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(54) **Burner apparatus and methods**

(57) A burner assembly for and method of combusting fuel gas in a furnace is provided. The burner assembly (10) includes a burner tile (18) having a burner throat (48) disposed therethrough. Combustion air is conducted through the burner throat into a combustion zone in the furnace. A pilot assembly (20) is used to generate a pilot flame (62) within the burner throat. Fuel gas is injected into an ignition zone (80) located outside the burner throat and ignited therein. The pilot flame (62) generated in the burner throat (48) can be used to ignite the fuel gas in the ignition zone (80). The ignited fuel gas is admixed with combustion air in the combustion zone. The burner assembly can be operated without admixing a significant amount of fuel gas with combustion air in the burner throat, which can help control the formation of undesirable nitrogen oxides (NO_X).

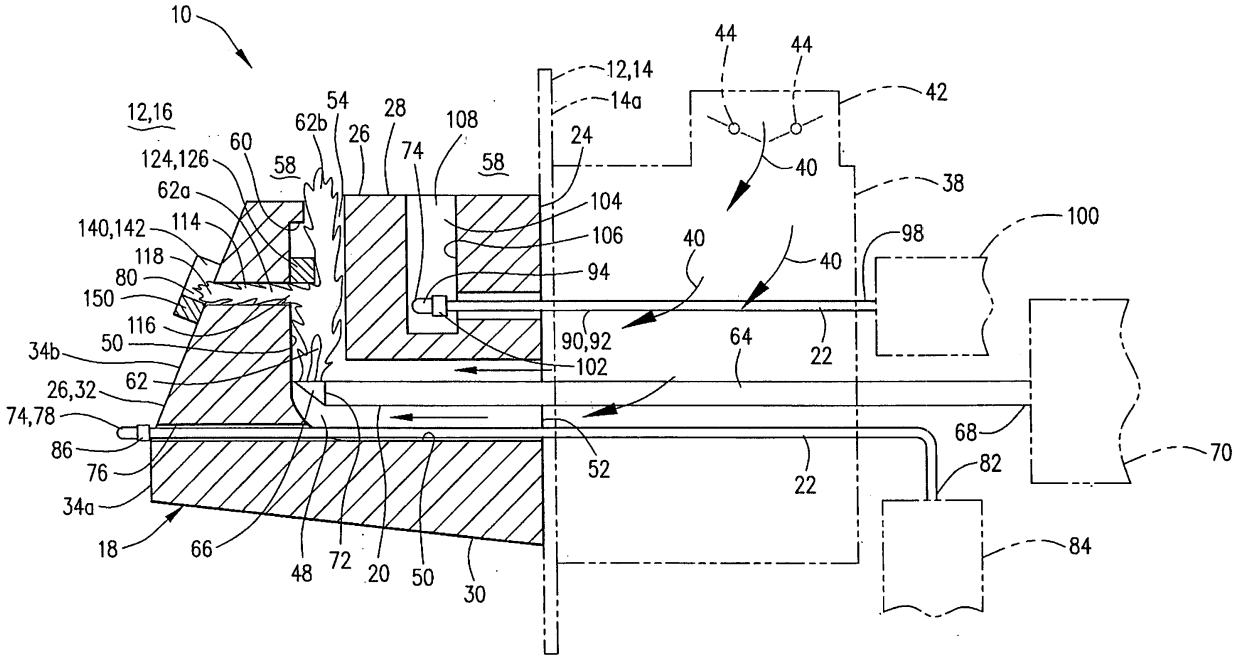

FIG. 2

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Description

[0001] Burner assemblies are used in many applications. For example, process burner assemblies are used in connection with industrial furnaces in petroleum refineries, chemical plants and similar facilities. The specific type and configuration of burner assemblies used will vary depending on the specific application, the type of furnace, the applicable emissions regulations and other factors known to those skilled in the art.

[0002] A typical process burner includes a burner tile having a burner throat extending therethrough. The burner tile extends into the furnace. Combustion air is conducted through the burner throat to create a combustion zone in the furnace adjacent to the outlet of the burner throat. Fuel is injected into the burner throat, admixed with the combustion air and burned in the combustion zone.

[0003] Many government authorities have adopted regulations relating to the amount of nitrogen oxides (commonly designated as "NO_X" and primarily including NO and NO_2) and other potentially polluting compounds that can be emitted into the atmosphere from process furnaces and other combustion equipment. The United States, for example, has stringent regulations relating to nitrogen oxides emissions. These regulations have led to the development of burner apparatus and corresponding methods of operation that result in significantly lower nitrogen oxide emissions.

[0004] In one approach, the fuel admixed with combustion air in the burner throat (commonly referred to as primary fuel) is burned in a first combustion zone. Additional fuel (often referred to as secondary or staged fuel) is burned in a second combustion zone. In such a burner assembly, the secondary or staged fuel becomes dilute with furnace flue gas thereby lowering the combustion temperature of the gases. The flue gas functions as a heat sink in that it absorbs heat from the flame. The flue gas can come from the furnace stack (external flue gas) or from the furnace itself (internal flue gas). Lowering the combustion temperature of the gases lowers the formation of nitrogen oxides in the produced flue gases. Secondarily, flue gas admixed with the combustion reactants reduces the species concentration of oxygen necessary for nitrogen oxide formation, thereby contributing to further nitrogen oxide reduction.

[0005] It has been thought heretofore that it is necessary to admix primary fuel with combustion air in the throat of the burner, even in staged combustion burner assemblies. The primary fuel in the throat of the burner helps assure that the mixture of fuel and combustion air is ignited in the combustion zone and helps stabilize the burner. Unfortunately, in some applications, the admixture of primary fuel with combustion air in the throat of the burner can generate temperatures therein that are high enough to allow nitrogen oxides to form. Of secondary importance, the combustion air in the burner throat includes a substantially higher concentration of oxygen than the concentration of oxygen in flue gas. Combining a relatively high concentration of oxygen in the burner throat with higher temperatures caused by introducing primary fuel to the burner throat can cause a significant amount of nitrogen oxides to form. This diminishes the significance of the other steps taken to reduce the formation of nitrogen oxides.

[0006] The invention provides a burner assembly for a furnace. The invention also provides a method of using a burner assembly that includes a burner tile and a burner throat extending therethrough to combust fuel gas in a furnace space in order to generate heat.

[0007] In a first aspect, the inventive burner assembly comprises a burner tile for association with the furnace, a burner pilot assembly and a fuel injection assembly.

[0008] The burner tile of the first aspect of the burner assembly may include an exterior surface to be positioned within the furnace, and a burner throat disposed through the burner tile. The burner throat preferably has an inlet and an outlet. The inlet of the burner throat may be adapted to receive combustion air from outside the burner throat. The outlet of the burner throat may be positioned adjacent to the exterior surface of the burner tile, and may be positioned to introduce combustion air into a combustion zone located within the furnace and adjacent to the exterior surface of the burner tile.

[0009] The burner pilot assembly of the first aspect of the burner assembly may be for generating a pilot flame within the burner throat. The burner pilot assembly may include a pilot fuel tip and a pilot fuel riser. The pilot fuel riser preferably has an inlet adapted to be fluidly connected to a source of fuel, and an outlet fluidly connected to the pilot fuel tip. The pilot fuel tip is preferably disposed within the burner throat.

[0010] The fuel injection assembly of the first aspect of the burner assembly is preferably adapted to inject essentially all of the fuel needed for operation of the burner assembly into the furnace from one or more fuel tips located outside the burner throat. The fuel injection assembly may include a main fuel tip and a main fuel riser for injecting main fuel into an ignition zone located within the furnace and adjacent to the exterior surface of the burner tile. The main fuel riser may have an inlet adapted to be fluidly connected to a source of fuel, and an outlet fluidly connected to the fuel tip. The fuel tip is preferably at least partially disposed within the furnace and positioned adjacent to the exterior surface of the burner tile.

[0011] In a second aspect, the inventive burner assembly includes a burner tile for association with the furnace, an ignition passageway, a burner pilot assembly and a fuel injection assembly.

[0012] The burner tile of the second aspect of the burner assembly may include an exterior surface to be positioned within the furnace and a burner throat disposed through the burner tile. The burner throat preferably has an inlet and an outlet. The inlet of the burner throat is preferably adapted to receive combustion air from outside the burner throat. The

outlet of the burner throat is preferably positioned adjacent to the exterior surface of the burner tile, and positioned to introduce combustion air into a combustion zone located within the furnace and adjacent to the exterior surface of the burner tile.

[0013] The ignition passageway of the second aspect of the burner assembly may extend through the burner tile between the burner throat and the exterior surface of the burner tile, and has an inlet and an outlet. The inlet of the ignition passageway is preferably positioned adjacent to the burner throat, and the outlet of the ignition passageway is preferably positioned adjacent to the exterior surface of the burner tile.

[0014] The burner pilot assembly of the second aspect of the burner assembly is preferably for generating a pilot flame within the burner throat. The burner pilot assembly may include a pilot fuel tip and a pilot fuel riser. The pilot fuel riser preferably has an inlet adapted to be fluidly connected to a source of fuel, and an outlet fluidly connected to the pilot fuel tip. The pilot fuel tip is preferably disposed within the burner throat.

[0015] The fuel injection assembly of the second aspect of the burner assembly is preferably adapted to inject fuel into the furnace from one or more fuel tips located outside of the burner throat. The fuel injection assembly may include a main fuel tip and a main fuel riser for injecting main fuel into an ignition zone located within the furnace and adjacent to the exterior surface of the burner tile. The main fuel riser preferably has an inlet adapted to be fluidly connected to a source of fuel, and an outlet fluidly connected to the main fuel tip. The main fuel tip is preferably at least partially disposed within the furnace and positioned adjacent to the exterior surface of the burner tile.

[0016] The ignition passageway of the second aspect of the burner assembly may receive at least a portion of the pilot flame generated by the burner pilot assembly, and may conduct the flame, or portion thereof, to the ignition zone such that the flame or portion thereof can contact and ignite the main fuel injected by the main fuel tip into the ignition zone.

[0017] In a first aspect, the inventive method is carried out without admixing a significant amount of fuel with combustion air in the burner throat. The method may comprise the following steps:

(a) conducting combustion air through the burner throat into a combustion zone located within the furnace, and adjacent to the exterior surface of the burner tile;
(b) generating a pilot flame in the burner throat with pilot fuel provided by a burner pilot assembly;
(c) injecting essentially all of the fuel needed for operation of the burner assembly into the furnace from one or more fuel tips located outside of the burner throat, the one or more fuel tips including a main fuel tip for injecting main fuel into an ignition zone located within the furnace, and adjacent to the exterior surface of the burner tile;
(d) igniting main fuel in the ignition zone; and
(e) admixing ignited main fuel with combustion air conducted through the burner throat in the combustion zone.

[0018] In a second aspect, the inventive method may comprise the following steps:

(a) conducting combustion air through the burner throat into a combustion zone located within the furnace, and adjacent to the exterior surface of the burner tile;
(b) generating a pilot flame in the burner throat with pilot fuel provided by a burner pilot assembly;
(c) injecting fuel into the furnace from one or more fuel tips located outside of the burner throat, the one or more fuel tips including a main fuel tip for injecting main fuel into an ignition zone located within the furnace and adjacent to the exterior surface of the burner tile;
(d) conducting at least a portion of the pilot flame from the burner throat to the ignition zone and using said pilot flame, or portion thereof, to ignite main fuel in the ignition zone; and
(e) admixing ignited main fuel with combustion air conducted through the burner throat into the combustion zone.

[0019] The present invention provides a burner assembly for a furnace comprising: a burner tile for association with the furnace, said burner tile including: an exterior surface to be positioned within the furnace; and a burner throat disposed through said burner tile, said burner throat having an inlet and an outlet, said inlet of said burner throat adapted to receive combustion air from outside said burner throat, said outlet of said burner throat being positioned adjacent to said exterior surface of said burner tile and positioned to introduce combustion air into a combustion zone located within said furnace and adjacent to said exterior surface of said burner tile; a burner pilot assembly for generating a pilot flame within said burner throat, said burner pilot assembly including a pilot fuel tip and a pilot fuel riser, said pilot fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet fluidly connected to said pilot fuel tip, said pilot fuel tip being disposed within said burner throat; and a fuel injection assembly adapted to inject essentially all of the fuel needed for operation of said burner assembly into said furnace from one or more fuel tips located outside of said burner throat, said fuel injection assembly including a main fuel tip and a main fuel riser for injecting main fuel into an ignition zone located within said furnace and adjacent to said exterior surface of said burner tile, said main fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet fluidly connected to said fuel tip, said fuel tip being at least partially disposed within said furnace and positioned adjacent to said exterior surface of said burner tile.

[0020] Optionally, said burner tile further includes an ignition passageway for receiving at least a portion of the flame generated by said burner pilot and conducting said flame or portion thereof to said ignition zone whereby said flame or portion thereof can contact and ignite main fuel injected by said main fuel tip into said injection zone, said injection passageway extending through said burner tile between said burner throat and said exterior surface of said burner tile and having an inlet and an outlet, said inlet of said ignition passageway being positioned adjacent to said burner throat and said outlet of said ignition passageway being positioned adjacent to said exterior surface of said burner tile.

[0021] Optionally, said burner pilot assembly is adapted to pre-mix oxygen with fuel in said burner pilot assembly prior to generating said flame.

[0022] Optionally, said ignition passageway includes a Coanda surface for causing at least a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway.

[0023] Optionally, said burner assembly further comprises a flame diverter for causing at least a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway.

[0024] Optionally, said flame diverter is adapted to cause a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway and a portion of the flame generated by said burner pilot assembly to be conducted through said outlet of said burner throat into said combustion zone.

[0025] Optionally, said flame diverter is an impingement member located in said burner throat.

[0026] Optionally, said flame diverter is a fluid injection assembly associated with said ignition passageway for injecting fluid into said ignition passageway toward said ignition zone.

[0027] Optionally, said fluid injection assembly is adapted to be fluidly connected to a source of fuel whereby said fluid injection assembly can inject fuel into said ignition passageway.

[0028] Optionally, said exterior surface of said burner tile includes a top section, a bottom section and a sidewall section connecting said top section to said bottom section.

[0029] Optionally, said main fuel combustion tip and said ignition zone are located adjacent to said sidewall section of said exterior surface of said burner tile.

[0030] Optionally, said fuel injection assembly further includes a supplemental fuel tip and supplemental fuel riser for injecting supplemental fuel into said combustion zone, said supplemental fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet connected to said supplemental fuel tip.

[0031] Optionally, said supplemental fuel riser is partially disposed through the burner tile and extends into a trough disposed in the burner tile that includes an outlet positioned adjacent to said combustion zone, and said supplemental fuel tip is disposed in said trough.

[0032] Optionally, said burner assembly further comprises a turning member, said turning member located adjacent to said exterior surface of said burner tile and positioned to redirect said flame or a portion thereof from said outlet of said ignition passageway across said exterior surface of said burner tile.

[0033] Optionally, said burner assembly further comprises a stabilizing member, said stabilizing member positioned on said exterior surface of said burner tile to receive said flame or a portion thereof and facilitate contact of said flame or a portion thereof with fuel injected by said main fuel tip.

[0034] Optionally, said stabilizing member is attached to said turning member and extends substantially perpendicularly therefrom along said exterior surface of said burner tile, and said stabilizing member receives said flame or a portion thereof from said turning block.

[0035] Optionally, said fuel injection assembly further includes a supplemental fuel tip and supplemental fuel riser, said supplemental fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet connected to said supplemental fuel tip, said supplemental fuel tip being at least partially disposed within said furnace and positioned to discharge said supplemental fuel into said combustion zone.

[0036] The present invention further provides a burner assembly for a furnace comprising: a burner tile for association with the furnace, said burner tile including: an exterior surface to be positioned within the furnace; and a burner throat disposed through said burner tile, said burner throat having an inlet and an outlet, said inlet of said burner throat adapted to receive combustion air from outside said burner throat, said outlet of said burner throat being positioned adjacent to said exterior surface of said burner tile and positioned to introduce combustion air into a combustion zone located within said furnace and adjacent to said exterior surface of said burner tile; an ignition passageway extending through said burner tile between said burner throat and said exterior surface of said burner tile and having an inlet and an outlet, said inlet of said ignition passageway being positioned adjacent to said burner throat and said outlet of said ignition passageway being positioned adjacent to said exterior surface of said burner tile; a burner pilot assembly for generating a pilot flame within said burner throat, said burner pilot assembly including a pilot fuel tip and a pilot fuel riser, said pilot fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet fluidly connected to said pilot fuel tip, said pilot fuel tip being disposed within said burner throat; and a fuel injection assembly adapted to inject fuel into said furnace from one or more fuel tips located outside of said burner throat, said fuel injection assembly including a main fuel tip and a main fuel riser for injecting main fuel into an ignition zone located within said furnace and adjacent to said exterior surface of said burner tile, said main fuel riser having an inlet adapted to be fluidly connected to a source of fuel

gas and an outlet fluidly connected to said main fuel tip, said main fuel tip being at least partially disposed within said furnace and positioned adjacent to said exterior surface of said burner tile, whereby said ignition passageway receives at least a portion of said pilot flame generated by said burner pilot assembly and conducts said flame or portion thereof to said ignition zone such that said flame or portion thereof can contact and ignite main fuel injected by said main fuel tip into said ignition zone.

[0037] Optionally, said fuel injection assembly is adapted to inject essentially all of the fuel needed for operation of said burner assembly into said furnace from one or more fuel tips located outside of said burner throat.

[0038] Optionally, said burner pilot assembly is adapted to pre-mix oxygen with pilot fuel in said burner pilot assembly prior to generating said flame.

[0039] Optionally, said ignition passageway includes a Coanda surface for causing at least a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway.

[0040] Optionally, said burner assembly further comprises a flame diverter for causing at least a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway.

[0041] Optionally, said flame diverter is adapted to cause a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway and a portion of the flame generated by said burner pilot assembly to be conducted through said outlet of said burner throat into said combustion zone.

[0042] Optionally, said flame diverter is an impingement member located in said burner throat.

[0043] Optionally, said flame diverter is a fluid injection assembly associated with said ignition passageway for injecting fluid into said ignition passageway toward said ignition zone.

[0044] Optionally, said fluid injection assembly is adapted to be fluidly connected to a source of fuel whereby said fluid injection assembly can inject fuel into said ignition passageway.

[0045] Optionally, said exterior surface of said burner tile includes a top section, a bottom section and a sidewall section connecting said top section to said bottom section.

[0046] Optionally, said main fuel combustion tip and said ignition zone are located adjacent to said sidewall section of said exterior surface of said burner tile.

[0047] Optionally, said fuel injection assembly further includes a supplemental fuel tip and supplemental fuel riser for injecting supplemental fuel into said combustion zone, said supplemental fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet connected to said supplemental fuel tip.

[0048] Optionally, said supplemental fuel riser is partially disposed through the burner tile and extends into a trough disposed in the burner tile that includes an outlet positioned adjacent to said combustion zone, and said supplemental fuel tip is disposed in said trough.

[0049] Optionally, said burner assembly includes more than one ignition passageway, more than one ignition zone and more than one main fuel combustion tip, said ignition zones and main fuel combustion tips being located adjacent to said sidewall section of said exterior surface of said burner tile.

[0050] Optionally, said fuel injection assembly includes more than one supplemental fuel tip, said supplemental fuel tips being positioned to discharge supplemental fuel into said combustion zone.

[0051] Optionally, said burner assembly further comprises a turning member, said turning member located adjacent to said exterior surface of said burner tile and positioned to redirect said flame or a portion thereof from said outlet of said ignition passageway across said exterior surface.

[0052] Optionally, said burner assembly further comprises a stabilizing member, said stabilizing member positioned on said exterior surface of said burner tile to receive said flame or a portion thereof and facilitate contact of said flame or a portion thereof with fuel injected by said main fuel tip.

[0053] Optionally, said stabilizing member is attached to said turning member and extends substantially perpendicularly therefrom along said exterior surface of said burner tile, and said stabilizing member receives said flame or a portion thereof from said turning block.

[0054] The present invention further provides a method of using a burner assembly that includes a burner tile and a burner throat extending therethrough to combust fuel in a furnace space in order to generate heat without admixing a significant amount of fuel with combustion air in the burner throat, comprising: conducting combustion air through the burner throat into a combustion zone located within the furnace and adjacent to the exterior surface the burner tile; generating a pilot flame in the burner throat with pilot fuel provided by a burner pilot assembly; injecting essentially all of the fuel needed for operation of the burner assembly into the furnace from one or more fuel tips located outside of the burner throat, the one or more fuel tips including a main fuel tip for injecting main fuel into an ignition zone located within the furnace and adjacent to the exterior surface of the burner tile; igniting main fuel in the ignition zone; and admixing ignited main fuel with combustion air conducted through the burner throat in the combustion zone.

[0055] Optionally, at least a portion of the pilot flame generated in the burner throat is used to ignite main fuel in the ignition zone.

[0056] Optionally, the pilot flame or portion thereof is used to ignite main fuel in the ignition zone by conducting the pilot flame or portion thereof into the ignition zone through an ignition passageway extending through the burner tile

between the burner throat and the exterior surface of the burner tile whereby the pilot flame or portion thereof can contact and ignite fuel in the injection zone.

[0057] Optionally, said method further comprises the step of pre-mixing oxygen with the pilot fuel in the burner pilot assembly prior to generating the pilot flame.

[0058] Optionally, said method further comprises the step of diverting the pilot flame or portion thereof into the ignition passageway.

[0059] Optionally, said method further comprises diverting a first portion of the pilot flame into the ignition passageway and allowing a second portion of the pilot flame to be conducted through the burner throat into the combustion zone.

[0060] Optionally, the pilot flame or portion thereof is diverted into the ignition passageway by impinging the pilot flame or portion thereof on a diverting member located in the burner throat.

[0061] Optionally, the ignition passageway includes a Coanda surface, and the pilot flame or portion thereof is diverted into the ignition passageway by directing the pilot flame or portion thereof on the Coanda surface.

[0062] Optionally, the pilot flame or portion thereof is diverted into the ignition passageway by causing the pressure in the ignition passageway to be lower than the pressure in the burner throat.

[0063] Optionally, the pressure in the ignition passageway is caused to be lower than the pressure in the burner throat by injecting an eductor fluid into the ignition passageway toward the ignition zone.

[0064] Optionally, the eductor fluid is fuel.

[0065] Optionally, the one or more fuel tips include a supplemental fuel tip for injecting supplemental fuel into the combustion zone, and said method further comprises the step of injecting supplemental fuel into the combustion zone.

[0066] The present invention further provides a method of using a burner assembly that includes a burner tile and a burner throat extending therethrough to combust fuel in a furnace space in order to generate heat, comprising: conducting combustion air through the burner throat into a combustion zone located within the furnace and adjacent to the exterior surface of the burner tile; generating a pilot flame in the burner throat with pilot fuel provided by a burner pilot assembly; injecting fuel into the furnace from one or more fuel tips located outside of the burner throat, the one or more fuel tips including a main fuel tip for injecting main fuel into an ignition zone located within the furnace and adjacent to the exterior surface of the burner tile; conducting at least a portion of the pilot flame from the burner throat to the ignition zone and using said pilot flame or portion thereof to ignite main fuel in the ignition zone; and admixing ignited main fuel with combustion air conducted through the burner throat into the combustion zone.

[0067] Optionally, the pilot flame or portion thereof is conducted from the burner throat to the ignition zone by conducting the pilot flame or portion thereof through an ignition passageway extending through the burner tile between the burner throat and said exterior surface of the burner tile.

[0068] Optionally, essentially all of the fuel needed for operation of the burner assembly is injected into the furnace from one or more fuel tips located outside of the burner throat.

[0069] Optionally, said method further comprises the step of pre-mixing oxygen with the pilot fuel in the burner pilot assembly prior to generating the pilot flame.

[0070] Optionally, said method further comprises the step of diverting the pilot flame or portion thereof into the ignition passageway.

[0071] Optionally, said method further comprises diverting a first portion of the pilot flame into the ignition passageway and allowing a second portion of the pilot flame to be conducted through the burner throat into the combustion zone.

[0072] Optionally, the pilot flame or portion thereof is diverted into the ignition passageway by impinging the pilot flame or portion thereof on a diverting member located in the burner throat.

[0073] Optionally, the ignition passageway includes a Coanda surface, and the pilot flame or portion thereof is diverted into the ignition passageway by directing the pilot flame or portion thereof on the Coanda surface.

[0074] Optionally, the pilot flame or portion thereof is diverted into the ignition passageway by causing the pressure in the ignition passageway to be lower than the pressure in the burner throat.

[0075] Optionally, the pressure in the ignition passageway is caused to be lower than the pressure in the burner throat by injecting an eductor fluid into the ignition passageway toward the ignition zone.

[0076] Optionally, the eductor fluid is fuel.

[0077] Optionally, the one or more fuel tips include a supplemental fuel tip for injecting supplemental fuel into the combustion zone, and said method further comprises the step of injecting supplemental fuel into the combustion zone.

[0078] The present invention will now be further described, by way of non-limitative example only, with reference to the accompanying drawings, in which:-

[0079] FIG. 1 is a front perspective view of the inventive burner assembly.

[0080] FIG. 2 is a section view of the inventive burner assembly taken along line 2-2 in FIG. 1. FIG. 2 also illustrates the flow of combustion air and the flame generated by the burner pilot assembly the inventive burner assembly.

[0081] FIG. 3 is a front view of the inventive burner assembly and further illustrates the deflection of a flame across the exterior of the burner tile.

[0082] FIG. 4 is an enlarged detail view of the burner tile exterior shown by FIG. 3.

[0083] FIG. 5 is a partial top view of the inventive burner assembly.

[0084] FIG. 6 is an enlarged front perspective view of a turning member and stabilizing member of the inventive burner assembly.

[0085] FIG. 7 is a section view taken along line 7-7 in FIG. 6.

[0086] FIG. 8 is a section view of an alternative configuration of the inventive burner assembly.

[0087] FIG. 9 is a section view of another configuration of the inventive burner assembly.

[0088] FIG. 10 is a section view of yet another configuration of the inventive burner assembly.

[0089] FIG. 11A is a front view of the burner tile exterior and illustrates an alternative embodiment of the inventive burner assembly.

[0090] FIG. 11B is a partial top view of the embodiment shown by FIG. 11A.

[0091] FIG. 11C is a section view taken along line 11C-11C of FIG. 11A.

[0092] FIG. 12A is a front view of the burner tile exterior and illustrates another alternative embodiment of the inventive burner assembly.

[0093] FIG. 12B is a partial top view of the embodiment of the inventive burner assembly shown by FIG. 12A.

[0094] FIG. 12C is a section view taken along line 11C-11C of FIG. 12A.

[0095] FIG. 13A is a front view of the burner tile exterior and illustrates yet another alternative embodiment of the inventive burner assembly.

[0096] FIG. 13B is partial top view of the embodiment of the inventive burner assembly shown by FIG. 13A.

[0097] FIG. 13C is a section view taken along line 11C-11C of FIG. 13A.

[0098] Referring to the drawings, the inventive burner assembly is illustrated and generally designated by the numeral 10. As shown by the drawings and understood by those skilled in the art, the burner assembly 10 and components thereof are designed to be associated with a furnace 12 (the overall furnace is not shown) and can be used to generate heat in a petroleum refinery, chemical plant or other applications. The burner assembly 10 is attached to a wall 14 of the furnace 12 (for example, a side wall, bottom wall (or floor) or top wall (or ceiling)) and extends into a furnace space 16 of the furnace. The burner assembly 10 can also freely stand in the furnace 12, for example on the floor of the furnace. The furnace wall 14 includes an internal layer of insulating material 14(a) attached thereto.

[0099] The burner assembly 10 shown by FIGS. 1 and 2 is attached to and horizontally associated with a side wall 14 of a furnace and fired upwardly (up-fired) with respect thereto. As discussed further below, the burner assembly 10 can be configured and associated with the furnace 12 in other ways as well. The burner assembly 10 discharges a mixture of fuel gas and air into furnace space 16 where the mixture is burned in the presence of flue gas while producing a relatively low content of nitrogen oxides (NO_X) and carbon products. Typically, multiple burner assemblies 10 are installed in a single furnace 12.

[0100] The burner assembly 10 comprises a burner tile 18 for association with the furnace 12, a burner pilot assembly 20 and a fuel injection assembly 22. As understood by those skilled in the art, the burner assembly 10 can be a natural draft burner (i.e., the air required for combustion is naturally drafted into burner tile 18), a forced draft burner (for example, a blower is used to blow the combustion air into burner tile 18), a balanced draft burner (for example, blowers are used to blow air both in and out of the burner to achieve an appropriate balance of combustion air) or variations thereof.

[0101] The burner tile 18 includes a base 24, and an exterior surface 26 to be positioned within the furnace 12 (to extend within the furnace space 16). The exterior surface 26 includes a top section 28, a bottom section 30, and a sidewall section 32 connecting the top section to the bottom section. The base 24 of the burner tile 18 is attached to the furnace wall 14. The bottom section 30 is slightly tapered from the base 24 to the sidewall section 32. The sidewall section 32 includes a front face 34 and side faces 36. The front face 34 includes a lower front face 34(a) and a sloped front face 34(b). The sloped front face 34(b) tapers inwardly from the lower front face 34(a) to the top section 28 of the exterior surface 26 of the burner tile 18.

[0102] As illustrated in the drawings, the burner assembly 10 is a natural draft burner (i.e., the air required for combustion is naturally drafted into burner tile 18). A plenum 38 is attached to the back of the furnace wall 14 and to the base 24 of the burner tile 18 to provide combustion air (illustrated in the drawings by arrows 40) from outside the furnace 12 to the burner assembly 10. The plenum 38 includes an air inlet 42. A damper assembly 44 is attached to the air inlet 42 for regulating the amount of air that is introduced into the plenum 38 and burner assembly 10. An air opening 46 extends through the furnace wall 14 to allow air to be conducted from the plenum 38 to the burner tile 18.

[0103] A burner throat 48 is disposed through the burner tile 18. The burner throat 48 includes a throat wall 50 that defines and surrounds burner throat. The burner throat 48 has an inlet 52 and an outlet 54. The inlet 52 is adapted to receive combustion air (designated by arrows 40) from outside of the burner throat 48 (specifically, the plenum 38). The inlet 52 of the burner throat 48 is aligned over the air opening 46 extending through the furnace wall 14, thereby providing fluid communication between the burner throat 48 and the plenum 38. The outlet 54 of the burner throat 48 is positioned adjacent to the exterior surface 26 of the burner tile, and is positioned to introduce combustion air (designated by the arrows 40) into a combustion zone 58 located within the furnace 12 and adjacent to the exterior surface of the burner tile 18. Combustion air is discharged into the combustion zone 58 in the furnace 12 through the outlet 54 of the burner

throat 48.

[0104] The wall 50 of the burner throat 48 extends inwardly adjacent to the outlet 54 of the burner throat 48 to form a throat ledge 60. The throat ledge 60 functions to stabilize the flame.

[0105] The burner pilot assembly 20 is utilized to generate a pilot flame 62 within the burner throat 48. The burner pilot assembly 20 includes a pilot fuel riser 64 and a pilot fuel tip 66. The pilot fuel riser 64 has an inlet 68 adapted to be connected to a source of fuel 70, and an outlet 72 fluidly connected to the pilot fuel tip 66. The pilot riser extends through the air opening 46 in the furnace wall 14 into the burner throat 48. The pilot tip 66 is disposed within the burner throat 48. Preferably, the burner pilot assembly 20 pre-mixes the fuel with oxygen in the burner pilot assembly prior to generating the flame 62. This can be accomplished, for example, by using a mixer jet at the inlet of the pilot riser. The motive force of the fuel in the mixer jet draws in and admixes air (including oxygen) with the fuel.

[0106] The fuel injection assembly 22 is preferably adapted to inject essentially all of the fuel needed for operation of the burner assembly 10 into furnace 12 from one or more fuel tips 74 located outside of the burner throat. As used herein and in the appended claims, "essentially all" of the fuel needed for operation of the burner assembly 10 means all of the fuel needed to operate the burner except for fuel used in operating the burner pilot assembly 20. The fuel injection assembly 22 includes main fuel risers 76 and main fuel tips 78 for injecting main fuel into ignition zones 80 located within the furnace 12 and adjacent to the exterior surface 26 of the burner tile 18. The main fuel risers 76 have inlets 82 adapted to be fluidly connected to a source of fuel 84, and outlets 86 fluidly connected to the main fuel tips 78. Preferably, the portions of the main fuel risers 76 that would otherwise extend into the furnace 14 are disposed through the burner tile 18. The main fuel tips 78 are at least partially disposed within the furnace 12 and positioned adjacent to the lower front face 34(a)of the front face 34 of the sidewall section 32 of the burner tile 18. The main fuel tips 78 are positioned to inject main fuel along the front face 34 into the ignition zones 80. The ignition zones 80 are positioned adjacent to the sloped front face 34(b) of the front face 34. A plurality of main fuel risers 76 and main fuel tips 78 and a plurality of ignition zones 80 can be used. FIGS. 1 and 3-5 all depict two main fuel risers 76 and two corresponding main fuel tips 78, each injecting main fuel toward a separate ignition zone 80.

[0107] The fuel injection assembly 22 also includes a supplemental fuel injection assembly 90. The supplemental fuel injection assembly 90 is positioned to inject supplemental fuel into the combustion zone 58. The supplemental fuel injection assembly 90 includes supplemental fuel risers 92 and supplemental fuel tips 94. The supplemental fuel risers 92 have inlets 98 that are adapted to be fluidly connected to a source of fuel 100, and outlets 102 that are fluidly connected to the supplemental fuel tips 94. The supplemental fuel risers 92 are partially disposed through the burner tile 18 and extend into troughs 104 that are disposed in the burner tile 18. Each trough 104 includes a trough wall 106 and a trough outlet 108. The supplemental fuel risers 92 extend through the walls 106 of the troughs 104. The supplemental fuel tips 94 are positioned within the troughs 104 and positioned to inject supplemental fuel into the combustion zone 58 through the outlets 108 of the troughs. A plurality of supplemental fuel risers 92, supplemental fuel tips 94 and corresponding troughs 104 can be utilized. As depicted, the fuel injection assembly 22 includes two supplemental fuel risers 92, two supplemental fuel tips 94 and two corresponding troughs 104.

[0108] The burner assembly 10 further comprises ignition passageways 114 for receiving at least a portion of the flame 62 generated by the burner pilot assembly 20. The ignition passageways 114 conduct the flame 62 or portion thereof to the ignition zones 80 whereby the flame 62 or portion thereof can ignite main fuel injected by the main fuel tips 78 into the ignition zones. The ignition passageways 114 extend through the burner tile 18 between the burner throat 48 and the exterior surface 26 of the burner tile 18, specifically the sloped front face 34(b) of the front face 34 of the sidewall section 32 of the exterior surface 26 of the burner tile 18. The ignition passageways 114 include inlets 116 positioned adjacent to the burner throat 48, and outlets 118 positioned adjacent to the sloped front face 34(b).

[0109] As illustrated, each ignition passageway 114 receives a portion 62(a) of the flame 62 and conducts the flame portion 62(a) to an ignition zone 80. The flame portions 62(a) contact and ignite main fuel injected by the main fuel tips 78 into the ignition zones 80. A plurality of ignition passageways 114 may be used. As illustrated, the burner assembly includes two ignition passageways 114.

[0110] The burner assembly 10 further comprises flame diverters 124 for causing at least a portion of the flame 62 generated by the burner pilot assembly 20 to be diverted into the ignition passageways 114. As illustrated, the flame diverters 124 are adapted to cause a portion of the flame 62 generated by the burner pilot assembly 20, flame portion 62(a), to be diverted into the ignition passageways 114, and a portion of the flame 62 generated by said burner pilot assembly, flame portion 62(b), to be conducted through the outlet 54 of the burner throat 48 into the combustion zone 58. The relative amounts of the flame 62 forming the flame portions 62(a) and 62(b) can be adjusted as necessary. For example, the amount of the flame 62 diverted into flame portions 62(a) needs to be sufficient to allow the flame portions 62(a) to reach the ignition zones 80 and ignite main gas therein.

[0111] In the embodiment of the burner assembly 10 shown by FIGS. 1-7, the flame diverters 124 are impingement blocks 126 that are attached to the wall 50 of the burner throat 48 adjacent to the ignition passageway inlets 116. The impingement blocks 126 split the flame 62 into flame portions 62(a) and 62(b). They can also be configured to divert the entire pilot flame 62 into the ignition passageways 114.

[0112] As best shown by FIGS. 4-7, the flame portions 62(a) that are conducted through the ignition passageways 114 are also manipulated on the outside of the burner tile. In this respect, the burner assembly 10 includes turning members 140, the turning members 140 being located adjacent to the exterior surface 26 of the burner tile 18 and positioned to redirect the flame portions 62(a) from the outlets 118 of the ignition passageways across the exterior surface of the burner tile. In one embodiment, the turning members 140 are turning blocks 142 that are positioned on the sloped front face 34(b) of the front face 34 of the sidewall section 32 of the exterior surface 26 over the ignition passageway outlets 118. The flame portions 62(a) conducted through the ignition passageway outlets 118 impinge on the turning blocks 142 and are redirected through channels 144 that are disposed in the front sloped front face 34(b) across the sloped front face 34(b).

[0113] Stabilizing members 150 are positioned on the exterior surface 26 of the burner tile 18 to receive the flame portions 62(a) (or a portion thereof) and facilitate contact of the received flame with main fuel injected by the main fuel tips 78. Specifically, each stabilizing member 150 is attached to a corresponding turning block 142 and extends substantially perpendicularly therefrom below the corresponding channel 144 and along the sloped front face 34(b). The stabilizing members 150 act as bluff bodies in that they receive both the flames (or a portion thereof) from the turning blocks 142 and main fuel that is discharged from the main fuel tips 78. Main fuel discharged from the main fuel tips 78 is caused to slow down or impinge on the stabilizing members 150 where it is ignited by the flames.

[0114] A plurality of turning blocks 142, channels 144 and stabilizing members 150 can be utilized. As illustrated, a turning block 142, channel 144 and stabilizing member 150 are used in association with each of the two ignition passageways 114.

[0115] Referring now to FIGS. 8-10, additional configurations of the burner assembly 10 are illustrated. As mentioned above, the burner assembly 10 can be configured and associated with the furnace 12 in various ways. For example, the burner assembly 10 can be associated with the furnace 12 horizontally or vertically and can be fired upwardly (up-fired) or fired downwardly (down-fired). The burner assembly 10 can be associated with the furnace 12 at any orientation.

[0116] As shown by FIGS. 1 and 2, the burner assembly 10 is designed and configured to be horizontally mounted on a wall 14 of the furnace 12 and vertically fired adjacent to a side wall of the furnace. FIG. 8 illustrates a design and configuration of the burner assembly 10 that is adapted to be vertically mounted on a wall 14 of the furnace 12 and vertically fired adjacent to a side wall of the furnace. The inventive burner assembly shown by FIG. 8 is fired along the side wall of the furnace. For example, unlike the burner throat 48 illustrated by FIGS. 1 and 2, the burner throat 48 in the configuration shown by FIG. 8 is not "L" shaped but is straight.

[0117] FIG. 9 illustrates a design and configuration of the burner assembly 10 that is adapted to be vertically mounted on the floor 14 of the furnace and vertically fired into the interior 160 of the furnace. The inventive burner assembly shown by FIG. 9 can be attached or free standing in a middle area 162 of the interior 160 of the furnace. This configuration includes multiple main fuel tips and risers, ignition passageways and corresponding components. It does not include the troughs 104 and corresponding components for supplemental fuel injection.

[0118] FIG. 10 illustrates a design and configuration of the burner assembly 10 that is similar to the inventive burner assembly shown by FIG. 9, except in this configuration the inventive burner assembly is adapted to be vertically mounted from the ceiling 14 of the furnace 12 and vertically down fired into a middle area 162 of the interior 160 of the furnace.

[0119] Referring now to FIGS. 11A-11C, an alternative embodiment of the inventive burner assembly 10 is illustrated. In this embodiment, the ignition passageways 114 include Coanda surfaces 170 adjacent to the inlets 116 for causing at least a portion of the flame 62 generated by the burner pilot assembly 20 to be diverted into the ignition passageways 114. As a result, the flame diverters 124 are not necessarily needed. The flame 62 emitted from the pilot tip 66 or a portion thereof (depending on the velocity of the flame, the curvature of the Coanda surfaces and other factors known to those skilled in the art) adheres to and follows the path of the Coanda surfaces 170 into the ignition passageways 114. The Coanda surfaces 170 can be utilized in association with flame diverters 124 if desired.

[0120] As illustrated by FIGS. 11A-11C, the ignition passageways 114 can also include Coanda surfaces 174 adjacent to the outlets 118 of the ignition passageways 114 for causing at least a portion of the flame portions 62(a) conducted through the outlets 118 to be redirected across the sloped front face 34(b) of the front face 34 of the sidewall section 32 of the exterior surface 26 of the burner tile 18. As a result, the turning members 140 are not necessarily needed. The flame portions 62(a) conducted through the outlets 118 of the ignition passageways 114 adhere to and follow the paths of the Coanda surfaces 174 such that they are received by the stabilizing member 150. In this embodiment, the stabilizing member 150 is a ledge 178 positioned below the outlets 118. Turning members 140 can still be utilized if desired.

[0121] Referring now to FIGS. 12A-12C, another alternative embodiment of the inventive burner assembly 10 is illustrated. In this embodiment, the flame diverters 124 are fluid injection assemblies 180 associated with the ignition passageways 114 for injecting fluid into the ignition passageways toward the ignition zones 80 to create pressures in the injection passageways 114 that are lower than the pressure in the burner throat 48. The relatively low pressures in the injection passageways draw the pilot flame 62 or a portion thereof (flame portions 62a) into the injection passageways 114. The fluid injection assemblies 180 are adapted to be fluidly connected to a source of fuel 182 whereby the fluid injection assemblies can inject fuel into the ignition passageways 114. As best shown by FIG. 12C, fuel eductor pas-

sageways 190 are formed in the burner tile 18. Each fluid eductor passageways 190 extends from a main fuel riser 76 to the corresponding ignition passageway 114. An inlet 192 of each fuel eductor passageway 190 is fluidly connected to and receives main fuel from the corresponding main fuel riser 76. An outlet 194 of each fuel eductor passageway 190 is fluidly connected to the corresponding ignition passageway 114. In this way, fuel can be directly injected from the main fuel risers 76 into the ignition passageways 114 to educt the pilot flame 62 or a portion thereof into the ignition passageways. The main fuel in the fuel eductor passageways 190 is either ignited by the flame 62 and burned in the passageways or ignited and burned in the ignition zones.

[0122] Referring now to FIGS. 13A-13C, another alternative embodiment of the inventive burner assembly 10 is illustrated. In this embodiment, the ignition passageways 114 are disposed through the burner tile 18 at angles diverging radially outward from the burner throat 48. In this embodiment, the passageways 114 diverge radially outwardly at much greater angles from the burner throat 48 (as compared to the angles at which the passageways 114 diverge radially outwardly from the burner throat 48 as shown in FIG. 5). This places the flames emitted from the passageways 114 in closer proximity to the main fuel tips 78 and helps direct the flames across the sloped front face 34(b). Due to the location of the outlets 118 and the angle of injection of the flame therefrom, the turning members 140 are not necessarily needed. The flame portions 62(a) conducted through the outlets 118 of the ignition passageways 114 are received by stabilizing members 196. The stabilizing members 196 are ledges 198 positioned below the outlets 118. Turning members 140 can still be utilized if desired.

[0123] The sloped front face 34(b) can be steeply sloped or gently sloped. One determining factor includes the pressure used to inject main fuel from main fuel tips 78 onto the sloped front face 34(b).

Operation of the Inventive Burner Assembly

[0124] A variety of different types of fuels can be burned by the inventive burner assembly 10, including natural gas, methane, hydrogen, propane, propylene, ethane, ethylene, butane, butane, butylene, other typical refinery-type fuels and mixtures thereof. Preferably the fuel is in gaseous form, although with a fuel atomizer and other equipment as known in the art liquid fuel can be used.

[0125] The inventive burner assembly 10 can be used to combust fuel in the furnace space 16 in order to generate heat without admixing a significant amount of fuel with combustion air in the burner throat 48. As used herein and in the appended claims, "without admixing a significant amount of fuel with combustion air in the burner throat 48" means without adding fuel (e.g., primary fuel) to the burner throat except for fuel added to the burner throat in connection with generating the pilot flame 62 therein.

[0126] The inventive burner assembly 10 is attached to the furnace wall 14 such that the exterior surface of the burner tile 18 extends into the furnace space 16. The burner assembly 10 can also freely stand in the interior of the furnace 12. As explained above, combustion air (illustrated in the drawings by arrows 40) is provided to the burner throat inlet 52 from plenum 38 through the air opening 46.

[0127] Combustion air is conducted from the plenum 38 into the burner throat 48 and through the outlet 54 of the burner throat into the combustion zone 58. The combustion zone 58 is located within the furnace 12 and adjacent to exterior surface 26 of burner tile 18. A pilot flame 62 is generated within burner throat 48 with pilot fuel provided by the burner pilot assembly 20. Prior to generating the pilot flame, oxygen is pre-mixed with the pilot fuel in the burner pilot assembly 20.

[0128] Essentially all of the fuel needed for operation of burner assembly 10 is injected into the furnace 12 from fuel tips 74 located outside of burner throat 48. As stated above, as used herein and in the appended claims, "essentially all" of the fuel needed for operation of the burner assembly 10 means all of the fuel needed to operate the burner except for fuel used in operating the burner pilot assembly 20. The fuel tips 74 include main fuel tips 78. Main fuel tips 78 inject main fuel into the ignition zones 80 located within the furnace 12 and adjacent to the exterior surface 26 of burner tile 18. Main fuel is ignited in ignition zones 80. The ignited main fuel is then admixed with combustion air in the combustion zone 58. The primary combustion of the fuel for generating heat in the furnace occurs in the combustion zone 58.

[0129] In one embodiment, at least a portion of the pilot flame 62 generated in the burner throat 48 is used to ignite main fuel in the ignition zones 80. The pilot flame 62 or portion thereof is conducted into the ignition zones 80 through ignition passageways 114 extending through the burner tile 18 between the burner throat 48 and the exterior surface 26 of the burner tile whereby the pilot flame or portion thereof can contact and ignite fuel in the ignition zones 80.

[0130] The pilot flame 62 or portion thereof is diverted into the ignition passageways 114. Preferably, first portions 62 (a) of the pilot flame are diverted into the ignition passageways 114 and a second portion 62(b) of the pilot flame is allowed to be conducted through the burner throat 48 into the combustion zone 58. In one embodiment, the pilot flame or portions thereof are diverted into the ignition passageways by impinging the pilot flame or portions thereof on the flame diverters 124 located in the burner throat. In another embodiment, the ignition passageways 114 include Coanda surfaces, and the pilot flame 62or portions thereof are diverted into the ignition passageways by directing the pilot flame or portions thereof on the Coanda surfaces. In yet another embodiment, the pilot flame 62 or portions thereof are diverted

into the ignition passageways 114 by causing the pressures in the ignition passageways to be lower than the pressure in the burner throat 48. The pressures in the ignition passageways 114 are preferably caused to be lower than the pressure in the burner throat 48 by injecting an eductor fluid into the ignition passageways toward the ignition zones 80. Preferably, the eductor fluid is fuel.

[0131] The fuel tips 74 also include supplemental fuel tips 94 for injecting supplemental fuel into the combustion zone 58. Supplemental fuel is injected from the supplemental fuel tips 94 into the troughs 104 and into the combustion zone 58. As the supplemental fuel burns, it controls the flame in the combustion zone 58 by drawing the flame closer to the side wall 14 of the furnace 12. Use of the term "supplemental" herein should not be construed to mean that less fuel is conducted through the supplemental fuel tips 94 than through the main fuel tips 78. The volume of supplemental fuel discharged into the combustion zone 58 by the supplemental fuel tips 94 may exceed the volume of the main fuel discharged by the main fuel tips 78 in some applications.

[0132] In order to further illustrate the invention, the following example and test data are provided.

[0133] The inventive burner assembly 10 was tested for performance. The burner assembly 10 that was tested was generally configured like the burner assembly 10 shown in FIGS. 1-7.

[0134] The furnace 12 was cold when each test was started. The test data shown below was derived following a light-off procedure. The light-off procedure included the steps of opening the furnace damper, warming up the furnace with a heat release of about 0.75 MMBtu/hr for about 10 minutes at 12% O_2, and then increasing the heat release to about 1.25 MMBtu/hr for about 30 minutes at 9% O_2.

[0135] During startup, main fuel was injected onto the sloped front face 34(b) and impinged on flame stabilizing members 150. A portion of the pilot flame 62 (pre-mixed with oxygen) was diverted through ignition passageways 114 by flame diverter 124. The diverted flame was discharged from the ignition passageway 114 and was redirected onto the flame stabilizing members 150 by turning blocks 142. The diverted flame and main fuel injected from the main fuel tips 78 made contact in the ignition zones 80, and main fuel was ignited therein. The ignited main fuel continued to flow upwardly over the sloped front face 34(b) into the combustion zone 58. A portion of the flame 62 exited the outlet 54 of the burner throat 48 thereby providing an additional source of ignition and stabilizing the burner. In the combustion zone 58, supplemental fuel, combustion air from the burner throat 48 and the ignited main fuel further combusted in a manner in which a relatively low level of nitrogen oxides were produced.

[0136] The following test data was generated.

Test Data	
Data Set 1 (light off):	
Fuel	100% TNG*
Fuel Flow Rate	793.0 scfh
Fuel Temperature	94°F
Combustion Air Temperature	76°F
Stack Temperature	648°F
Furnace Temperature	799°F
Lower Furnace Temperature	278°F
Furnace Draft	0.24 in. H_2O
dP Burner	0.21 in. H_2O
Fuel Pressure	2.6 psig
Pre-Mixed Gas For Pilot	
Burner Heat Release	0.72 MMBtu/hr
Burner Flow Rate	793 soch
Burner Lower Heating Value	913.00 Btu/scf
NO_X Emissions	9.72 ppmvd
CO Emissions	307.94 ppmvd
O_2 (Dry)	14.34%vd
* Tulsa Natural Gas	

(continued)

Data Set 2 (rapid warm up):	
Fuel	100% TNG*
Fuel Flow Rate	1102.0 scfh
Fuel Temperature	94°F
Combustion Air Temperature	77°F
Stack Temperature	796°F
Furnace Temperature	960°F
Lower Furnace Temperature	394°F
Furnace Draft	0.25 in. H_2O
dP Burner	0.23 in. H_2O
Fuel Pressure	4.8 psig
Pre-Mixed Gas For Pilot	
Burner Heat Release	1.01 MMBtu/hr
Burner Flow Rate	1102 scfh
Burner Lower Heating Value	913.00 Btu/scf
NO_X Emissions	9.99 ppmvd
CO Emissions	653.77 ppmvd**
O_2 (Dry)	12.23%vd
* Tulsa Natural Gas	
**this value can be substantially decreased	with a slower warm-up rate
Data Set 3 (normal operation, TNG*):	
Fuel	100% TNG*
Fuel Flow Rate	1806.0 scfh
Fuel Temperature	99°F
Combustion Air Temperature	83°F
Stack Temperature	1417°F
Furnace Temperature	1573°F
Lower Furnace Temperature	1249°F
Furnace Draft	0.22 in. H_2O
dP Burner	0.15 in. H_2O
Fuel Pressure	12.1 psig
Pre-Mixed Gas For Pilot	
Burner Heat Release	1.65 MMBtu/hr
Burner Flow Rate	1806 scfh
Burner Lower Heating Value	913.00 Btu/scf
NO_x Emissions	10.92 ppmvd
CO Emissions	0.0 ppmvd
O_2 (Dry)	4.01%vd
* Tulsa Natural Gas	
Data Set 4 (normal operation, high hydrogen fuel):	
Fuel	47.70% TNG*
	20.79% Propane
	31.51% H_2
Fuel Flow Rate	811.0 scfh TNG

(continued)

Data Set 4 (normal operation, high hydrogen fuel):	
	353 scfh Propane
	536 scfh H_2
Fuel Temperature	106°F
Combustion Air Temperature	82°F
Stack Temperature	1448°F
Furnace Temperature	1591°F
Lower Furnace Temperature	1283°F
Furnace Draft	0.24 in. H_2O
dP Burner	0.17 in. H_2O
Fuel Pressure	12.1 psig
Pre-Mixed Gas For Pilot	
Burner Heat Release	1.71 MMBtu/hr
Burner Flow Rate	1701 scfh
Burner Lower Heating Value	1003.00 Btu/scf
NO_x Emissions	20.27 ppmvd
CO Emissions	0.0 ppmvd
O_2 (Dry)	3.88%vd
* Tulsa Natural Gas	
Data Set 5 (normal operation, high hydrogen fuel with air pre-heat):	
Fuel	48.01% TNG*
	20.47% Propane
	31.53% H_2
Fuel Flow Rate	818.0 scfh TNG
	350 scfh Propane
	537 scfh H_2
Fuel Temperature	120°F
Combustion Air Temperature	554°F
Stack Temperature	1525°F
Furnace Temperature	1674°F
Lower Furnace Temperature	1361°F
Furnace Draft	0.28 in. H_2O
dP Burner	0.24 in. H_2O
Fuel Pressure	14.0 psig
Pre-Mixed Gas For Pilot	
Burner Heat Release	1.70 MMBtu/hr
Burner Flow Rate	1704 scfh
Burner Lower Heating Value	998.39.00 Btu/scf
NO_x Emissions	26.06 ppmvd
CO Emissions	0.0 ppmvd
O_2 (Dry)	2.97%vd
* Tulsa Natural Gas	

[0137] Thus, the inventive burner assembly 10 performed very well. Essentially no carbon monoxide emissions were observed during normal operation of the burner assembly. Nitrogen oxide emissions were very low.

[0138] Other embodiments of the current invention will be apparent to those skilled in the art from a consideration of this specification or practice of the invention disclosed herein. Thus, the foregoing specification is considered merely exemplary of the current invention with the true scope thereof being defined by the following claims.

[0139] Thus, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned and alluded to as well as those which are inherent therein.

Claims

1. A burner assembly for a furnace comprising:

a burner tile for association with the furnace, said burner tile including:

an exterior surface to be positioned within the furnace; and
a burner throat disposed through said burner tile, said burner throat having an inlet and an outlet, said inlet of said burner throat adapted to receive combustion air from outside said burner throat, said outlet of said burner throat being positioned adjacent to said exterior surface of said burner tile and positioned to introduce combustion air into a combustion zone located within said furnace and adjacent to said exterior surface of said burner tile;

a burner pilot assembly for generating a pilot flame within said burner throat, said burner pilot assembly including a pilot fuel tip and a pilot fuel riser, said pilot fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet fluidly connected to said pilot fuel tip, said pilot fuel tip being disposed within said burner throat; and
a fuel injection assembly adapted to inject essentially all of the fuel needed for operation of said burner assembly into said furnace from one or more fuel tips located outside of said burner throat, said fuel injection assembly including a main fuel tip and a main fuel riser for injecting main fuel into an ignition zone located within said furnace and adjacent to said exterior surface of said burner tile, said main fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet fluidly connected to said fuel tip, said fuel tip being at least partially disposed within said furnace and positioned adjacent to said exterior surface of said burner tile.

2. The burner assembly of claim 1, wherein said burner tile further includes an ignition passageway for receiving at least a portion of the flame generated by said burner pilot and conducting said flame or portion thereof to said ignition zone whereby said flame or portion thereof can contact and ignite main fuel injected by said main fuel tip into said injection zone, said injection passageway extending through said burner tile between said burner throat and said exterior surface of said burner tile and having an inlet and an outlet, said inlet of said ignition passageway being positioned adjacent to said burner throat and said outlet of said ignition passageway being positioned adjacent to said exterior surface of said burner tile.

3. The burner assembly of claim 1 or 2, wherein said burner pilot assembly is adapted to pre-mix oxygen with fuel in said burner pilot assembly prior to generating said flame.

4. The burner assembly of any one of the preceding claims, wherein said ignition passageway includes a Coanda surface for causing at least a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway.

5. The burner assembly of any one of the preceding claims, further comprising a flame diverter for causing at least a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway;
wherein said flame diverter is optionally any one, some or all of:

(a) adapted to cause a portion of the flame generated by said burner pilot assembly to be diverted into said ignition passageway and a portion of the flame generated by said burner pilot assembly to be conducted through said outlet of said burner throat into said combustion zone;
(b) an impingement member located in said burner throat;
(c) a fluid injection assembly associated with said ignition passageway for injecting fluid into said ignition passageway toward said ignition zone, wherein, optionally, said fluid injection assembly is adapted to be fluidly connected to a source of fuel whereby said fluid injection assembly can inject fuel into said ignition passageway.

6. The burner assembly of any one of the preceding claims, wherein said exterior surface of said burner tile includes a top section, a bottom section and a sidewall section connecting said top section to said bottom section;
wherein, optionally, said main fuel combustion tip and said ignition zone are located adjacent to said sidewall section of said exterior surface of said burner tile;
wherein, optionally, said fuel injection assembly further includes a supplemental fuel tip and supplemental fuel riser for injecting supplemental fuel into said combustion zone, said supplemental fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet connected to said supplemental fuel tip;

wherein in such a case, optionally, said supplemental fuel riser is partially disposed through the burner tile and extends into a trough disposed in the burner tile that includes an outlet positioned adjacent to said combustion zone, and said supplemental fuel tip is disposed in said trough.

7. The burner assembly of any one of the preceding claims, further comprising a turning member, said turning member located adjacent to said exterior surface of said burner tile and positioned to redirect said flame or a portion thereof from said outlet of said ignition passageway across said exterior surface of said burner tile;
wherein said burner assembly optionally further comprises a stabilizing member, said stabilizing member positioned on said exterior surface of said burner tile to receive said flame or a portion thereof and facilitate contact of said flame or a portion thereof with fuel injected by said main fuel tip;
wherein, optionally, said stabilizing member is attached to said turning member and extends substantially perpendicularly therefrom along said exterior surface of said burner tile, and said stabilizing member receives said flame or a portion thereof from said turning block.

8. The burner assembly of any one of the preceding claims, wherein said fuel injection assembly further includes a supplemental fuel tip and supplemental fuel riser, said supplemental fuel riser having an inlet adapted to be fluidly connected to a source of fuel and an outlet connected to said supplemental fuel tip, said supplemental fuel tip being at least partially disposed within said furnace and positioned to discharge said supplemental fuel into said combustion zone.

9. A method of using a burner assembly that includes a burner tile and a burner throat extending therethrough to combust fuel in a furnace space in order to generate heat without admixing a significant amount of fuel with combustion air in the burner throat, comprising:

conducting combustion air through the burner throat into a combustion zone located within the furnace and adjacent to the exterior surface the burner tile;
generating a pilot flame in the burner throat with pilot fuel provided by a burner pilot assembly;
injecting essentially all of the fuel needed for operation of the burner assembly into the furnace from one or more fuel tips located outside of the burner throat, the one or more fuel tips including a main fuel tip for injecting main fuel into an ignition zone located within the furnace and adjacent to the exterior surface of the burner tile;
igniting main fuel in the ignition zone; and
admixing ignited main fuel with combustion air conducted through the burner throat in the combustion zone.

10. The method of claim 9, wherein at least a portion of the pilot flame generated in the burner throat is used to ignite main fuel in the ignition zone.

11. The method of claim 9 or 10, wherein the pilot flame or portion thereof is used to ignite main fuel in the ignition zone by conducting the pilot flame or portion thereof into the ignition zone through an ignition passageway extending through the burner tile between the burner throat and the exterior surface of the burner tile whereby the pilot flame or portion thereof can contact and ignite fuel in the injection zone.

12. The method of claim 9, 10 or 11, further comprising the step of pre-mixing oxygen with the pilot fuel in the burner pilot assembly prior to generating the pilot flame.

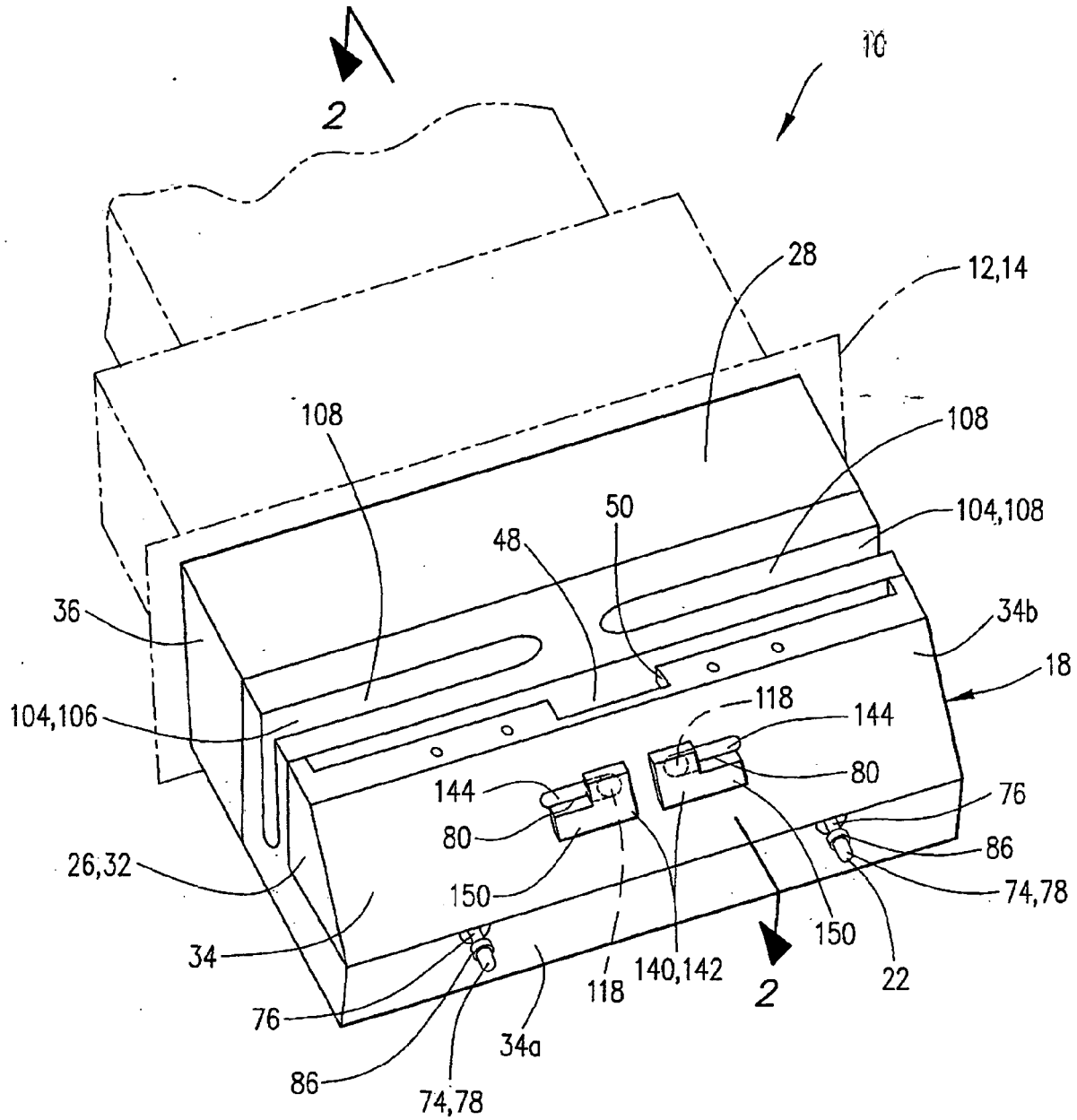
13. The method of any one of claims 9 to 12, further comprising diverting a first portion of the pilot flame into the ignition passageway and allowing a second portion of the pilot flame to be conducted through the burner throat into the combustion zone.

14. The method of any one of claims 9 to 13, further comprising the step of diverting the pilot flame or portion thereof into the ignition passageway;
wherein any one, some or all of the following apply:

(a) the pilot flame or portion thereof is diverted into the ignition passageway by impinging the pilot flame or portion thereof on a diverting member located in the burner throat;
(b) the ignition passageway includes a Coanda surface, and the pilot flame or portion thereof is diverted into the ignition passageway by directing the pilot flame or portion thereof on the Coanda surface;
(c) the pilot flame or portion thereof is diverted into the ignition passageway by causing the pressure in the ignition passageway to be lower than the pressure in the burner throat, wherein, optionally, the pressure in the

ignition passageway is caused to be lower than the pressure in the burner throat by injecting an eductor fluid into the ignition passageway toward the ignition zone, wherein the eductor fluid is preferably fuel.

15. The method of any one of claims 9 to 14, wherein the one or more fuel tips include a supplemental fuel tip for injecting supplemental fuel into the combustion zone, and said method further comprises the step of injecting supplemental fuel into the combustion zone.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74,78

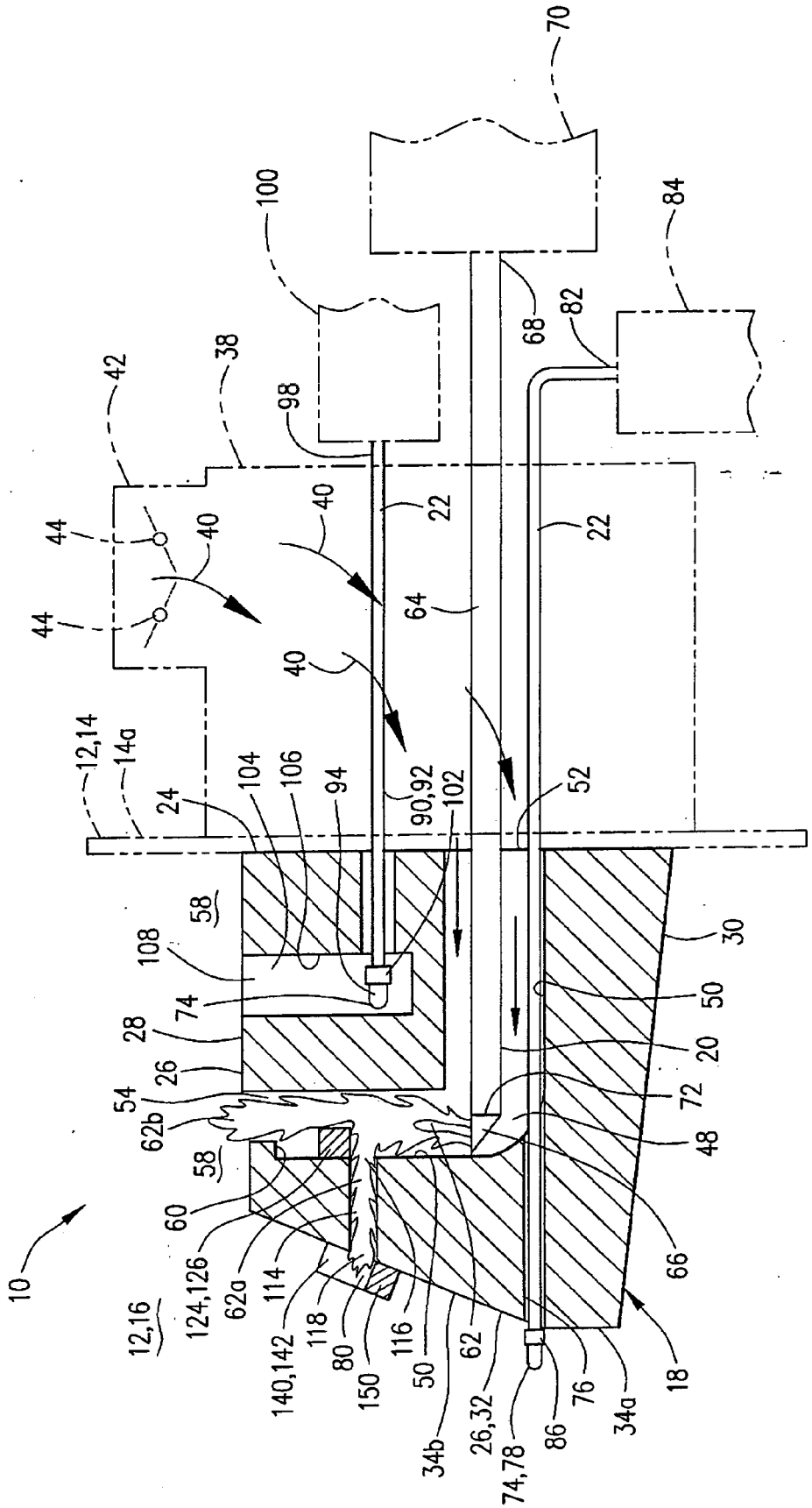

10
12,16
124,126
62a
114
118
80
150
140,142
116
50
62
34b
26,32
74,78
86
76
34a
18
66
48
72
20
50
30
58
108
74
28
26
54
62b
58
60
12,14
14a
24
104
106
94
90,92
102
52
64
40
44
22
38
42
98
100
68
82
84
70

FIG. 2

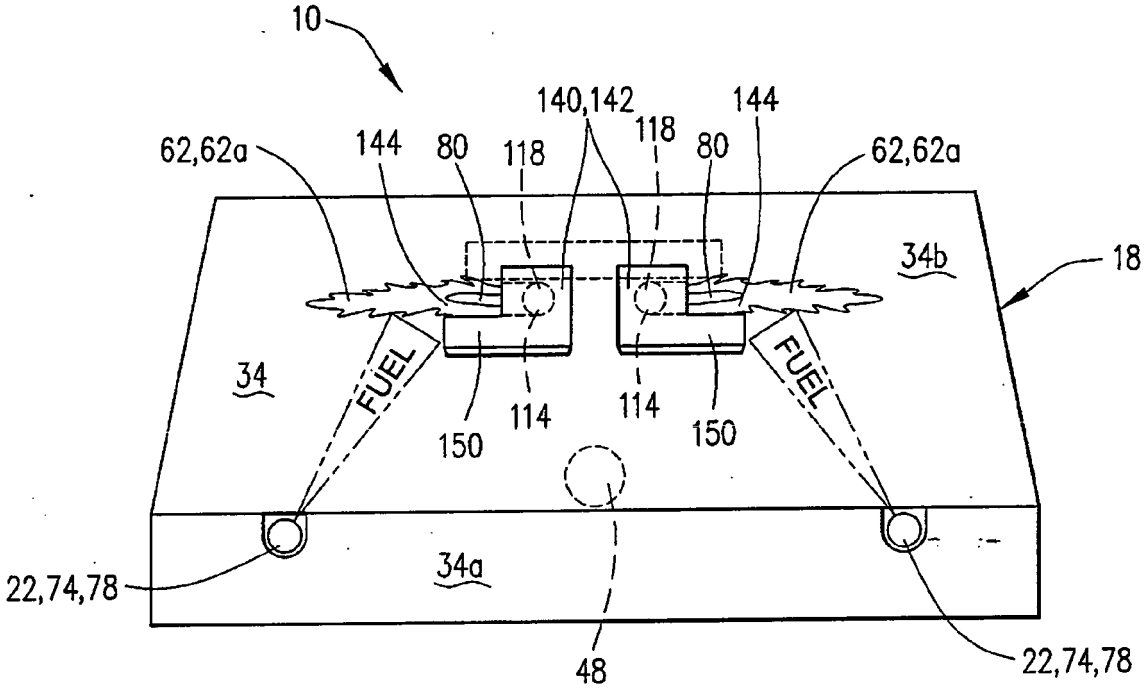

10
140,142
144
62,62a
144
80
118
118
80
62,62a
34b
18
34
FUEL
FUEL
150
114
114
150
34a
22,74,78
48
22,74,78

FIG. 3

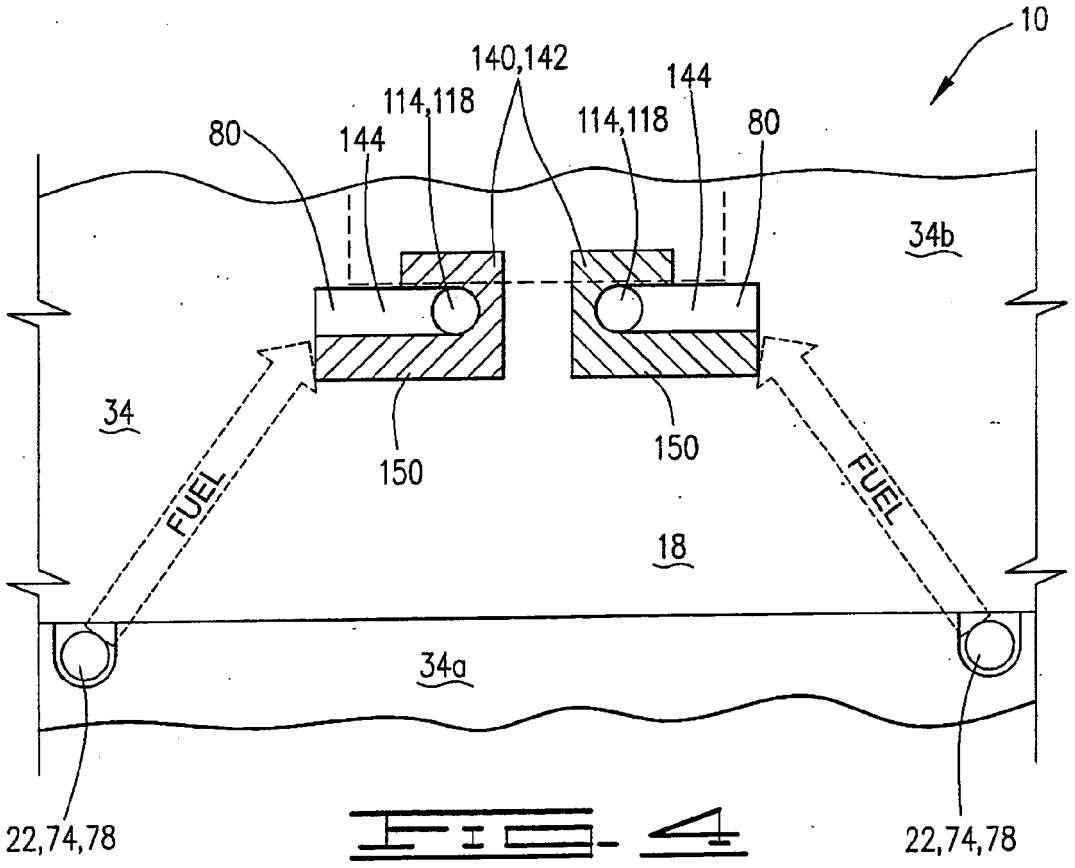

10
140,142
144
114,118
114,118
80
144
80
34b
34
FUEL
FUEL
150
150
18
34a
22,74,78
22,74,78

FIG. 4

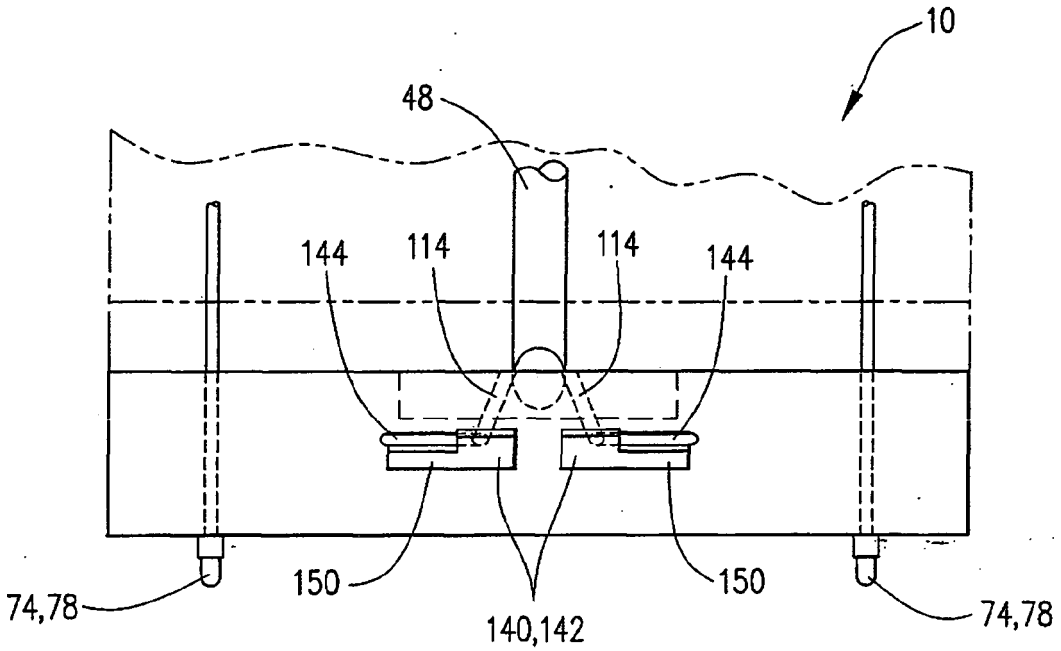


FIG. 5

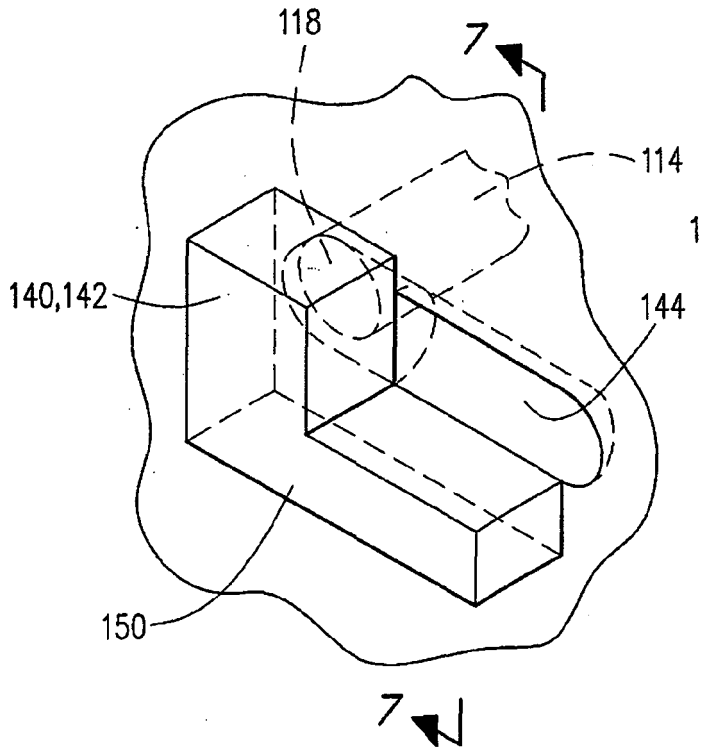


FIG. 6

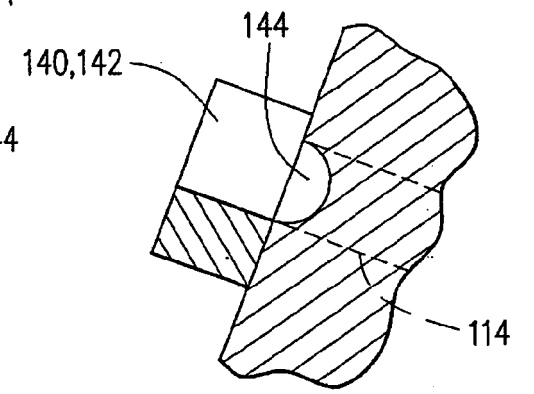
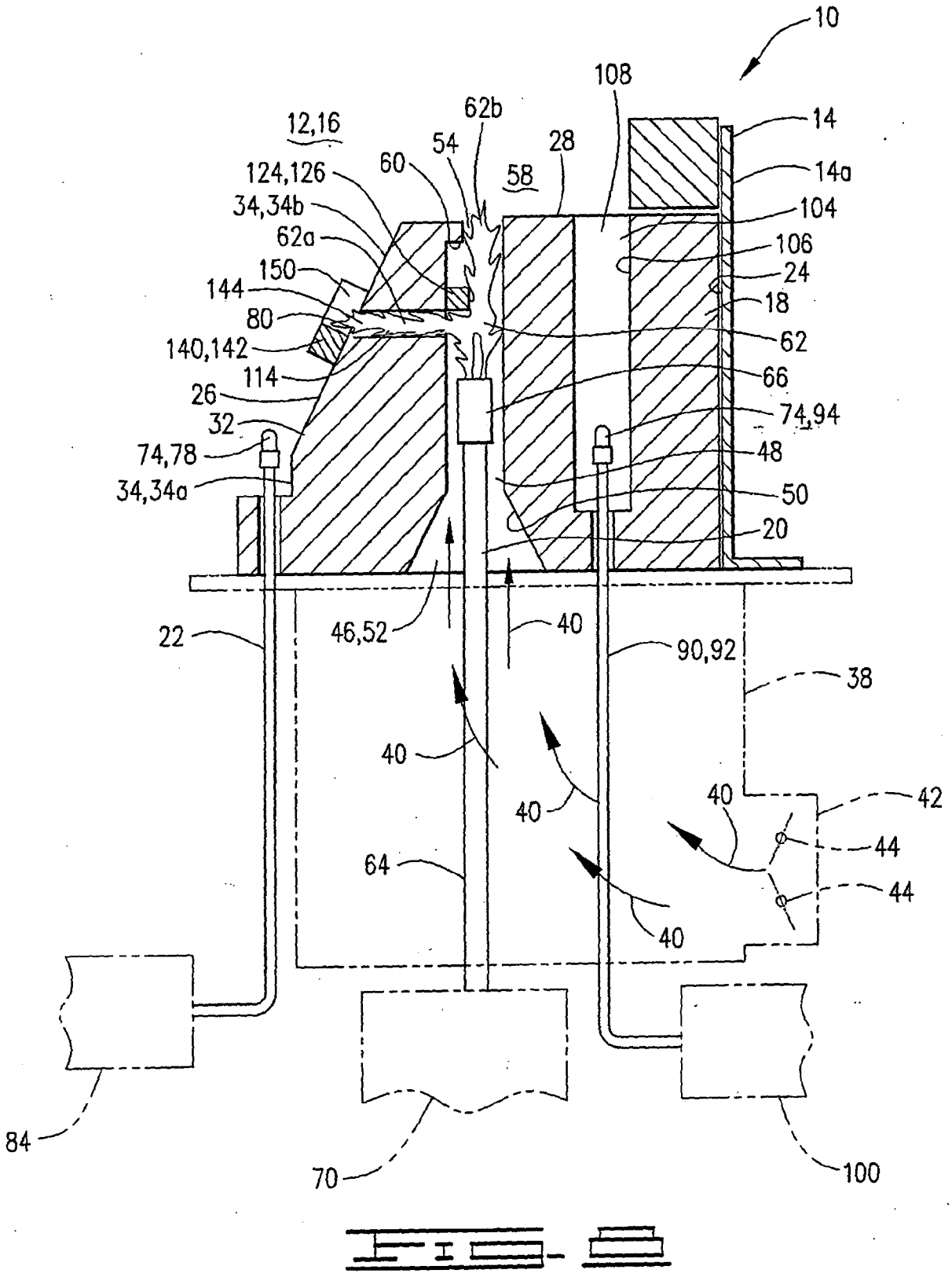


FIG. 7


10
108
12,16
62b
14
54
28
14a
60
58
124,126
104
34,34b
106
62a
24
150
18
144
62
80
140,142
66
114
74,94
26
48
32
74,78
50
34,34a
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22
46,52
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90,92
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42
40
44
64
44
40
84
70
100

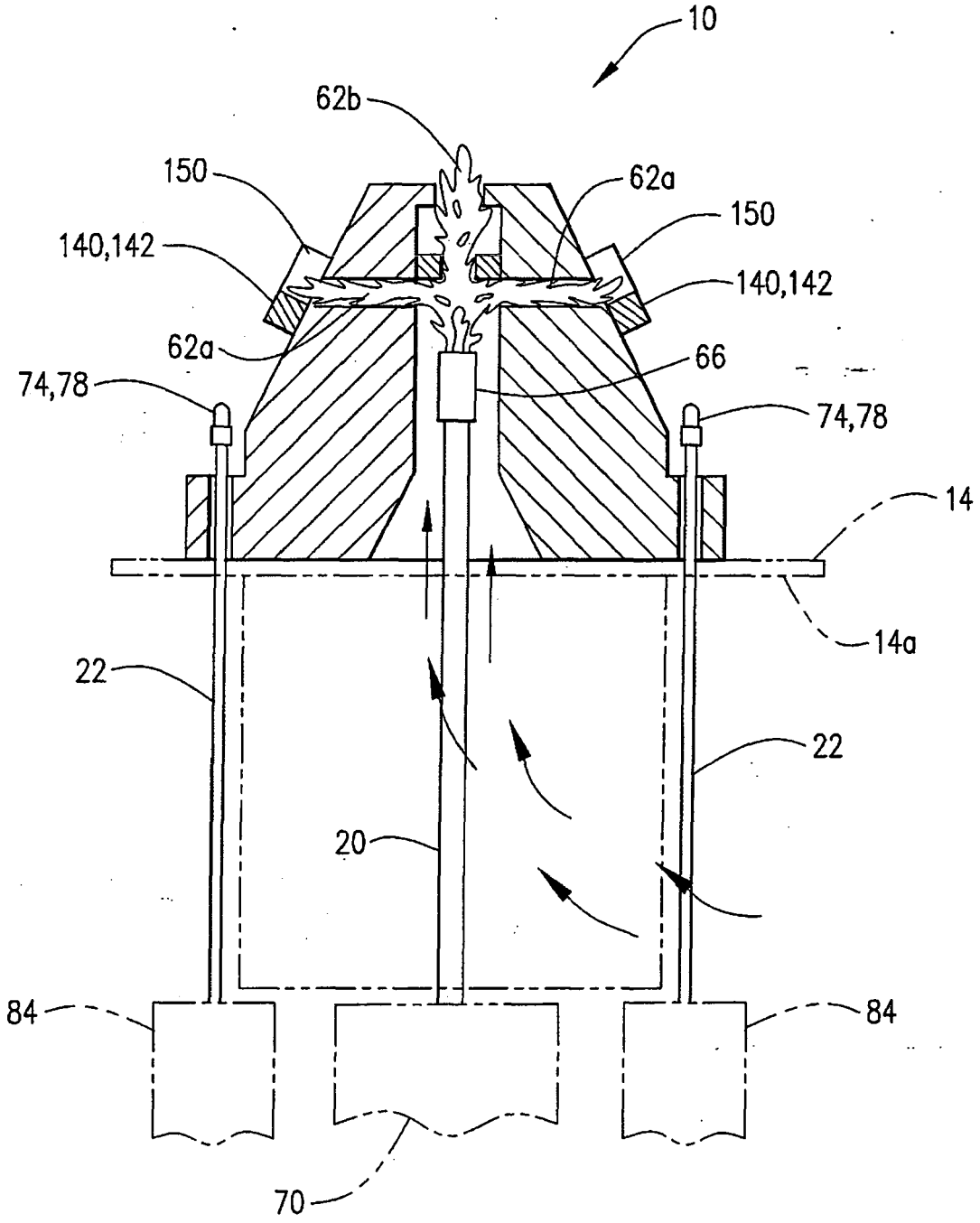
10
62b
150
62a
140,142
150
140,142
62a
66
74,78
74,78
14
14a
22
22
20
84
84
70

FIG. 3

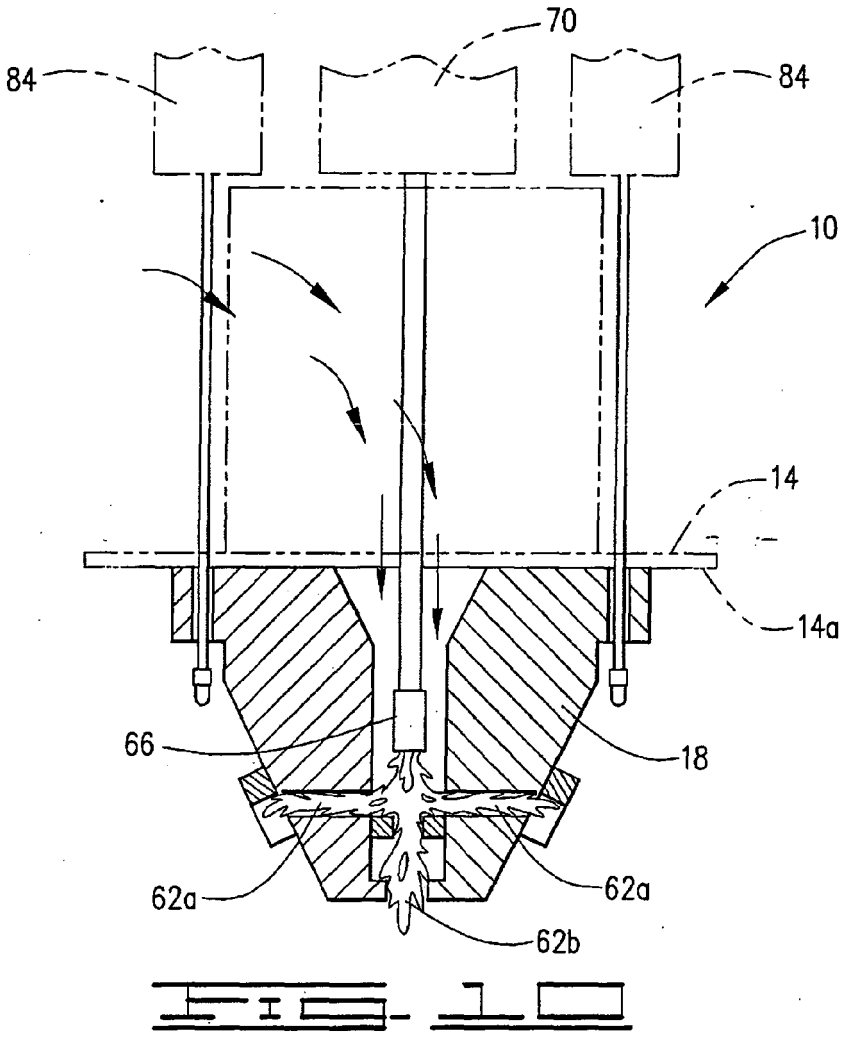

FIG. 10

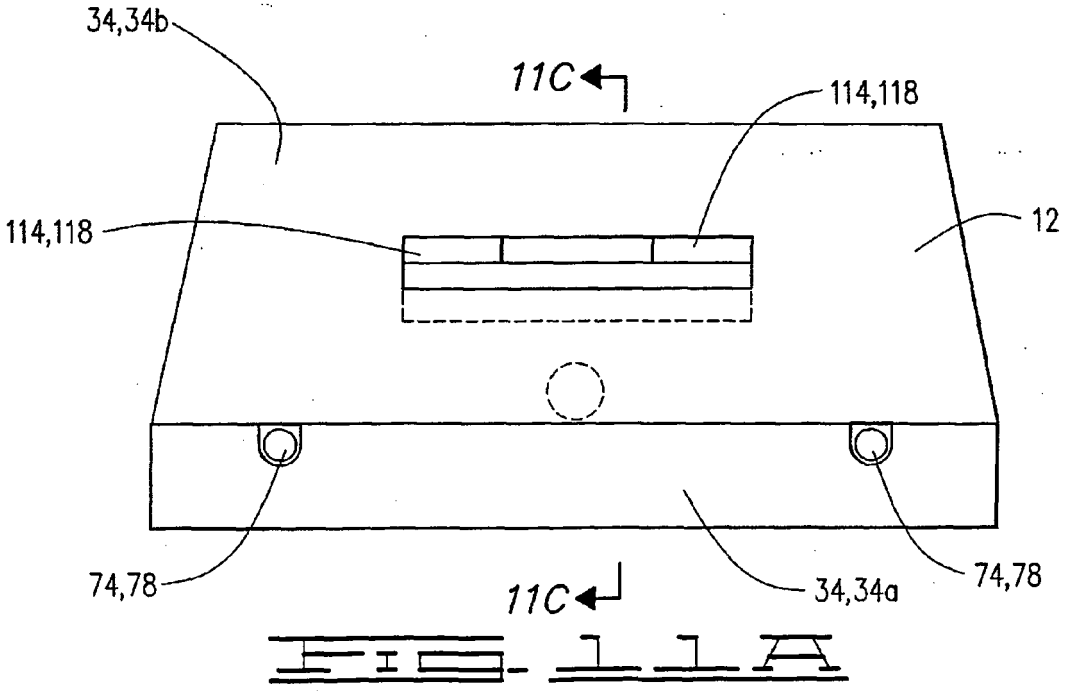

FIG. 11A

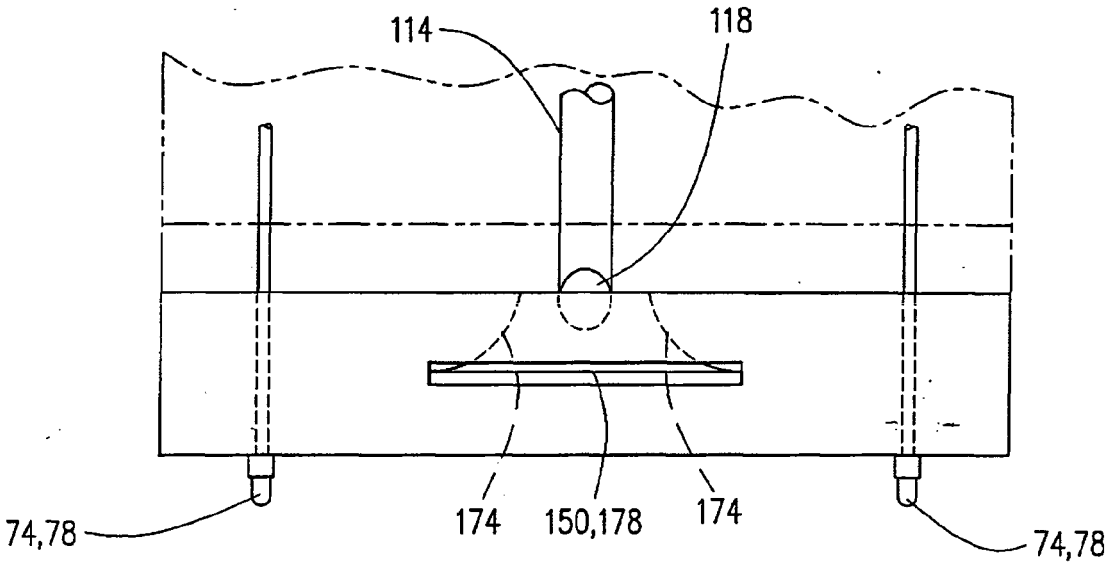

FIG. 11B

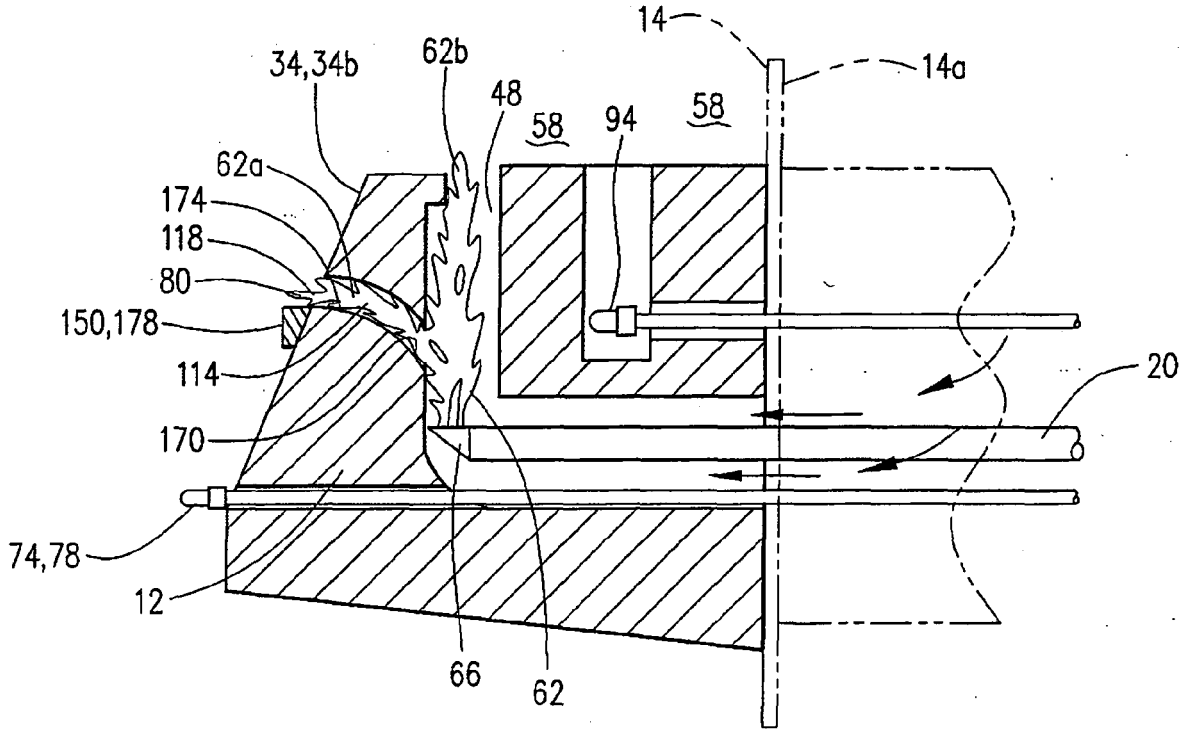

FIG. 11C

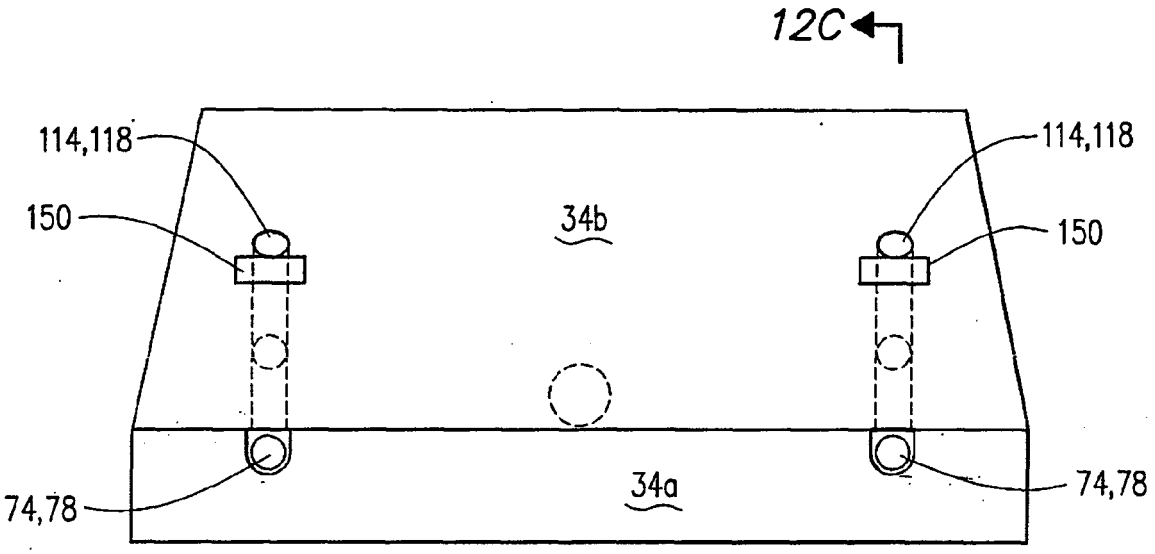

FIG. 12A

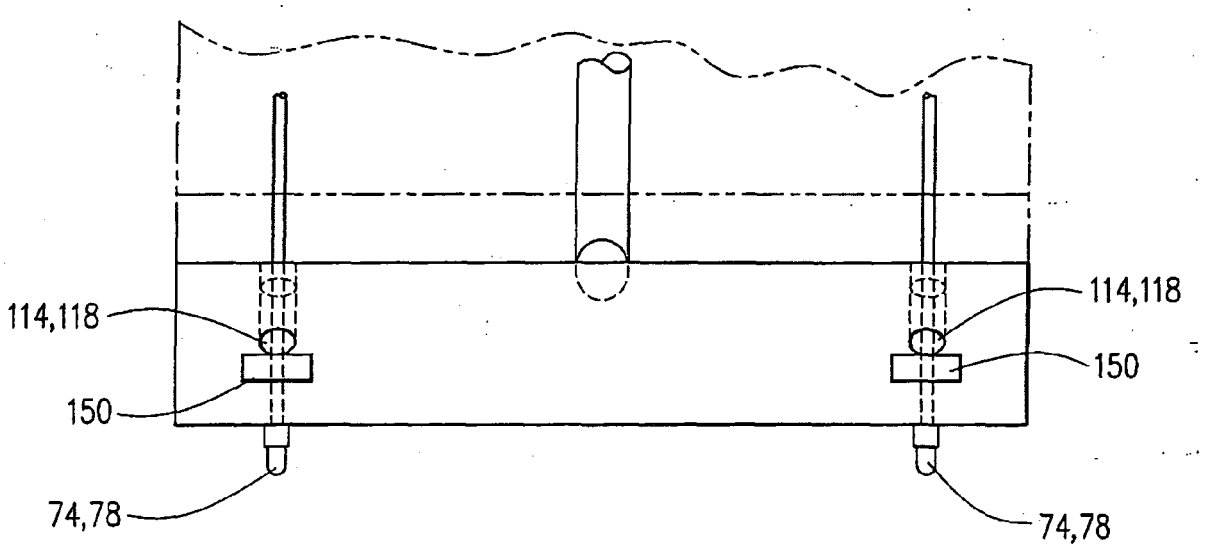

FIG. 12B

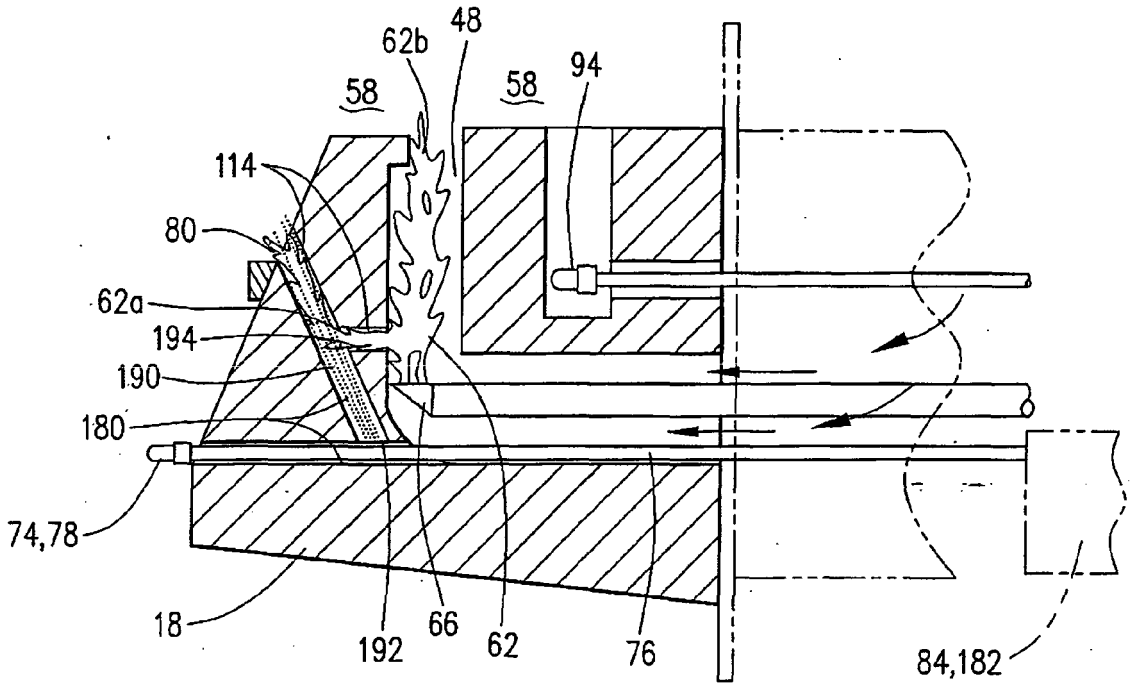

FIG. 12C

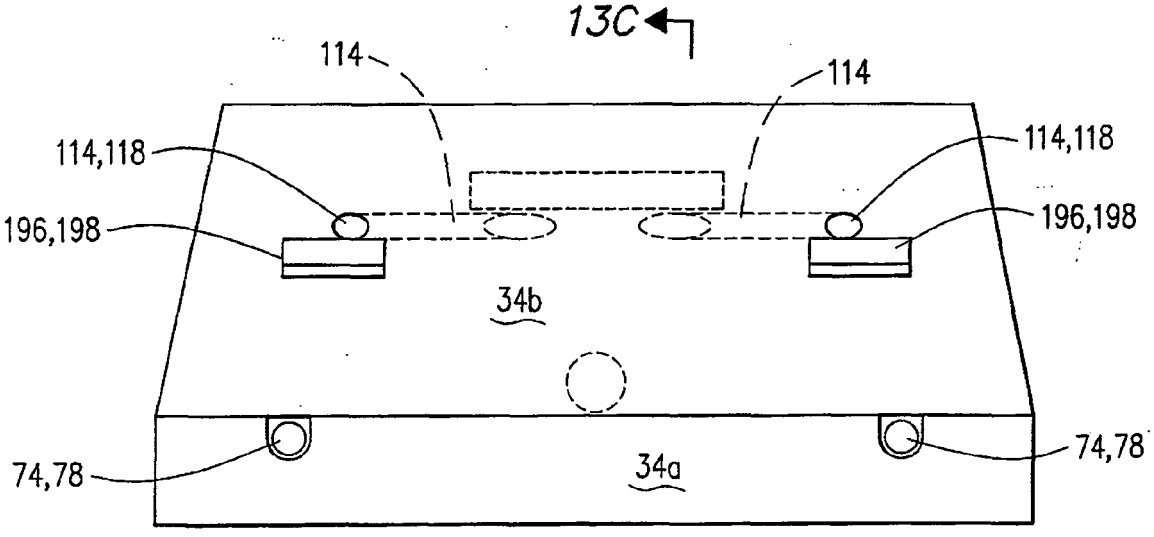

FIG. 13A

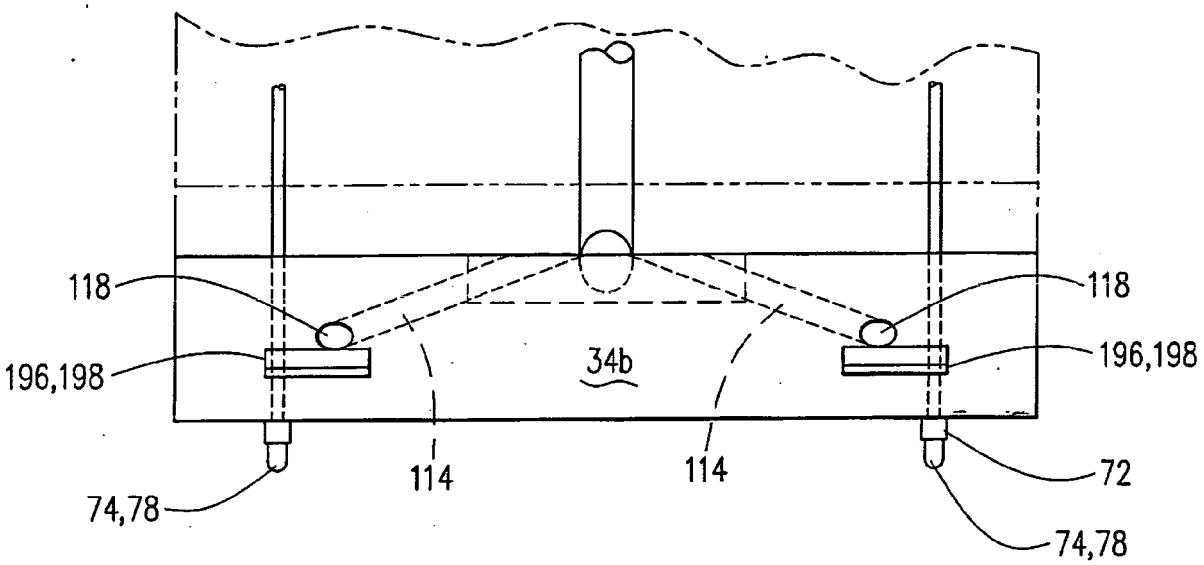

FIG. 13B

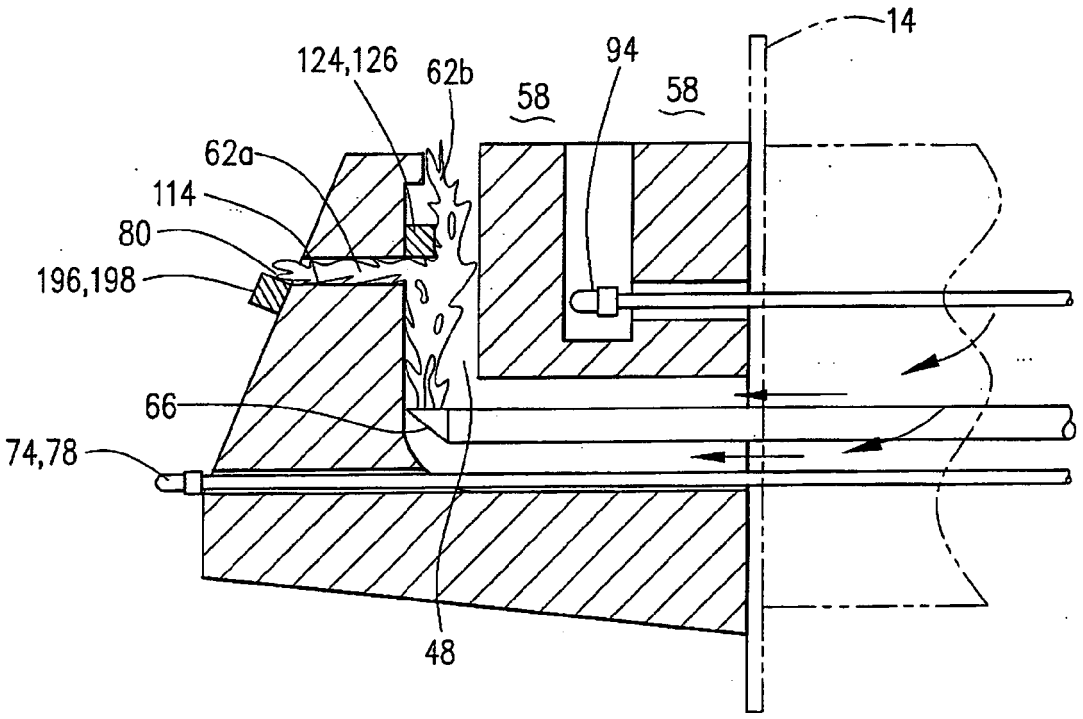

FIG. 13C