

INCINERATING SYSTEM

FIELD

[0001] The invention relates generally to incinerator and flare systems for combustion of waste gases and liquids occurring at gas or oil drilling sites, or waste process gases and liquids from various chemical and petrochemical applications.

BACKGROUND

[0002] Flammable hydrocarbons are generally used as energy sources but some situations may require their destruction, for instance in the event of a production surplus or an unexpected shutdown of equipment. Some flammable hydrocarbons are byproducts of natural or industrial processes where the source cannot be stopped and/or be easily controlled, and cannot be stored for a later use.

[0003] One example of source of a flammable gas that cannot be stopped and/or be easily controlled is a landfill site. In a landfill site, organic matter contained in the waste slowly decays over time using a natural process, generating a gas stream containing methane (CH_4). Methane is a flammable gas and is mixed with other flammable and non-flammable gases in varying proportions when coming out of the landfill site. Methane gas is a valuable source of energy but is also a greenhouse gas if released directly into the atmosphere. Thus, if the methane gas contained in a gas stream coming out of a landfill site cannot be readily used or stored, it should be destroyed by combustion in a gas flare. Gas streams containing methane gas can also be created by other processes, for instance in an anaerobic digester. Many other situations and contexts exist.

[0004] Systems such as flare apparatus for burning and disposing of combustible gases and fluids are well known. Flare apparatus are commonly mounted on flare stacks and are located at production, refining, processing plants and the like for disposing of flammable waste gases or other flammable gas streams which are diverted for any reason, including, but not limited to venting, shut-downs, upsets and/or emergencies.

[0005] It is generally desirable that the flammable gas/liquid be burned without producing smoke and typically such smokeless or substantially smokeless burning is mandatory. One method for accomplishing smokeless burning is by supplying combustion air with a steam jet pump, which is sometimes referred to as an eductor. Combustion air is provided to insure that the flammable gas is fully oxidized to prevent the production of smoke. Thus, steam is commonly used as a motive force to move air in a flare apparatus. When a sufficient amount of combustion air is supplied, and the supplied air mixes well with combustible gas, the steam/air mixture and flammable gas can be burned with minimal or no smoke.

[0006] In a typical flare apparatus, the required combustion air is supplied using motive force such as blower, a jet pump using steam, compressed air or other gas, to drive the internal flow in the desired direction as well supply air for combustion. As a result flare systems have several moving parts, which render these systems quite complex.

[0007] Flare stacks involving vertical combustors are more robust as they can rely heavily on the chimney effect and the natural desire of hot gases to rise in order to promote flow out of the stack as well as draw cold air into the system from the bottom of the intake. However, vertical configurations can be cumbersome to deploy, require substantial structural considerations due to height, and are difficult to service and maintain.

[0008] Flare stacks involving horizontal combustors require more motive force than vertical combustors in order to push flame to continue through the burner in the desired direction, as flame and hot gases take the path of least resistance.

[0009] Thus, there is a need for improved flare stack/incinerating systems for smokeless burning of combustible gases and liquids with air efficiently, while being simpler, cheaper, and faster to deploy and easy to maintain during operation.

SUMMARY OF THE INVENTION

[0010] The present invention relates to an incinerating system comprising an ejector system comprising an ejection nozzle and a fuel-air mixing system, a combustor, and an exhaust

system, wherein the fuel-air mixing system and/or at least a portion of the combustor are oriented in a non-conventional direction/configuration, and wherein the ejector system provides required motive force in order to drive flame to continue through the burner in a desired direction.

[0011] In accordance with an aspect of the present invention, there is provided a fuel incinerating system comprising: a) an ejector system comprising an ejection nozzle configured to eject fuel at a predefined forced velocity, and a multi-stage fuel-air mixing system having an inlet end and an outlet end, the inlet end being in fluidic communication with the fluid ejection nozzle to receive the fuel ejected from the nozzle, wherein the fuel-air mixing system is configured to entrain air to be mixed with the fuel to form a fuel-air mixture, wherein the multi-stage fuel-air mixing system comprising a plurality of concentric fuel intake tubes arranged in series, each intake tube having an inlet and an outlet, wherein the inlet of each intake tube has a cross sectional area greater than a cross sectional area of the outlet of a preceding intake tube, thereby providing an annular gap between adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into a subsequent intake tube; b) a combustor positioned downstream of the multi-stage fuel-air mixing system, the combustor having an inlet end in fluidic communication with the outlet end of the multi-stage fuel-air mixing system, and an outlet end, the combustor defining a combustion chamber between the inlet and the outlet thereof, the combustor further being in communication with a primary ignition source; and c) an exhaust system comprising a primary exhaust pipe having an inlet end in fluidic communication with the outlet end of the combustor and an outlet end to exhaust products of fuel combustion; wherein the multi-stage fuel-air mixing system and/or at least a portion of the combustor are oriented horizontally, oriented at an angle relative to horizontal, or oriented vertically downwardly, such that the fuel-air mixture and/or the products of the fuel combustion move in a respective axial direction.

[0012] In accordance with an embodiment of the present invention, there is provided fuel incinerating system comprising an ejector system, a combustor and an exhaust system as described above, wherein the multi-stage fuel-air mixing system and at least a portion of the combustor are coaxial and oriented horizontally, oriented at an angle relative to

horizontal, or oriented vertically downwardly, such that the fuel-air mixture and the products of the products of the fuel combustion move in a respective axial direction.

[0013] In accordance with another aspect of the present invention, there is provided a method of enhancing incineration of a fuel using the incinerating system as described herein.

BRIEF DESCRIPTION OF THE FIGURES

[0014] Further features and advantages of the present improvements/invention will become apparent from the following detailed description, taken in combination with the appended figures, in which:

[0015] Fig. 1 is a perspective view of the incinerating system in accordance with an embodiment of the present invention.

[0016] Fig. 1a is a partial enlarged view of Fig. 1.

[0017] Fig. 2 is a schematic cross-sectional view of the incinerating system of Fig. 1.

[0018] Fig. 3 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

[0019] Fig. 4 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

[0020] Fig. 5 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

[0021] Fig. 6 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

[0022] Fig. 7 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

[0023] Fig. 8 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

[0024] Fig. 9 is a perspective view of the incinerating system in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION

[0025] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

[0026] The term "fuel" as used herein includes waste gases and liquids occurring at gas and oil drilling sites or waste process gases and liquids from chemical and petrochemical application. Non limiting examples of waste gases are gases comprising methane, propane, butane and pentane and mixture thereof.

[0027] The expression "substantially complete combustion" as used herein refers to the combustion wherein at least 80% of the fuel has been combusted.

[0028] The term "combustion region" as used herein refers to at least $\frac{1}{4}$ of the length of the combustor.

[0029] The term "ejection" as used in the context of the present invention refers to discharge of a fuel by use of a high pressure, high velocity jet to entrain and pressurize an ambient fluid, such as air. The term "ejection" is sometimes used in the art interchangeably with the term "injection", and is intended in the present context to encompass those embodiments where the fuel is being introduced into the fuel-air mixer.

[0030] As used herein, the term "about" refers to approximately a +/-10% variation from a given value. It is to be understood that such a variation is always included in any given value provided herein, whether or not it is specifically referred to.

[0031] In the context of the present invention, the fuel intake tubes and exhaust pipes/ducts having a length to diameter (or width) ratio of less than 1:1 (or having diameter to length ratio more than 1:1) are also referred to as “diffuser ducts”. The fuel intake tubes having a length to diameter/width ratio of 1:1 or more (or having diameter to length ratio less than 1:1) are also referred to as “concentrator ducts”.

[0032] The present invention provides an incinerating system wherein fuel combustion can be achieved in a combustor oriented in a non-conventional direction, and the flame and combustion products are driven in a desired direction without requiring cumbersome motive forces, such as mechanical blower/fan, a jet pump using steam, etc. which are conventionally used in such systems.

[0033] The Applicant has surprisingly established that ejection of a fuel at a predefined forced velocity at the entrance of a multi-stage fuel-air mixing system as described herein, provides adequate fuel velocity for a fuel-air mixture to flow in any non-conventional direction (such as horizontal, at an angle relative to horizontal, and vertically downward direction i.e. upside down configuration) and entrain additional air on the way to form a fuel-air mixture having a fuel to air ratio sufficient for a substantially complete combustion reaction without requiring use of motive forces, while achieving positive flow of the products of the fuel combustion from a combustor oriented in a non-conventional direction (in line with the fuel-air mixing system) towards the outlet of the exhaust system without the use of motive forces.

[0034] Waste gases have a substantial amount of stored potential energy - chemical (due to the potential for combustion) and mechanical (due to the stored pressure relative to the atmosphere). The present application has surprisingly established that an ejector system comprising the multi-stage fuel-air mixing system as described herein, can harness both forms of energy to drive air entrainment for combustion within the unit, and promote flow of the flame and products of fuel combustion from a combustor oriented in a non-conventional direction, toward and out of the stack as intended.

[0035] The system of the present application surprisingly achieves an effective incineration process without requiring or relying on the chimney effect achieved by the natural

tendency of hot gases to rise in order to promote flow out of the stack as well as draw cold air into the bottom of the intake.

[0036] The incinerating system of the present invention is much simpler, cheaper and faster to deploy and easy to maintain during operation than conventional systems, as it does not require the presence of equipment such as blowers, fans, etc. to generate motive force. Nor does it require supporting equipment, such as guy wires, as it does not need to be erected in vertically upward direction. The non-conventional configurations (i.e. horizontal, angled, or vertically downward) of the system of the present invention allows for easier integration as a line heater, easier/simpler conversion of waste gas to electricity as units may be located relatively low to the ground, and/ or simpler and more economical collection of exhaust H₂O from a condenser.

[0037] The present invention provides an improved fuel incinerating system, which comprises an ejector system comprising an ejection nozzle configured to eject fuel at a defined forced velocity and a multi-stage fuel-air mixing system, a combustor, and an exhaust system.

[0038] The multi-stage fuel-air mixing system has an inlet end in fluidic communication with the fluid ejection nozzle to receive the fuel ejected from the nozzle, and an outlet end. The fuel-air mixing system is configured to entrain air to be mixed with the fuel to form a fuel-air mixture. The combustor has an inlet end in fluidic communication with the outlet end of the multi-stage fuel-air mixing system, and an outlet end, and defines a combustion chamber between the inlet and the outlet thereof. The combustor also communicates with a primary ignition source. The exhaust system comprises a primary exhaust pipe having an inlet end in fluidic communication with the outlet end of the combustor and an outlet end to exhaust products of fuel combustion.

[0039] The multi-stage fuel-air mixing system and/or at least a portion of the combustor are oriented at an angle relative to horizontal, or oriented vertically downwardly, such that the fuel-air mixture and/or the products of the fuel combustion move in a respective axial direction (i.e. in a horizontal direction, at an desired angle relative to horizontal, or in a vertically downward direction).

[0040] In some embodiments, the multi-stage fuel-air mixing system and at least a portion of the combustor are coaxial and oriented horizontally, oriented at an angle relative to horizontal, or oriented vertically downwardly, such that the fuel-air mixture and the products of the products of the fuel combustion move in a respective axial direction.

[0041] The multi-stage fuel-air mixing system of the present invention comprises a plurality of concentric fuel intake tubes arranged in series, each intake tube having an inlet and an outlet, wherein the inlet of each intake tube has a cross sectional area greater than a cross sectional area of the outlet of a preceding intake tube, thereby providing an annular gap between adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into a subsequent intake tube.

[0042] In some embodiments, the inlet of the first inlet tube is configured to entrain air to be mixed with the fuel to form the fuel-air mixture.

[0043] In some embodiments of the incinerating system of the present invention, the multi-stage fuel-air mixing system and the combustor are oriented horizontally. The primary exhaust pipe in some embodiments can be oriented horizontally to exhaust the products of fuel combustion in a horizontal direction. In some embodiments, the primary exhaust pipe is provided with a vertically oriented portion having the outlet end to exhaust the products of fuel combustion vertically in an upward direction through the outlet end.

[0044] In some embodiments, the primary exhaust pipe comprises a horizontally oriented portion having the inlet end in fluid communication with the outlet of the combustor, and a curved connecting portion between a vertically oriented portion and the horizontally oriented portion.

[0045] In some embodiments of the incinerating system of the present invention, the multi-stage fuel-air mixing system and the combustor are oriented at an angle relative to horizontal, such that the fuel-air mixture moves axially through the fuel-air mixing system and toward the combustor in an upward direction or a downward direction. The primary exhaust pipe in some embodiments can be oriented horizontally to exhaust the products of fuel combustion in a horizontal direction. In other embodiments, the primary exhaust pipe is provided with a vertically oriented portion having the outlet end to exhaust the

products of fuel combustion vertically in an upward direction. In some embodiments, the primary exhaust pipe comprises a curved connecting portion between the vertically oriented portion and the angled portion.

[0046] In some embodiments of the incinerating system of the present invention, the multi-stage fuel-air mixing system and the combustor are oriented vertically downwardly (i.e. in an inverted configuration), such that the fuel-air mixture and the products of the fuel combustion move axially through the fuel-air mixing system and the combustor in a downward direction. The primary exhaust pipe in these embodiments can be oriented horizontally to exhaust the products of fuel combustion in a horizontal direction, or can be provided with a vertically oriented portion having the outlet end to exhaust the products of fuel combustion vertically in a downward direction.

[0047] In preferred embodiments, the ejection nozzle is coaxial with the multi-stage fuel-air mixing system.

[0048] The ejector system of the present invention is contemplated to be suitable for use with different nozzle configurations. In some embodiments, the ejector system comprises a high pressure nozzle. In some embodiments, the nozzle is a subsonic, supersonic, or hypersonic fluid nozzle. In some embodiments, the fuel is ejected at a pressure of less than or equal to about 15psi. In some embodiments, the fuel is ejected at a pressure above 15psi.

[0049] The fuel intake tubes, combustor and/or the exhaust system of the incinerating system of the present invention can be configured individually or in combination so that the fuel ejected by the ejector nozzle and the initially entrained air move via the fuel-air mixing system with a velocity/speed sufficient to reach the combustion chamber while simultaneously entraining desired amount of additional air when air-fuel mixture is ejected from the outlet of one fuel intake tube into the inlet of the adjacent fuel intake tube, to achieve a desired retention time of the mixed fuel and air within the combustion chamber and a positive flow of the products of the fuel combustion from the combustor towards the outlet of the exhaust system to exit the system.

- [0050] In some embodiments, one or more of the plurality of fluid intake tubes increases in diameter from the inlet towards the outlet. In some embodiments, one or more of the plurality of fluid intake tubes can decrease in diameter from the inlet towards the outlet, and/or one or more of the plurality of fluid intake tubes can have a continuous diameter.
- [0051] The required velocity/speed for the fuel-air mixture for a particular fuel and the desired retention time/residency of the fuel-air mixture in the combustion chamber can be achieved by selection of the ejector nozzle for initial fuel ejection/injection, size and positioning of annular gaps for the air entrainment, size and positioning of the air intake tubes and/or the size and positioning of the combustor.
- [0052] The length to width/diameter ratio of fuel intake tubes closer to the ejection nozzle is generally higher than the length to width ratio of the fuel intake tubes closer to the combustor.
- [0053] The selection of the number of the intake tubes and their relative lengths and widths depends upon the size and type of combustor and/or the type and/or volume of the fuel to be incinerated.
- [0054] In some embodiments, the system includes one or more diffuser ducts positioned between the outlet end of the fluid intake tube proximate the combustor, and the inlet portion of the combustor.
- [0055] The diffuser duct can be used to decelerate the flow of the fuel-air mixture before it enters the combustor to further improve combustion performance. The cross sectional area of one or more of the diffuser ducts increases from the inlet end toward the outlet end.
- [0056] In some embodiments, the combustor has a combusting canister provided in the combustion chamber. In some embodiments, the combusting canister is coupled to the outlet end of the combustor via a flanged ring. In some embodiments, the combustion canister has a plurality of perforations or slots on its walls. In some embodiments, the canister is configured as a closed-bottom cylinder including a plurality of holes therein,

on the side walls and the bottom. In some embodiments the bottom is cone shaped. In some embodiments, the bottom is a flat wall.

[0057] In some embodiments, the combustor further comprises a flame holder.

[0058] The primary exhaust pipe can have a constant cross sectional area or a cross sectional area increasing or decreasing from the inlet end to the outlet end.

[0059] In some embodiments, the exhaust pipe further comprises one or more air intake vents.

[0060] In some embodiments, the exhaust system further comprises one or more diffuser ducts, each having an inlet and an outlet, positioned downstream of the primary exhaust pipe.

[0061] In some embodiments, the cross sectional area of one or more of the diffuser ducts increases from the inlet end toward outlet end. In some embodiments, the cross sectional area of one or more diffuser duct is constant.

[0062] In some embodiments the cross sectional area of at least the first diffuser ducts increases from the inlet end toward outlet end, and the cross sectional area of the last diffuser duct is constant.

[0063] In some embodiments, the exhaust system further comprises a secondary exhaust pipe concentric with the primary exhaust pipe, and having an inlet in communication with the outlet of the primary exhaust pipe and an outlet, wherein the inlet of the secondary exhaust pipe has a cross sectional area greater than a cross sectional area of the outlet of the primary exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from the primary exhaust pipe into the secondary exhaust pipe.

[0064] In some embodiments, the exhaust system further comprises one or more diffuser ducts, each having an inlet and an outlet, and being positioned downstream of the outlet end of the secondary exhaust pipe, wherein at least one of the diffuser ducts has a cross sectional area increasing from the inlet end to the outlet end thereof. In some embodiments, the diffuser duct having the inlet in communication with the outlet end of

the primary exhaust pipe has a cross sectional area increasing from the inlet end to the outlet end thereof.

[0065] In some embodiments, the exhaust system further comprises a plurality of concentric secondary exhaust pipes, each having an inlet and an outlet, wherein the first of the plurality of the secondary exhaust pipes is concentric with the primary exhaust pipe, and the inlet of at least one of the secondary exhaust pipes has a cross sectional area greater than a cross sectional area of the outlet of the preceding exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from one exhaust pipe into a subsequent exhaust pipe.

[0066] In some embodiments, each one of the secondary exhaust pipes has a cross sectional area greater than the cross sectional area of the outlet of the preceding exhaust pipe.

[0067] In some embodiments, the outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring connection.

[0068] In some embodiments, the outlet of the fuel air mixing system and the inlet of the combustor are connected via a flange-ring connection.

[0069] In some embodiments, the system comprises one or more support members to secure the fuel-air mixing system, the combustor, and/or the inlet portion of the exhaust pipe to a surface. In some embodiments, the surface is a concrete pad or a skid.

[0070] To gain a better understanding of the invention described herein, the following examples are set forth. It will be understood that these examples are intended to describe illustrative embodiments of the invention and are not intended to limit the scope of the invention in any way.

EXAMPLES

[0071] Fig. 1 schematically illustrates an example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **12** configured to receive fuel from a fuel source, a horizontally oriented multi-stage fuel-air mixing system **14**, a horizontally

oriented combustor **20**, and an exhaust system **22**. Fig. 1a is a partial enlarged view of Fig. 1.

[0072] As shown in Fig. 1a, the fuel-air mixing system **14** comprises concentric fluid intake tubes **15**, **16**, **17** and **18**, each having an inlet end (**15a**, **16a**, **17a** and **18a**, respectively) and an outlet end (**15b**, **16b**, **17b** and **18b**, respectively), and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end **15a** of the first fluid intake tube **15** is in fluidic communication with the fluid ejection nozzle **12** and the outlet end **15b** of the fluid intake tube **15** is in fluidic communication with the inlet end **16a** of the second fluid intake tube **16**, and so on. The outlet end **18b** of the intake tube **18** is in fluidic communication with inlet **20a** of combustor **20**. The outlet **20b** of combustor is in fluidic communication with exhaust system **22**.

[0073] The exhaust system comprises primary exhaust pipe comprising a horizontally oriented portion **24** having inlet **24a** in communication with the outlet **20b** of the combustor, a vertically oriented portion **26** having exhaust outlet **26b**, and a curved connecting portion **27** between the vertically oriented portion and the horizontally oriented portion. In this example, the vertically oriented portion of the primary exhaust pipe is provided with optional secondary cold air intake vents **28**. The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **30**. The system is securable to a concrete pad or a skid **32** via support members **34**.

[0074] Fig. 2 is a schematic cross-sectional view of the system of Fig. 1, showing a combustion canister **40** provided within the combustor **20**.

[0075] Fig. 3 schematically illustrates another example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **112**, a horizontally oriented multi-stage fuel-air mixing system **114**, and a horizontally oriented combustor **120**. The fuel-air mixing system **114** comprises concentric fluid intake tubes **115**, **116**, **117** and **118**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding

intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end of the first fluid intake tube **115** is in fluidic communication with the fluid ejection nozzle **112** and the outlet end of the fluid intake tube is in fluidic communication with the inlet end of the second fluid intake tube **116**, and so on, similar to the example depicted in Fig. 1a. The outlet end **118b** of the intake tube **118** is in fluidic communication with inlet **120a** of combustor **120**. The outlet **120b** of combustor is in fluidic communication with exhaust system.

[0076] In this example, the exhaust system comprises a primary exhaust pipe comprising a horizontally oriented portion **124** having inlet **124a** in communication with the outlet **120b** of the combustor **120**, a vertically oriented portion **126** having an outlet **126b**, and a curved connecting portion **127** between the vertically oriented portion and the horizontally oriented portion. The exhaust system also comprises a secondary exhaust pipe **136** concentric with the vertical portion of the primary exhaust pipe, having an inlet **136a** in communication with the outlet **126b** of the vertical portion of the primary exhaust pipe, and an outlet **136b**. The exhaust system further comprises a diffuser duct **138** in communication with outlet **136b** of the secondary exhaust pipe **136**, and a tertiary exhaust duct **140** in communication with outlet **138b** of the diffuser duct **138**. The tertiary exhaust duct **140** has exhaust outlet **140b**. The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **130**. The system is securable to a concrete pad or a skid **132** via support members **134**.

[0077] Fig. 4 schematically illustrates another example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **212**, a horizontally oriented multi-stage fuel-air mixing system **214**, a horizontally oriented combustor **220**. The fuel-air mixing system **214** comprises concentric fluid intake tubes **215**, **216**, **217** and **218**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end of the first fluid intake tube **215** is in fluidic communication with the fluid ejection nozzle **212** and the outlet end of the fluid intake tube is in fluidic communication with the inlet end of the second fluid intake tube **216**,

and so on, similar to the example depicted in Fig. 1a. The outlet end **218b** of the intake tube **218** is in fluidic communication with inlet **220a** of combustor **220**. The outlet **220b** of combustor is in fluidic communication with exhaust system.

[0078] In this example, the exhaust system comprises a primary exhaust pipe comprising a horizontally oriented portion **224** having inlet **224a** in communication with the outlet **220b** of the combustor **220**, a vertically oriented portion **226** having an outlet (not shown), and a curved connecting portion **227** between the vertically oriented portion and the horizontally oriented portion. The exhaust system also comprises a secondary exhaust pipe **236** concentric with the vertical portion of the primary exhaust pipe, having an inlet **236a** in communication with the outlet (not shown) of the vertical portion of the primary exhaust pipe, and an outlet **236b**. The inlet **236a** of the secondary exhaust pipe has a cross sectional area greater than the cross sectional area of the outlet of the vertical portion of the primary exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from the primary exhaust pipe into the secondary exhaust pipe. The exhaust system further comprises a diffuser duct **238** in communication with outlet **236b** of the secondary exhaust pipe, and a tertiary exhaust duct **240** is in communication with outlet **238b** of the diffuser duct **238**. The tertiary exhaust duct **240** has exhaust outlet **240b**. The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **230**. The system is securable to a concrete pad or a skid **232** via support members **234**.

[0079] Fig. 5 schematically illustrates another example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **312**, a horizontally oriented multi-stage fuel-air mixing system **314**, and a horizontally oriented combustor **320**. The fuel-air mixing system **314** comprises concentric fluid intake tubes **315**, **316**, **317** and **318**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end **315a** of the first fluid intake tube **315** is in fluidic communication with the fluid ejection nozzle **312** and the outlet end of the fluid intake tube **315** (not shown) is in fluidic communication with the inlet end **316a** of the second fluid intake tube **316**, and so on, similar to the example depicted in Fig. 1a. The outlet

end **318b** of the intake tube **318** is in fluidic communication with inlet **320a** of combustor **320**. The outlet **320b** of combustor is in fluidic communication with exhaust system.

[0080] In this example, the exhaust system comprises a primary exhaust pipe comprising a horizontally oriented portion **324** having inlet **324a** in communication with the outlet **320b** of the combustor **320**, a vertically oriented portion **326** having an outlet, a curved connecting portion **327** between the vertically oriented portion and the horizontally oriented portion. The exhaust system also comprises two concentric secondary exhaust pipes **336** and **338**. The first secondary exhaust pipe **336** is concentric with the vertical portion of the primary exhaust pipe, and has inlet **336a** having a cross sectional area greater than the cross sectional area of the outlet (not shown) of the primary exhaust pipe. The second exhaust pipe **338** has inlet **338a** having a cross sectional area greater than the cross sectional area of the outlet (not shown) of the primary exhaust pipe. The second exhaust pipe **338** has exhaust outlet **338b**.

The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **330**. The system is securable to a concrete pad or a skid **332** via support members **334**.

[0081] Fig. 6 schematically illustrates another example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **412**, a horizontally oriented multi-stage fuel-air mixing system **414** and a horizontally oriented combustor **420**. The fuel-air mixing system **414** comprises concentric fluid intake tubes **415**, **416**, **417** and **418**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end of the first fluid intake tube **415** is in fluidic communication with the fluid ejection nozzle **412** and the outlet end of the fluid intake tube is in fluidic communication with the inlet end of the second fluid intake tube **416**, and so on, similar to the example depicted in Fig. 1a. The outlet end **418b** of the intake tube **418** is in fluidic communication with inlet **420a** of combustor **420**. The outlet **420b** of combustor is in fluidic communication with exhaust system.

[0082] In this example, the exhaust system comprises a horizontally oriented primary exhaust pipe **424** having inlet **424a** in communication with the outlet **420b** of the combustor **420**, a horizontally oriented diffuser duct **436** extending from the primary exhaust pipe **424**. The diffuser duct **436** has exhaust outlet **436b** and/or a plurality of perforations **438** provided in the walls.

[0083] The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **430**. The system is securable to a concrete pad or a skid **432** via support members **434**.

[0084] Fig. 7 schematically illustrates an example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **512**, a multi-stage fuel-air mixing system **514**, and a combustor **520**, all oriented at an angle relative to horizontal, and an exhaust system. In this example, the multi-stage fuel-air mixing system and combustor are oriented such that the fuel-air mixture and the products of the fuel combustion move in an upward direction.

[0085] The fuel-air mixing system **514** comprises concentric fluid intake tubes **515**, **516**, **517** and **518**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end of the first fluid intake tube **515** is in fluidic communication with the fluid ejection nozzle **512** and the outlet end of the fluid intake tube is in fluidic communication with the inlet end of the second fluid intake tube, and so on, similar to the previous examples. The outlet end **518b** of the intake tube **518** is in fluidic communication with inlet **520a** of combustor **520**. The outlet **520b** of combustor is in fluidic communication with exhaust system.

[0086] In this example, the exhaust system comprises a primary exhaust pipe having an angled portion **524** having inlet **524a** in communication with the outlet **520b** of the combustor **520**, a vertically oriented portion **526** having an outlet (not shown), and a connecting portion **527** between the vertically oriented portion and the angled portion. The exhaust system also comprises a secondary exhaust pipe **536** concentric with the outlet of the

vertical portion of the primary exhaust pipe and having an inlet **536a** in communication with the outlet of the primary exhaust pipe, and an outlet **536b**. The inlet of the secondary exhaust pipe has a cross sectional area greater than the cross sectional area of the outlet of the primary exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from the primary exhaust pipe into the secondary exhaust pipe. The exhaust system further comprises a diffuser duct **538** having an inlet portion **538a** in communication with outlet **536b** of the secondary exhaust pipe, and a tertiary exhaust duct **540** is in communication with outlet **538b** of the diffuser duct **538**. The tertiary exhaust duct **540** has exhaust outlet **540b**. The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **530**. The system is securable to a concrete pad or a skid **532** via support members **534**.

[0087] Fig. 8 schematically illustrates an example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **612**, a multi-stage fuel-air mixing system **614**, a combustor **620**, all oriented at an angle relative to horizontal, and an exhaust system. In this example, the multi-stage fuel-air mixing system and combustor are oriented such that the fuel-air mixture move in a downward direction and the products of the fuel combustion are exhausted in an upward direction

[0088] The fuel-air mixing system **614** comprises concentric fluid intake tubes **615**, **616**, **617** and **618**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end of the first fluid intake tube **615** is in fluidic communication with the fluid ejection nozzle **612** and the outlet end of the fluid intake tube is in fluidic communication with the inlet end of the second fluid intake tube, and so on, similar to the previous examples. The outlet end (not shown) of the intake tube **618** is in fluidic communication with inlet **620a** of combustor **620**. The outlet **620b** of combustor is in fluidic communication with exhaust system.

[0089] In this example, the exhaust system comprises a primary exhaust pipe having an angled portion **624** having inlet **624a** in communication with the outlet **620b** of the combustor

620, a vertically oriented portion **626** having an outlet (not shown), and a connecting portion **627** between the vertically oriented portion and the angled portion. The exhaust system also comprises a secondary exhaust pipe **636** concentric with the vertical portion **626** of the primary exhaust pipe, having an inlet **636a** in communication with the outlet of the vertical portion of the primary exhaust pipe, and an outlet **636b**. The inlet of the secondary exhaust pipe has a cross sectional area greater than the cross sectional area of the outlet of the primary exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from the primary exhaust pipe into the secondary exhaust pipe. The exhaust system further comprises a diffuser duct **638** having an inlet portion **638a** in communication with outlet **636b** of the secondary exhaust pipe, and a tertiary exhaust duct **640** is in communication with outlet **638b** of the diffuser duct **638**. The tertiary exhaust duct **640** has exhaust outlet **640b**. The outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring **630**. The system is securable to a concrete pad or a skid **632** via support members **634**.

[0090] Fig. 9 schematically illustrates an example of the fuel incinerating system of the present invention, which comprises a fluid ejection nozzle **712**, a vertically oriented multi-stage fuel-air mixing system **714**, a vertically oriented combustor **720**, and vertically oriented exhaust system **722**, such that the fuel-air mixture and the products of the fuel combustion move vertically in a downward direction.

[0091] The fuel-air mixing system **714** comprises concentric fluid intake tubes **715**, **716**, **717** and **718**, each having an inlet end and an outlet end, and wherein the inlet of each tube has a cross sectional area greater than the cross sectional area of the outlet of the preceding intake tube, thereby providing an annular gap between two adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into the subsequent intake tube. The inlet end of the first fluid intake tube **715** is in fluidic communication with the fluid ejection nozzle **712** and the outlet end of the fluid intake tube is in fluidic communication with the inlet end of the second fluid intake tube, and so on, similar to the previous examples. The outlet end **718b** of the intake tube **718** is in fluidic communication with inlet **720a** of combustor **720**. The outlet **720b** of combustor is in fluidic communication with exhaust system **722**.

[0092] In this example, the exhaust system comprises a vertically oriented primary exhaust pipe **724** having inlet (not shown) in communication with the outlet **720b** of the combustor **720**, and a secondary exhaust pipe **726** concentric with the primary exhaust pipe, having an inlet **726a** in fluidic communication with the outlet (not shown) of the primary exhaust pipe, and an outlet **726b**. The inlet of the secondary exhaust pipe has a cross sectional area greater than the cross sectional area of the outlet of the primary exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from the primary exhaust pipe into the secondary exhaust pipe. The exhaust system further comprises a diffuser duct **738** having an inlet portion **738a** in fluidic communication with outlet **726b** of the secondary exhaust pipe, and a tertiary exhaust duct **740** in communication with outlet **738b** of the diffuser duct **738**. The tertiary exhaust duct **740** has exhaust outlet **740b**. The system is securable to a concrete pad or a skid **732**.

[0093] Although the invention has been described with reference to certain specific embodiments, various modifications thereof will be apparent to those skilled in the art without departing from the spirit and scope of the invention. All such modifications as would be apparent to one skilled in the art are intended to be included within the scope of the following claims.

CLAIMS:

1. A fuel incinerating system comprising:
 - a) an ejector system comprising:

an ejection nozzle configured to eject fuel at a predefined forced velocity, and

a multi-stage fuel-air mixing system having an inlet end and an outlet end, the inlet end being in fluidic communication with the fluid ejection nozzle to receive the fuel ejected from the nozzle, wherein the fuel-air mixing system is configured to entrain air to be mixed with the fuel to form a fuel-air mixture,

the multi-stage fuel-air mixing system comprising a plurality of concentric fuel intake tubes arranged in series, each intake tube having an inlet and an outlet, wherein the inlet of each intake tube has a cross sectional area greater than a cross sectional area of the outlet of a preceding intake tube, thereby providing an annular gap between adjacent intake tubes for entraining additional air when the fuel-air mixture is passed from one intake tube into a subsequent intake tube;
 - b) a combustor positioned downstream of the multi-stage fuel-air mixing system, the combustor having an inlet end in fluidic communication with the outlet end of the multi-stage fuel-air mixing system, and an outlet end, the combustor defining a combustion chamber between the inlet and the outlet thereof, the combustor further being in communication with a primary ignition source; and
 - c) an exhaust system comprising a primary exhaust pipe having an inlet end in fluidic communication with the outlet end of the combustor and an outlet end to exhaust products of fuel combustion;

wherein the multi-stage fuel-air mixing system and/or at least a portion of the combustor are oriented horizontally, oriented at an angle relative to horizontal, or oriented vertically downwardly, such that the fuel-air mixture and/or the products of the fuel combustion move in a respective axial direction.
2. A fuel incinerating system, wherein the multi-stage fuel-air mixing system and at least a portion of the combustor are coaxial and oriented horizontally, oriented at an angle

relative to horizontal, or oriented vertically downwardly, such that the fuel-air mixture and the products of the products of the fuel combustion move in a respective axial direction.

3. The incinerating system according to claim 1 or 2, wherein multi-stage fuel-air mixing system and the combustor are oriented horizontally.
4. The incinerating system according to claim 3, wherein the primary exhaust pipe is oriented horizontally.
5. The incinerating system according to claim 3, wherein the primary exhaust pipe comprises a vertically oriented portion having the outlet end to exhaust the products of fuel combustion vertically in an upward direction.
6. The incinerating system according to claim 5, wherein the primary exhaust pipe comprises a horizontally oriented portion having the inlet end, and a connecting portion between the vertically oriented portion and the horizontally oriented portion.
7. The incinerating system according to claim 1 or 2, wherein multi-stage fuel-air mixing system and the combustor are oriented at an angle relative to horizontal.
8. The incinerating system according to claim 7, wherein the primary exhaust pipe comprises a vertically oriented portion having the outlet end to exhaust the products of fuel combustion vertically in an upward direction.
9. The incinerating system according to claim 8, wherein the primary exhaust pipe comprises an angled portion having the inlet end, and a connecting portion between the vertically oriented portion and the angled portion.
10. The incinerating system according to claim 1, wherein the multi-stage fuel-air mixing system and the combustor are oriented vertically downwardly, such that the fuel-air mixture and the products of the fuel combustion move vertically in a downward direction.

11. The incinerating system according to claim 10, wherein the primary exhaust pipe comprises a vertically oriented portion having the outlet end to exhaust the products of fuel combustion vertically in a downward direction.
12. The incinerating system according to any one of claims 1 to 11, wherein the ejection nozzle is coaxial with the multi-stage fuel-air mixing system.
13. The incinerating system according to any one of claims 1 to 12, wherein the combustor further comprises a flame holder.
14. The incinerating system according to any one of claims 1 to 13, wherein the exhaust pipe further comprises one or more air intake vents.
15. The incinerating system according to any one of claims 1 to 14, wherein the exhaust system further comprises one or more diffuser ducts, each having an inlet and an outlet, and stacked downstream from the outlet end of the primary exhaust pipe, wherein at least one of the diffuser ducts has a cross sectional area increasing from the inlet end to the outlet end thereof.
16. The incinerating system according to claim 15 wherein the diffuser duct having an inlet in communication with the outlet end of the primary exhaust pipe has the cross sectional area increasing from the inlet end to the outlet end thereof.
17. The incinerating system according to any one of claims 1 to 14, wherein the exhaust system further comprises a secondary exhaust pipe concentric with the primary exhaust pipe, and having an inlet in communication with the outlet of the primary exhaust pipe and an outlet, wherein the inlet of the secondary exhaust pipe has a cross sectional area greater than a cross sectional area of the outlet of the primary exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from the primary exhaust pipe into the secondary exhaust pipe.
18. The incinerating system according to claim 17, wherein the exhaust system further comprises one or more diffuser ducts, each having an inlet and an outlet, and stacked

vertically upward from the outlet end of the secondary exhaust pipe, wherein at least one of the diffuser ducts has a cross sectional area increasing from the inlet end to the outlet end thereof.

19. The incinerating system according to claim 18, wherein the diffuser duct having an inlet in communication with the outlet end of the primary exhaust pipe has the cross sectional area increasing from the inlet end to the outlet end thereof.
20. The incinerating system according to any one of claims 1 to 14, wherein the exhaust system further comprises a plurality of concentric secondary exhaust pipes, each having an inlet and an outlet, wherein a first of the plurality of the secondary exhaust pipes being concentric with the primary exhaust pipe, and the inlet of at least one of the secondary exhaust pipes has a cross sectional area greater than a cross sectional area of the outlet of the preceding exhaust pipe, thereby providing an annular gap between adjacent pipes for entraining air when the products of fuel combustion are passed from one exhaust pipe into a subsequent exhaust pipe.
21. The incinerating system according to claim 20, each one of the secondary exhaust pipes has a cross sectional area greater than the cross sectional area of the outlet of the preceding exhaust pipe.
22. The incinerating system according to any one of claims 1 to 21, wherein the outlet of the combustor and the inlet of the primary exhaust pipe are connected via a flange-ring connection.
23. The incinerating system according to any one of claims 1 to 22, wherein the system comprises one or more support members to horizontally secure the combustor and the inlet portion of the exhaust pipe to a surface.
24. The incinerating system according to claim 23, wherein the surface is a concrete pad or a skid.