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COMBUSTION APPARATUS AND LIQUID FUEL DISCHARGE APPARATUS ADAPTED FOR USE THEREWITH

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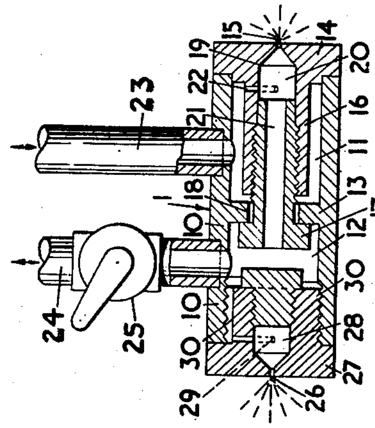

Fig. 1

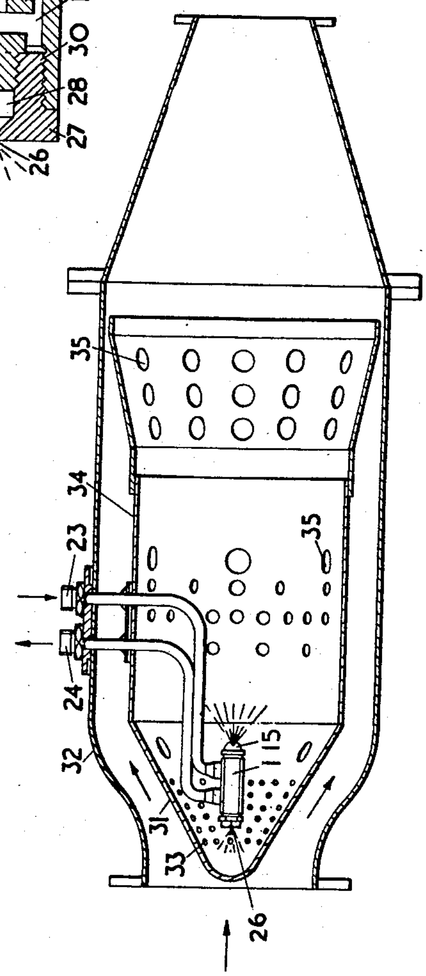

Fig. 2

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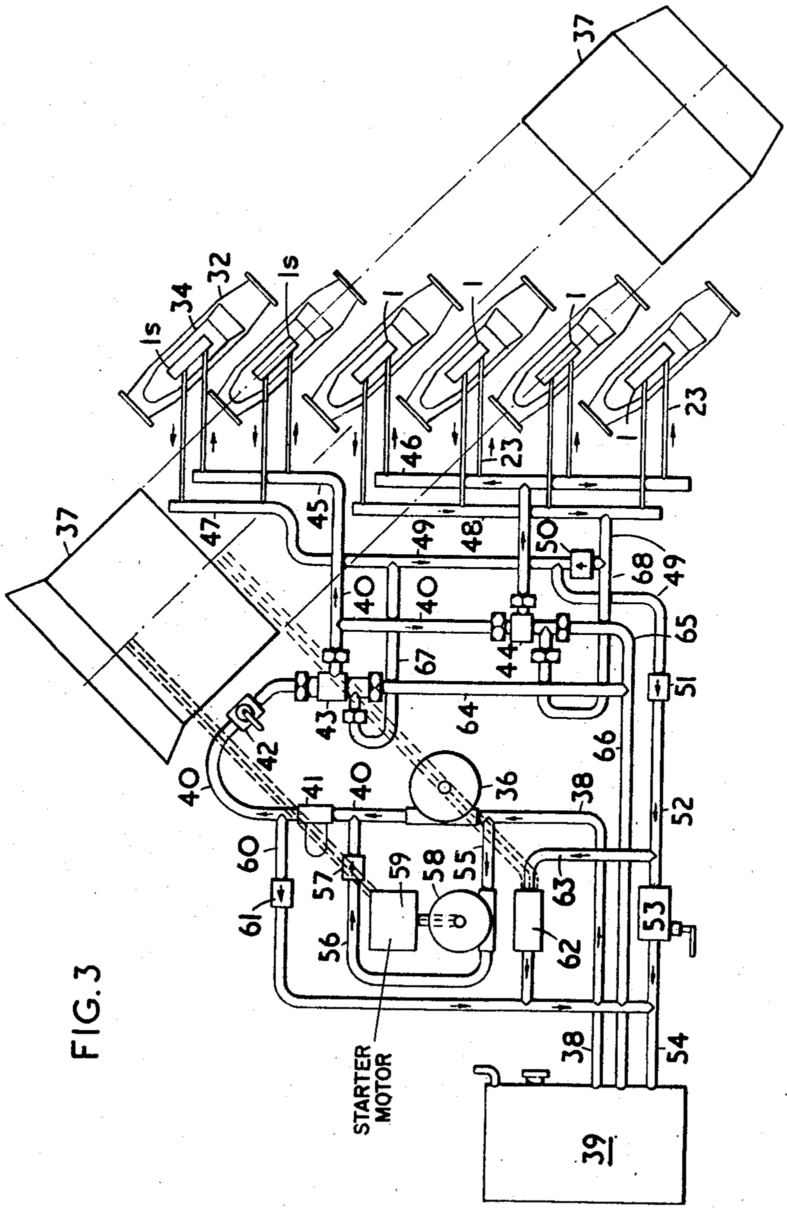

FIG. 3

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COMBUSTION APPARATUS AND LIQUID FUEL DISCHARGE APPARATUS ADAPTED FOR USE THEREWITH

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8 Claims. (Cl. 60—39.74)

This invention relates to combustion apparatus and to liquid discharge apparatus adapted for use therewith and its primary odbject, stated in general terms, is the provision of a combustion apparatus and liquid fuel burner, which will offer the possibility of effective and efficient combustion over a wide range of operating conditions.

Whilst, as will be seen after consideration of its details, the liquid discharge apparatus of the invention has possible application in a wider field, the invention is primarily concerned and is at present conceived to have its maximum utility in connection with liquid fuel combustion apparatus in which special problems arise due to the necessity for supporting combustion by means of a fast moving air current involving a large mass flow as for example, in gas turbine or/and jet propulsion power units, the description "fast moving" being used here to indicate that the mean speed of the combustion supporting air current in its general direction of flow past a combustion zone, calculated from the ratio air volume passing in unit time/cross sectional area of flow path, is substantially higher than the speed of flame propagation in the fuel/air mixture concerned. For hydrocarbon fuels burning in air the speed of flame propagation is considered as being of the order of one foot per second at atmospheric temperature; the invention is especially applicable to combustion apparatus for gas turbine or/and jet propulsion power units in which the air current in its general direction of flow past a combustion zone, calculated on the basis indicated, might be of an order as low as 10 or as high as 300 feet per second or even more, depending on the design.

Satisfactory operation of a combustion system of the kind indicated over a wide range of air mass flow and density requires that the fuel input should be capable of variation between wide limits while maintaining a high standard of atomisation over the entire range. An additional requirement is that the flame should not be extinguished under any conditions of operation and in order to prevent this the range of air/fuel ratios over which burning will take place must be as wide as possible whilst maintaining combustion efficiency at a reasonable level with weak mixtures. Further, it is desirable that pressure losses should be low.

The invention may be considered from two aspects; first as an improved combustion apparatus capable as a whole of being made to satisfy some or all of the requirements mentioned in the foregoing; and secondly as an improved liquid discharge apparatus, applicable more particularly to the discharge of liquid fuel in combustion apparatus.

Considered in its first aspect, the invention proposes a combustion apparatus in which there is both a main discharge of liquid fuel into a combustion zone and a subsidiary or "pilot" discharge producing a pilot flame serving to ignite the main discharge, the latter coming into operation automatically, but only when the fuel delivery requirements rise above a predetermined minimum and the pilot discharge alone operating below that minimum, and in which the introduction of air from the main supply to the main pilot discharge respectively for their combustion is controlled in such a way that the actual air supply to the latter remains substantially constant, or at least varies only over a relatively small range as compared with the actual air supply to the former, which is allowed to be influenced to a major extent by variations in the main air supply.

According to the invention in its second aspect there is provided a liquid discharge apparatus, in which there is a main liquid discharge device of the spill type as defined below and a pilot liquid discharge device which is supplied and maintained from the spill of liquid from the main liquid discharge device. The expression "spill type" is used here to indicate the known arrangement of liquid discharge device in which the discharge takes place from a chamber in which the liquid is caused to swirl and which has a spill or return port for returning liquid to source and a discharge port or atomising jet both on the axis of swirl, the output from the discharge port or atomising jet being controlled by varying the rate of spill and the discharge ceasing entirely at a given high rate of spill. An example of this principle as applied to an atomising nozzle is to be found in the specification of co-pending patent application No. 597,807, now abandoned.

In principle, the structural relationship of the main and pilot discharge devices is immaterial and they can be suitably disposed and connected by appropriate liquid ducts in accordance with the requirements of any particular case. According to a further feature of the invention, however, the two devices are combined in one structural unit.

It will be seen that with an arrangement of this character, by suitably relating the flow capacities of the main discharge port and the spill or return line, it can be arranged that after discharge from the main port has ceased due to reduction of the spill rate the pilot discharge will continue to take place. A liquid discharge apparatus in accordance with the invention has the advantage that it combines with the extremely good atomisation for all outputs characteristic of the spill type of discharge device, a pilot discharge capable of dealing with special circumstances outside the scope of the main discharge and this with fully automatic initiation of the main discharge not involving any discontinuity or even possibility of discontinuity of the flow. As applied to a fuel burner system for combustion apparatus the device can therefore be used to advantage to provide a pilot discharge of fuel at low demands and a main discharge at higher demands whilst increasing the maximum input of fuel in the latter case and maintaining continuity of output throughout the entire range, there being no interruption of supply when the main discharge commences.

The invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a sectional elevation of a liquid discharge device.

Figure 2 is a sectional elevation of a combustion apparatus with a liquid discharge device as shown in Figure 1.

Figure 3 is a diagrammatic layout of a fuel system and combustion system of a compressor gas-turbine unit for combustion apparatus and liquid discharge device as shown in other figures.

The liquid discharge device 1 as shown in Figure 1 comprises a hollow cylindrical body 10 divided into two compartments or chambers 11 and 12 by an intermediate dividing partition 13. The chamber 11, which is annular is closed at one end by an inserted cap 14 containing a main discharge port 15. The cap 14 has a tubular extension 16 of less diameter than the body 10 into which it extends. The cap 14 is retained in position by a headed plug 17 which is passed through a hole 18 in the dividing partition 13 from the chamber 12 and threaded into the bore 19 of the extension 16, this plug 17 axially filling the bore 19 of the main discharge cap 14 except for a main discharge swirl chamber 20 containing the main discharge port 15, but having an axial passage 21 communicating with the compartment 12 of the body 10. The main discharge swirl chamber 20, which is of circular section co-axial with but of larger diameter than the discharge port 15 and the axial passage or spill way 21 to the other compartment 12 has tangential inlets 22 communicating with the annular chamber 11 between the cap 14 and the body 10, to which space the supply is connected by a pipe 23. The fuel on entering the main discharge chamber 20 through the tangential inlets 22 will be rapidly swirled therein. The second compartment or chamber 12 of the body 10 is connected to a spill return or pipe 24 in which is a controllable valve 25 to vary the flow resistance; the axial passage 21 through which the discharge chamber 20 of the main delivery port 15 communicates with the second compartment 12 thus constitutes a spill passage from the main discharge swirl chamber 20, this spill passage being of a diameter intermediate between that of the chamber 20 and its discharge port 15 so that according as the resistance in the spill line is raised or lowered, so the discharge from the main port 15 will be brought into operation or cut out.

A pilot discharge port 26 is formed in a screwed plug 27 threading into the chamber 12 of the body 10 at the end remote from the main discharge port 15. The plug 27 is provided with a swirl chamber 28 co-axial with and of larger diameter than the discharge port 26 which is in communication with the chamber or spill compartment 12 of the body 10 through tangential inlets 29 communicating with passages 30 formed between the plug 27 and the body 10.

It will be evident that the liquid discharge apparatus described above is admirably suited to the requirements of a combustion apparatus in accordance with the first aspect of the invention one form of which is shown by way of example in Figure 2; in that connection, the invention contemplates in general an arrangement in which the pilot discharge port 26 is placed upstream of the main discharge port 15 with reference to the direction of flow of combustion supporting air, and in the case of the constructional example of discharge apparatus described, the main discharge would be directed downstream.

The pilot discharge port 26 would be screened from the main air flow by means of a perforated conical baffle 31 in a main outer air casing 32 allowing only a restricted air entry through air inlet holes 33 to ensure burning of the pilot fuel discharge under relatively constant conditions. The conical baffle 31 may also be extended in the downstream direction within the outer casing 32 to form a flame tube 34 enclosing the main discharge of fuel from the port 15 for combustion thereof and extending for a substantial distance downstream thereof, the main airflow passing around the flame tube 34 and the latter being provided at intervals downstream of the main discharge with further series of air inlets 35 which may be designed ultimately to introduce the whole of the supply of air, either into the combustion zone of the flame tube 34, or into a mixing zone downstream of the combustion zone proper in which any air surplus to the chemical requirements of combustion is mixed with the combustion products.

It will be appreciated from the foregoing that it is contemplated that the flame tube 34 should be enclosed by the outer casing 32 which constitutes the principal air duct of the combustion apparatus; and in this connection it may be noted that when the pilot discharge port 26 is directed upstream, the baffle may incorporate the

features of co-pending patent application No. 609,532, now U. S. Patent No. 2,529,506, that is to say, it may be constructed to direct a part only of the main air supply at one or more points into a radially inner region of the pilot discharge port 26. The general construction of the flame tube 34 would thus conform to the construction described in co-pending patent application No. 793,375, now U. S. Patent No. 2,667,033. Alternatively or additionally, the baffle might be of conical form with its apex directed upstream so that its walls form with the outer casing a diffusion passage in accordance with co-pending patent application No. 793,375, now U. S. Patent No. 2,667,033.

The invention as applied to gas turbines is shown diagrammatically in Figure 3 together with a spill controlled fuel system which is essential to that type of combustion apparatus.

In the application of the invention to a gas turbine 37 there may be a number of individual burners 1 each with its main discharge port 15 and pilot discharge 26 annularly disposed about the axis of the turbine-compressor unit 37 and contained either within separate air casings 32 or within a single annular air casing, not shown. In certain circumstances also the downstream extension of the baffle to form a flame tube might be omitted.

In Figure 3 a main fuel pump 36 of substantially positive displacement type is driven from a compressor-gas turbine unit 37. It draws fuel through a suction pipe 38 from a fuel tank 39 and delivers fuel by the main delivery pipe 40 through a high pressure filter 41 through a manually operated stop cock 42, a dump valve 43 and a dump valve 44, manifold pipes 45 and 46 and pipes 23 to starting spill burners 15 and main spill burners 1 in flame tubes 34 in air casings 32.

The fuel is spilled back through individual spill ways 21 in the burners (see Figure 1) through spill or return pipe 24 to spill manifolds 47 and 48 to return pipe 49, non-return valves 50 and 51, pipe 52, throttle valve 53 and return pipe 54 to fuel tank 39. The throttle valve 53 is a manually controlled valve having a barometrically controlled relief valve to control the flow in accordance with ambient barometric pressure to obviate the adjustment of the throttle valve by the pilot to maintain constant turbine speed due to change in altitude or barometric pressure at constant altitude as described in co-pending patent application No. 597,810 now U. S. Patent No. 2,669,245.

In parallel with pump 36 is a supplementary pump circuit comprising a feed branch 55, a delivery branch 56 with a non-return valve 57, a pump 58 driven by the compressor-gas turbine starter motor 59.

A pipe 60 having a non-return valve 61 is arranged to lead fuel from a point between the filter and stop cock 42 back to the fuel tank 39 as the fuel pump 36 is selected and adjusted to deliver fuel at a higher rate than the turbine demands at any speed.

In addition to the barometric control of spill return flow a speed control is provided. A centrifugal speed controlling a governor valve 62 operating in accordance to the speed of the compressor gas-turbine 37 is arranged in a pipe 63 leading from the pipe 52 to the pipe 60.

The dump valves 43 and 44 which are change-over pressure operated valves operated by the fuel pressure are provided with drain connections 64 and 65 respectively joining common drain 66 leading to the fuel tank 39 to enable supply manifolds 45 and 46 to be drained when the system is shut down. The dump valves 43 and 44 are also provided with spill connections 67 and 68 respectively to connect the spill manifolds 47 and 48 to drain when the fuel supply is shut down.

In the system two dump valves 43 and 44 are provided, dump valve 44 opening at a slightly higher pressure than dump valve 43. Thus when the dump valve 43 opens it admits fuel to the burners 15 fed by manifold 45 and admits fuel to dump valve 44. When the fuel pressure has risen sufficiently, dump valve **44** opens admitting fuel to main burners **1** fed by manifold **46**. The dump valves **43** and **44** are arranged in this manner to enable the starting burners **15** fed by manifold **45** to be set in operation first in conjunction with spark ignition to start the compressor gas turbine unit **37**. The function of the non-return valve **50** is to prevent fuel entering the main burners **1** by way of manifold **48** when the starting burners **15** begin to operate.

To start the compressor-gas turbine unit **37** the cock **42** is opened and the starter motor **59** is energised. The compressor-gas turbine unit **37** is thus accelerated from rest and the pump **36** begins to operate as well as the pump **58** directly coupled to the starter motor **59**. It is not economical to make pump **36** sufficiently large in capacity or to arrange its drive gear ratio with the compressor-gas turbine unit in such a way that its output in pressure and delivery is adequate for starting, hence the provision of pump **58**. At starting it can be assumed that pump **58** supplies the fuel. It draws fuel from the tank **39** through pipes **38** and **55** and delivers it through pipe **56** to pipe **40** as long as the motor **59** is running. The fuel flows by pipe **40** to the valves **43** and thence to the burners **15** when fuel pressure is sufficient to operate dump valve **43**. As soon as dump valve **43** opens and fuel commences to issue from the burners **15** igniters operate to start combustion in the starter burners **15**. The compressor gas turbine unit **37** then begins to accelerate and the pump **36** begins to operate and quickly raises the pressure in the pipe **40**. When the pressure in pipe **40** exceeds the pressure due to the pump **59** the non-return valve **57** closes and the starter motor is stopped. The increased pressure in the pipe **40** also enables the dump valve **44** to open and supply fuel to the main burners **1** which are ignited and the compressor-gas turbine unit is running under its own power.

To stop the compressor turbine unit all that is required is to shut off the cock **42**. When this is done, the dump valves **43** and **44** close cutting off the fuel supply to the burners and opening the burners **15** and **1**, supply manifolds **45** and **46** and spill return manifolds **47** and **48** to drain. Any air pressure in the flame tubes **34** and air casings **32** to which the burners **15** and **1** are exposed tends to flow back through the burners **15** and **1** and out through the valves **43** and **44** to the fuel tank **39**, preventing dribbling of the burners and emptying of the manifold pipes **45**, **46**, **47** and **48**, which is found to be good practice.

It will be evident that although the invention has been described primarily with the problems of combustion apparatus particularly for gas turbines in mind, the features of the liquid discharge apparatus are capable of application in the wider field of spray-producing devices provided that the general requirement arises that there should be both a pilot and a main discharge giving continuity of operation when the main discharge comes into operation and effective over a wide range.

In the particular case of the gas turbine, combustion apparatus designed in accordance with the invention has been found to give satisfactory operation with good efficiency at weak mixtures and over a wide range of air/fuel ratios. For example, an efficiency of 65% at a mixture strength of 700:1 has been obtained with a weak flame extinction limit as high as 900:1. It has also been found that the pressure loss can be kept very low and that a combustion can be produced whose operation is very stable and in which it is exceedingly difficult to extinguish the flame by violent alterations of the fuel flow.

We claim:

1. Combustion apparatus for burning a variable quantity of liquid fuel in a high-velocity variable air stream comprising, in combination, a fuel injector body lying along the said air stream, which injector incorporates therein, at opposite ends thereof, a main injector and a continuously-operating pilot injector, the said pilot injector being at the upstream end of the body, a source of supply of fuel to said injector body feeding both said injectors, control means for varying the rate of discharge of fuel from the said source through said main injector without affecting appreciably the discharge of fuel from the same source through said pilot injector, and an air-restrictor which is proportioned to restrict the flow of air to the region of the discharge from the pilot injector to a small and substantially invariable part of the main air stream.

2. Combustion apparatus for burning a variable quantity of liquid fuel in a high-velocity variable air stream comprising, in combination, a flame tube for the passage of the air stream, open at its downstream end, a fuel injector lying along the stream within said tube, in the neighborhood of the upstream end of the tube, which injector has a continuously-operating pilot nozzle in its upstream end and a main nozzle in its downstream end, a source of supply of fuel to said injector feeding both said nozzles, control means for varying the rate of discharge of fuel from the said source through said main nozzle without appreciably affecting the discharge of fuel from the same source through said pilot nozzle, and a closure element at the upstream end of said flame tube finely perforated to admit to the region of the discharge from the pilot nozzle only a small and substantially invariable portion of air from said stream, the flame tube being apertured further downstream to admit main combustion air for the burning of the fuel from said main nozzle.

3. Combustion apparatus for burning a variable quantity of liquid fuel in a high-velocity variable air stream comprising, in combination, a spill type main fuel injector, a fuel-supply line to said main injector, a spill return line from said main injector, means for varying the relationship of the flow in said supply line to that in said return line, a pilot fuel injector, proportioned to discharge only a minor part of the liquid fuel supply, said pilot injector being continuously fed from the spill stream from the said main injector, and an air-restrictor proportioned to restrict the flow of air to the region of the pilot nozzle to a small and substantially invariable part of the main air stream.

4. Combustion apparatus according to claim 3 wherein said main and pilot injectors are constituted by a main and a pilot nozzle at the downstream and upstream ends respectively of an injector unit lying along the air stream, the main nozzle discharging downstream and the pilot nozzle discharging continuously upstream from a spillway extending upstream from said main nozzle.

5. Combustion apparatus for burning a variable quantity of liquid fuel in a high-velocity variable air stream comprising, in combination, a flame tube defining a passage for the air stream, said tube being open at its downstream end, finely perforated at its upstream end to admit to an upstream region only a small and substantially invariable part of the air from the said stream and intermediately apertured to admit main combustion air from said stream, a fuel injector device lying along the air stream at the upstream end of said flame tube, a main fuel injector therein of the spill type with its nozzle discharging towards the incoming main combustion air, a fuel supply line connected to said main injector, a spill return line therefrom, a pilot fuel injector in said injector device continuously fed from the spill stream from said main injector with its nozzle discharging only a minor part of the fuel supply into said upstream region and, means for varying the relationship of the flow in said supply line to that in said spill return line to vary the rate of discharge of fuel from the said main injector without appreciably affecting the rate of discharge from said pilot injector.

6. A liquid fuel discharge apparatus for producing a

main fuel jet which can be varied over a wide range, and a continuously operating pilot jet from the same fuel supply, not appreciably affected by the variation of the main jet, comprising a fuel discharge device, a fuel circulating system therethrough constituted by a supply connection thereto, and a spill return line therefrom, and means in said circulating system for causing the flow in said spill return line to differ variably from that in said supply connection, said fuel discharge device having a main nozzle of the spill type at one end, fed by said supply connection, a spillway extending from said main nozzle to said spill return line, and a pilot nozzle at the other end of the device fed from said spillway.

7. An apparatus according to claim 6 wherein said means for causing the flow in said spill-return line to differ variably from that in said supply connection is a valve in said spill-return line.

8. An apparatus according to claim 6 wherein said discharge device consists of a body enclosing a main swirl chamber formed on the axis of the body at one end thereof, from which chamber the main nozzle discharges axially, a tangential inlet to said chamber with which said supply connection is in communication, a co-axial pilot swirl chamber at the other end of the body from which chamber the pilot nozzle discharges, an intermediate space with which said return line is in communication, a spillway extending axially from the rear of said main whirl chamber to said intermediate space and a tangential inlet to said pilot swirl chamber in communication with said intermediate space.

No references cited.