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(58) Field of Search
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(54) Abstract Title
Multi-fuel gas turbine engine combustor

(57) A multi-fuel gas-turbine engine combustor has a burner head having both pilot gas and pilot liquid-fuel injection arrangements, the pilot gas arrangement comprising an annular gallery 19, 32 communicating with a downstream face of the head and a deflecting arrangement adjacent the gallery for directing the pilot gas-fuel towards a longitudinal axis 21 of the combustor and over a central part of the downstream face 22. The combustor is designed so that, during both gas- and liquid-fuel operations, the flame front face FF is located close to the burner head and during liquid-fuel operation air is forced across the downstream face to cool the head. Advantageously, the cooling air is made to replace the pilot gas-fuel in the annular gallery, so that it is deflected, like the gas-fuel, and contacts the central part of the downstream face. The burner head also features main gas 23 and liquid-fuel (27, Fig.3) injection arrangements, these communicating with one or more passageways in a radial swirler 14 attached to the head.

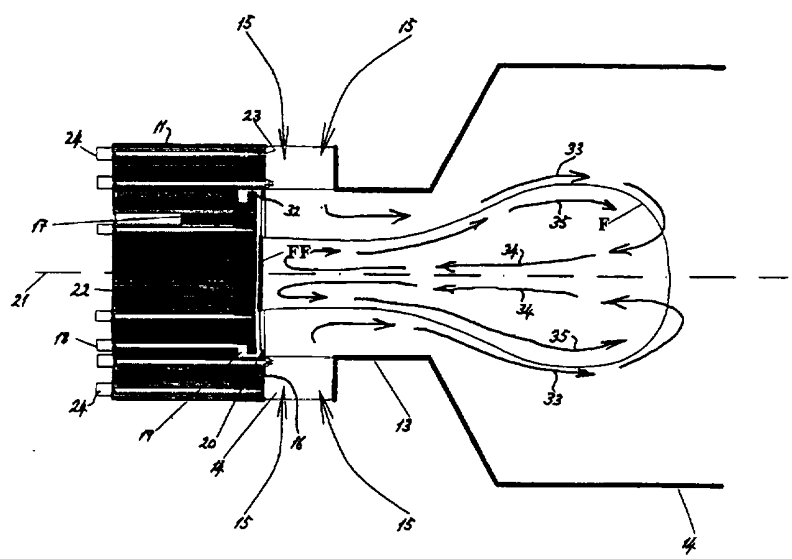

Fig 2

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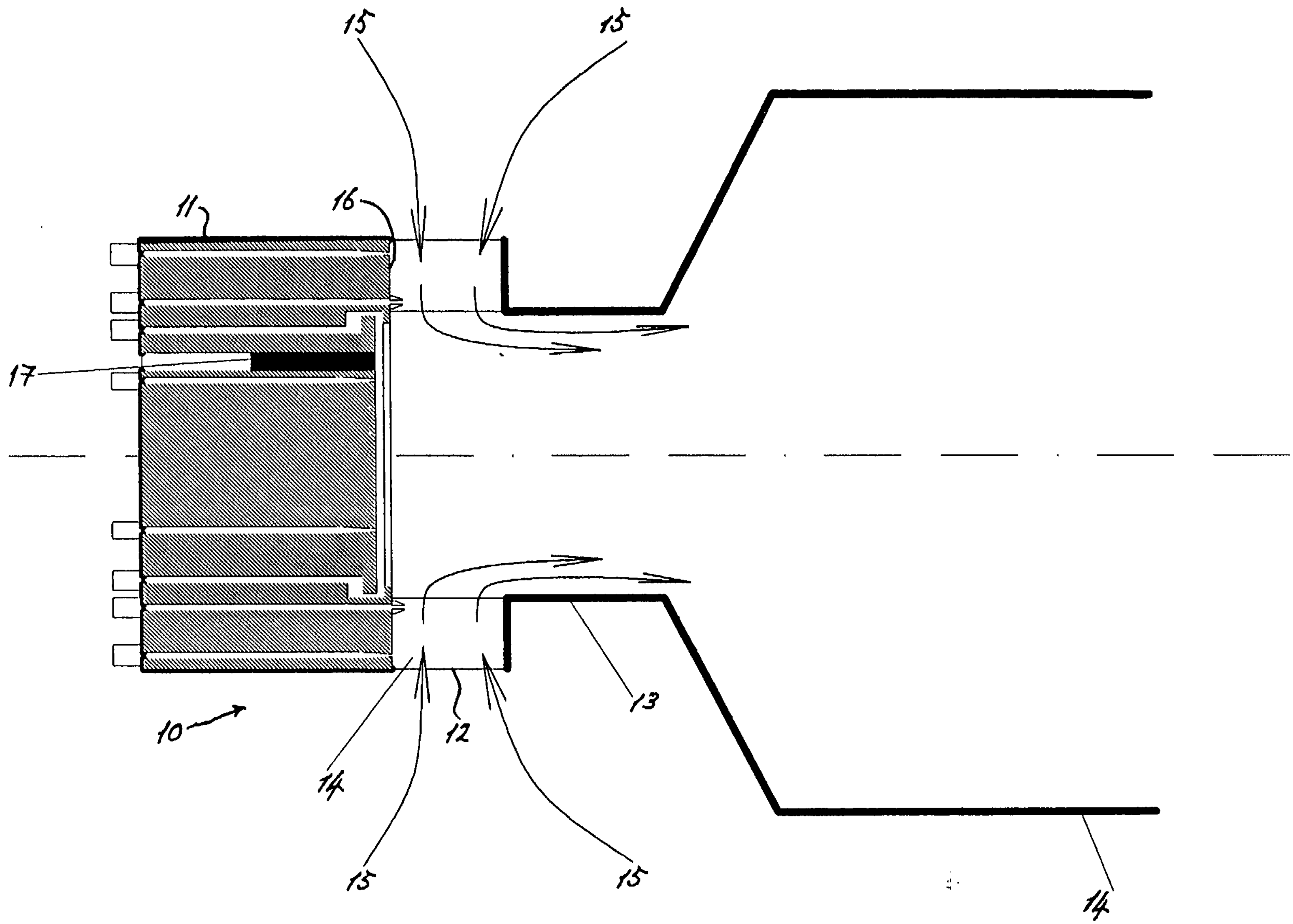

Fig 1

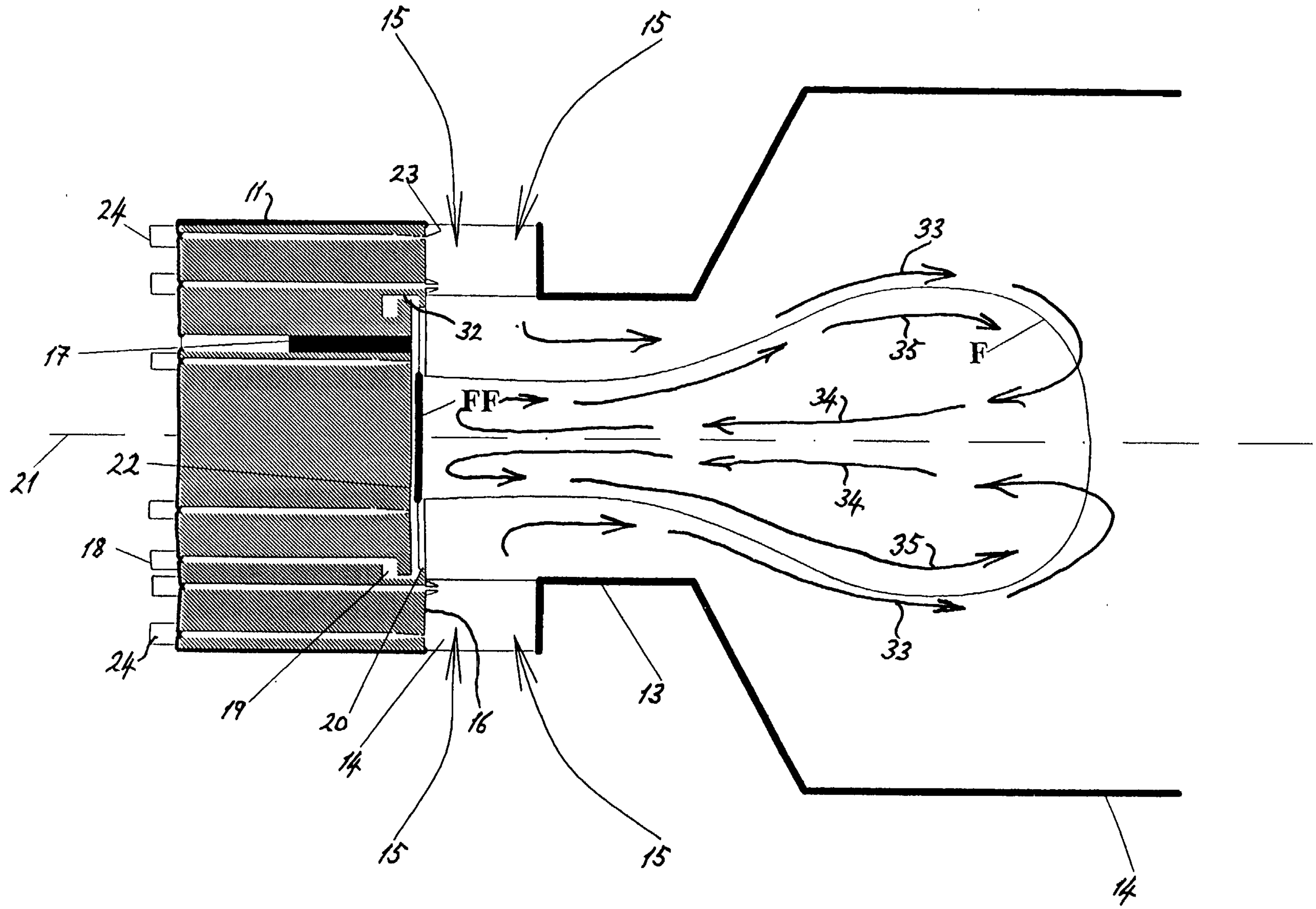
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Fig 2

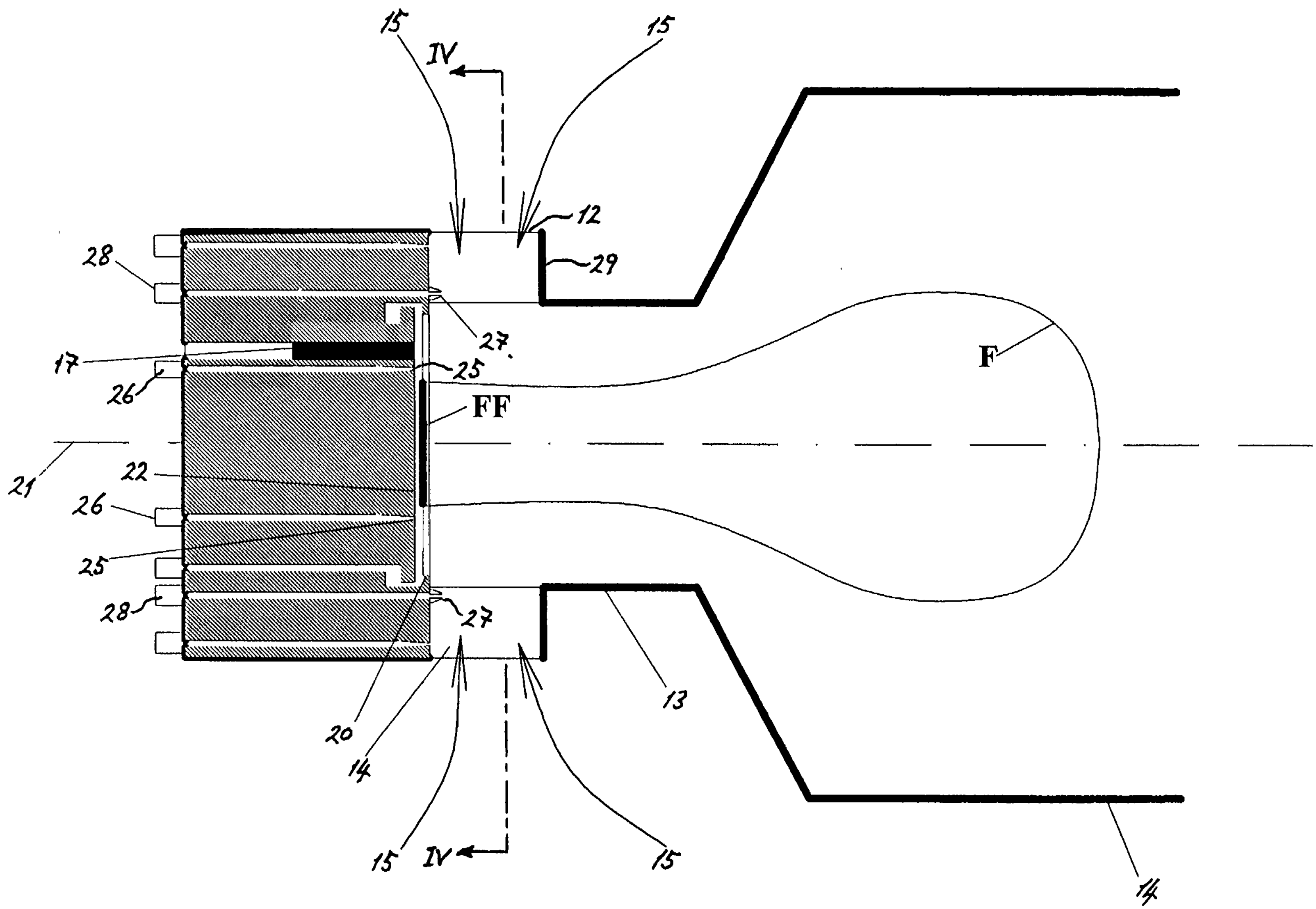

Fig 3

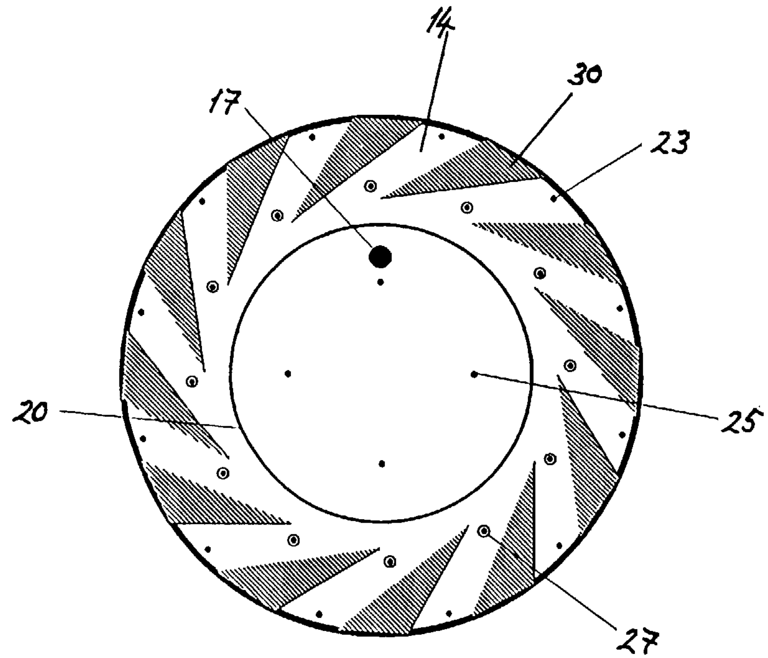

Fig 4

MULTI-FUEL GAS-TURBINE ENGINE COMBUSTOR

The invention relates to a multi-fuel gas-turbine engine combustor and in particular, but not exclusively, a combustor operating under a lean-burn combustion process.

Lean-burn combustor designs, in which very little if any combustion air is introduced into the combustor downstream of the location of the burner air-fuel mixing arrangement, are currently prevalent. The great advantage of lean-burn systems is the reduction of the levels of harmful emissions under high engine-load conditions. A drawback, however, is the difficulty that is experienced in maintaining the integrity of the combustor flame during low-load conditions, so that "flame-out", i.e. the simple extinction of the flame, does not occur.

To avoid flame-out at low engine-load conditions, prior-art designs have used techniques such as fuel-rich pilot-flame systems and staged fuel systems. The former are inclined to increase emission levels and the latter generally result in a complicated and expensive design.

The present invention aims to combine a reduction in harmful emissions with a reduction in complexity and consequently cost.

According to a first aspect of the present invention there is provided a multi-fuel gas-turbine engine combustor of the lean-burn type, comprising a burner and a combustion pre-chamber and combustion main chamber disposed in series downstream of the burner, the burner comprising a burner head having a fuel-injection means for the injection of gas-fuel or liquid-fuel from the burner into the pre-chamber, and a gas-fuel directing means for directing the gas-fuel towards a central part of a downstream face of the head during a gas-fuel operation of the combustor, the combustor being arranged such that, during gas or liquid-fuel operation of the combustor a front face of the combustion flame burns closely adjacent the burner head, and during a liquid-fuel operation of the combustor a flow of air is directed towards the central part of the downstream burner-head face thereby to cool it.

The injection means may include a gas-duct arrangement for injecting the gas-fuel in an annular configuration about a longitudinal axis of the head.

Preferably, the flow of gas-fuel is replaced by the flow of cooling air in the gas-duct arrangement during liquid-fuel operation.

The gas-fuel directing means may comprise an annular lip provided at the downstream face and extending towards the longitudinal axis, the lip being disposed relative to the gas-duct arrangement such as to deflect gas-fuel or air exiting the gas-duct arrangement towards the longitudinal axis.

The fuel-injection means may comprise a liquid-fuel duct arrangement disposed between the gas-duct arrangement and the longitudinal axis and communicating with the downstream face. An igniter may be disposed between the gas-fuel duct arrangement and the liquid-fuel duct arrangement, or at the radius of the liquid-fuel duct arrangement itself.

The gas-duct arrangement and liquid-fuel duct arrangement may be pilot duct arrangements, the fuel-injection means comprising also a main gas-duct arrangement and a main liquid-fuel duct arrangement disposed radially outside the pilot gas-duct arrangement and communicating with the downstream face. The main gas-duct arrangement is advantageously disposed radially outside the main liquid-fuel duct arrangement.

The burner may comprise a radial swirler attached to the burner head at the downstream face thereof and forming an interface between the burner and the pre-chamber, the swirler having a plurality of passages for the flow of combustion air through the swirler towards the longitudinal axis. The main gas-duct arrangement preferably communicates with one or more of the swirler passages adjacent a radially outer part of the passages, while the main liquid-fuel duct arrangement communicates with one or more of the passages adjacent a radially inner part of the passages.

A fuel-inlet arrangement will normally communicate with the pilot and main gas-fuel and liquid-fuel duct arrangements for the supply of fuel thereto, and a control means may be connected to the fuel-inlet arrangement for controlling the flow of fuel into the pilot and main gas-fuel and liquid-fuel duct arrangements.

The control means may be configured such that, during a gas-fuel operation of the combustor, the fuel injected into the combustion region comprises both pilot fuel and main fuel, the injected fuel varying continuously between, for start-up and low-load conditions of the engine, predominantly pilot fuel and, for full-load conditions of the engine, predominantly main fuel. Preferably, the control means provides ≤ 5%, approximately, main gas-fuel and ≥ 95%, approximately, pilot gas-fuel at start-up and low-load conditions of the engine and ≥95%, approximately, main gas-fuel and ≤5%, approximately, pilot gas-fuel at full-load conditions of the engine.

The control means may also be configured such that, during a liquid-fuel operation of the combustor, the fuel injected into the combustion region comprises solely pilot fuel during start-up, main fuel being introduced at a predetermined fraction of full engine loading and the supply thereof being increased, and the supply of pilot fuel being decreased, as loading approaches maximum. The fraction of full engine loading may be approximately 70% and the full-load proportions of pilot and main fuel ≤5%, approximately, and ≥95%, approximately, respectively.

During liquid-fuel operation, the control means may be arranged to divert pilot gas-fuel away from the pilot gas-fuel duct arrangement and to connect to the latter a source of the cooling air.

An embodiment of the invention will now be described with reference to the accompanying drawings, of which:

Figure 1 is a simplified axially sectioned view of a combustor according to the invention;

Figure 2 is the combustor of Figure 1 operating in gas-fuel mode;

Figure 3 is the combustor of Figure 1 operating in liquid-fuel mode, and

Figure 4 is a transverse section IV-IV through the burner of Figure 3.

Referring now to Figure 1, a longitudinal section of a combustor according to the invention is illustrated, consisting of a burner 10, comprising a burner-head portion 11 attached to a radial-inflow swirler portion 12, a combustion pre-chamber 13 and a main combustion chamber 14. The main chamber has a diameter larger than that of the pre-chamber. The swirler 12 has a number of spaced-apart vanes 30 (see Figure 4) which define passages 14 therebetween,

In operation, compressed air 15, flowing in the direction of the arrows shown, is supplied to the burner (usually from the gas-turbine compressor) and moves through the passages 14 between the swirler vanes. The air mixes with fuel injected from the downstream burner-head face 16 and, on arriving in the pre-chamber 13, the mixture is ignited by means such as the electric igniter unit 17. Once lit, the flame continues to burn without further assistance from such igniter.

The gas-fuel and liquid-fuel modes of operation of the combustor will now be separately described.

The gas-fuel arrangement is shown in Figure 2 and comprises a pilot-fuel system and a main-fuel system which work together in a progressive manner to give a seamless change in operation from one to the other. When the engine is started, the majority of gas-fuel is directed to the pilot system, whereby gas supplied through connector 18 at the burner head 11 moves through passages in the head eventually arriving at an annular gallery 19 from where it is directed, via either a series of spaced-apart bores 32 or a continuous annular duct, to the underside of a directing means in the form of a circumferential lip 20 extending radially inwards towards the longitudinal axis 21 of the combustor. The lip 20 deflects the pilot gas across a central portion 22 of the face 16, i.e. radially inwards in a direction generally normal to the axis 21. The pilot gas mixes with incoming compressed air 15 and main gas-fuel exiting the swirler-vane passages 14 (the main gas-fuel exits the burner head at the openings 23), igniter 17 being then activated to start a pilot flame. The main gas-fuel jets 23 are located at the swirler air-inlet region, i.e. adjacent a radially outer part of the passages 14, and are fed from connectors 24 through interconnecting ducts, as shown.

At starting of the engine and at low load, the great majority (for example, ≥95%) of the fuel injected is pilot gas-fuel, leaving the balance to be supplied by the main gas system. However, as engine load and speed increase, the main gas supply to the connectors 24 is increased so that progressively more main fuel is injected from jets 23. The main gas and air mix together as they pass inwardly through the swirler passages 14 on their way to the combustion flame within the pre-chamber 13 and main chamber 14. As load further increases, progressively more fuel is introduced through the main gas connector 24 and less through the pilot connector 18, so that eventually at full load approximately 95% of the total fuel requirement is met via the main connector 24 and the rest via the pilot connector 18.

Thus there is always arranged to be some flow of gas from the pilot system across the centre face 22.

Figure 2 shows a combustion-flame envelope represented by the boundary line "F" and flame front face "FF". The flame front FF is created by the recirculation of fluid 33 entering the combustion chamber along the radially outer parts of the chamber back along the central axial part of the chamber (axis 21) towards the burner (see arrows 34) and then back again towards the main chamber (see arrows 35), the front face itself being the point at which the axial flow 34 in the direction of the burner turns back on itself (35).

It is a feature of the present burner that at all engine load settings the flame front remains adjacent the face 22. (It should be noted that in known pre-chamber/main-chamber combustion systems it is conventional for the flame front of the main flame, though not necessarily the pilot flame, to be positioned not so far upstream in the pre-chamber.)

The present invention causes the front face FF to reach near to the burner face 22 by, for example, employing a high ratio of pre-chamber diameter to length (in a working example this ratio was 2:1); and by dispensing with axially issuing air or fuel jets which conventionally might be provided at the central region of the face 22, such jets acting against the flow 34 to limit progress of the flame face toward the burner face 22.

It could be supposed that having a flame front adjacent the face 22 would ordinarily cause overheating and damage to that face, and hence lead to problems of reliability. However, the curtain of pilot gas washing across the face 22 provides an effective insulation to prevent such damage. This design of the burner, whereby the front face of the flame is always maintained adjacent the downstream face 22 of the burner head, and therefore within the pre-chamber, is advantageous in the sense that the air-fuel mixture within the pre-chamber has sufficient velocity to prevent ignition flash-back into the swirler; this is due to the relatively small cross-sectional area of the pre-chamber 13 in relation to the mass of fuel and air passing through it.

Turning now to the liquid-fuel arrangement of the present combustor (see Figure 3), this mode of operation employs, as with the gas-mode, both pilot- and main-fuel systems and the flame front in this mode is also situated adjacent the burner face 22 at all load settings.

At least one liquid-fuel pilot jet 25, located at the burner face 22, is provided which is fed liquid fuel for pilot-flame operation from connection(s) 26 through appropriate ducts in the burner head. Such pilot jets are positioned on the face outside the outer circumference of the combustion flame adjacent the face 22. Main liquid-fuel jets 27, fed from fuel connectors 28 via suitable passageways, are situated at the air-exit region of the swirler 12, i.e. near a radially inner portion of the swirler passages 14.

When the engine is started, liquid pilot fuel is injected from pilot jets 25 into the pre-chamber 13 in an axial direction parallel, or approximately parallel, to the central longitudinal axis 21, where it mixes with air 15 exiting the swirler passages 14, the air-fuel mixture being ignited by a spark from the igniter unit 17. On start-up all the fuel requirement is met by the pilot jet(s), the main fuel system playing no part at this stage.

As engine load increases from start-up to approximately 70% full load, progressively more fuel is fed through the pilot jet(s) until at approximately 70% full load there occurs a change in the fuel scheduling whereby main fuel is introduced from jets 27. The main fuel system then takes over to provide approximately 95% of the total engine fuel requirement between 70 and 100% full load, so that in that load range about 5% only is supplied from the pilot jet(s). It is significant that there is at all times some pilot fuel flow, even at full-load conditions.

The main liquid-fuel jets 27 are located in the air-exit region of the swirler passages 14 and inject fuel in a direction approximately perpendicular to the airstream flow 15. It is important that all the liquid-fuel injected should be carried into the airstream and none be allowed to contact the upstream/downstream sidewalls of the swirler 12, or the vane walls, to the extent that a wall becomes wetted. To this end, the fuel jet bodies are positioned proud of the mounting surface 16 with the jet orifices distant from the surface so that at low fuel-pressure settings the fuel does not dribble onto the surface. For similar reasons, when operating at higher fuel-pressure settings, the pressure is controlled so that it is not sufficient to force the fuel into contact with a downstream passage wall 29 of the swirler.

Whilst operating on liquid fuel, to avoid overheating of, and consequent damage to, the face 22, air under pressure is routed through the pilot-gas system to wash over the face 22 in the same manner that pilot gas is brought into contact with the face during gas operation. Such air functions as a coolant and an insulating barrier to protect the face 22 from the heat of the flame.

Figure 4 is a section "IV-IV" through Figure 3 and illustrates the configuration of the swirler vanes and passages and the disposition of the gas and liquid fuel jets as employed in the embodiment of the invention described above. The hatched triangular areas 30 are the vane sections, while the clear areas between the vanes are the air passageways 14.

While the preferred method of conveying cooling air to the downstream face of the burner head is to employ the pilot gas ducts themselves to carry the air, an alternative scheme is to use dedicated outlets (not shown) in the head, situated, for example, between the spaced-apart gas outlets 32. These dedicated outlets will be fed from similarly dedicated passageways (also not shown) supplied from suitable inlets.

Also, although the igniter 17 has been represented as being located at a radius between that of the pilot liquid-fuel jets 25 and that of the annular gallery 19, it may alternatively be at the same radius as the jets 25.

CLAIMS

1. A multi-fuel gas-turbine engine combustor of the lean-burn type, comprising a burner and a combustion pre-chamber and combustion main chamber disposed in series downstream of the burner, the burner comprising a burner head having a fuel-injection means for the injection of gas-fuel or liquid-fuel from the burner into the pre-chamber, and a gas-fuel directing means for directing the gas-fuel towards a central part of a downstream face of the head during a gas-fuel operation of the combustor, the combustor being arranged such that, during gas or liquid-fuel operation of the combustor a front face of the combustion flame burns closely adjacent the burner head, and during a liquid-fuel operation of the combustor a flow of air is directed towards the central part of the downstream burner-head face thereby to cool it.

2. Combustor as claimed in Claim 1, wherein the injection means includes a gas-duct arrangement for injecting the gas-fuel in an annular configuration about a longitudinal axis of the head.

3. Combustor as claimed in Claim 2, wherein a flow of the gas-fuel is replaced by the flow of cooling air in the gas-duct arrangement during the liquid-fuel operation.

4. Combustor as claimed in Claim 3, wherein the gas-fuel directing means comprises an annular lip provided at the downstream face and extending towards the longitudinal

axis, the lip being disposed relative to the gas-duct arrangement such as to deflect gas-fuel or air exiting the gas-duct arrangement towards the longitudinal axis.

5. Combustor as claimed in Claim 4, wherein the fuel-injection means comprises a liquid-fuel duct arrangement disposed between the gas-duct arrangement and the longitudinal axis and communicating with the downstream face.

6. Combustor as claimed in Claim 5, comprising an igniter disposed between the gas-fuel duct arrangement and the liquid-fuel duct arrangement.

7. Combustor as claimed in any one of the preceding claims, wherein the gas-duct arrangement and liquid-fuel duct arrangement are pilot duct arrangements, the fuel-injection means comprising also a main gas-duct arrangement and a main liquid-fuel duct arrangement disposed radially outside the pilot gas-duct arrangement and communicating with the downstream face.

8. Combustor as claimed in Claim 7, wherein the main gas-duct arrangement is disposed radially outside the main liquid-fuel duct arrangement.

9. Combustor as claimed in Claim 8, wherein the burner comprises a radial swirler attached at one end to the burner head at the downstream face thereof and at the other end

to the pre-chamber, the swirler having a plurality of passages for the flow of combustion air through the swirler towards the longitudinal axis.

10. Combustor as claimed in Claim 9, wherein the main gas-duct arrangement communicates with one or more of the swirler passages adjacent a radially outer part of the passages, and the main liquid-fuel duct arrangement communicates with one or more of the passages adjacent a radially inner part of the passages.

11. Combustor as claimed in Claim 10, comprising a fuel-inlet arrangement communicating with the pilot and main gas-fuel and liquid-fuel duct arrangements for the supply of fuel thereto, and a control means connected to the fuel-inlet arrangement for controlling the flow of fuel into the pilot and main gas-fuel and liquid-fuel duct arrangements.

12. Combustor as claimed in Claim 11, wherein the control means is configured such that, during a gas-fuel operation of the combustor, the fuel injected into the combustion region comprises both pilot fuel and main fuel, the injected fuel varying continuously between, for start-up and low-load conditions of the engine, predominantly pilot fuel and, for full-load conditions of the engine, predominantly main fuel.

13. Combustor as claimed in Claim 12, wherein the control means is configured such as to provide $\leq 5\%$, approximately, main gas-fuel and $\geq 95\%$, approximately, pilot gas-

fuel at start-up and low-load conditions of the engine and ≥95%, approximately, main gas-fuel and ≤5%, approximately, pilot gas-fuel at full-load conditions of the engine.

14. Combustor as claimed in Claim 11, wherein the control means is configured such that, during a liquid-fuel operation of the combustor, the fuel injected into the combustion region comprises solely pilot fuel during start-up, main fuel being introduced at a predetermined fraction of full engine loading and the supply thereof being increased, and the supply of pilot fuel being decreased, as loading approaches maximum.

15. Combustor as claimed in Claim 14, wherein the fraction of full engine loading is approximately 70% and the full-load proportions of pilot and main fuel are ≤5%, approximately, and ≥95%, approximately, respectively.

16. Combustor as claimed in any one of Claims 11 to 15 as appendent to Claim 3, wherein, during liquid-fuel operation, the control means is arranged to divert pilot gas-fuel away from the pilot gas-fuel duct arrangement and to connect to the latter a source of the cooling air.

17. Multi-fuel gas-turbine engine combustor substantially as shown in, or as hereinbefore described with reference to, the drawings.

The Patent Office

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Application No: GB 9802021.7
Claims searched: 1-17

Examiner: R F Pharoah
Date of search: 8 April 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F4T: TAH,TAJ,TAP

Int Cl (Ed.6): F23R: 3/36

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2175993 A	(ROLLS-ROYCE) see page 1 lines 112-114	1-4,8
X	EP 0071420 A1	(SOLAR TURBINES) see page 11 line 13- page 12 line 3; page 17 lines 8-14	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the a
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but bef the filing date of this invention.
		E	Patent document published on or after, but with priority date ea than, the filing date of this application.
&	Member of the same patent family		