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(54) FLUID COMBUSTION DEVICE

FLÜSSIGKEITSVERBRENNUNGSVORRICHTUNG

DISPOSITIF DE COMBUSTION DE FLUIDE

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(73) Proprietor: **Elmac Technologies Limited**
Holywell, Flintshire CH8 9DP (GB)

(72) Inventors:
- **BINGHAM, Lewis**
  Holywell
  Flintshire CH8 9DP (GB)
- **HONG, Daomin**
  Holywell
  Flintshire CH8 9DP (GB)

(74) Representative: **HGF Limited**
Cavendish House
39-41 Waterloo Street
Birmingham, West Midlands B2 5PP (GB)

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Description

[0001] This invention relates generally to a fluid combustion device for use in flaring. More specifically, although not exclusively, this invention relates to fluid combustion devices for use in flare pilots or gas flares or flare stacks and to methods for operating such devices. Even more specifically, although not exclusively, this invention relates to flame front generators for use in flare pilots.

[0002] Flare systems 1', which commonly include flare stacks 2' and a fluid combustion device 3' such as a flare pilot 30' (as shown in Figure 1), find use in many gas processing facilities as a means to safely dispose of undesirable gases. These gases may be in the form of flammable and/or combustible waste gas streams and may be continuously vented or may be collected from one or more sources prior to disposal via a system of relief valves, blowdown valves and/or control valves.

[0003] Flare stacks 2' (also known as gas flares or flares) are upwardly directed ducts designed for the disposal by burning of the unwanted quantities of flammable and/or combustible gases and are commonly used in process industries, e.g. the petroleum industry. Flare stacks 2' typically have a first end 21' which is open to the atmosphere and a second end (not shown) which is connected to the source of flammable and/or combustible gases. A typical condition of operation is one in which the quantity of gas required to be disposed of varies greatly over time and/or is discontinuous. In order to ensure ongoing operation of the flare stack, it is typical to provide a continually burning pilot flame PF' adjacent the flare stack 2', such that emission at any time of unwanted flammable and/or combustible gas may be ignited. This ignition prevents the generation of a potentially dangerous cloud of explosive gas in the surrounds of the flare system 1' and is therefore intended to render any quantity of vented flammable and/or combustible gas benign. Furthermore, this ignition of unwanted flammable and/or combustible gas may prevent an environmentally harmful discharge of said gas into the environment. Flare stacks 2' typically provide a relatively elevated location for the combustion of such emissions, for example 30m or more above ground level, such that heat generated by said combustion is spaced from ground level (where personnel and/or other equipment may be located).

[0004] The pilot flame PF' is commonly generated by a flare pilot 30', in which a continuous flow of gaseous fuel, *e.g.* natural gas or plant gas, is provided through a supply conduit 5'. The supply conduit 5' is connected to a pilot tip 61' by a pilot mixer 6b' and a downstream conduit 6'.

[0005] Air is supplied via an air intake 7' and mixed with the fuel flow in a pilot mixer 6b', the fuel and air mixture then flowing through the downstream conduit 6' and being ignited adjacent the pilot tip 61', thereby generating a continuous pilot flame PF' at the pilot tip 61'. Flare pilots 30' are known in which air is continuously supplied at pressure thereto, *e.g.* in the form of compressed air. However, if the supply of such pressurised air is interrupted or stopped the pilot flame PF' may be extinguished. Other flare pilots 30' are known in which air is self-inspirated, *e.g.* entrained, by the flow of fuel within the flare pilots 30'.

[0006] It is important that the flare pilot 30' is able to reliably ignite the waste gases from the flare stack 2'. However, pilot flames PF' may be susceptible to being extinguished, for example under the influence of strong winds or other environmental conditions or by a reduction or interruption in the supply of fuel and/or air. Although only one flare pilot 30' is shown in Figure 1 it will be appreciated by one skilled in the art that in practice multiple such flare pilots 30' may be disposed, generally at regularly spaced intervals, around the flare stack 2'. Multiple such flare pilots 30' are commonly provided in an attempt to mitigate against the possibility of extinguishment of pilot flames PF'. Moreover, in some industries it is a regulatory requirement to provide continuous pilot flames PF', the presence or absence of which may be monitored via a thermocouple or an equivalent means.

[0007] In order to address the above issues, each flare pilot 30' is typically provided with an ignition means 4' which is designed to reliably reignite a pilot flame PF' should such a flame be extinguished, where reignition should typically be achievable even during a power failure and should be achievable independently of any other flare pilots 30' (if present). Such ignition means 4' are generally operable remotely from a generated pilot flame PF'. One such ignition means 4' may be a spark ignition, located adjacent or interior to the pilot tip 61' of a flare pilot 30'. A further ignition means 4' is a flame front generator 3" (as shown in Figure 2) which is a fluid combustion device 3".

[0008] A flame front generator 3" typically includes a supply conduit 5" providing a non-continuous flow of fuel to which air is supplied, via an air intake 7", and is mixed in a mixing chamber 6b". Downstream of the mixing chamber 6b" the fuel and air mixture is ignited, for example via an ignition means such as a spark generator 41", in order to generate a flame front which travels along a downstream conduit 6" to a distal end 61" thereof. The distal end 61" of the flame front generator 3" is typically disposed adjacent a pilot tip of a flare pilot 30". The air may be supplied at pressure, *e.g.* in the form of compressed air, or may be self-inspirated, *e.g.* entrained, into the fuel flow. The flame front, upon reaching the distal end 61" ignites or reignites a pilot flame PF" of the flare pilot 30". The air intake 7", mixing chamber 6b" and/or spark generator 41" are typically located at or about ground level, thereby enabling ease of manual operation and/or maintenance.

[0009] Flame front generators 3" are known to suffer from a propensity to form moisture within the downstream conduit 6" which can lead to corrosion of said conduit 6". A flame front generated by a known flame front generator 3" may be extinguished within the downstream conduit 6" prior to reaching the distal end 61" thereof, hence fail-

ing to ignite or reignite a pilot flame PF". Extinguishment may be caused by accumulated moisture within the downstream conduit 6". Such an occurrence may result in the continuous supply of fuel from a flare pilot 30" failing to combust and hence generating a potentially hazardous mass of fuel in the vicinity of a flare stack 2' (and any equipment or personnel thereabout). Furthermore, any emission of gas through a flare stack 2' may not be ignited, due to the absence of a pilot flame PF", which may therefore generate a potentially hazardous mass of said emitted gas in the vicinity of the flare stack 2' (and any equipment or personnel thereabout). In use, therefore, such a system may be wasteful of fuel, having both economic and environmental consequences, and can produce an unreliable pilot flame PF" which may be hazardous.

[0010] Another known issue with such systems is that when the flow of fuel is removed or interrupted, the flame front may travel back along the downstream conduit 6", consuming the fuel retained therein. Furthermore, the flame front may travel back from the ignition means 41' toward the air intake 7", for example when the velocity of the flame front exceeds the velocity of the fuel within the flame front generator 3". Such an occurrence is commonly known as flashback. The flame front may propagate along the downstream conduit 6" by deflagration and/or detonation.

[0011] The flame propagation will typically start as a deflagration. The deflagration is characterised by combustion occurring behind the pressure wave with the expansion of the combustion products driving the flame front forwards. However, as the flame accelerates the flame front can become unstable, which causes turbulence. Turbulence leads to faster mass transport and increases the surface area of material, *e.g.* gas (for example natural gas or plant gas), to burn which, in turn, leads to rapid flame acceleration and possibly the formation of shock waves ahead of the flame front. In certain circumstances, this can lead to the deflagration transitioning into a detonation. Both deflagration and detonation cause damage to the conduit and/or equipment through which they travel and may additionally result in damage to and/or failure of adjacent structures. In certain circumstances, this damage may be catastrophic and entail danger to personnel as well as structures and/or equipment, for example if the deflagration or detonation reaches the air intake 7", mixing chamber 6b" and/or spark generator 41" which may be located at or about ground level.

[0012] A flame front propagating by means of a deflagration travels through unburnt material, for example fuel or a fuel and air mixture, at subsonic speeds. In contrast, a flame front propagating by means of a detonation travels through unburnt material, *e.g.* fuel or a fuel and air mixture, at supersonic speeds, the shock wave associated with detonation and the flame front being coupled or superimposed. Clearly, due to the higher speeds and the greater destructive force, detonations are capable of causing more damage than are deflagrations. Therefore, it is particularly important to protect against flashback detonation. It is also important to protect against flashback deflagration.

[0013] US Patent 4,248,585 discloses an igniter for a flare stack for waste gases where a fuel gas for ignition aspirates combustion air through openings in a housing enclosing a supply line for the fuel gas. US Patent 4,025,281 discloses apparatus for flaring combustible waste gases including a vertical flare stack.

[0014] It would be desirable to provide a fluid combustion device that mitigates one or more of the aforementioned issues. It is a non-exclusive aim of the invention to provide such a device. It is a more general, non-exclusive aim of the invention to provide an improved fluid combustion device.

[0015] Accordingly, a first aspect of the invention provides a fluid combustion device, in accordance with Claim 1.

[0016] The fluid combustion device may be attached or attachable, *e.g.* associated or associable, at or adjacent an or the upper or open end of a flare stack.

[0017] According to the invention, the or each air inlet surrounds the primary flow axis or path and/or the flow conduit. According to the invention, the or each air inlet surrounds and/or is concentric with the primary flow axis or path and/or the flow conduit. The or each air inlet may be disposed symmetrically or substantially symmetrically about the primary flow axis or path. It will be appreciated that a single, continuous, air inlet may include more orders of symmetry than plural air inlets, particularly if said continuous air inlet is concentric with the primary flow axis or path and/or the flow conduit.

[0018] Where there are plural air inlets each air inlet may be positioned or arranged at evenly spaced locations circumferentially around the primary flow axis or path and/or the flow conduit. Alternatively, the plural air inlets may be positioned or arranged at non-evenly spaced locations circumferentially around the primary flow axis or path and/or the flow conduit. Additionally or alternatively, one or more of the plural air inlets may be located or positioned upstream or downstream of the other air inlet(s).

[0019] We have determined that the use of a symmetrical arrangement or substantially symmetrical arrangement of air inlet(s) and/or protection means enables an improved efficiency of entrainment of air into a flow of fuel and/or facilitates a more effective attenuation of flashback and/or facilitates a more balanced weight distribution, which is beneficial with such tall and thin structures.

[0020] The flow area of the flow conduit may increase or decrease at, adjacent or upstream of the air inlet or inlets, for example to encourage air to be entrained, in use, into a flow of fuel passing through the flow conduit.

[0021] There is further provided a fluid combustion device, *e.g.* for use with or in a flare pilot or burner, the fluid combustion device comprising a flow conduit with a fuel

inlet, an outlet and a continuous air inlet or plural air inlets between the fuel inlet and the outlet, wherein the or each air inlet comprises protection means mounted in or on or otherwise associated therewith, and wherein the flow area of the flow conduit increases and/or decreases at, adjacent or upstream of the or each air inlet to encourage air to be entrained, in use, through said protection means and into a flow of fuel passing along the flow conduit for ignition (or and ignited) in, at or downstream of the outlet to produce a flame, *e.g.* a flame front.

[0022] Also provided is a fluid combustion device, *e.g.* for use with or in a flare pilot or burner, the fluid combustion device comprising a flow conduit with a fuel inlet, an outlet and a throttle between the fuel inlet and the outlet, where a continuous air inlet or plural air inlets is or are disposed between the fuel inlet and the throttle and/or adjacent the fuel inlet or the throttle, the or each air inlet comprising protection means mounted in or on or otherwise associated therewith, and wherein, in use, the throttle is configured to throttle a flow of fuel along the flow conduit thereby to entrain air through said protection means and into said flow of fuel for ignition (or and ignited) in, at or downstream of the outlet to produce a flame, *e.g.* a flame front.

[0023] In embodiments, the flow conduit may comprise a constriction or restriction or flow restriction at, adjacent or upstream of the air inlet or inlets, for example to encourage air to be entrained, in use, into a flow of fuel passing through the flow conduit, *e.g.* by a venturi or jet effect.

[0024] The flow conduit may comprise first and second parts, for example an upstream part and a downstream part. The first or upstream part may comprise the fuel inlet of the fluid combustion device and/or the second or downstream part may comprise the outlet of the fluid combustion device. The first or upstream part may be upstream the air inlet or inlets and/or the second or downstream part may be downstream the air inlet or inlets. The first or upstream part may comprise a fuel outlet, which may be in fluid communication with an inlet of the second or downstream part. The one or more air inlets may be in fluid communication with the or an inlet of the second or downstream part.

[0025] The fuel outlet of the first or upstream part may be smaller than the inlet of the second or downstream part. According to the invention, when the or each air inlet surrounds and/or is concentric with the primary flow axis or path and/or the flow conduit, the inlet of the second or downstream part may comprise or correspond to the combined flow areas of the fuel outlet of the first or upstream part and the one or more inlets. The first or upstream part may comprise the or a constriction or restriction, for example it may taper from a first flow area to the fuel outlet, which may have a second flow area smaller than the first flow area.

The flow conduit may comprise a pipe or duct. The flow conduit may be of constant or substantially constant cross-section and/or cross-sectional area, e.g. along its length. Alternatively, the flow conduit may be of varied cross-section and/or cross-sectional area, *e.g.* varied along its length. The flow conduit may comprise a first end, for example which may comprise the fuel inlet and/or may be connected or connectable to a source (*e.g.* container) of fuel. The flow conduit may comprise a second end, for example which may comprise the outlet.

[0026] The air inlet or inlets may comprise or may each comprise an air inlet passageway, which may have a secondary flow axis or path. The secondary flow axis or path may extend at least in part at an acute angle relative to the primary flow axis or path. The secondary flow axis or path may extend at least in part perpendicularly or substantially perpendicularly relative to the primary flow axis or path. The primary flow axis or path may comprise a principal flow axis or path through the flow conduit, *e.g.* a first principal flow axis or path. The secondary flow axis or path may comprise a principal flow axis or path through or into the air inlet or air inlet passageway, *e.g.* a second principal flow axis or path.

[0027] There is also provided a fluid combustion device, *e.g.* for use in a gas flare or flare stack, the fluid combustion device comprising a flow conduit with a fuel inlet, an outlet, a primary flow axis or path through the flow conduit, a continuous air inlet passageway or plural air inlet passageways between the fuel inlet and the outlet and a secondary flow axis or path through the or each air inlet passageway, wherein the or each air inlet passageway comprises a protection means mounted in or on or otherwise associated therewith, and wherein the secondary flow axis or path extends at least in part at an acute angle relative to the primary flow axis or path such that air is entrained, in use, into a flow of fuel passing along the conduit for ignition (or and ignited) in, at or downstream of the outlet to produce a flame, *e.g.* a flame front.

[0028] At least part of the air inlet passageway may be tapered and/or conical, e.g. frusto-conical, in shape. The air inlet passageway may comprise one or two or more portions, which may comprise respective flow axes or paths. The air inlet passageway may comprise two or more portions, a first of which may extend along a first direction, which may extend or be parallel to the primary flow axis or path orflow conduit, and/or a second of which may extend along a second direction, which may extend at an acute angle relative to the primary flow axis or path. The second portion of the air inlet passageway may extend into the flow conduit and/or primary flow path and/or may be tapered and/or conical, e.g. frusto-conical, in shape. According to the invention, when the air inlet surrounds and/or is concentric to the primary flow axis or path or flow conduit, the secondary flow path may comprise an annular flow path.

[0029] The fluid combustion device may comprise a flame front generator, for example that is mounted or mountable to a pilot flare or burner at or adjacent its upper end or outlet. The flame front generator may comprise an ignition means, for example configured to ignite the

fuel or fuel and air mixture, *e.g.* in order to produce a flame (for example a flame front or a non-continuous flame). The ignition means may comprise a spark generating device.

[0030] The flow conduit may further comprise a mixing chamber, *e.g.* downstream of the fuel inlet and upstream of the outlet. The mixing chamber may be configured or configurable to achieve, in use, homogenous or substantially homogenous mixing of air and fuel flowing therealong, for example the mixing chamber may comprise a volume and/or length suitable for such mixing. Where an ignition means is provided the ignition means is preferably located downstream and/or adjacent the mixing chamber. In embodiments the outlet may comprise the mixing chamber. In embodiments the ignition means may be located in or adjacent the outlet and/or may be in communication with the outlet, *e.g.* adjacent the mixing chamber.

[0031] Where the or each air inlet comprises an air inlet passageway, the protection means may be located upstream a fluid connection between the air inlet and the flow conduit. The protection means may be located in or on or otherwise associated with, *e.g.* connected upstream, either the first or second portion of the air inlet passageway, preferably the first portion. The protection means may be configured to attenuate deflagration and/or detonation flashback, *e.g.* a propagating flame front and/or shock wave. The protection means may be configured to only partially attenuate deflagration flashback, *e.g.* a propagating flame front. Where the protection means is configured to only partially attenuate deflagration flashback, the pressure of any deflagration flashback passing therethrough may have a pressure below an accepted or acceptable value.

[0032] Said protection means may comprise a flame arrester or flame arrester element and/or an explosion safety protection device and/or an explosion safety device and/or an explosion venting element and/or an explosion venting device. Where the protection means comprises a flame arrester or flame arrester element, the flame arrester or flame arrester element may comprise an explosion safety protection device and/or an explosion safety device and/or an explosion venting panel and/or an explosion venting element and/or an explosion venting device. The explosion safety protection device and/or the explosion safety device and/or the explosion venting panel and/or the explosion venting element and/or the explosion venting device, where provided, may be configured or configurable to reduce or remove, in use, an explosion pressure thereagainst (*e.g.* via at least partial venting of an explosion therethrough) and/or to vent the combustion gasses and pressures resulting from deflagration/explosion. The explosion safety protection device and/or the explosion safety device and/or the explosion venting panel and/or the explosion venting element and/or the explosion venting device may be configured or configurable to at least partially move, in use, *e.g.* in order to allow passage therethrough of an explosion.

[0033] Most preferably the protection means comprises a flame arrester or flame arrester element. The protection means, *e.g.* the flame arrester or flame arrester element and/or the explosion safety protection device and/or the explosion safety device and/or the explosion venting element and/or the explosion venting device may comprise a plurality of small passageways, for example tortuous and/or small passageways or channels, arranged to attenuate deflagration and/or detonation flashback, for example arranged to at least partially attenuate deflagration flashback. The protection means, *e.g.* the flame arrester or flame arrester element and/or the explosion safety protection device and/or the explosion safety device and/or the explosion venting element and/or the explosion venting device may be configured to allow (for example substantially unhindered) passage of air, therethrough. The protection means, *e.g.* the flame arrester or flame arrester element and/or the explosion safety protection device and/or the explosion safety device and/or the explosion venting panel and/or the explosion venting element and/or the explosion venting device may be configured to prevent the passage therethrough of undesirable matter, *e.g.* waste and/or detritus and/or sources of ignition, for example sparks (for example from the surrounding environment). The protection means, *e.g.* the flame arrester or flame arrester element and/or the explosion safety protection device and/or the explosion safety device and/or the explosion venting panel and/or the explosion venting element and/or the explosion venting device may comprise one or more crimped ribbon elements. Additionally or alternatively, the protection means, *e.g.* the flame arrester or flame arrester element and/or the explosion safety protection device and/or the explosion safety device and/or the explosion venting panel and/or the explosion venting element and/or the explosion venting device may comprise one or more plate packs and/or annular plate stacks. Additionally or alternatively, the protection means, *e.g.* the flame arrester or flame arrester element and/or the explosion safety protection device and/or the explosion safety device and/or the explosion venting panel and/or the explosion venting element and/or the explosion venting device may comprise one or more wire gauze elements and/or one or more sintered metal elements and/or one or more perforated plates. We prefer to use a flame arrester element which is static in use, for example has no moving parts to effect a flame arrester function, in use.

[0034] In embodiments, where the fluid combustion device comprises plural air inlets (for example air inlet passageways) between the fuel inlet and the outlet, some or each of the plural air inlets (or air inlet passageways) may comprise separate or discrete protection means, *e.g.* separate or discrete flame arrester elements. The separate or discrete protection means, (*e.g.* separate or discrete flame arrester elements) may extend at least partially into (*e.g.* may be provided at least partially within) some or each of the plural air inlets (or air inlet passageways).

[0035] In embodiments, the fluid combustion device comprises a housing that includes, describes or defines at least part of the air inlet passageway. The housing may comprise a tapered and/or conical, *e.g.* frusto-conical, portion. The housing may comprise the protection means received therein.

[0036] The fluid combustion device may further comprise one or more diverter plates, *e.g.* configured to divert or direct, in use, the flow of fuel and/or air. The one or more diverter plates may be configured to divert or direct a flashback, *e.g.* a reversed deflagration and/or detonation. Where provided, the housing and/or the air inlet passageway may comprise the one or more diverter plates. In use, the one or more diverter plates may be configured to divert or direct at least a portion of a flow, *e.g.* a flashback or a flow of air and/or fuel. The one or more diverter plates may be configured to divert or direct, in use, a portion of a flashback toward the protection means and/or away from the fuel inlet.

[0037] The fluid combustion device may comprise one or more baffle members, *e.g.* configured to alter, in use, the flow, for example the flow pattern, of the fuel and/or air. The one or more baffle members may be located downstream of the fuel inlet, where provided. A portion of one or more of the baffle member or members may be located within the fuel inlet, where provided. Additionally or alternatively, one or more baffle members may be located within the fuel inlet, where provided. The one or more baffle members may comprise any suitable shape and/or size. The one or more baffle members may be configured or configurable to alter the direction of flow of fuel and/or air thereagainst. Alteration of the direction of flow of fuel may result in enhanced entrainment of air and an improvement of mixing air and fuel thereinto, for example according to the Coanda effect or any other mechanism.

The flow of fuel may comprise a first mass flow rate and the flow of air may comprise a second mass flow rate. The ratio of first to second mass flow rates may be configured or configurable, *e.g.* to a desired ratio thereof, for example to provide a stoichiometric fuel to air ratio. In other embodiments the ratio may be configured to generate a lean or rich fuel and air mixture. In one embodiment the ratio may be configured by adjusting the velocity and/or mass flow rate of the fuel.

[0038] The fluid combustion device may be configured such that air added to the fuel mixes therewith, *e.g.* substantially or entirely mixes therewith. Where the fluid combustion device comprises first and second flow conduit parts, one or more features, *e.g.* the length, of the second part of the flow conduit may be configured or configurable in order to promote mixing of the air and fuel. Additionally or alternatively, air and fuel may mix, *e.g.* partially mix, at or adjacent a fluid connection between the air inlet and the flow conduit, for example within one or more chambers within the housing (if provided).

[0039] A further aspect of the invention provides a flare pilot or flare stack comprising a fluid combustion device as described above.

[0040] A further aspect of the invention provides a method of generating a flame or flame front in accordance with Claim 15.

[0041] The method comprises entraining air into the flow of fuel via a continuous air inlet or plural air inlets that surround and/or are concentric with the primary flow axis or path and/or the flow conduit. The method may comprise entraining air into the flow of fuel via a continuous air inlet or plural air inlets disposed symmetrically or substantially symmetrically about the primary flow axis or path. The method may comprise entraining air into the flow of fuel via a continuous air inlet or plural air inlets through a portion of the flow conduit at or adjacent or upstream which the flow area is increased or decreased. The method may comprise entraining air into the flow of fuel via a continuous air inlet or plural air inlets that comprises an inlet passageway having a secondary flow axis or path therethrough which extends at least in part at an acute angle relative to the primary flow axis or path. Additionally or alternatively, the method may comprise entraining air into the flow of fuel via a continuous air inlet or plural air inlets that comprise an inlet passageway having a secondary flow axis or path therethrough which extends at least in part perpendicularly or substantially perpendicularly to the primary flow axis or path.

[0042] The method may further comprise igniting the fuel or fuel and air mixture and/or preventing or mitigating the propagation, *e.g.* the flashback, of a flame front through the flow conduit using the protection means. The method may comprise controlling or adjusting the flow of fuel, which in turn controls or adjusts the flow of air entrained through the one or more inlets.

[0043] Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 shows a side view of a flare system incorporating a prior art fluid combustion device;

Figure 2 shows a side view of a second prior art fluid combustion device;

Figure 3 shows a side view of a flare system incorporating a fluid combustion device according to a first embodiment of the invention;

Figure 4 shows a partial sectional view of the fluid combustion device of Figure 3;

Figure 5 shows a sectional plan view through the plane defined by line X-X in Figure 4;

Figure 6 shows a partial sectional view of a second embodiment of a fluid combustion device according to the invention;

Figure 7 shows a partial sectional view of a third embodiment of a fluid combustion device according to the invention;

Figure 8 shows a partial sectional view of a fourth embodiment of a fluid combustion device according to the invention;

Figure 9 shows a partial sectional view of a fifth em-

bodiment of a fluid combustion device according to the invention;

Figure 10 shows a partial sectional view of a sixth embodiment of a fluid combustion device according to the invention;

Figure 11 shows a partial sectional view of a seventh embodiment of a fluid combustion device according to the invention;

Figure 12 shows a partial sectional view of an eighth embodiment of a fluid combustion device according to the invention; and

Figure 13 shows a partial sectional view of a ninth embodiment of a fluid combustion device according to the invention.

[0044] Referring now to Figure 3, there is shown a flare system 1 including an improved fluid combustion device 3 according to a first embodiment of the invention, where like references (absent the prime (')) depict like features to those shown in Figure 1, which will not be described further herein.

[0045] The fluid combustion device 3 includes an upstream, inlet conduit 5 and a downstream, outlet conduit 6 connected by an air intake housing 7. A source (not shown) of gaseous fuel is fluidly connected to the inlet conduit 5. The outlet conduit 6 has an open first end 61, disposed adjacent the pilot tip of a flare pilot 30 which is in turn disposed adjacent an open first end 21 of the flare stack 2.

[0046] In use, a flow of air and fuel is mixed in a mixing chamber 6b downstream of the air intake housing 7. The flow of mixed air and fuel flows along the outlet conduit 6 to the open first end 61 thereof. The flow of mixed air and fuel is ignited by an ignition means 41, generating a flame front which travels along the outlet conduit 6 to the open first end 61 thereof. The ignition means 41, which may be a spark ignition, is in communication with the interior of the outlet conduit 6. Preferably the ignition means 41 is located downstream and adjacent the mixing chamber 6b and is spaced from the open first end 61 of the outlet conduit 6. When the flame front reaches the open first end 61 of the outlet conduit 6 it ignites or reignites a pilot flame PF on a flare pilot 30.

[0047] Figure 4 shows a partial sectional view of the fluid combustion device 3 shown in Figure 3. The inlet conduit 5 is generally cylindrical with a diameter D_1 and has a free first end 51. The outlet conduit 6 is generally cylindrical and has a diameter D_2, which may be smaller than, equal to or larger than the diameter D_1 of the inlet conduit 5. Preferably the diameter D_2 of the outlet conduit 6 is larger than the diameter D_1 of the inlet conduit 5.

[0048] The free first end 51 of the inlet conduit 5 includes an inwardly flaring frusto-conical taper 52, defining a baffle plate 53. In this embodiment an optional extension 54 projects from the taper 52. The taper 52 defines an opening 55 in the inlet conduit 5 which has a smaller diameter D_4 than the diameter D_1 of the inlet conduit 5, in this embodiment, though may be equal thereto in other embodiments. The diameter D_4 of the opening 55 of the inlet conduit 5 is smaller than the diameter D_2 of the outlet conduit 6.

[0049] The air intake housing 7 is generally cylindrical and has a diameter D_3, which is larger than the diameter D_1 of the inlet conduit 5 (see Figure 5). The air intake housing 7 has an end wall 71 which is fluidly sealed to the second end 62 of the outlet conduit 6 and a second, open end 72 which is open to the surrounding atmosphere. The end wall 71 is frusto-conical in this embodiment. Disposed within the air intake housing and adjacent the end wall 71 of the air intake housing 7 is a mixing chamber 73. The free first end 51 of the inlet conduit 5 is located inside the air intake housing 7, such that a circumferential and continuous air inlet 74a defining an air inlet passageway 74 is formed between the external surface of the inlet conduit 5 and the internal surface of the air intake housing 7. A protection means 8A which is a flame arrester element 8 is disposed within the air inlet passageway 74 such that it spans the entire circumference of the inlet conduit 5. The ignition means 41 (as shown in Figure 3) may be located adjacent and downstream of the mixing chamber. The ignition means 41 may be located at a distance equal to or greater than $2D_2$, for example equal to or greater than $5D_2$, say equal to or greater than $10D_2$ from the second end 62 of the outlet conduit 6. Alternatively, the ignition means 41 may be located at a distance less than $10D_2$, for example than $5D_2$, say less than $2D_2$ from the second end 62 of the outlet conduit 6. It will be appreciated that this distance between the ignition means 41 and the second end 62 of the outlet conduit 6 defines a mixing chamber 6b within the outlet conduit 6.

[0050] The flame arrester element 8 is substantially annular in plan (as may be seen with reference to Figure 5) and may be fabricated by any means known in the art, for example a knitted metal mesh, a perforated plate, a coiled crimped ribbon or a sintered metal mesh structure. The flame arrester element 8 is configured to seat around the inlet conduit 5 and within the air intake housing 7, thereby spanning the air inlet passageway 74 therebetween. The flame arrester element 8 is preferably located adjacent the open end 72 of the air intake housing 7. Most preferably the flame arrester element 8 is constructed from a coiled crimped ribbon. Fabrication of such a flame arrester element 8 is particularly simple, requiring winding of the ribbon element and crimping thereof, with this simplicity of manufacture resulting in savings of time, materials and expenditure. The flame arrester element 8 may comprise more than one crimped ribbon element. Where more than one crimped ribbon element is provided each crimped ribbon element may be similar or may be different.

[0051] It is important that use of the flame arrester element 8 within the air inlet passageway 74 does not, so far as is possible, interfere with the normal operation thereof. For example, the flame arrester element 8 should not cause a substantial impediment to flow of air A flowing

into the air intake housing 7 from outside thence. A substantial flow impediment may reduce the mass flow rate of flow of air A flowing into the air intake housing 7 and thence entraining into the flow of fuel F. Therefore, the radial width of the air inlet passageway 74 between the external surface of the inlet conduit 5 and the internal surface of the air intake housing 7 (and hence the radial width of the flame arrester element 8) is selected in order to compensate for any restriction to the flow of air A caused by the presence of the flame arrester element 8. The radial width of the air inlet passageway 74 may be selected by altering the diameter D_1 of the inlet conduit 5 and/or the diameter D_3 of the air intake housing 7. The diameter D_4 of the opening 55 in the inlet conduit 5 may be altered in concert with any alteration to the diameter D_1 of the inlet conduit 5 and/or the diameter D_3 of the air intake housing.

[0052] In use, a flow of fuel F flows along the inlet conduit 5 towards the free first end 51 thereof and is emitted therefrom. The fuel flows along a primary flow path. As the flow of fuel F passes through the taper 52 the local flow velocity is increased whilst the local pressure of the flow is decreased, according to the Venturi effect. The flow of fuel F is then emitted from the opening 55 in the taper 52 with air A within the air intake housing 7 subsequently entrained into the flow due to the known principle of jetting. By increasing the local velocity and reducing the local pressure of the flow of fuel F, air A is more efficiently entrained thereinto.

[0053] The air A is partially mixed with the fuel F within the mixing chamber 73 prior to flowing out of the air intake housing 7 and into the outlet conduit 6. The partially mixed air A and fuel F is then further mixed, preferably fully mixed, during passage along the mixing chamber 6b of the outlet conduit 6, due to turbulent flow of the mixture. As a consequence of entrainment of air A into the flow of fuel F a pressure differential is created between the air intake housing 7 and the ambient surroundings such that further air A is drawn into the air intake housing 7, through the flame arrester element 8 and the air inlet passageway 74. The air flows through the air inlet passageway 74 along a secondary flow path. The flow of air A along the secondary flow path is then entrained into the flow of fuel F, as described above.

[0054] A flame arrester element 8 constructed of a coiled crimped ribbon comprises generally regular channels therethrough which may provide a guide to the flow of air A. Advantageously, these generally regular channels may direct a flow of air A into a desirable direction. Thus, the flow of air A may be introduced into the air intake housing 7 with improved uniformity of direction and/or with altered direction. Hence the secondary flow path may be effected and/or improved by the presence of a flame arrester element 8 including generally regular channels.

[0055] Advantageously, entrainment of air A into the flow of fuel F symmetrically or substantially symmetrically thereabout and/or the provision of mixing chambers 73, 6b ensures that air A and fuel F mix more fully and rapidly than in prior art systems. Beneficially, this mixture of air A and fuel F ignites and burns more efficiently and rapidly such that the generated flame front is therefore more reliable and/or robust, consequently having a reduced likelihood of extinguishment prior to reaching the open first end 61 of the outlet conduit 6.

[0056] We have surprisingly found that a fluid combustion device 3 according to the invention, having a circumferential air inlet passageway 74, which is upstream of the ignition means 41, provides more efficient mixing of air A and fuel F prior to ignition thereof. Providing means for the ingress of a flow of air A concentrically around the majority or entirety of the circumference of the flow of fuel F maximises the surface area of the flow of fuel F against which air A is entrained, thereby maximising entrainment. As a result, air A is entrained into the flow of fuel F both more efficiently and more rapidly than were the flow of air A provided around a minor portion of the circumference of the flow of fuel F.

[0057] Furthermore, by providing the flow of air A in a secondary flow path at an acute angle relative to the primary flow path of the flow of fuel F resistance to the flow thereof is minimised.

[0058] It has also been found that by controlling the flow rate of fuel F travelling along the inlet conduit 5 it is possible to control the concentration of air A in the fuel/air mixture emitted from the open first end 61 of the outlet conduit 6 of the fluid combustion device 3. Reducing or increasing the flow rate of fuel F travelling along the inlet conduit 5 results in a consequent reduction or increase in the rate of entrainment of air A into the fuel F within the air intake housing 7. The flow rate of the flow of fuel F may therefore be adjusted or configured such that an ideal and/or stoichiometric mixture of air A and fuel F is advantageously produced prior to emission of the mixture from the open first end 61 of the outlet conduit 6. The mixture of air A and fuel F may therefore be adjusted to a required concentration of fuel F, for example a concentration of fuel F which is easily ignitable. A generated flame front burning from a stoichiometric mixture of air A and fuel F burns without wasting fuel F, resulting in reduced expenditure, and without an excess of air A, hence producing a more robust and/or reliable flame front. If the fluid combustion device 3 becomes partially blocked the fuel/air mixture may diverge from an ideal and/or stoichiometric mixture. Advantageously, by controlling the rate at which fuel F flows along the inlet conduit 5 the concentration of air A to fuel F within the mixture may be adjusted and therefore may be returned or maintained at or near to an ideal and/or stoichiometric mixture.

[0059] If the flow of fuel F through the inlet conduit 5 ceases or is interrupted or the flow rate thereof is decreased, either intentionally or unintentionally, a flame front generated by the ignition means 41 may travel back (reversed flow) along the outlet conduit 6 towards the air intake housing 7 (known as flashback). Such an event may result in a flame front and possibly a detonation prop-

agating back along the outlet conduit 6 until they enter the air intake housing 7. In a fluid combustion device absent the flame arrester element 8 the thus formed flame front and/or detonation may exhaust from the air intake housing 7 directly into the surrounds thereof, which may present a considerable danger to the integrity of the structure and to any personnel thereabout. However, the fluid combustion device 3 of the invention includes a flame arrester element 8 in the air inlet passageway 74 between the inlet conduit 5 and the air intake housing 7. Because the air intake housing 7 generally has a greater cross-sectional area than the outlet conduit 6, the detonation, if generated, will expand as it enters the air intake housing 7 and as a result the detonation will be, at least partially, attenuated and hence more easily contained.

[0060] Advantageously, the baffle plate 53 of the inlet conduit 5 will act to divert a first portion of a flame front and/or detonation towards the flame arrester element 8. Furthermore, the opening 55 in the inlet conduit 5 has a smaller diameter D_4 than the diameter D_2 of the outlet conduit 6. A second portion of the flame front and/or detonation will enter the inlet conduit 5 and propagate therealong. However, due to the smaller diameter D_4 of the opening 55 in the inlet conduit 5 relative to the diameter D_2 of the outlet conduit 6, the second portion is advantageously reduced in size. Furthermore, a flame front entering the opening 55 in the inlet conduit 5 cannot be sustained because the fuel F air A mixture is too rich with fuel F to combust.

[0061] The first portion of the flame front and/or detonation, which does not enter the inlet conduit 5, passes through the passageways 74 within the air intake housing 7 and collides with the flame arrester element 8, which will act to remove further energy from the flame front, thereby attenuating and ultimately quenching the flame front according to a known process. Alternatively, it may not be necessary to attenuate a flame but instead only to attenuate the pressure of an explosion. So long as the surrounds of the protection means 8A is free from significant quantities of flammable or combustible material which might be ignited by a flame (and so long as the protection means 8A is suitably spaced from any potentially vulnerable personnel and/or machinery) it may be sufficient only to attenuate, e.g. partially attenuate, the pressure of a flashback explosion. In such a case the protection means 8A may additionally or alternatively comprise an explosion safety protection device and/or an explosion venting panel and/or an explosion venting element and/or an explosion venting device.

[0062] Providing a concentrically disposed or substantially concentrically disposed air intake housing 7 and flame arrester element 8 further protects the fluid combustion device 3, flare stack 2 and any surrounding structures or personnel from flashback. By providing an air intake housing 7 which is relatively wider than the outlet conduit 6 an explosion (deflagration and/or detonation) travelling back along the fluid combustion device 3 will expand upon entering the air intake housing 7. Beneficially, this expansion will result in a consequential reduction in the pressure of the explosion, resulting in, at least partial, attenuation thereof. The expanded explosion will then collide with the flame arrester element 8, being attenuated or contained thereby. The expansion of the explosion in the air intake housing 7 reduces the pressure of the explosion which subsequently collides with the flame arrester element 8, thereby protecting it from a collision with a relatively higher pressure explosion which may otherwise cause damage to the flame arrester element 8. Furthermore, the explosion is split into a first portion which collides with the flame arrester element 8 within the air intake housing 7 and a second portion which enters the inlet conduit 5. By splitting the explosion into two portions in this way the intensity thereof which collides with the flame arrester element 8 within the air intake housing 7 is reduced and consequently more readily attenuated or contained.

[0063] Moreover, the flame arrester element 8 also serves a secondary purpose as a protective barrier to prevent ingress of potentially harmful matter, for example elements capable of causing ignition, such as sparks, into the air intake housing 7 from the ambient surroundings. By orienting the fluid combustion device 3 vertically (with the outlet conduit 6 above the inlet conduit 5) the flame arrester element 8 may be retained with the air intake housing 7 relatively thereabove. Advantageously, in such an orientation the flame arrester element 8 is protected from gravity feeding of unwanted particulate and fluid matter, e.g. dust and rain. The flame arrester element 8 is therefore less likely to become blocked and/or damaged and/or corroded and will consequently require reduced maintenance and may have an increased useful life, both of which result in reduced expenditure. Furthermore, in this vertical orientation the flame arrester element 8 may be visible from below for visible inspection by maintenance personnel, thereby reducing the difficulty (and hence expense) of periodic inspections.

[0064] The symmetrical configuration of the fluid combustion device 3 in plan (as shown in Figure 5) results in an even and balanced distribution of weight, e.g. relative to a primary axis along the inlet conduit 5 and/or the outlet conduit 6. Advantageously, this distribution of weight provides a more stable fluid combustion device 3 able to be supported safely, e.g. relative to the flare stack 2 and/or flare pilot 30. Moreover, due to the simplicity of the design of the fluid combustion device 3, for example absent air pumps, it is consequently relatively light weight and therefore readily and simply supported. Furthermore, by including a flame arrester element 8 and air intake housing 7 within an integrated design the fluid combustion device 3 is simple and consequently has a reduced expense of manufacture relative to separate systems. Even further, the flame arrester element 8 may be accessed and even repaired or replaced during operation of the flare stack 2 and/or flare pilot 30.

[0065] Referring now to Figures 6 to 9, there are shown

alternative embodiments of the fluid combustion device showing different configurations of the free first end 51 of the inlet conduit 5 and/or in which the air intake housing 7 cooperates in differing ways with the free first end 51 of the inlet conduit 5 and/or with the second end 62 of the outlet conduit 6.

[0066] Figure 6 shows a partial sectional view of a further fluid combustion device 103 according to the invention in which features that are similar to those of the first embodiment are identified by a preceding '10'. In this embodiment, the air intake housing 107 is integrally formed with (or replaced by) the outlet conduit 106, with the flame arrester element 108 disposed therewithin and external to the inlet conduit 105. Furthermore, in this embodiment the free first end 1051 of the inlet conduit 105 does not include a taper or an extension (integers 52 and 54 in the embodiment shown in Figure 4). This embodiment of the fluid combustion device 103 is simpler than the embodiment shown in Figure 4 and may, as a consequence, be less expensive to manufacture.

[0067] Figure 7 shows a partial sectional view of a further fluid combustion device 203 according to the invention in which features that are similar to those of earlier embodiments are identified by a preceding '20'. In this embodiment, the free first end 2051 of the inlet conduit 205 does not include an extension (in contrast to the embodiment shown in Figure 4).

[0068] Furthermore, the end wall 2071 of the air intake housing 207 is configured to direct the flow of air A along a secondary flow path having a first portion extending generally parallel to the primary flow path and a second portion directed towards the primary flow path of the flow of fuel F at an angle α. The configuration of the embodiment shown in Figure 7 results in a secondary flow path of air having a more constant and defined flow pattern.

[0069] Figure 8 shows a partial sectional view of a further fluid combustion device 303 in which features that are similar to those of earlier embodiments are identified by a preceding '30'. In this embodiment, the diameter D_1 of the inlet conduit 305 is less than the diameter D_2 of the outlet conduit 306. The air intake housing 307 of this fluid combustion device 303 includes concentric or substantially concentric outer and inner walls configured to remain equidistant from one another and to thereby provide an air inlet passageway 3074 therebetween. The inner wall of the air intake housing 307 includes a tapered first end 3073 connected to the free first end 3051 of the inlet conduit 305. The end wall 3071 of the air intake housing 307 is similarly tapered, such that a portion of the secondary flow path of air A is generated between the tapered first end 3073 and the end wall 3071. In embodiments the diameter D_1 of the inlet conduit 305 may be equal to or greater than the diameter D_2 of the outlet conduit 306, where a nozzle (not shown) is provided on the free first end 3051 of the inlet conduit 305 and where the nozzle has an outlet diameter less than (or significantly less than) the diameter D_2 of the outlet conduit 306.

[0070] Furthermore, the fluid combustion device 303 of Figure 8 differs from the embodiment of the fluid combustion device 203 shown in Figure 7 in that the inlet conduit 305 does not include a taper at its free first end 3051 and therefore does not have an opening of reduced diameter relative to the diameter D_1 of the inlet conduit 305. Consequently, the flow of fuel F along the inlet conduit 305 is not restricted in the embodiment of the fluid combustion device 303 shown in Figure 8 such that greater flow rates may be possible with this embodiment than with the embodiment shown in Figure 7.

[0071] Figure 9 shows a partial sectional view of a further fluid combustion device 403 in which features that are similar to those of earlier embodiments are identified by a preceding '40'. In this embodiment the flame arrester element 408 and air intake housing 407 are arranged such that a portion of the second open end 4072 of the air intake housing 407 projects beyond the flame arrester element 408. This portion of the second open end 4072 of the air intake housing 407 may be angled with respect to the remainder of the air intake housing 407 and/or with respect to a primary flow path of fuel F through the inlet conduit 405. This portion of the second open end 4072 of the air intake housing 407 may comprise a frusto-conical portion thereof. Advantageously, provision of such a portion of the second open end 4072 of the air intake housing 407 reduces air flow losses adjacent this region and consequently enhances the flow of air A into the air intake housing 407 and thence entrainment of said air A into the flow of fuel F.

[0072] Figure 10 shows a partial sectional view of a further fluid combustion device 503 in which features that are similar to those of earlier embodiments are identified by a preceding '50'. In this embodiment a baffle member 509 is provided adjacent the opening 5055 in the inlet conduit 505. The baffle member 509 is preferably formed from metal, such as steel, though in alternative embodiments it may be formed from any other suitable material. The baffle member 509 is attached to the air intake housing 507 and/or the inlet conduit 505 via attachment arms (not shown). Although the baffle member 509 is shown as being downstream of the opening 5055 this need not be the case and the baffle member 509 may instead be upstream of the opening 5055 or may instead be located at least partly in the opening 5055. The baffle member 509 is shown as being oval in cross-section in Figure 10 but it may have any suitable shape, for example circular, rectangular, square, triangular, irregularly shaped, etc. The baffle member 509 may be hollow or solid or may comprise a porous structure. Advantageously, the baffle member 509 alters the flow patterns of the flow of fuel F from the inlet conduit 505 consequently resulting in enhanced entrainment and/or mixing of air A into the flow of fuel F. Without wishing to be bound by any theory it is believed that by selecting the shape and/or size and/or location of the baffle member 509, a flow of fuel F thereagainst may be diverted according to the Coanda effect. A flow of fuel F diverted in this way may advantageously entrain an increased volume of air A relative to a non-

diverted flow of fuel F. In embodiments the shape and/or size and/or location of the baffle member 509 may be selected according to the dimensions and/or arrangement of the surrounding components and/or according to the operating flow rate and/or pressure of the flow of fuel F. In embodiments there may be multiple baffle members 509, which may be the same size or different sizes, may be of the same shape in cross-section or different shapes in cross-section and/or may be positioned at a similar or different location relative to the opening 5055 of the inlet conduit 505.

[0073] Figure 11 shows a partial sectional view of a further fluid combustion device 603 in which features that are similar to those of earlier embodiments are identified by a preceding '60'.

[0074] In this embodiment a further flame arrester element 608b is located in the air intake housing 607 downstream of flame arrester element 608. The further flame arrester element 608b entirely extends around the perimeter of the air intake housing 607. The further flame arrester element 608b is a plate pack flame arrester element, while the flame arrester element 608 is a crimped ribbon flame arrester element. The further flame arrester element 608b may comprise any suitable number of plates of suitable thickness and spacing from one another. Furthermore, the plates of the further flame arrester element 608b may be oriented in any suitable direction relative to the other components of the fluid combustion device 603. The wall of the air intake housing 607 includes an air inlet 608c adjacent the further flame arrester element 608b. The spaces between the plates of the plate pack flame arrester element of the further flame arrester element 608b provide fluid communication between the exterior and interior of the air intake housing 607, through the air inlet 608c. In use, air A may flow through the air inlet 608c, through the further flame arrester element 608b and thence be entrained into a flow of fuel F in the fluid combustion device 603. Additionally or alternatively, in embodiments the flame arrester element 608 may not be provided and only the further flame arrester element 608b may be provided. In embodiments where only the further flame arrester element 608b is provided the further flame arrester element 608b may instead be a crimped ribbon flame arrester element or may be a plate pack flame arrester element or may be a perforated plate flame arrester element or may be any other suitable type of flame arrester element. In embodiments where both a flame arrester element 608 and a further flame arrester element 608b are provided both may be crimped ribbon flame arrester elements or both may be plate pack flame arrester elements or both may be perforated plate flame arrester elements. In embodiments the flame arrester element 608 and the further flame arrester element 608b may be of different types.

Figure 12 shows a partial sectional view of a further fluid combustion device 703 in which features that are similar to those of earlier embodiments are identified by a preceding '70'. In this embodiment a further flame arrester element 708b is located within air inlet 708c in the wall of the air intake housing 707. The further flame arrester element 708b is a plate pack flame arrester element. Channels between the plates of the further flame arrester element provide fluid communication between the inside of the air intake housing 707 and the surroundings thereof. The further flame arrester element 708b may have a first portion internal and a second portion external to the air intake housing 707. Alternatively, the further flame arrester element 708b may be entirely internal or entirely external to the air intake housing 707. The plates of the plate pack flame arrester element of the further flame arrester element 708b are substantially planar and are parallel to (and spaced from) one another. Planes defined by the major surfaces of one, some or all of the plates of the plate pack flame arrester element of the further flame arrester element 708b are substantially perpendicular to a primary flow path of a flow of fuel F, in use, through the inlet conduit 705. The further flame arrester element 708b entirely extends around the perimeter of the air intake housing 707.

[0075] In use, a flow of air A is entrained into a flow of fuel F through the further flame arrester element 708b and through the flame arrester element 708. The further flame arrester element 708b is configured to direct the flow of air A along a flow path which is substantially perpendicular to the primary flow path of the flow of fuel F. In embodiments planes defined by the major surfaces of the plates of the plate pack of the further flame arrester element 708b may not be substantially perpendicular to a primary flow path of a flow of fuel F, in use, through the inlet conduit 705. Alternatively, the plates of the plate pack may be oriented at any suitable angle and may, for example define a frusto-conical shape directed either upstream or downstream of a flow of fuel F, in use. Additionally or alternatively, the flame arrester element 708 and/or the further flame arrester element 708b may be any suitable type of flame arrester element, for example may comprise a crimped ribbon flame arrester element, a plate pack flame arrester element, perforated plate flame arrester element, etc. Additionally or alternatively, the flame arrester element 708 and the further flame arrester element 708b may be the same type of flame arrester element or may be different types of flame arrester element. Additionally or alternatively, the flame arrester element 708 may not be provided. Where the flame arrester element 708 is not provided the flow of air A, in use, may flow only through the further flame arrester element 708b.

[0076] Figure 13 shows a partial section view of a further fluid combustion device 803 in which features that are similar to those of earlier embodiments are identified by a preceding '80'. In this embodiment the air intake housing 807 includes a throttle 807a located downstream of the inlet conduit and upstream of the outlet conduit 806. The throttle 807a is defined by a converging portion 807b of the air intake housing 807, which converges or narrows in a downstream direction, and a diverging por-

tion 807c of the air intake housing 807, which diverges or expands in a downstream direction. The throttle 807a is located downstream of the opening 8055 of the inlet conduit 805. In embodiments, the throttle 807a may be located adjacent the opening 8055 of the inlet conduit 805 or, alternatively, upstream thereof. In use, the throttle 807a is configured to throttle a flow of fuel F therethrough and hence to increase the local velocity whilst reducing the local pressure thereof.

[0077] A further embodiment of the invention provides a fluid combustion device, *e.g.* for use with or in a gas flare or flare stack, the fluid combustion device comprising a flow conduit with a fuel inlet, an outlet, a primary flow axis or path through the flow conduit and a continuous air inlet or plural air inlets between the fuel inlet and the outlet, wherein the or each air inlet comprises a protection means mounted in or on or otherwise associated therewith, and wherein the one or more air inlets is or are disposed symmetrically or substantially symmetrically about the primary flow axis or path such that air is entrained, in use, into a flow of fuel passing along the flow conduit for ignition (or and ignited) in or at the outlet to produce a flame, *e.g.* a continuous flame or flame front.

[0078] As will be appreciated, features of each of the above embodiments may be combined within a single fluid combustion device. For example, it is quite conceivable that any of the above-described features may be included in or with the first embodiment of the present invention.

[0079] It will be appreciated by those skilled in the art that several variations to the aforementioned embodiments are envisaged without departing from the scope of the invention as defined in the appended claims. For example, although the flame arrester element has been shown as comprising only a plate pack or crimped ribbon structure, alternatively the flame arrester element may include a solid portion which may also be included at its core (*e.g.* its centre) or at one of its edges. Additionally or alternatively, although the flame arrester elements have been shown as toroidal they need not be and may instead be any suitable shape, for example frusto-conical and/or flared or inclined inwardly or outwardly with respect to the primary flow path along the inlet conduit. Additionally or alternatively, although the flame arrester element (and the further flame arrester element, where provided) is described as being either a crimped ribbon flame arrester element or a plate pack flame arrester element this need not be the case and instead the flame arrester element (and/or the further flame arrester element, where provided) may be any suitable type of flame arrester element, for example comprising one or more perforated plates.

Additionally or alternatively, although the air inlet (as shown in any of the above described embodiments) is described as being continuous this need not be the case and instead the air inlet may be interrupted at one or more location, *e.g.* circumferentially, in order to provide plural air inlets. Where more than one air inlet is provided each may be provided with a flame arrester element. Additionally or alternatively, the flame arrester element (and/or the further flame arrester element if provided) may be continuous or may comprise plural flame arrester sub-elements, for example which may be separated from one another by any suitable means.

[0080] Moreover, although the inlet conduit, outlet conduit and housing are shown as cylindrical they need not be and any or all of them may instead have a square or hexagonal cross-section or any other suitable shape.

[0081] Additionally or alternatively, although component parts of the above described embodiments are shown in the Figures as comprising sharp edges or corners or junctions this need not be the case and instead the edges and/or corners and/or junctions may be rounded or curved, *e.g.* smoothly curved. For example, the junction between the side wall of the air intake housing 7 and the end wall 71 thereof (shown in Figure 4) may be rounded or curved, *e.g.* smoothly curved.

[0082] Additionally or alternatively, the air inlet may comprise a compressed air supply, for example may be connected to a source of compressed air. The connection may extend in a direction parallel to the inlet conduit. As will be appreciated by one skilled in the art, the protection means or flame arrester element may thereby protect the source of compressed air, for example one or more pump, from explosion damage.

Claims

1. A fluid combustion device (3) for use with a flare pilot (30), the fluid combustion device (3) comprising a flow conduit with a fuel inlet (5), an outlet (6), a primary flow path through the flow conduit and a continuous air inlet (74) or plural air inlets (74; 608C; 708C) between the fuel inlet (5) and the outlet (6), wherein the or each air inlet (74; 608C; 708C) comprises a protection means (8A, 608b, 708b) mounted in or on or otherwise associated therewith, wherein air is entrained, in use, into a flow of fuel passing along the flow conduit for ignition in, at or downstream of the outlet (6) to produce a flame front, **characterised in that** the or each air inlet (74; 608c; 708c) comprises an annular air inlet that surrounds the primary flow path.

2. Fluid combustion device (3) according to Claim 1, wherein the or each air inlet (74; 608c; 708c) comprises an annular air inlet that is concentric with the primary flow path.

3. Fluid combustion device (3) according to Claim 1 or 2, wherein the protection means (8A, 608b, 708b) is annular and received within and/or aligned with the or each air inlet (74; 608c; 708c).

4. Fluid combustion device (3) according to any of

Claims 1, 2 or 3, wherein the protection means (8A, 608b, 708b) comprises one or more crimped ribbon elements, and/or one or more perforated plates, and/or one or more plate packs and/or annular plate stacks.

5. Fluid combustion device (3) according to any preceding Claims, wherein the protection means (8A, 608b, 708b) comprises an explosion venting device.

6. Fluid combustion device (3) according to any preceding Claims, wherein the flow area of the flow conduit increases at, adjacent or upstream of the air inlet or inlets (74; 608c; 708c) to encourage air to be entrained, in use, into a flow of fuel passing through the flow conduit.

7. Fluid combustion device (3) according to any preceding Claims, wherein the flow conduit comprises a flow restriction (55) at, adjacent or upstream of the air inlet or inlets (74; 608c; 708c) to encourage air to be entrained, in use, into a flow of fuel passing through the flow conduit.

8. Fluid combustion device (3) according to any preceding Claims, wherein the flow conduit comprises a first part upstream the air inlet or inlets (74; 608c; 708c) and a second part downstream the air inlet or inlets (74; 608c; 708c), the first part comprising a fuel outlet (55) in fluid communication with and smaller than an inlet (62) of the second part, preferably the first part of the flow conduit tapers from a first flow area to the fuel outlet (55) which has a second flow area smaller than the first flow area thereby providing the or a flow restriction to encourage air to be entrained, in use, into a flow of fuel passing through the flow conduit, and/or wherein the second part may comprise the outlet (6) of the fluid combustion device.

9. Fluid combustion device (3) according to any preceding Claims, wherein the or each air inlet (74; 608c; 708c) comprises an air inlet passageway having a secondary flow path extending at least in part at an acute angle relative to the primary flow path preferably at least part of the air inlet passageway is tapered or conical.

10. Fluid combustion device (3) according to Claim 9, wherein the air inlet passageway comprises two or more portions each with a respective flow path, a first portion of the air inlet passageway extending along a first direction parallel to the primary flow path and a second portion thereof extending along a second direction at an acute angle relative to the primary flow path and into the flow conduit, wherein the second portion of the air inlet passageway may be tapered or conical.

11. Fluid combustion device (3) according to any of Claims 1 to 8, wherein the or each air inlet (74; 608c; 708c) comprises an air inlet passageway having a secondary flow path extending at least in part perpendicularly relative to the primary flow path.

12. Fluid combustion device (3) according to any preceding Claims, the fluid combustion device (3) further comprising one or more baffle members (53) configured to alter the direction of flow of fuel and/or air the repast.

13. Fluid combustion device (3) according to any preceding Claims, wherein the protection means (8A, 608b, 708b) comprises a flame arrester element (8).

14. A flare pilot (30) or flare stack (2) comprising a fluid combustion device (3) according to any preceding Claims.

15. A method of generating a flame front for igniting a flare pilot (30), the method comprising passing a flow of fuel through a flow conduit along a primary flow path, entraining air via a continuous annular air inlet or plural annular air inlets (74; 608c; 708c) into the flow of fuel passing through the flow conduit for ignition of the fuel and air mixture in, at or downstream of the outlet (6) to produce a flame front, wherein the or each air inlet (74; 608c; 708c) comprises a protection means (8A, 608b, 708b) or flame arrester element (8) mounted in or on or otherwise associated therewith, and **characterised in that** the air inlet/s (74; 608c; 708c) surround and/or are concentric with the primary flow axis or path and/or the flow conduit.

Patentansprüche

1. Fluidverbrennungsvorrichtung (3) zur Verwendung mit einem Fackelpilot (30), wobei die Fluidverbrennungsvorrichtung (3) eine Strömungsröhre mit einem Brennstoffeinlass (5), einem Auslass (6), einem primären Strömungspfad durch die Strömungsröhre und einen kontinuierlichen Lufteinlass (74) oder mehrere Lufteinlässe (74; 608C; 708C) zwischen dem Brennstoffeinlass (5) und dem Auslass (6) umfasst, wobei der oder jeder Lufteinlass (74; 608C; 708C) ein Schutzmittel (8A, 608b, 708b) umfasst, da darin oder daran angebracht oder anderweitig zugeordnet ist, wobei im Einsatz Luft in einer Brennstoffströmung mitgeführt wird, die entlang der Strömungsröhre verläuft, um in, an oder stromabwärts des Auslasses (6) zu zünden, um eine Flammenfront zu erzeugen, **dadurch gekennzeichnet, dass** der oder jeder Lufteinlass (74; 608c; 708c) einen ringförmigen Lufteinlass umfasst, der den primären Strömungspfad umgibt.

2. Fluidverbrennungsvorrichtung (3) nach Anspruch 1, wobei der oder jeder Lufteinlass (74; 608c; 708c) einen ringförmigen Lufteinlass umfasst, der mit dem primären Strömungspfad konzentrisch ist.

3. Fluidverbrennungsvorrichtung (3) nach Anspruch 1 oder 2, wobei das Schutzmittel (8A, 608b, 708b) ringförmig ist und in dem oder jedem Lufteinlass (74; 608c; 708c) aufgenommen wird oder damit ausgerichtet ist.

4. Fluidverbrennungsvorrichtung (3) nach Anspruch 1, 2 oder 3, wobei das Schutzmittel (8A, 608b, 708b) ein oder mehrere Crimpbandelemente und/oder ein oder mehrere perforierte Platten und/oder eine oder mehrere Plattenpackungen und/oder ringförmige Plattenstapel umfasst.

5. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei das Schutzmittel (8A, 608b, 708b) eine Explosionsentlastungsvorrichtung umfasst.

6. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei der Strömungsquerschnitt der Strömungsröhre an, angrenzend an oder stromaufwärts des Lufteinlasses oder der Lufteinlässe (74; 608c; 708c) zunimmt, um unterstützend dabei zu wirken, dass Luft im Einsatz in einer Brennstoffströmung mitgeführt wird, die durch die Strömungsröhre verläuft.

7. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei die Strömungsröhre eine Strömungsbegrenzung (55) an, angrenzend an oder stromaufwärts des Lufteinlasses oder der Lufteinlässe (74; 608c; 708c) umfasst, um unterstützend dabei zu wirken, dass Luft im Einsatz in einer Brennstoffströmung mitgeführt wird, die durch die Strömungsröhre verläuft.

8. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei die Strömungsröhre einen ersten Teil stromaufwärts des Lufteinlasses oder der Lufteinlässe (74; 608c; 708c) umfasst und einen zweiten Teil stromabwärts des Lufteinlasses oder der Lufteinlässe (74; 608c; 708c), wobei der erste Teil einen Brennstoffauslass (55) in Fluidkommunikation mit einem Einlass (62) und kleiner als dieser Einlass des zweiten Teils aufweist, wobei der erste Teil der Strömungsröhre vorzugsweise eine Verjüngung von einem ersten Strömungsquerschnitt zu dem Brennstoffauslass (55) aufweist, der einen zweiten Strömungsquerschnitt aufweist, der kleiner ist als der erste Strömungsquerschnitt, wodurch die oder eine Strömungsbegrenzung bereitgestellt wird, um unterstützend dabei zu wirken, dass Luft im Einsatz in einer Brennstoffströmung mitgeführt wird, die durch die Strömungsröhre verläuft, und/oder wobei der zweite Teil den Auslass (6) der Fluidverbrennungsvorrichtung umfassen kann.

9. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei der oder jeder Lufteinlass (74; 608c; 708c) einen Lufteinlasskanal mit einem sekundären Strömungspfad umfasst, der sich wenigstens teilweise in einem spitzen Winkel im Verhältnis zu dem primären Strömungspfad erstreckt, wobei vorzugsweise wenigstens ein Teil des Lufteinlasskanals verjüngt oder konisch ist.

10. Fluidverbrennungsvorrichtung (3) nach Anspruch 9, wobei der Lufteinlasskanal zwei oder mehr Teile umfasst, die jeweils einen entsprechenden Strömungspfad aufweisen, wobei sich ein erster Teil des Lufteinlasskanals entlang einer ersten Richtung parallel zu dem primären Strömungspfad erstreckt, und wobei sich ein zweiter Teil dessen entlang einer zweiten Richtung in einem spitzen Winkel im Verhältnis zu dem primären Strömungspfad und in die Strömungsröhre erstreckt, wobei der zweite Teil des Lufteinlasskanals verjüngt oder konisch sein kann.

11. Fluidverbrennungsvorrichtung (3) nach einem der Ansprüche 1 bis 8, wobei der oder jeder Lufteinlass (74; 608c; 708c) einen Lufteinlasskanal mit einem sekundären Strömungspfad umfasst, der sich wenigstens teilweise senkrecht zu dem primären Strömungspfad erstreckt.

12. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei die Fluidverbrennungsvorrichtung (3) ferner ein oder mehrere Umlenkelemente (53) umfasst, die so gestaltet sind, dass sie die Strömungsrichtung des Brennstoffs und/oder von Luft dort vorbei ändern.

13. Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche, wobei das Schutzmittel (8A, 608b, 708b) ein Flammenabsperrelement (8) umfasst.

14. Fackelpilot (30) oder Fackel (2), der bzw. die eine Fluidverbrennungsvorrichtung (3) nach einem der vorstehenden Ansprüche umfasst.

15. Verfahren zur Erzeugung einer Flammenfront zum Zünden eines Fackelpiloten (30), wobei das Verfahren folgendes umfasst: Leiten einer Brennstoffströmung durch eine Strömungsröhre entlang eines primären Strömungspfads, wobei Luft über einen kontinuierlichen Lufteinlass oder mehrere ringförmige Lufteinlässe (74; 608c; 708c) in dem durch der Strömungsröhre verlaufenden Brennstoffströmung mitgeführt wird, um das Gemisch aus Brennstoff und Luft in, an oder stromabwärts des Auslasses (6) zu

zünden, um eine Flammenfront zu erzeugen, wobei der oder jeder Lufteinlass (74; 608c; 708c) ein Schutzmittel (8A, 608b, 708b) oder ein Flammenabsperrelement (8) umfasst, das darin oder daran angebracht oder damit anderweitig zugeordnet ist, und **dadurch gekennzeichnet, dass** der Lufteinlass bzw. die Lufteinlässe (74; 608c, 708c) die primäre Strömungsachse oder den Pfad und/oder die Strömungsröhre umgeben und/oder damit konzentrisch sind.

Revendications

1. Dispositif de combustion de fluide (3) destiné à être utilisé avec un pilote de torche (30), le dispositif de combustion de fluide (3) comprenant un conduit d'écoulement avec une entrée de combustible (5), une sortie (6), un chemin d'écoulement primaire à travers le conduit d'écoulement et une entrée d'air continue (74) ou plusieurs entrées d'air (74 ; 608C ; 708C) entre l'entrée de combustible (5) et la sortie (6), la ou chaque entrée d'air (74 ; 608C ; 708C) comprenant un moyen de protection (8A, 608b, 708b) monté dans ou sur ou autrement associés à celle-ci, l'air étant entraîné, lors de l'utilisation, dans un écoulement de carburant passant le long du conduit d'écoulement pour s'enflammer dans, au niveau ou en aval de la sortie (6) pour produire un front de flamme, **caractérisé en ce que** la ou chaque entrée d'air (74 ; 608c ; 708c) comprend une entrée d'air annulaire qui entoure le chemin d'écoulement primaire.

2. Dispositif de combustion de fluide (3) selon la revendication 1, la ou chaque entrée d'air (74 ; 608c ; 708c) comprenant une entrée d'air annulaire qui est concentrique avec le chemin d'écoulement primaire.

3. Dispositif de combustion de fluide (3) selon la revendication 1 ou 2, le moyen de protection (8A, 608b, 708b) étant annulaire et reçu à l'intérieur et/ou aligné avec la ou chaque entrée d'air (74 ; 608c ; 708c).

4. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications 1, 2 ou 3, le moyen de protection (8A, 608b, 708b) comprenant au moins un élément de ruban serti, et/ou au moins une plaque perforée, et/ou au moins un paquet de plaques et/ou pile de plaques annulaires.

5. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, le moyen de protection (8A, 608b, 708b) comprenant un dispositif d'évent d'explosion.

6. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, la surface d'écoulement du conduit d'écoulement augmentant au niveau, à proximité ou en amont de l'entrée ou des entrées d'air (74 ; 608c ; 708c) pour encourager l'air à être entraîné, lors de l'utilisation, dans un écoulement de carburant passant à travers le conduit d'écoulement.

7. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, le conduit d'écoulement comprenant une restriction d'écoulement (55) au niveau, à proximité ou en amont de l'entrée ou des entrées d'air (74 ; 608c ; 708c) pour encourager l'air à être entraîné, lors de l'utilisation, dans un écoulement de carburant passant à travers le conduit d'écoulement.

8. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, le conduit d'écoulement comprenant une première partie en amont de l'entrée ou des entrées d'air (74 ; 608c ; 708c) et une seconde partie en aval de l'entrée ou des entrées d'air (74 ; 608c ; 708c), la première partie comprenant une sortie de carburant (55) en communication fluidique avec et plus petite qu'une entrée (62) de la seconde partie, de préférence la première partie du conduit d'écoulement se rétrécissant d'une première zone d'écoulement vers la sortie de carburant (55) qui a une seconde zone d'écoulement plus petite que la première zone d'écoulement, fournissant ainsi la ou une restriction d'écoulement pour encourager l'air à être entraîné, lors de l'utilisation, dans un écoulement de carburant passant à travers le conduit d'écoulement, et/ou la seconde partie pouvant comprendre la sortie (6) du dispositif de combustion de fluide.

9. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, la ou chaque entrée d'air (74 ; 608c ; 708c) comprenant un passage d'entrée d'air ayant un chemin d'écoulement secondaire s'étendant au moins en partie à un angle aigu par rapport au chemin d'écoulement primaire, de préférence au moins une partie du passage d'entrée d'air étant conique ou effilée.

10. Dispositif de combustion de fluide (3) selon la revendication 9, le passage d'entrée d'air comprenant deux ou plusieurs parties ayant chacune un chemin d'écoulement respectif, une première partie du passage d'entrée d'air s'étendant le long d'une première direction parallèle au chemin d'écoulement primaire et une seconde partie de celui-ci s'étendant le long d'une seconde direction à un angle aigu par rapport au chemin d'écoulement primaire et dans le conduit d'écoulement, la seconde partie du passage d'entrée d'air pouvant être conique ou effilée.

11. Dispositif de combustion de fluide (3) selon l'une

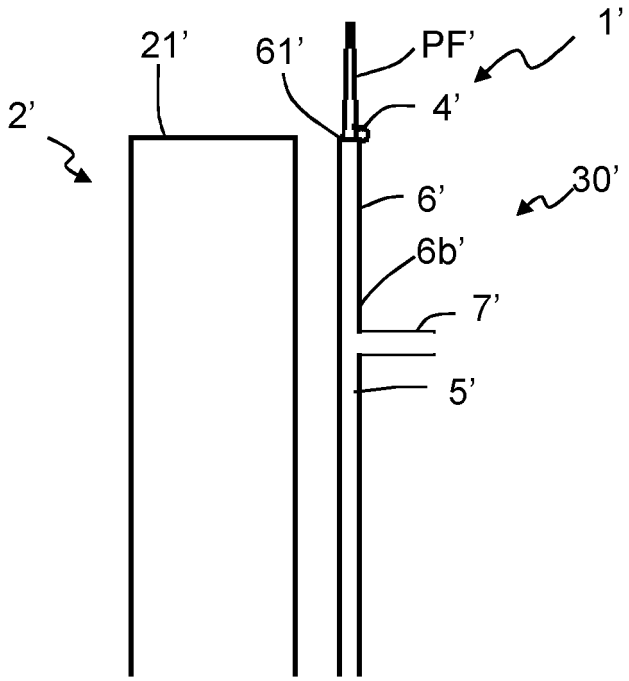
quelconque des revendications 1 à 8, la ou chaque entrée d'air (74 ; 608c ; 708c) comprenant un passage d'entrée d'air ayant un chemin d'écoulement secondaire s'étendant au moins en partie perpendiculairement au chemin d'écoulement primaire.

12. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, le dispositif de combustion de fluide (3) comprenant en outre au moins un élément déflecteur (53) conçu pour modifier la direction de l'écoulement du carburant et/ou de l'air qui le traverse.

13. Dispositif de combustion de fluide (3) selon l'une quelconque des revendications précédentes, le moyen de protection (8A, 608b, 708b) comprenant un élément pare-flammes (8).

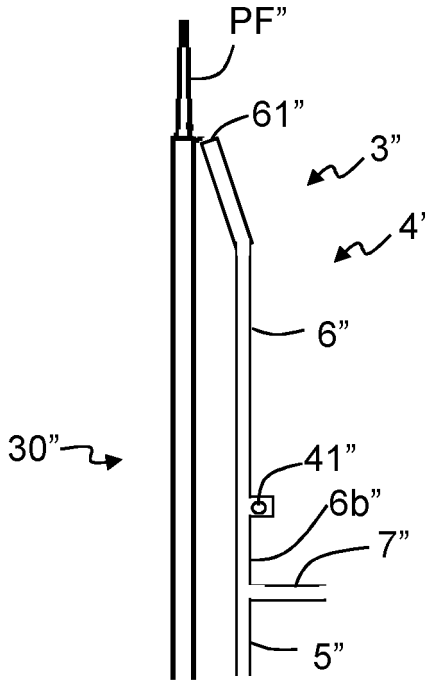
14. Pilote de torche (30) ou tour de torche (2) comprenant un dispositif de combustion fluide (3) selon l'une quelconque des revendications précédentes.

15. Procédé de génération d'un front de flamme pour allumer un pilote de torche (30), le procédé comprenant le passage d'un écoulement de carburant à travers un conduit d'écoulement le long d'un chemin d'écoulement primaire, l'entraînement de l'air via une entrée d'air annulaire continue ou plusieurs entrées d'air annulaires (74 ; 608c ; 708c) dans l'écoulement de carburant passant à travers le conduit d'écoulement pour l'allumage du mélange de carburant et d'air dans, au niveau ou en aval de la sortie (6) pour produire un front de flamme, la ou chaque entrée d'air (74 ; 608c ; 708c) comprenant un moyen de protection (8A, 608b, 708b) ou un élément pare-flammes (8) monté dans ou sur ou autrement associé à celui-ci, et **caractérisé en ce que** la ou les entrées d'air (74 ; 608c ; 708c) entourent et/ou sont concentriques à l'axe ou au chemin d'écoulement primaire et/ou au conduit d'écoulement.



[Prior Art]

FIGURE 1



[Prior Art]

FIGURE 2

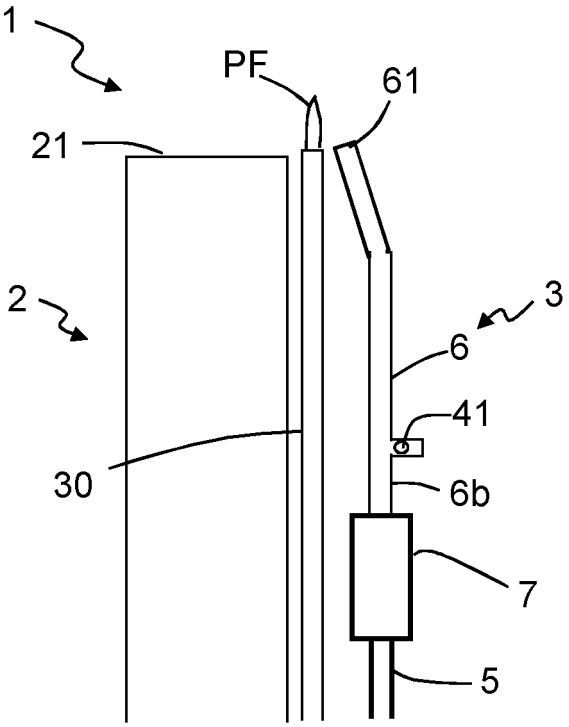


FIGURE 3

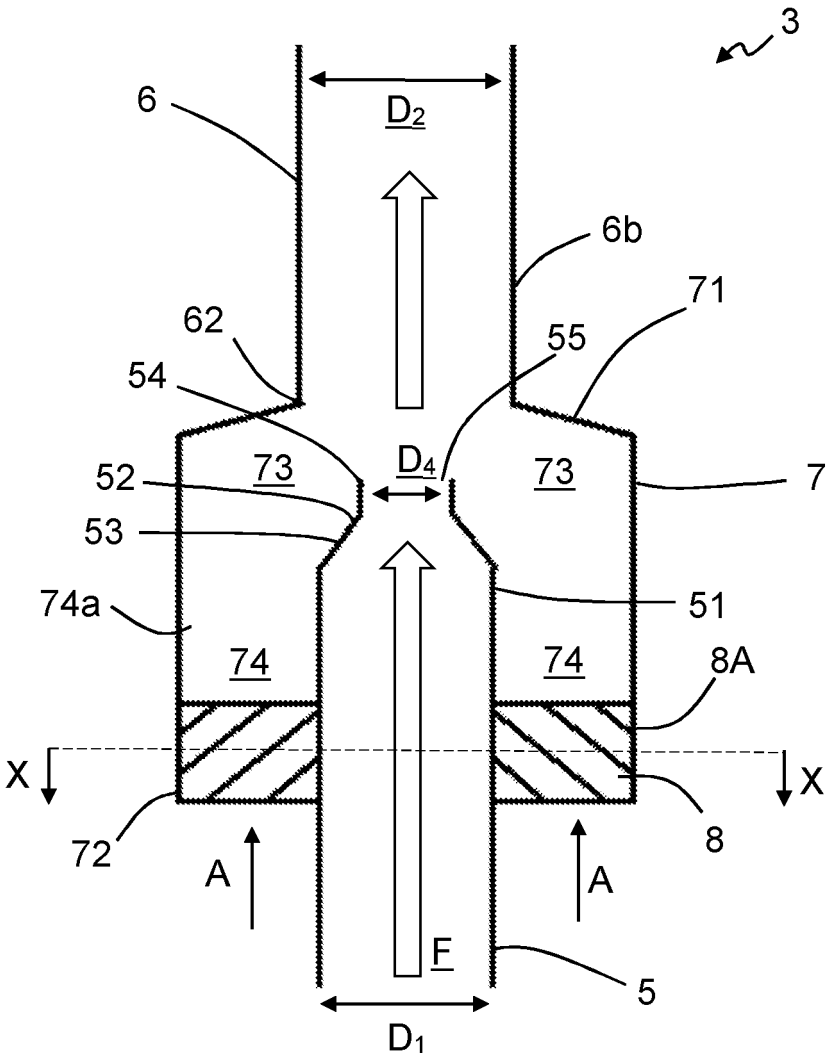


FIGURE 4

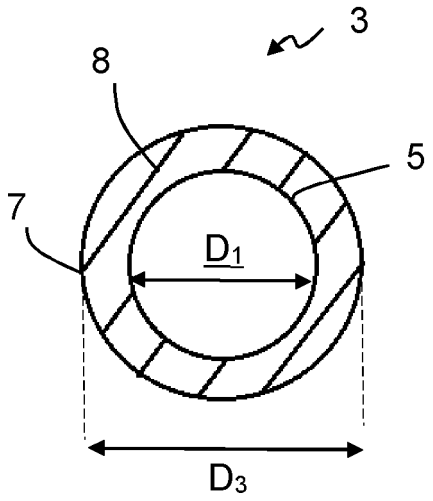


FIGURE 5

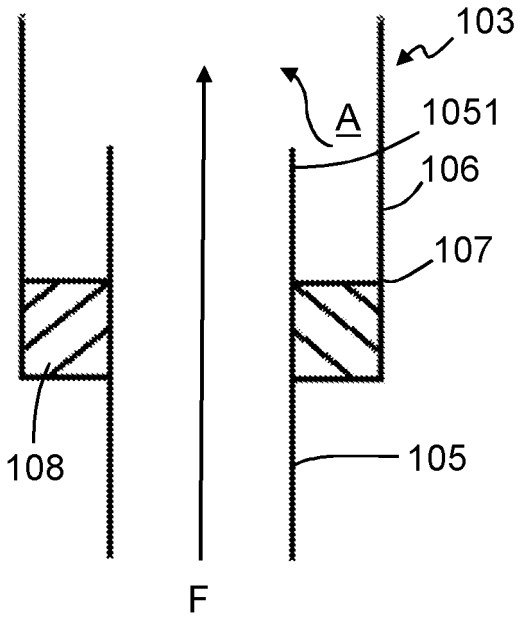


FIGURE 6

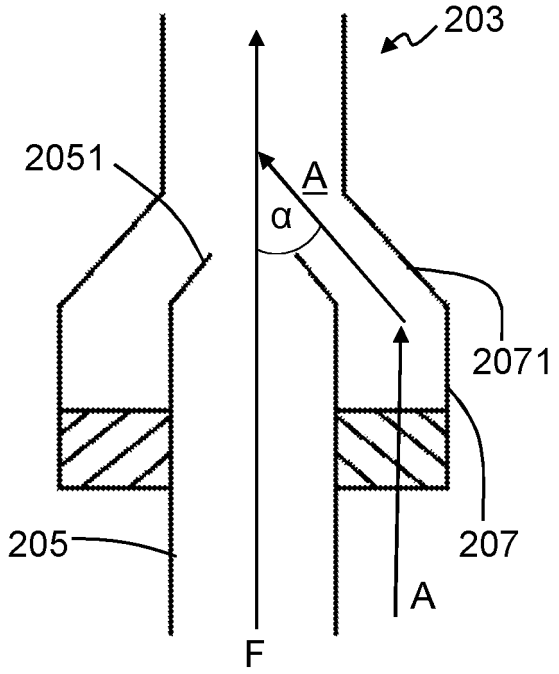


FIGURE 7

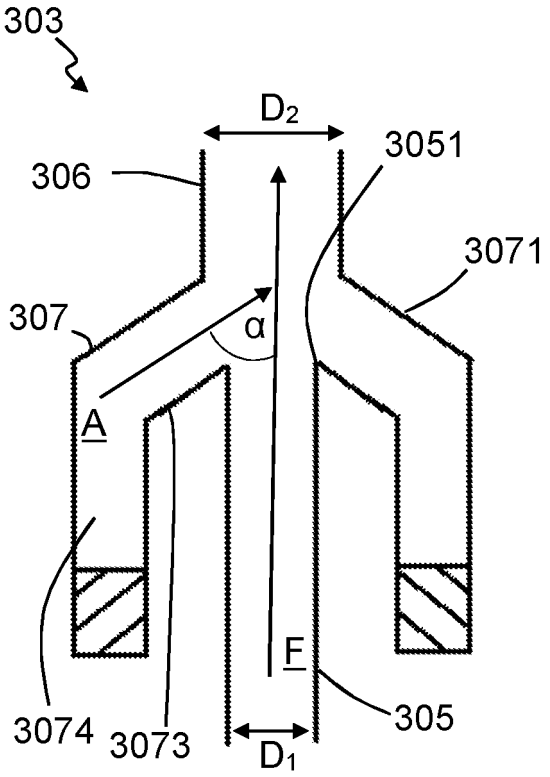


FIGURE 8

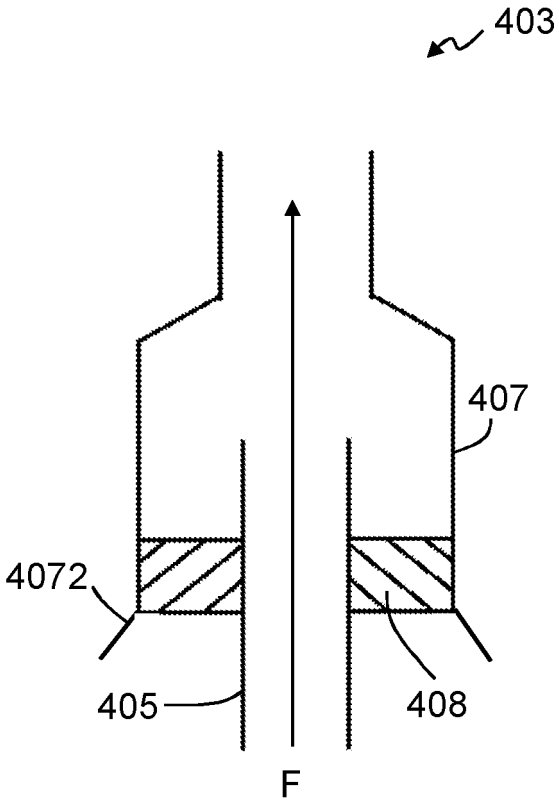


FIGURE 9

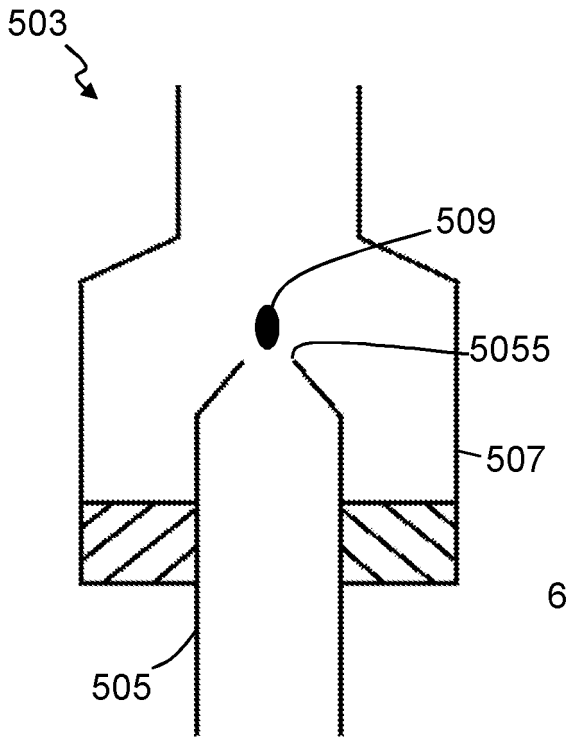


FIGURE 10

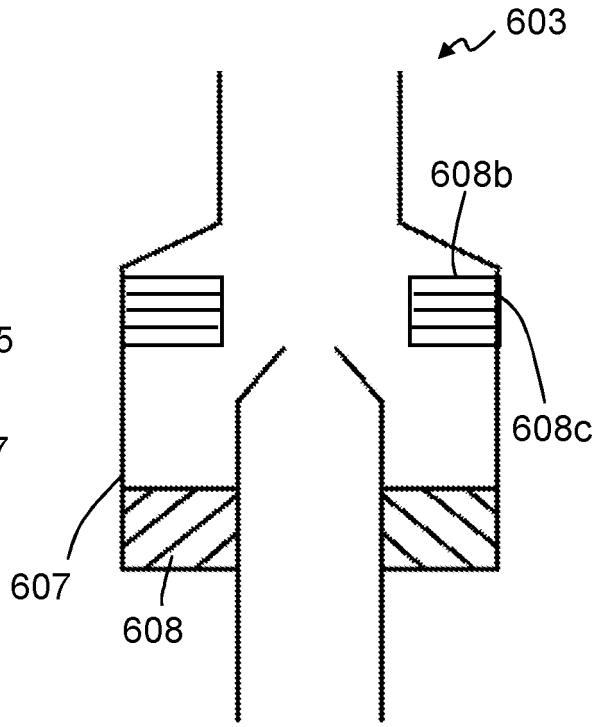


FIGURE 11

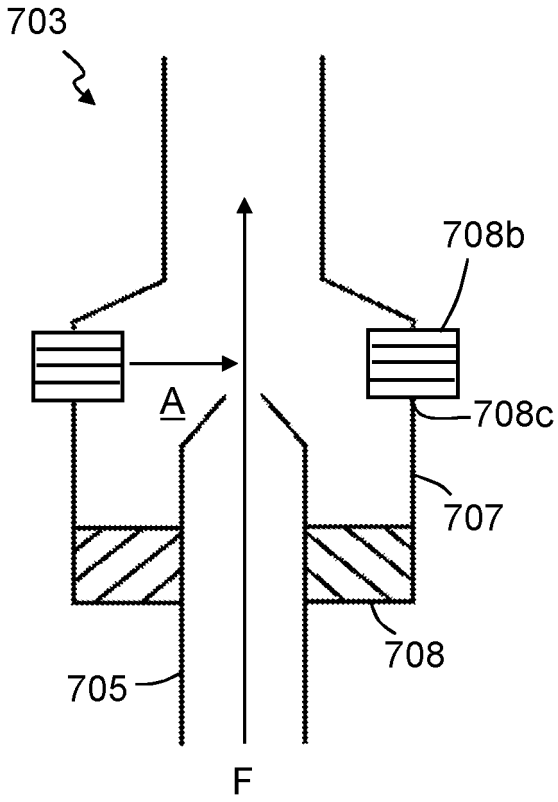


FIGURE 12

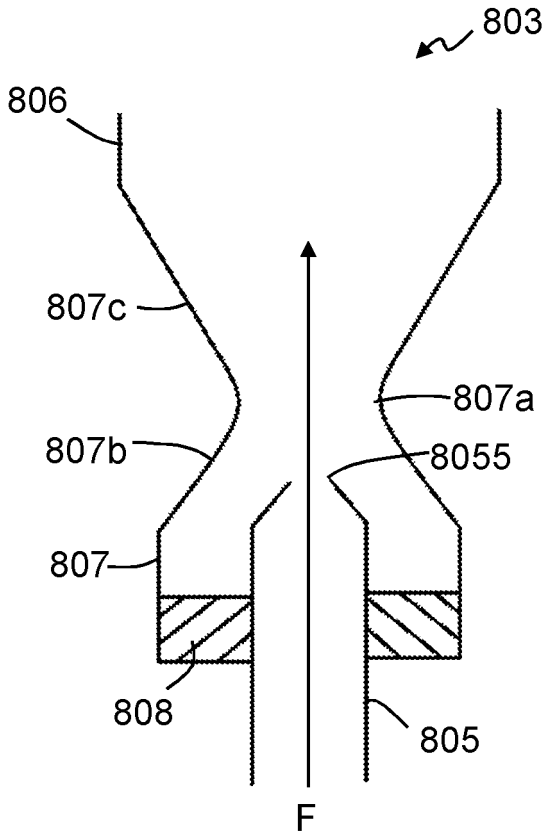


FIGURE 13

REFERENCES CITED IN THE DESCRIPTION

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- US 4025281 A **[0013]**