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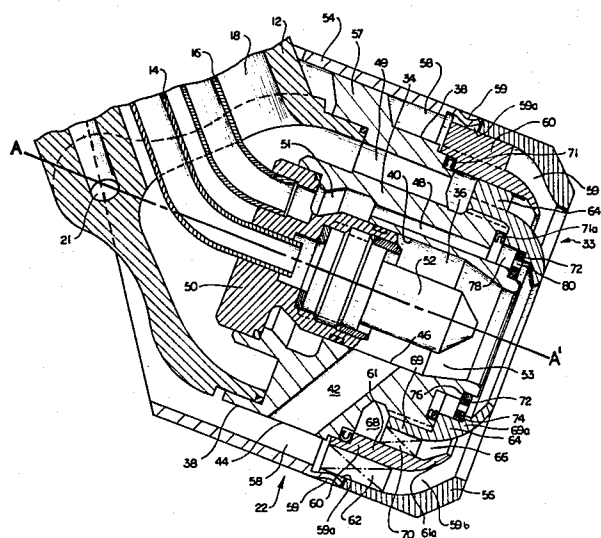
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⑤④ Fuel nozzle with intermediate swirl circuit.

⑤⑦ A fuel nozzle assembly including a nozzle (22) connected to a holder and selectively supplied with primary and secondary liquid fuel through inlet pipes (14, 16) and gas or other fluids through ducts (18, 21). A discharge orifice (33) of the nozzle (22) provides a spray from a primary atomizer (52) and a swirl plate (72), either alone or separately. The spray pattern is defined and atomized by air flow from an air swirl annulus (59b) and a passageway (53). An annulus (66) provides a swirling gas flow that is mixed with air flow from the air swirl annulus (59b). Alternatively, the annulus (66) provides a supplemental air flow to atomize the liquid spray.



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FUEL NOZZLE WITH INTERMEDIATE
SWIRL CIRCUIT

The invention relates to fuel nozzles and more particularly to fuel nozzles suitable for mixing air with both liquid and gaseous fuels.

For many years, turbine engines used in industrial applications were generally fueled by petroleum based, liquid fuels or, alternatively, by natural gas. Often, the fuel nozzles, as well as the engine itself, were compatible with only one of these types of fuels. For example, in a typical gas nozzle, the gas was injected in divergent directions from a plurality of holes and mixed with a swirling air blast. In contrast, in a typical fuel oil nozzle, fuel oil was divided into a primary flow and a secondary flow. The primary flow was pressure atomized and the secondary flow was atomized by a swirling air blast. Specific examples of such prior fuel nozzles are shown and described in U.S. Patents 3,013,732; 3,912,164; 3,980,233; and 4,365,753. Thus, turbine engines were powered by one type of fuel exclusively; there was no freedom to choose between available fuels on the basis of cost or availability.

Fuel shortages and price fluctuations resulted in the development of industrial turbine engines that could selectively be operated on any of several different types of fuels. However, such turbine engines relied on the use of a separate, parallel fuel supply system for each type of fuel used. This arrangement resulted in multiple sets of fuel nozzles with each set of nozzles designed to provide a pattern of injection, atomization or mixing as preferred for improved engine performance with the respective fuel. For example, a typical industrial turbine engine that operated on either natural gas or fuel oil would require a first set of nozzles that provided an injection pattern as preferred for natural gas, and a second set of nozzles that provided a spray pattern as preferred for fuel oil.

The use of multiple sets of fuel nozzles had several disadvantages. Such arrangements tended to be costly and were difficult to fit within the space available in the engine. Accordingly, there was a need for a more compact, cost effective, nozzle that could serve in place of two or more fuel nozzles designed for different types of fuels.

According to one aspect of the invention there is provided a fuel nozzle that provides a mixture of fuel and air at an output orifice, characterised in that the nozzle comprises:

a nozzle body having an internal cavity;

5 a cover that circumferentially surrounds the nozzle body;

a first swirler that is connected to the body and radially located between the body and the cover, the first swirler co-operating with the cover to form an outer annulus therebetween;

10 a second swirler that is connected to the body and radially located between the body and the first swirler, the second swirler co-operating with the first swirler to form an intermediate fluid annulus therebetween; and

means for atomizing fuel, the atomizing means being connected to the body and located radially inwardly of the intermediate annulus.

15 Preferably, the atomizing means includes a primary fuel atomizer located in an internal cavity of the body, and a swirl plate that is maintained between the body and the intermediate swirler. The swirl plate provides a passageway between a secondary fuel supply annulus in the body and the discharge orifice of the nozzle.

20 Advantageously, the primary fuel atomizer co-operates with the body to provide an inner air annulus between the atomizer and the cavity wall. The body includes a plurality of passageways, each passageway having an opening in the wall of the internal cavity and an opening in the peripheral surface of the body and being obliquely aligned with respect to the longitudinal axis of the nozzle such that a swirled flow of air is provided to
25 the inner air annulus from the periphery of the body.

One or both of the outer air swirler and the intermediate swirler may include a plurality of swirl vanes that are circumferentially spaced and canted with respect to the longitudinal axis of the nozzle to swirl air or fuel in the intermediate annulus, and to swirl air in the outer air swirl annulus.

30 According to another aspect of the invention there is provided a fuel nozzle that provides a mixture of fuel and air through an output orifice, characterised in that the nozzle comprises:

a body having an internal cavity and a passageway between an opening in the cavity and an opening in the peripheral surface of the body;

35 a cover that circumferentially surrounds the nozzle body;

a first swirler that is connected to the body and that is radially located between the body and the cover, the first swirler co-operating with the cover to form an outer air annulus therebetween;

5 a second swirler that is connected to the body and that is radially located between the body and the first swirler, the second swirler co-operating with the first swirler to form an intermediate annulus therebetween; and

a fuel atomizer located in the internal cavity of the body, the fuel atomizer co-operating with the body to provide an inner air annulus between the atomizer and the wall of the internal cavity.

10 According to a still further aspect of the invention there is provided a fuel nozzle comprising:

a body having an internal cavity and a plurality of passageways that are regularly, circumferentially arranged in the body, each of the passageways being between a respective opening in the wall of the cavity and a
15 respective opening in the peripheral surface of the body and obliquely aligned with respect to the longitudinal centre axis of the nozzle;

a fuel atomizer located in the internal cavity of the body, the fuel atomizer co-operating with the wall of the internal cavity to provide an inner air annulus between the atomizer and the wall of the cavity;

20 a cover that is open on at least one end and that circumferentially surrounds the nozzle body;

a first swirler that is connected to the body and that is radially located between the body and the cover, the first swirler co-operating with the cover to form an outer air annulus therebetween; and

25 a second swirler connected to the body and radially located between the body and the first swirler, the second swirler co-operating with the first swirler to form an intermediate annulus therebetween, the second swirler also co-operating with the first swirler and the peripheral surface of the body to form an annular cavity that is in communication with the
30 intermediate annulus.

The invention is diagrammatically illustrated by way of example in the accompanying drawings, in which:-

Figure 1 is an elevational cross-section of a fuel nozzle assembly according to the invention; and

35 Figure 2 is an enlarged view of a nozzle of the assembly shown in Figure 1.

As shown in Figures 1 and 2, the preferred embodiment of the invention provides a nozzle that is physically compact, but has the flexibility to provide a mixture of air and either liquid or gaseous fuels as well as additives thereto. In Figure 1, a nozzle assembly 10 includes a holder 12 that envelops tubes 14 and 16 in a central conduit 18. A sidewall 19 of the holder 12 is provided with a passageway 20 having a hole 21 at the end thereof. At one end, the holder 12 secures a nozzle 22 and, at the other end, the holder 12 is connected to a manifold 24.

The manifold 24 is provided with inlet fittings 26, 28, 30 and 32 for respective connection to supplies of pressurized primary liquid fuel, pressurized secondary liquid fuel, natural gas and water. The inlet fittings 26 and 28 are respectively connected to the tubes 14 and 16, the inlet fitting 30 is connected to the conduit 18, and the inlet fitting 32 is connected to the passageway 20. Thus, when the inlet fittings 26, 28, 30 and 32 are connected to their respective liquid fuel, natural gas and water supplies, the nozzle 22 is provided with pressurized liquid fuel through the tube 14, pressurized liquid fuel through the tube 16, natural gas through the conduit 18, and water through the passageway 20.

Referring specifically to Figure 2, the nozzle 22 is connected to the holder 12 at one end and at the other end is provided with a discharge orifice 33. the nozzle 22 includes a body 34 having an internal cavity 36 aligned with the longitudinal centre axis A-A' of the nozzle 22. The body 34 has an outer peripheral surface 38 and the cavity 36 has a cavity wall 40. The body 34 is also provided with typically four or more passageways 42 that are regularly spaced circumferentially around the body 34. Each of the passageways 42 connects a respective opening or port 44 in the peripheral surface 38 with a respective opening or port 46 in the cavity wall 40. The passageways 42 are aligned obliquely on non-intersecting axes with respect to the longitudinal centre axis A-A' of the nozzle 22. The passageways 42 thus co-operate to provide a swirled flow of air to the internal cavity 36 from the peripheral surface 38. Also, the body 34 is provided with at least one secondary fuel bore 48 and a gas bore 49.

A retainer 50 is connected to one end of the body 34 and co-operates with the body 34 to form an annular secondary fuel chamber 51. A primary atomizer 52 of the pressure atomization type as well known in the art is mounted in the retainer 50 such that it projects into the internal cavity 36

of the body 34 and co-operates with the internal wall 40 to form an inner air annulus 53 that is in communication with the ports 46. The retainer 50 is also connected to the tubes 14 and 16 of the holder 12. The tube 14 extends through the retainer 50 and is in fluid communication with the primary atomizer 52. The tube 16 is in communication with the annular secondary fuel chamber 51.

A cover that includes a housing 54 and a shroud 56 circumferentially surrounds the body 34. More specifically, the housing 54 is a generally cylindrical member that is connected to the body 34 by a plurality of posts 57 and co-operates with the body 34 to form an annular cavity 58 therebetween. The housing 54 is provided with a cylindrical rim 59 that is in crimped engagement with a plurality of longitudinal slots 59a in the shroud 56. Thus, the rim 59 co-operates with the slots 59a of the shroud 56 to prevent rotation of the shroud 56 with respect to the housing 54.

An air swirler 60 also circumferentially surrounds the body 34 and is radially located from the central longitudinal axis A-A' between the shroud 56 and the body 34. The air swirler 60 co-operates with the shroud 56 to form an outer air annulus 59b. More specifically, the air swirler 60 includes an annular ring 61 located adjacent to the body 34 and a cone 61a that is integrally connected to the discharge end of the annular ring 61. The cone 61a co-operates with the shroud 56 to define the air annulus 59b. The swirler 60 further includes a plurality of swirl vanes 62 that are regularly spaced circumferentially around the peripheral surface of the annular ring 61. The swirl vanes 62 are located adjacent the shroud 56 and between the shroud 56 and the annular ring 61 such that the annulus 59b is in communication between the vanes 62 with the annular cavity 58 formed between the body 34 and the housing 54. As more particularly shown and described in U.S. Patents 3,980,233 and 4,365,753, the relevant portions of which are hereby specifically incorporated by reference, the vanes 62 are canted with respect to the longitudinal axis A-A' such that a swirling motion is imparted to air flowing into the annulus 59b from the annular cavity 58. Preferably the adjacent edges of the swirl vanes 62 are fastened to the shroud 56 by brazing or other equivalent means to secure the swirler 60 and the shroud 56.

An intermediate swirler 64 also circumferentially surrounds the body 34. The intermediate swirler 64 is radially located from the central axis

A-A' between the swirler 60 and the body 34 and is screwthreaded onto the body 34. The intermediate swirler 64 co-operates with the air swirler 60 to form an intermediate annulus 66 of the discharge orifice 33. The intermediate swirler 64 also co-operates with the swirler 60 and with the
5 body 34 to form an annular cavity 68 that is in communication with the gas bore 49 and the central conduit 18.

More specifically, the intermediate swirler 64 includes an annular ring 69 located adjacent the body 34 and screwthreaded thereto. The intermediate swirler also includes a cone 69a that is integrally connected to
10 the discharge end of the annular ring 69. The cone 69a co-operates with the cone 61a to define an intermediate annulus 66. The intermediate swirler 64 is further provided with a plurality of swirl vanes 70 that are regularly spaced circumferentially around the peripheral surface of annular ring 69. Swirl vanes 70 are located adjacent the annular ring 61 of the air swirler 60
15 such that the annulus 66 is in communication with the annular cavity 68 between the vanes 70. In a manner similar to the swirl vanes 62, the swirl vanes 70 are canted with respect to the longitudinal axis A-A' such that a swirling motion is imparted to fluid flowing into the annulus 66 from the cavity 68. Preferably, the edges of the swirl vanes 70 adjacent the annular
20 ring 61 of the air swirler 60 are fastened thereto by brazing or other equivalent means to secure the swirler 60 with respect to the intermediate swirler 64.

Thus, the intermediate swirler 64, the outer air swirler 60 and the shroud 56 are secured together and are threadedly connected to the body 34
25 at the intermediate air swirler 64. Rotation of the intermediate swirler 64 on the threads is prevented through connection with the housing 54 through the air swirler 60 and the shroud 56. The housing 54 is rigidly connected to the body 34 by the posts 57 and is crimped to the shroud 56 at the rim 59 and the slots 59a. Flexible metal seals 71 and 71a are located between the
30 body 34 and respective end faces of the annular ring 61 and the annular ring 69. Thus, the metal seals 71 and 71a respectively provide a fluid seal between the body 34 and the outer air swirler 60 and between the body 34 and the intermediate swirler 64.

At the end of body 34 adjacent the discharge orifice 33, a swirl plate
35 72 is maintained between a shoulder 74 of the swirler 64 and a shoulder 76 of the body 34. The swirl plate 72 co-operates with the swirler 64 and the

body 34 to define an annular cavity 78 that is in communication with the secondary fuel bore 48, the annular secondary fuel chamber 51, and the tube 16. The swirl plate 72 is provided with a plurality of holes 80 such that fuel in the annular cavity 78 can flow past the swirl plate 72 to the discharge orifice 33. The swirl holes 80 are circumferentially spaced around the swirl plate 72 and are canted with respect to the longitudinal axis A-A' such that swirling motion is imparted to fuel flowing past the swirl plate 72 to the discharge orifice 33.

The nozzle assembly shown in Figures 1 and 2, has various operational modes in which it provides liquid fuel, natural gas, or various combinations thereof either with or without water mixed therein. When only a liquid fuel and air mixture is to be provided, the liquid fuel is provided under pressure to the primary atomizer 52 through the tube 14. The primary atomizer 52 provides a primary spray pattern through the nozzle discharge orifice 33.

When a secondary liquid fuel spray pattern is to be used in combination with the primary pattern, liquid fuel is provided through the tube 16, the secondary fuel chamber 51, the secondary fuel bore 48 and the annular cavity 78 to the swirl plate 72. From the swirl plate 72, the secondary fuel flows out of the discharge orifice 33 in a swirled pattern.

Generally it is preferable to mix the primary and swirled secondary fuel spray patterns with swirled air better to atomize and define the spray pattern and retard accumulation of carbon on surfaces of the nozzle 22 adjacent the discharge orifice 33. In the preferred embodiment of the invention, this is accomplished by supplying high velocity or pressurized air to the annular cavity 58. The air in the cavity 58 is swirled by the vanes 62 as it flows into the outer air annulus 59b such that it forms an outer swirling air flow at the discharge orifice 33. Also, the air in the cavity 58 flowing to the discharge orifice 33 through the passageways 42 is swirled by the passageways 42 as it flows into the inner air annulus 53 to further define and atomize the spray pattern.

When the nozzle assembly 10 is to provide natural gas, or another alternate fluid as fuel, the gas is supplied through the conduit 18, the bore 49, and the annular cavity 68 to the intermediate annulus 66. The swirl vanes 70 cause the gas in the annulus 66 to exit at the discharge orifice 33 in a swirling pattern. To better define and mix the injection pattern of gas from the annulus 66, it is generally preferred to provide a swirling air from

the outer air annulus 59b and the inner air annulus 53 in a manner similar to that explained above with regard to liquid fuel.

5 The nozzle 22 can supply liquid fuel and gas simultaneously in the manner described above by supplying liquid fuel to the tubes 14 and 16 and gas to the conduit 18. In this case, the swirling flow of gas from the intermediate annulus 66 supplements the swirling air flow from the outer air annulus 59b and the inner air annulus 53 further to improve atomization of the liquid spray pattern. Alternatively, the inlet fitting 30 and the conduit 18 can be coupled to a supply of high velocity or pressurized air instead of a
10 gas supply. In that case, the intermediate annulus 66 would provide a swirling air flow pattern that would supplement the swirling air flow from the outer air annulus 59b and the inner air annulus 53 further to improve the definition and atomization of the liquid spray pattern from the primary atomizer 52 and the swirl plate 72.

15 Liquid fuel injected through the primary atomizer 52, or the swirl plate 72 as well as gaseous fuel injected through the intermediate annulus 66 can be mixed with other additives. The additives are provided through the hole 21 which is in communication with the annular cavity 58. The additives are mixed and atomized in the annular cavity 58, the outer air annulus 59b
20 and the inner air annulus 53 and injected with the swirled air through the discharge orifice 33. For example, it is sometimes desirable to mix certain proportions of water with fuel oil or natural gas so that when the mixture is combusted, the water vapour will reduce the quantity of nitrogen oxides in the combustion exhaust.

25 Test have empirically demonstrated that the use of swirling fluid from the intermediate annulus 66 to supplement the definition and atomization of the liquid spray pattern as herein described has resulted in unexpectedly large improvements in liquid fuel atomization. In one example, fuel was supplied only to the primary atomizer 52 and the spray
30 pattern atomized by swirling air from the outer air annulus 59b and the inner air annulus 53. A fuel flow rate of 3.09 kilos (6.8 pounds) per hour of 12×10^{-6} sq. m/sec (12 centistokes) viscosity fluid and an air pressure drop of 249 Pa (1 inch of water) across the vanes 62 resulted in a mean drop diameter of 136 micrometers, Sauter Mean Diameter. When air at
35 10.34 k Pa (1.5 psi) was additionally supplied to the conduit 18, the air swirl from the intermediate annulus 66 caused a reduction in mean drop diameter to 52 micrometers.

5 In another example, fuel was supplied only to the swirl plate 72 and the spray pattern atomized by an air swirl from the outer air annulus 59b and the inner air annulus 53. A fuel flow rate of 11.8 kilos (26 pounds) per hour of 12×10^{-6} sq. m/sec (12 centistokes) viscosity fluid and an air pressure drop of 747 Pa (3 inches of water) across the vanes 62 resulted in a mean drop diameter of 90 micrometers, Sauter Mean Diameter. When air at 27.56 k Pa (4.0 psi) was additionally supplied to the conduit 18, the air swirl from the intermediate annulus 66 caused a reduction in a mean drop diameter to 23 micrometers, Sauter Mean Diameter.

CLAIMS

1. A fuel nozzle that provides a mixture of fuel and air at an output orifice (33), characterised in that the nozzle (22) comprises:
a nozzle body (34) having an internal cavity (36);
a cover (54, 56) that circumferentially surrounds the nozzle body (24);
5 a first swirler (60) that is connected to the body (34) and radially located between the body (34) and the cover (54, 56), the first swirler (60) co-operating with the cover (54, 56) to form an outer annulus (59b) therebetween;
a second swirler (64) that is connected to the body (34) and radially located
10 between the body (34) and the first swirler (60), the second swirler (64) co-operating with the first swirler (60) to form an intermediate fluid annulus (66) therebetween; and
means (52, 72) for atomizing fuel, the atomizing means being connected to the body (34) and located radially inwardly of the intermediate annulus (66).
15
2. A fuel nozzle according to claim 1, wherein the atomizing means comprises a fuel atomizer (52) located in the internal cavity (36) of the body (34).
- 20 3. A fuel nozzle according to claim 1 or claim 2, wherein the body (34) has a secondary fuel supply annulus (78) and wherein the atomizing means includes:
a swirl (72) that is maintained between the body (34) and the second swirler (64), the swirl plate (72) providing a passageway (80) between the secondary
25 fuel supply annulus (78) and the output orifice (33) of the nozzle (22).
4. A fuel nozzle according to any one of claims 1 to 3, wherein the body (34) includes a plurality of passageways (42) that are regularly, circumferentially arranged in the body (34), each of the passageways (42)
30 being between a respective opening (46) in the wall (40) of the internal cavity (36) and a respective opening (44) in the peripheral surface (38) of the body (34) and obliquely aligned with respect to the longitudinal centre axis (A-A') of the nozzle.

5. A fuel nozzle that provides a mixture of fuel and air through an output orifice (33), characterised in that the nozzle (22) comprises:
a body (34) having an internal cavity (36) and a passageway (42) between an opening (46) in the cavity (36) and an opening (44) in the peripheral surface (38) of the body (34);
5 a cover (54, 56) that circumferentially surrounds the nozzle body (34);
a first swirler (60) that is connected to the body (34) and that is radially located between the body (34) and the cover (54, 56), the first swirler (60) co-operating with the cover (54, 56) to form an outer air annulus (59b) therebetween;
10 a second swirler (64) that is connected to the body (34) and that is radially located between the body (34) and the first swirler (60), the second swirler (64) co-operating with the first swirler (60) to form an intermediate annulus (66) therebetween; and
15 a fuel atomizer (52) located in the internal cavity (36) of the body (34), the fuel atomizer (52) co-operating with the body (34) to provide an inner air annulus (53) between the atomizer (52) and the wall (40) of the internal cavity (36).
- 20 6. A fuel nozzle of claim 5, wherein the first swirler (60) includes an annular ring (61);
a defining cone (61a) connected to one end of the annular ring (61); and
a plurality of swirl vanes (62) that are circumferentially spaced about the peripheral surface of the annular ring (61) and connected to the cover (56),
25 the swirl vanes (62) being canted with respect to the longitudinal axis (A-A') of the nozzle (22) to swirl fluid flowing through the outer air annulus (59b).
7. A fuel nozzle according to claim 5 or claim 6, wherein the second swirler (64) includes
30 an annular ring (69);
a defining cone (69a) connected to one end of the annular ring (69); and
a plurality of swirl vanes (70) that are circumferentially spaced about the peripheral surface of the annular ring (69) and connected to the first swirler (60), the swirl vanes (70) being canted with respect to the longitudinal axis (A-A') of the nozzle to swirl fluid flowing through the intermediate annulus (66).
35

8. A fuel nozzle according to any one of claims 5, 6 or 7, wherein the body (34) includes a second fuel supply annulus (78) and the nozzle further comprises:

5 a swirl plate (72) that is maintained between the body (34) and the second swirler (64), the swirl plate (72) providing a passageway (80) between the secondary fuel supply annulus (78) and the output orifice (33) of the nozzle.

9. A fuel nozzle according to claim 8, wherein the swirl plate (72) includes a plurality of swirl holes (80) that are circumferentially spaced
10 around the swirl plate (72), the swirl holes (80) being canted with respect to the longitudinal axis (A-A') of the nozzle to swirl fluid flowing from the secondary fuel supply annulus (78) to the output orifice (33) of the nozzle.

10. A fuel nozzle comprising:

15 a body (34) having an internal cavity (36) and a plurality of passageways (42) that are regularly, circumferentially arranged in the body (34), each of the passageways (42) being between a respective opening (46) in the wall (40) of the cavity (36) and a respective opening (44) in the peripheral surface (38) of the body (34) and obliquely aligned with respect to the longitudinal centre
20 axis (A, A') of the nozzle (22);

a fuel atomizer (52) located in the internal cavity (36) of the body (34), the fuel atomizer (52) co-operating with the wall (40) of the internal cavity (36) to provide an inner air annulus (53) between the atomizer and the wall (40)
25 of the cavity (36);

a cover (54, 56) that is open on at least one end and that circumferentially surrounds the nozzle body (34);

a first swirler (60) that is connected to the body (34) and that is radially located between the body (34) and the cover (54, 56), the first swirler (60)
30 co-operating with the cover (54, 56) to form an outer air annulus (59b) therebetween; and

a second swirler (64) connected to the body (34) and radially located between the body (34) and the first swirler (60), the second swirler (64) co-operating with the first swirler (60) to form an intermediate annulus (66)
35 therebetween, the second swirler (64) also co-operating with the first swirler (60) and the peripheral surface of the body (34) to form an annular cavity (68) that is in communication with the intermediate annulus (66).

