuel having a second, lower overall flame speed in fuel-air premix under the given set of conditions of temperature, pressure and fuel-to-air ratio.

7. An apparatus as defined in claim 6 wherein the flashback control means responds to flashback in the tube by providing the injector with fuel including only the second fuel from the second source.

8. An apparatus comprising:

- a furnace structure defining a combustion zone;
- a tube configured to form premix from fuel and oxidant flowing along the length of the tube, having an open inner end configured to receive unmixed fuel and oxidant, and having an outlet configured to discharge the premix into the combustion zone;

an injector configured to inject fuel into the open inner end of the tube; and

a reactant supply system that provides the injector with a first fuel selected from the group consisting of hydrogen, acetylene, ethylene, propylene, ethylene oxide, and mixtures thereof, including flashback control means for responding to flashback in the tube by providing the injector with a second fuel selected from the group consisting of methane, ethane, propane, butane, and mixtures thereof.

9. An apparatus as defined in claim 8 wherein the flashback control means responds to flashback in the tube by providing the injector with only the second fuel.

10. An apparatus comprising:

a furnace structure defining a combustion zone; and
a tube having an outlet that discharges fuel-oxidant premix into the combustion zone, an open upstream end that receives unmixed fuel and oxidant for forming the premix, and a fluid inlet at an intermediate location between the outlet and the open upstream end;
wherein the fluid inlet comprises a porous media fluid inlet structure.

11. An apparatus as defined in claim 10 further comprising a source of non-flammable fluid coupled to the fluid inlet.

12. An apparatus comprising:

a furnace structure defining a combustion zone;
an outer tube configured to form fuel-oxidant premix from fuel and oxidant flowing within the outer tube, having an open inner end, and having an outlet configured to discharge fuel-oxidant premix into the combustion zone;
an inner tube configured to form fuel-oxidant premix from fuel and oxidant flowing within the inner tube, the inner tube reaching longitudinally within the outer tube to define an annular flow space between the inner and outer tubes, having an open inner end, and having an outlet configured to discharge fuel-oxidant premix into the outer tube at a location upstream of the outlet of the outer tube; and

a reactant supply system configured to provide the annular flow space with only a reactant stream that is free of fuel, and to provide the open inner end of the inner tube with unmixed reactant streams of fuel and oxidant.

13. An apparatus as defined in claim 12 wherein the inner tube is a first inner tube, and further comprising a second inner tube nested within the first inner tube, with each of the inner tubes having an open inner end, and with each of the inner tubes having an outlet configured to discharge a respective stream of fuel-oxidant premix into the outer tube at a location spaced upstream from the outlet of the outer tube.

14. An apparatus as defined in claim 13 wherein the reactant supply system is configured to provide the open inner end of the first inner tube with unmixed reactant streams of fuel and oxidant at a first fuel-to-oxidant ratio, and to provide the open inner end of the second inner tube with unmixed reactant streams of fuel and oxidant at a second fuel-to-oxidant ratio that is more fuel rich than the first fuel-to-oxidant ratio.

15. An apparatus as defined in claim 13 wherein the reactant supply system is configured to provide the open inner end of the first inner tube with fuel that has an overall flame speed in fuel-air premix under a given set of conditions of temperature, pressure and fuel-to-air ratio, and to provide the open inner end of the second inner tube with fuel that has a second, higher overall flame speed in fuel-air premix under the given set of conditions of temperature, pressure and fuel-to-air ratio.

16. An apparatus comprising:

a furnace structure defining a combustion zone;
an outer tube configured to form fuel-oxidant premix from fuel and oxidant flowing within the outer tube, having an open inner end, and having an outlet configured to discharge fuel-oxidant premix into the combustion zone;
an inner tube configured to form fuel-oxidant premix from fuel and oxidant flowing within the inner tube, the inner tube reaching longitudinally within the outer tube to

define an annular flow space between the inner and outer tubes, having an open inner end, and having an outlet configured to discharge fuel-oxidant premix into the outer tube at a location upstream of the outlet of the outer tube; and

a reactant supply system configured to provide the annular flow space with unmixed streams of fuel and oxidant at a non-flammable fuel-to-oxidant ratio, and to provide the open inner end of the inner tube with unmixed streams of fuel and oxidant at a flammable fuel-to-oxidant ratio.

17. An apparatus as defined in claim 16 wherein the inner tube is a first inner tube, and further comprising a second inner tube nested within the first inner tube, with each of the inner tubes having an open inner end, and with each of the inner tubes having an outlet configured to discharge a respective stream of fuel-oxidant premix into the outer tube at a location spaced upstream from the outlet of the outer tube.

18. An apparatus as defined in claim 17 wherein the reactant supply system is configured to provide the open inner end of the first inner tube with unmixed reactant streams of fuel and oxidant at a first fuel-to-oxidant ratio, and to provide the open inner end of the second inner tube with unmixed reactant streams of fuel and oxidant at a second fuel-to-oxidant ratio that is more fuel rich than the first fuel-to-oxidant ratio.

19. An apparatus as defined in claim 17 wherein the reactant supply system is configured to provide the open inner end of the first inner tube with fuel that has a first overall flame speed in fuel-air premix under a given set of conditions of temperature, pressure and fuel-to-air, and to provide the open inner end of the second inner tube with fuel that has a second, higher overall flame speed in fuel-air premix under the given set of conditions of temperature, pressure and fuel-to-air ratio.

20. An apparatus comprising:

a furnace structure defining a combustion zone;
an outer tube configured to form fuel-oxidant premix from fuel and oxidant flowing within the outer tube, having an open inner end, and having an outlet configured to discharge fuel-oxidant premix into the combustion zone;
an inner tube configured to form fuel-oxidant premix from fuel and oxidant flowing within the inner tube, the inner tube reaching longitudinally within the outer tube to define an annular flow space between the inner and outer tubes, having an open inner end, and having an outlet configured to discharge fuel-oxidant premix into the outer tube at a location upstream of the outlet of the outer tube; and

a reactant supply system configured to provide the annular flow space with unmixed streams of oxidant and a first fuel, and to provide the open inner end of the inner tube with unmixed streams of oxidant and a second fuel, with the first fuel having a first overall flame speed in fuel-air premix under a given set of conditions of temperature, pressure and fuel-to-air ratio, and the second fuel having a second, higher overall flame speed in fuel-air premix under the given set of conditions of temperature, pressure and fuel-to-air ratio.

21. An apparatus as defined in claim 20 wherein the inner tube is a first inner tube, and further comprising a second inner tube nested within the first inner tube, with each of the inner tubes having an open inner end, and with each of the inner tubes having an outlet configured to discharge a respective

stream of fuel-oxidant premix into the outer tube at a location spaced upstream from the outlet of the outer tube.

22. An apparatus as defined in claim **21** wherein the reactant supply system is configured to provide the open inner end of the second inner tube with fuel that has a third overall flame speed which, in fuel-air premix under the given set of conditions of temperature, pressure and fuel-to-air ratio, is higher than the second overall flame speed.

23. An apparatus as defined in claim **21** wherein the reactant supply system is configured to provide the open inner end of the first inner tube with unmixed reactant streams of fuel and oxidant at a first fuel-to-oxidant ratio, and to provide the open inner end of the second inner tube with unmixed reactant streams of fuel and oxidant at a second fuel-to-oxidant ratio that is more fuel rich than the first fuel-to-oxidant ratio.

24. An apparatus comprising:

- a furnace structure defining a combustion zone;
- a tube that discharges fuel-oxidant premix into the combustion zone through an outlet from the tube;
- a reactant supply system that provides the tube with unmixed fuel and oxidant for forming the premix; and
- flashback control means for injecting non-flammable fluid across the tube, whereby the non-flammable fluid can form a curtain to block flashback of the premix.

25. An apparatus as defined in claim **24** wherein the flashback control means injects non-flammable fluid across the

outlet of the tube, whereby the non-flammable fluid can form a curtain to block flashback of the premix from the outlet.

26. An apparatus as defined in claim **24** wherein the flashback control means includes a line configured to provide non-flammable fluid to the injector, a valve in the line, a flashback sensor, and a controller configured to operate the valve in response to the flashback sensor.

27. An apparatus comprising:

- a furnace structure defining a combustion zone;
- a tube configured to form fuel-oxidant premix from fuel and oxidant flowing along the length of the tube, and having an outlet configured to discharge the fuel-oxidant premix into the combustion zone;
- an injector configured to inject fuel into the tube; and
- a reactant supply system configured to provide the injector with fuel, and to respond to flashback in the tube by providing the injector with diluent fluid.

28. An apparatus as defined in claim **27** wherein the reactant supply system includes a line configured to provide diluent fluid to the injector, a valve in the line, a flashback sensor, and a controller configured to operate the valve in response to the flashback sensor.

29. An apparatus as defined in claim **27** wherein the reactant supply system is configured to respond to flashback in the tube by interrupting the flow of fuel to the injector until the flashback is extinguished.

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