

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 728 989 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
28.11.2001 Bulletin 2001/48

(51) Int Cl.7: **F23D 14/24**, F23C 7/00,
F23D 14/74, F23D 23/00,
F23D 17/00

(21) Application number: **96300281.1**

(22) Date of filing: **15.01.1996**

(54) **Gas turbine engine combustor**

Verbrennungsgerät für Gasturbinenmotor

Appareil de combustion pour moteur de turbine à gaz

(84) Designated Contracting States:
CH DE FR GB LI SE

(30) Priority: **13.01.1995 GB 9500627**
29.09.1995 GB 9519826

(43) Date of publication of application:
28.08.1996 Bulletin 1996/35

(73) Proprietor: **EUROPEAN GAS TURBINES LIMITED**
Lincoln LN2 5DJ (GB)

(72) Inventors:
• **Norster, Eric Roy**
Harby, Newark,
Nottinghamshire, NG23 7EP (GB)
• **de Pietro, Simon Mario**
Lincoln LN1 3DX (GB)
• **Kowkabi, Mahmoud**
Lincoln LN2 2JU (GB)

(74) Representative: **Dargavel, Laurence Peter**
ALSTOM Corporate Intellectual Property Dept.
Alstom UK Limited,
PO Box 30,
Lichfield Road
Stafford ST17 4LN (GB)

(56) References cited:
EP-A- 0 132 213 **EP-A- 0 276 696**
GB-A- 1 465 689 **GB-A- 2 100 409**
GB-A- 2 104 641 **NL-A- 9 300 934**
US-A- 3 930 369 **US-A- 4 261 518**
US-A- 5 450 724

• **PATENT ABSTRACTS OF JAPAN vol. 018, no.**
325 (M-1625), 21 June 1994 & JP 06 074449 A
(MITSUI ENG & SHIPBUILD CO LTD;OTHERS:
02), 15 March 1994,

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 0 728 989 B1

Description

[0001] This invention relates to combustors for gas turbine engines, including the associated fuel burner and igniter components. It particularly, but not exclusively, relates to combustors suitable for sustaining lean burn combustion processes.

[0002] Gas turbines operate over a wide range of engine speed and load conditions, varying from initial start-up conditions, through various engine speed/load combinations up to a maximum. Typically, gas turbine combustor systems must include elements having the functions of fuel injection, ignition and subsequent sustaining of at least a pilot flame. This invention aims to improve combustor systems in respect of such elements.

[0003] For combustors of the lean-burn type (where more air is mixed with the fuel upstream of the combustion zone than is the case for combustors utilising diffusion-type flames), it is well known that flame stability is difficult to achieve in the lower power ranges, because the combustion process is being operated close to the weak extinction limit of the air/fuel mixture. This leads to the adoption of combustor arrangements in which a main fuel injector or burner operates to produce a fuel-lean mixture for lean burn combustion at high powers and a pilot fuel injector or burner operates to produce a fuel-rich mixture for diffusion-type combustion at lower powers, when the lean burn combustion process is likely to be unstable. The pilot burner is used not only to initiate combustion, but also to sustain lean burn combustion during start-up and part-load engine conditions, there being a gradual transfer of fuelling from the pilot to the main burner as combustion stability increases. Unfortunately, use of such a pilot burner leads to unwanted pollutants being produced at part load conditions of the gas turbine engine, due to the rich mixture.

[0004] It is therefore an object of the invention to provide a burner, particularly but not exclusively a pilot burner, capable of improving the stability of a lean burn combustion process in a combustor over a wide range of engine load conditions and reduce production of pollutants at part load conditions of the gas turbine engine.

[0005] An example of a lean-burn combustor arrangement for a gas turbine is shown in Published patent specification no. GB 2287312 A, see particularly Figures 1 to 4. This shows a series staged combustor with multiple stages, in which the first stage comprises a small diameter combustion chamber with a pilot burner located on its longitudinal centreline. A premixing main burner is disposed downstream and radially outwards of the pilot burner for injecting a premixed swirling fuel/air mixture radially into the chamber. At ignition of the combustor, fuel is sprayed from a central part of the pilot burner for ignition by an igniter located centrally of the pilot burner. Simultaneously, some of the pilot fuel is also mixed with air within the pilot burner and ejected as a premixed swirling fuel/air mixture from a peripheral part of the pilot burner, for ignition by igniters located near the combustor wall. The aim of this arrangement is that during ignition, the fuel spray and the premixed fuel/air mixture should mix together within the small combustion chamber to establish a stable, fuel-rich, diffusion-type flame. Then, as the amount of fuel supplied to the combustor is increased to build up the power of the turbine, the fuel flow to the pilot nozzle is transferred to the main burner, beginning with the fuel flow to the central part of the pilot nozzle, so that a completely lean-burn combustion mode is begun as soon as possible.

[0006] It is claimed that the above prior art arrangement enables low NO_x combustion over the entire gas turbine load range, but a disadvantage appears to be the number of ignition sources which may be required to maintain stable combustion; in Figures 3 and 4 of the prior patent specification, four igniters or so-called "micro-burners" are provided as ignition sources for the first and smallest diameter combustion region of the combustor. This adds an undesirable degree of complexity and production expense to the design. Furthermore, it is well known that gas turbine combustor igniters can suffer serious damage if subject to the continuous heat generated inside a working combustor.

[0007] It is therefore a further object of the invention to provide a lean burn combustor arrangement and a process for sustaining lean burn combustion which, while enabling at least a major part of the fuelling to be transferred from the diffusion combustion process to the lean burn combustion process at low load conditions of the gas turbine, also has sufficient combustion stability to enable use of a single, simple ignition source.

[0008] To reduce cost and complexity for manufacturing and maintenance purposes, it is desirable to minimise the number of separate combustion stages it is necessary to incorporate into the combustor.

[0009] It is therefore another object of the invention to provide a lean burn combustor arrangement in which stable lean burn combustion can be maintained over a wide range of engine powers using only a pilot burner and a main burner operating in conjunction with each other to inject fuel-rich and fuel-lean mixtures respectively into the combustor.

[0010] Also reasons of reduction in cost and complexity, it is further desirable to minimise the number of separate components (such as burner parts and their associated fuel passages and pipes) needed to support combustion in both the diffusion burn and lean-burn modes.

[0011] It is therefore also an object of the invention to provide a burner arrangement for a gas turbine combustor in which the pilot burner and main burner components are compactly and conveniently combined with each other in the combustor head.

[0012] Patent specification GB 1465689 discloses a combustion chamber for a boiler or the like in which a cylindrical flame tube is provided with a burner in which combustion air is fed tangentially into the flame tube from a circumferential

region at the upstream end of the tube. This causes a flow of air having swirling tangential and axial components along the inside surface of the flame tube towards its downstream end, with a counterflow of air back to its upstream end, where fuel is injected. However, the combustor has no provision for a separate pilot fuel supply as well as the main fuel supply, nor is the fuel supply premixed with the swirled air before it is injected into the chamber. Hence, this prior art cannot be utilised for lean-burn low NO_x combustion in a gas turbine engine.

[0013] According to the present invention, a lean burn combustor for a gas turbine engine is of generally circular cross-section and comprises in combustion flow sequence a combustor head incorporating a burner arrangement, a combustion pre-chamber and a main combustion chamber, the pre-chamber being of substantially smaller cross-sectional area than the main chamber, the burner arrangement comprising air flow swirler means and main fuel injection means disposed to inject fuel into said swirler means thereby to produce a fuel-lean fuel/air mixture in the swirler means, the swirler means forming a periphery of an upstream part of the pre-chamber and being disposed to inject the fuel/air mixture into the pre-chamber with a radially inward swirling motion, the burner arrangement further comprising a fuel body portion having fuel supply passages therein for supplying fuel to the main fuel injection means, the swirler means being attached to a substantially planar downstream-facing surface of the fuel body portion, the burner arrangement further comprising a pilot burner arranged on the axial centreline of the combustor to support a diffusion type of combustion process in the pre-chamber by injection of fuel thereinto, the fuel body portion of the burner arrangement comprising a radially outer fuel body to which the swirler means is attached and a radially inner fuel body nested within the outer fuel body, the inner fuel body constituting the pilot burner by inclusion of pilot fuel injection means and fuel supply passages leading to the pilot fuel injection means.

[0014] Conveniently, an ignition source may be housed in the pilot burner for ignition of the combustion process.

[0015] Preferably, the pilot burner further incorporates air injecting means, the pilot fuel injecting means surrounding the air injecting means and being substantially concentric therewith, the pilot fuel injecting means being configured to inject the fuel towards the air injecting means for producing a fuel-rich fuel/air mixture within the pre-chamber externally of the pilot burner. The air injecting means is configured to eject a divergent swirling column of air away from the pilot burner into the pre-chamber, the column of air being annular in cross section.

[0016] The invention is further defined in the appended claims.

[0017] The relative amounts of air, pilot fuel and main fuel injected into the combustion chamber should be varied with respect to each other such that at start-up and part-load engine conditions the fuel/air mixture in the sheltered combustion zone is sufficiently fuel-rich to sustain stable combustion for the overall combustion process, i.e. for the combustion process within the combustor considered as a whole. To minimise production of pollutants, as engine conditions vary from start-up through part load to full load, the overall combustion process should vary between fuel-rich and fuel-lean, the amount of pilot fuel injected as a proportion of total fuel injected being varied from substantially less than 50% at start-up to a major proportion at full speed with minimum load to about 0% at full speed with at full load. The provision of the sheltered combustion zone facilitates earlier transition of the overall combustion process from fuel rich to lean burn.

[0018] Exemplary embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a part sectional diagrammatic side elevation of the upstream end of a so-called "dry, low NO_x" lean burn combustor can incorporating an ignition, fuel burner and combustion stabilising arrangement in accordance with the present invention;

Figure 2 is an enlarged fully sectional view of part of Figure 1; and

Figure 3 is a view similar to Figure 2 but taken on a different diametrical section to show detail not illustrated in Figure 2.

[0019] Referring to Figure 1, a combustor 100 is similar in general layout to that shown in our copending patent application no. GB 9500627.6, which is a convention priority document for this application. Combustor 100 comprises a combustor can 102, being one of several such cans arranged around the circumference of a gas turbine engine. Each can 102 has a main combustion chamber 103 having a relatively large internal diameter D over most of its axial length as measured along the can's longitudinal axis or centreline CL, but near the combustor's upstream or head end, the main chamber 103 narrows quite abruptly to a smaller internal diameter d, forming a so-called "pre-chamber" 141 of the can 102. Although described with reference to this generally cylindrical type of combustor can, the invention should not necessarily be restricted to such, as some claimed aspects may be applicable to the annular type of combustor.

[0020] Each can 102 is provided with a gas fuel injector assembly 104 which comprises the head of the combustor and part of the pre-chamber 141. In the assembly 104, a central cylindrical igniter 110 is located in a central bore 112 of a pilot burner 114 on the centreline CL of the can 102. In turn, the pilot burner 114 is located or nested inside a central bore 116 of a main burner 118. The main burner 118 comprises a fuel body 120, and swirl passages 122

machined in a swirler 123 which is secured to a rear face 124 of the fuel body 120. The swirl passages 122 extend obliquely to the circumference of the pre-chamber 141 so that the flow exiting therefrom has both radial and tangential components of velocity relative to the pre-chamber. The swirler 123 is disposed radially outwards of the pilot burner 114, but concentric with it and immediately downstream (rearward) of it, so that it forms or defines the periphery of the most upstream part of the prechamber 141. For further details of a swirler similar to the swirler 123, our patent application no. GB9500627.6 should be consulted.

[0021] In operation, the fuel/air mixture from the burners is burnt in a combustion zone 106, whose extent is approximately indicated by a straight dashed line, the longitudinal axis of the zone 106 approximating to the can's centreline CL. In fact, dashed line 106 approximates to the location of a flame front within the can 102, the true configuration of the flame front probably being bell-shaped, as indicated by dashed line 106', with the most flared part of the bell shape extending downstream from the exit of the prechamber 141.

[0022] A base region or sub-zone 107 of the combustion zone 106 is located in the pre-chamber 141 near to the pilot burner 114 within the injector assembly 104 and is shown crosshatched. The overall combustion process in combustor can 102 is initiated and sustained at start-up and low engine loadings by combustion of a fuel-rich fuel/air mixture in region 107, as explained later, the mixture as burnt in region 107 being rich at these engine loadings to ensure stable combustion. However, at least at higher part-load and full load engine conditions, the overall combustion process is lean-burn and mostly takes place in the main combustion chamber 103 in a major region 108 of the combustion zone.

[0023] Within the pilot and main burners 114, 118 are pilot and main fuel supply passages 126, 128, respectively, together with pilot air supply passages for the pilot burner. For reasons of clarity, the details of the fuel and air passages for the pilot burner 114 and its operation are not shown in Figure 1, but will be described later with respect to Figures 2 and 3.

[0024] Concerning the operation of the main burner 118, the main gas fuel inlet passage 128 in the fuel body 120 feeds a first gallery 130, which in turn is connected through drillings 131 to a second gallery 132. From here, drillings 134 take the fuel to be injected either directly from the rear face 124 of the fuel body 120 into the inlets of the flow passages in the swirler 122, or from injector bars 136. The gas fuel thereby readily mixes with compressed air 138 as the air flows inwards towards the centreline CL of the can 102 from the swirl passages 122. The amount of air relative to the fuel is such as to achieve a lean mixture. The swirl passages 122 impart a rotating or swirling motion to the fuel/air mixture 139 as it passes through them, the motion becoming vortical as the mixture leaves the swirl passages and flows around the can's centreline CL axially and radially inwards towards the combustion zone 106. Air 138 for the main burner 118 is taken from the area 140 surrounding the combustor can 102 and is supplied in the usual way from the gas turbine compressor (not shown).

[0025] When the fuel and air exits the swirler 123, it is not yet fully mixed (particularly when high engine powers are being demanded and there are relatively large amounts of fuel and air to mix), and requires further equilibration time before it is ready for burning in a lean burn combustion process. As noted above, the combustor can has a narrow pre-chamber portion 141 of diameter d, and for lean burn combustion occurring downstream of it in region 108, the length L of the narrow portion provides the additional time needed for full mixing.

[0026] It is important to ensure that the combustion process does not propagate or "flash back" up the flow of fuel/air mixture from the main burner 118 to impinge on the swirler 123, since the heat of combustion would damage it and the rest of the burner. The narrow pre-chamber portion 141 of the can prevents this by ensuring (in the manner of a venturi) that the downstream flow velocity of the mixture after exit from the swirl passages is greater than the upstream propagation velocity of the combustion process. Furthermore, the high swirling velocity of the fuel-lean mixture in the pre-chamber 141 keeps the combustion process in region 107 away from the wall of the pre-chamber.

[0027] Support for the combustor can 102 in its location within the engine is conveniently provided at its rear, i.e. downstream, end (not shown) by attachment in known ways through a combustor exit nozzle to suitable static structure of the engine, such as nozzle guide vanes at the entry to a high pressure turbine. Support at the can's head end is conveniently provided by securing the injector assembly 104 to a portion of combustor casing 142. The latter has an aperture within which is secured the main burner fuel body 120. Connection of the can 102 to the casing 142 is completed by fixing an upstream flange 144 of the can to the rear face of a ring 145 attached to the swirler 123. Fixing of the various parts of the injector assembly 104 to each other and to the casing 142 is conventionally achieved by setscrews, bolts, or the like, unless otherwise noted.

[0028] Figure 2 shows a section through the igniter 110, pilot burner 114 and part of the main burner 118, indicating by arrows the route followed by the fuel 200 through the pilot burner 114. For clarity the air flow routes for the pilot burner are omitted from Figure 2 and shown separately in Figure 3, which also shows the fuel and air flow pattern issuing from the pilot burner 114.

[0029] As shown more particularly in Figure 2, electrical power is fed to the igniter 110 through an internally threaded coaxial cable socket 146 provided at the forward end of the igniter. When screwed home into a threaded part 148 of the central bore 112 of the pilot burner 114, the socket 146 also serves to crimp a compression collar 150 onto the end of the igniter 110 so preventing relative movement between the igniter and the pilot burner.

[0030] As can be seen in Figure 2, the igniter 110 comprises a rigid central electrode wire 202, an inner insulating ceramic layer 204 surrounding the central electrode, a rigid metallic sheath 206 surrounding the inner insulating layer, and an outer insulating ceramic layer 208 surrounding the sheath 206 and in contact with the bore 112 of the pilot burner 114. At its rear end, the sheath is provided with a small electrode 210, which in conjunction with the adjacent end of the central electrode 202, defines a spark gap. A fuel and air mixture is circulated over the spark gap as explained below and is of course ignited when sparks are caused to jump across the gap.

[0031] The pilot burner 114, with main burner 118, comprise synergistically interacting features as illustrated in Figures 2 and 3, which co-operate to achieve even fuelling and good flame stability in the combustion region 107 and adequate cooling of the igniter 110 when it is heated by the combustion process.

[0032] In pilot burner 114, fuel 200 flows through supply passage 126 to an annular gallery 211 and then through passages 212 to a further gallery 213. The fuel 200 is emitted from the head, i.e., the rearward face 214 of the pilot burner 114, through a circular array of apertures 215 near its outer circumference and is then immediately deflected across the burner face by a deflector lip 216 provided on a sleeve 218, which is brazed onto the end of the pilot burner 114. As shown particularly in Figure 3, after deflection by the lip 216, the fuel 200 meets a curtain or annular column of high pressure air 300 emitted rearwardly and divergently from a circular groove or slot 302 in the burner face. At this point, mixing of the pilot fuel and air begins due to the turbulence associated with the air and the cross flow of the fuel with respect to it. The air 300 firstly carries the fuel away from the pilot burner and establishes a hollow (i.e., of annular cross section) divergent columnar shear layer 303 (Figure 3) about centreline CL in the combustion can 102. To produce a good pilot fuel/air mixture, it is of course arranged that the pilot fuel 200 is injected substantially uniformly into the circumference of the column of air 300 which forms the base portion of the shear layer 303.

[0033] The establishment of the shear layer 303, which may be identified as defining the boundary of the combustion zone 106 (Figure 1) and the flame front in the combustion chamber, is important in achieving the object of sustaining a lean burn combustion process in the combustor over a range of engine load conditions. It should be noted that the fuel-lean main fuel/air mixture (139) is injected substantially uniformly towards the shear layer 303 from the swirl passages 122 surrounding the shear layer, and some mixing of the main fuel/air mixture with the pilot fuel/air mixture occurs in the shear layer 303.

[0034] The next part of the process is recirculation, as shown by arrows 304, of some the fuel/air mixture from all parts of the shear layer 303 back towards the igniter 110. This occurs because the air emission from the slot 302 creates an area of somewhat lower pressure adjacent the igniter. At start-up of the engine, it is arranged that the recirculated fuel/air mixture is fuel-rich and after ignition it burns with a stable flame in region 107, the flame seemingly being "anchored" to the slot 302 and being surrounded by the air column/shear layer 300/303. Even when increasing amounts of fuel-lean mixture are injected into the can 102 from the main burner 118 as engine speeds and loads increase, it appears that the slot 302, or at least its inner edge, acts to stabilise the combustion process in the recirculated fuel/air mixture. It is evident that the air column/shear layer 300/303 surrounds and shelters the region 107 near its base, the region 107 having substantially lower fluid velocities than neighbouring regions in and beyond the shear layer. It is found that by establishing stable combustion in this sheltered combustion region 107, the whole of the combustion process in the combustor 102, including the lean burn combustion in region 108, is stabilised at part load and full load conditions of the gas turbine engine.

[0035] It is much preferred, though probably not essential in every design of combustion chamber and burners based on the present invention, that the air 300 emitted from slot 302 in the pilot burner head possesses a swirl (rotational) component which is counter in swirl direction to the swirl component of the fuel/air mixture produced by the swirl passages 122 of the main burner 118. To achieve swirling of the air 300, it is supplied to the bottom of the slot 302 through an array of drillings 306 which connect through sleeve 218 to a gallery 308, the orientation of the drillings 306 being oblique to the sides of the slot so as to be approaching tangential to the circumference of the slot 302, though for convenience of illustration, this is not indicated in Figure 3. The gallery 308 is supplied from a number of passages 310, which may either take air from the swirl passages, as shown, or take air ducted from openings on the outer circumference of the swirler 123, to take advantage of possible higher stagnation pressures found there and/or to avoid contamination by fuel from the swirler passages.

[0036] The gallery 308 providing air to the circular slot 302 also provides further air for directly cooling and shielding the igniter 110, as indicated in Figure 3. Air from the gallery 308 is conveyed through drillings 310 to an annular feeder slot 312 cut into the bore 112 of the pilot burner. This air is emitted from the ends of a series of short, axially extending air channels or grooves 314 cut or otherwise formed in the bore of the pilot burner and equally spaced around it to conduct the air from the feeder slot 312 along the side of the hot end of the igniter 110 as shown, so removing heat therefrom. The channels 314 extend slightly beyond the electrode end of the igniter 110 and hence the cooling air exhausts from the ends of the channels across the end of the igniter, so cooling it and shielding it from the heating effect of the base of the pilot flame. The igniter cooling air may have a diluting effect on the fuel/air mixture in the region 107 and this should be taken into account in calculating optimum fuel/air ratios for different engine speeds and loadings.

[0037] The foregoing igniter air-cooling arrangement is only one of a number of alternative arrangements which can

be envisaged for effecting such air cooling. For instance, instead of providing a feeder slot 312 and channels 314 in the bore 112 of the pilot burner, the end of the igniter 110 could advantageously be held within a small sleeve having an external flange at each end and brazed into a widened portion of the bore 112, the feeder slot being replaced by an annular space defined between the bore 112 and the flanges of the sleeve, and the channels being replaced by holes drilled through the flange at the end of the sleeve nearest the pilot flame. Preferably, a suitable lip would be provided in the pilot burner face directly above the holes in the flange to deflect the air across the igniter tip.

[0038] To summarise the above described combustor and burner arrangement: the combustor is divided into a downstream main chamber and an upstream pre-chamber; the premixing swirler of the main burner is utilised to define the most upstream part of the prechamber periphery; the swirler receives its fuel supply from a fuel body forming part of the combustor head, to which the swirler is attached; the pilot burner is nested within the fuel body of the main burner in the combustor head; and the igniter 110 is positioned within the pilot burner 114, rather than elsewhere in the combustion system. By means of this arrangement, the installation is much simplified and the objectives of convenient manufacture, effectiveness and compactness are substantially achieved.

[0039] Because the above described main burner/pilot burner/igniter combination 118/114/110 enables stable combustion in the combustion region 107, the pilot and main burners can be operated in a complementary manner to maintain lean burn combustion over a wider range of engine operating powers and speeds than has hitherto been achievable in combustors of this type. The following table illustrates, in purely exemplary manner, how the total fuel supply may be shared between pilot and main burners over the entire operating range of an engine used for power generation.

Engine Condition	Percentage of Total Fuel Through Each Burner	
	Pilot Burner	Main Burner
Start-Up	30	70
Full Speed, Minimum Load	70	30
Full Speed, Maximum Load	0 to 2	98 to 100

[0040] Hence, the relative amounts of air, pilot fuel and main fuel injected into the can 102 are varied with respect to each other such that at start-up and part-load engine conditions the fuel/air mixture in the sheltered combustion region 107 is sufficiently fuel-rich to sustain stable combustion for the whole of the combustion process, much of which, even at part load conditions, is occurring in region 108 in a lean burn mode. As engine conditions vary from start-up through part load to full load, the combustion process within the combustor considered as a whole varies between fuel-rich and fuel-lean. It will be seen that when the engine is at full speed, the amount of pilot fuel injected as a proportion of total fuel injected varies from a major proportion (70%) at minimum load and full speed, to about 0% at full speed and load. Although the overall combustion process will therefore be somewhat fuel rich at low loads, these are only transitory conditions for most industrial engines, which tend to operate at high or full loads most of the time; hence, environmental legislation can be readily met. In tests, it was found that the burner and combustor design described above enabled an earlier transfer of fuelling from the pilot burner to the main burner and a corresponding earlier transition between the fuel-rich low part-load conditions to the lean-burn higher part-load and full-load conditions.

[0041] As illustrated, the pilot air supply slot 302 is a continuous circular slot of approximately rectangular section set in the face 214 of the pilot burner 114, but this is only one possible configuration. For instance, alternative sections, e.g. divergent or convergent towards the burner face, could be used instead. Furthermore, the single continuous slot could be replaced by two or more concentric continuous slots, or continuous slots could be replaced by a number of equally spaced discrete apertures arranged in a circle around the face of the pilot burner. As a further alternative, the slot or its equivalent apertures could be formed in or adjacent to a ridge or fence feature projecting from the surface of the pilot burner and acting to anchor and stabilise the combustion process.

[0042] Although the igniter 110 is shown located centrally of the pilot burner 114, this is exemplary only, and the burner could be advantageously located off the centreline CL of the pilot burner, e.g., at the same diameter as the slot 302 or an equivalent ring of apertures. This could reduce the heat input to the igniter from the flame in region 107.

[0043] The above described arrangement for injecting the pilot fuel and air has further advantages as follows.

(a) An anti-coking feature is provided by the annular fuel discharge gap under the lip 216, the radially inward discharge of the fuel being effective to avoid carbon build-up which could directly interfere with the fuel flow.

(b) The flow of fuel and air through the pilot burner 114 in close proximity to the igniter 110 helps to keep the igniter cool by removing heat from the burner.

(c) Swirling of the air 300 emitted from the slot 302 in the pilot burner head is believed to be effective to inhibit

actual attachment of the flame in region 107 to the burner, particularly if the swirl direction of air 300 is counter to the swirl direction of the fuel/air mixture exiting the main burner swirl vane ring 122.

Hence, the base of the flame stands off from the burner head 214, helping to prevent overheating of the igniter 110. In tests of one design according to the invention, it was found that if the pilot air 300 was given a swirling component of flow in the same direction as the fuel/air mixture from the main burner, the flame burnt closer to the igniter.

[0044] Although, for convenience, the drawings show injection of only one fuel (gas), dual fuel burner arrangements can be envisaged. For example, a liquid fuel supply passage extending parallel to the gas fuel supply passage and having an associated gallery and atomiser arrangement surrounding the gas injector features, could be provided in the body of a pilot burner having a larger diameter than pilot burner 114.

Claims

1. A lean burn combustor (100) for a gas turbine engine, the combustor being of generally circular cross-section and comprising in combustion flow sequence a combustor head incorporating a burner arrangement (104), a combustion pre-chamber (141) and a main combustion chamber (103), the pre-chamber being of substantially smaller cross-sectional area than the main chamber, the burner arrangement comprising air flow swirler means (122) and main fuel injection means (136) disposed to inject the fuel into said swirler means thereby to produce a fuel-lean fuel/air mixture (139) in the swirler means, the swirler means forming a periphery of an upstream part of the pre-chamber (141) and being disposed to inject the fuel/air mixture into the pre-chamber with a radially inward swirling motion, the burner arrangement further comprising a fuel body portion (120) having fuel supply passages (128, 130, etc.) therein for supplying fuel to the main fuel injection means (136), the swirler means being attached to a substantially planar downstream-facing surface of the fuel body portion, the burner arrangement (104) further comprising a pilot burner (114) arranged on the axial centreline (CL) of the combustor to support a diffusion type of combustion process in the pre-chamber (141) by injection of fuel thereinto, the fuel body portion of the burner arrangement comprising a radially outer fuel body (120) to which the swirler means (122) is attached and a radially inner fuel body (114) nested within the outer fuel body, the inner fuel body constituting the pilot burner by inclusion of pilot fuel injection means (215, 216) and fuel supply passages (126, 212) leading to the pilot fuel injection means.
2. A lean burn combustor according to claim 1 in which an ignition source is housed in the pilot burner for ignition of the combustion process.
3. A lean burn combustor according to claim 1 or claim 2, in which the pilot burner incorporates air injecting means, the pilot fuel injecting means surrounding the air injecting means and being substantially concentric therewith, the pilot fuel injecting means being configured to inject the fuel towards the air injecting means for producing a fuel-rich fuel/air mixture within the pre-chamber externally of the pilot burner.
4. A lean burn combustor according to any one of claims 1 to 3, in which the air injecting means is configured to eject a divergent swirling column of air away from the pilot burner into the pre-chamber, the column of air being annular in cross section.
5. A lean burn combustor according to claim 1, wherein the pilot burner is configured to separately and simultaneously inject pilot fuel (200) and air (300) into the combustor for mixing therein, the pilot burner having air injecting means (302) for injecting the air into the combustor as a columnar shear layer (303) of annular cross-section surrounding a central combustion region (107) adjacent the pilot burner, the pilot fuel injecting means (215, 216) being arranged to inject the pilot fuel towards the columnar shear layer for mixing with the air therein, the main burner being configured to inject a fuel-lean main fuel/air mixture (139) into the combustor towards the columnar shear layer, the shear layer establishing the central region (107) as a sheltered combustion zone to increase the stability of lean burn combustion in the combustor.
6. A lean burn combustor according to claim 5, in which the columnar shear layer is divergent away from the pilot burner.
7. A lean burn combustor according to claim 5 or claim 6, in which in the pilot burner the pilot fuel injecting means surrounds the air injecting means and is substantially concentric therewith.

8. A lean burn combustor according to claim 7, in which the pilot burner air injecting means is configured to impart a swirling flow component to the column of air.
9. A lean burn combustor according to claim 8, in which the directions of swirl imparted by the pilot and main burners are mutually opposed.
10. A lean burn combustor according to any one of claims 3 to 9, in which the air injecting means comprises means defining a circular slot (302) in the inner fuel body.
11. A lean burn combustor according to claim 10, in which the air injecting means further comprises a plurality of feeder passages for feeding air to the bottom of the slot (302), the feeder passages (306) entering the bottom of the slot obliquely with respect to the sides of the slot, whereby a swirling flow component is imparted to the air (300) issuing from the slot.
12. A lean burn combustor according to claim 11, in which the feeder passages enter the bottom of the slot tangentially thereof.
13. A lean burn combustor according to any one of claims 1 to 12, in which the pilot fuel injecting means comprises means (216) defining a circumferentially extending aperture near the periphery of the inner fuel body (214), the fuel exiting from the pilot burner through said aperture.
14. A lean burn combustor according to claim 13, in which the pilot fuel injecting means comprises an annular lip (216) spaced from and covering an outermost peripheral portion of the inner fuel body (214), the fuel exiting from the pilot burner between the inner fuel body and the lip.
15. A lean burn combustor according to claim 14, in which the pilot fuel injecting means further comprises a circular array of apertures (215) located in the inner fuel body under the lip (216).

Patentansprüche

1. Verbrennungsgerät (100) zum brennstoffarmen Verbrennen für einen Gasturbinenmotor, wobei das Verbrennungsgerät einen allgemein kreisförmigen Querschnitt besitzt und in Strömungsrichtung der Verbrennung einen Kopfteil mit einer Brenneranordnung (104), eine Vorbrennkammer (141) und eine Hauptbrennkammer (103) aufweist, wobei die Vorbrennkammer einen wesentlich geringeren Querschnitt als die Hauptbrennkammer besitzt, die Brenneranordnung ein Mittel zur Luftverwirbelung (122) sowie Mittel zum Einblasen der Hauptmenge an Brennstoff (136) aufweist, welche derart angeordnet sind, daß sie Brennstoff in das Mittel zum Verwirbeln einblasen und dadurch ein brennstoffarmes Gemisch aus Brennstoff und Luft (139) in dem Mittel zum Verwirbeln erzeugen, das Mittel zum Verwirbeln die Peripherie eines stromaufwärts liegenden Teils der Vorbrennkammer (141) bildet und derart angeordnet ist, daß es das Gemisch aus Brennstoff und Luft mit einer radial einwärts gerichteten Wirbelbewegung in die Vorbrennkammer einbläst, die Brenneranordnung außerdem einen Brennstoffversorgungskörper-Abschnitt (120) aufweist, der Brennstoffversorgungsdurchlässe (128,130 usw.) zum Heranführen von Brennstoff zu dem Mittel zum Einblasen der Hauptmenge an Brennstoff (136) besitzt, das Mittel zum Verwirbeln an der im wesentlichen ebenen, stromabwärts gerichteten Oberfläche des Brennstoffversorgungskörpers befestigt ist, die Brenneranordnung (104) außerdem einen auf der Achse (CL) des Verbrennungsgerätes angeordneten Hilfsbrenner (114) aufweist, um einen Verbrennungsvorgang vom Diffusionstyp in der Vorbrennkammer (141) durch Einblasen von Brennstoff zu unterhalten, der Brennstoffversorgungskörper-Abschnitt der Brenneranordnung einen radial außen sitzenden Brennstoffversorgungskörper (120), an dem das Mittel zum Verwirbeln (122) befestigt ist, sowie einen radial innen sitzenden Brennstoffversorgungskörper (114) aufweist, der innerhalb des äußeren Brennstoffversorgungskörpers angeordnet ist, und der innere Brennstoffversorgungskörper durch Einschluß von Hilfsbrennstoff-Einblasmitteln (215,216) und Brennstoffversorgungsdurchlässen (126,212), die zu den Hilfsbrennstoff-Einblasmitteln führen, den Hilfsbrenner darstellt.
2. Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 1, wobei in dem Hilfsbrenner eine Zündquelle zum Zünden des Verbrennungsvorganges angeordnet ist.
3. Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 1 oder 2, wobei der Hilfsbrenner ein Luft-einblasmittel enthält, die Hilfsbrennstoff-Einblasmittel das Lufteinblasmittel im wesentlichen konzentrisch umge-

ben, und die Hilfsbrennstoff-Einblasmittel derart gestaltet sind, daß sie den Brennstoff in Richtung auf das Lufteinblasmittel einblasen, um innerhalb der Vorbrennkammer außerhalb des Hilfsbrenners einen brennstoffreiches Gemisch aus Luft und Brennstoff zu erzeugen.

- 5 **4.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß einem der Ansprüche 1 bis 3, wobei das Lufteinblasmittel so gestaltet ist, daß es eine auseinandergehende verwirbelte Luftsäule von kreisförmigem Querschnitt vom Hilfsbrenner weg in die Vorbrennkammer ausstößt.

- 10 **5.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 1, wobei der Hilfsbrenner derart gestaltet ist, daß er Hilfsbrennstoff (200) und Luft (300) getrennt voneinander und gleichzeitig in das Verbrennungsgerät zum Vermischen einbläst, und ein Lufteinblasmittel (302) zum Einblasen von Luft in das Verbrennungsgerät in Form einer säulenförmigen Saumschicht (303) von kreisförmigem Querschnitt aufweist, die einen mittigen Verbrennungsbereich (107) angrenzend an den Hilfsbrenner umströmt, die Hilfsbrennstoff-Einblasmittel (215,216) derart angeordnet sind, daß sie den Hilfsbrennstoff in Richtung auf die säulenförmigen Saumschicht blasen, um sie mit der darin enthaltenden Luft zu vermischen, der Hauptbrenner derart gestaltet ist, daß er ein brennstoffarmes Gemisch aus Luft und Brennstoff (139) in das Verbrennungsgerät in Richtung auf die säulenförmigen Saumschicht einbläst, und die Saumschicht den mittigen Bereich (107) als abgeschirmte Verbrennungszone stabilisiert, um die Stabilität der brennstoffarmen Verbrennung im Verbrennungsgerät zu erhöhen.

- 20 **6.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 5, wobei die säulenförmige Saumschicht mit der Entfernung vom Hilfsbrenner auseinandergeht.

- 7.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 5 oder 6, wobei im Hilfsbrenner das Hilfsbrennstoff-Einblasmittel das Lufteinblasmittel im wesentlichen konzentrisch umgibt.

- 25 **8.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 7, wobei das Hilfsbrenner-Lufteinblasmittel derart gestaltet ist, daß es der Luftsäule eine verwirbelnde Strömungskomponente verleiht.

- 9.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 8, wobei die Richtungen der Verwirbelung, die von dem Hilfsbrenner und den Hauptbrennern erzeugt werden, einander entgegengesetzt sind.

- 30 **10.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß einem der Ansprüche 3 bis 9, wobei das Lufteinblasmittel ein Mittel um faßt, das in dem inneren Brennstoffversorgungskörper einen kreisförmigen Schlitz (302) definiert.

- 35 **11.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 10, wobei das Lufteinblasmittel außerdem eine Anzahl Zufuhrdurchlässe zum Heranführen von Luft an den Boden des Schlitzes (302) aufweist und die Zufuhrdurchlässe (306) in den Boden des Schlitzes schräg zu dessen Seitenwänden eintreten, wodurch der den Schlitz verlassenden Luft (300) eine Verwirbelungskomponente verliehen wird.

- 40 **12.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 11, wobei die Zufuhrdurchlässe in den Boden des Schlitzes tangential eintreten.

- 13.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß einem der Ansprüche 1 bis 12, wobei das Hilfsbrennstoff-Einblasmittel Mittel (216) umfaßt, die eine sich um den Umfang erstreckende Öffnung in der Nähe der Peripherie des inneren Brennstoffversorgungskörpers (214) definieren, und der Brennstoff aus dem Hilfsbrenner durch diese Öffnung austritt.

- 45 **14.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 13, wobei das Hilfsbrennstoff-Einblasmittel eine ringförmige Lippe (216) aufweist, die im Abstand von dem äußersten peripheren Abschnitt des inneren Brennstoffversorgungskörpers (214) angeordnet ist und diesen Abschnitt bedeckt, und der Brennstoff aus dem Hilfsbrenner zwischen dem inneren Brennstoffversorgungskörper und der Lippe austritt.

- 50 **15.** Verbrennungsgerät zum brennstoffarmen Verbrennen gemäß Anspruch 14, wobei das Hilfsbrennstoff-Einblasmittel außerdem eine kreisförmige Anordnung von Öffnungen (215) aufweist, die in dem inneren Brennstoffversorgungskörper unter der Lippe (216) angeordnet ist.

- 55

Revendications

1. Système de combustion à mélange pauvre (100) destiné à un moteur à turbine à gaz, le système de combustion ayant une section transversale généralement circulaire et comprenant, en suivant la séquence de l'écoulement de combustion, une tête de système de combustion incorporant un agencement de brûleur (104), une pré-chambre de combustion (141) et une chambre de combustion principale (103), la pré-chambre possédant une section transversale sensiblement inférieure à celle de la chambre principale, l'agencement de brûleur comportant des moyens tourbillonneurs d'écoulement d'air (122) et des moyens d'injection de combustible principal (136) disposés pour injecter le combustible dans lesdits moyens tourbillonneurs afin de produire ainsi un mélange combustible/air pauvre en combustible (139) dans les moyens tourbillonneurs, les moyens tourbillonneurs formant une périphérie d'une partie amont de la pré-chambre (141) et étant disposés pour injecter le mélange combustible/air dans la pré-chambre avec un mouvement tourbillonnant dirigé radialement vers l'intérieur, l'agencement de brûleur comportant en outre une partie corps combustible (120) ayant des passages d'alimentation de combustible (128, 130, etc.) formés dedans pour alimenter le combustible vers les moyens d'injection de combustible principal (136), les moyens tourbillonneurs étant attachés à une surface dirigée vers le bas sensiblement plane de la partie corps combustible, l'agencement de brûleur (104) comportant en outre un brûleur pilote (114) agencé sur la ligne centrale axiale (CL) du système de combustion pour supporter une combustion du type diffusion dans la pré-chambre (141) par l'injection du combustible à l'intérieur de celle-ci, la partie corps combustible de l'agencement de brûleur comportant un corps combustible radialement extérieur (120) auquel les moyens tourbillonneurs (122) sont attachés et un corps combustible radialement intérieur (114) encastré dans le corps combustible extérieur, le corps combustible intérieur constituant le brûleur pilote par l'inclusion de moyens d'injection de combustible pilote (215, 216) et de passages d'alimentation de combustible (126, 212) conduisant aux moyens d'injection de combustible pilote.
2. Système de combustion à mélange pauvre selon la revendication 1, dans lequel une source d'allumage est incorporée dans le brûleur pilote pour l'allumage de la combustion.
3. Système de combustion à mélange pauvre selon la revendication 1 ou 2, dans lequel le brûleur pilote incorpore des moyens d'injection d'air, les moyens d'injection de combustible pilote entourant les moyens d'injection d'air et étant sensiblement concentriques avec eux, les moyens d'injection de combustible pilote étant configurés pour injecter le combustible vers les moyens d'injection d'air pour produire un mélange combustible/air riche en combustible à l'intérieur de la pré-chambre à l'extérieur du brûleur pilote.
4. Système de combustion à mélange pauvre selon l'une quelconque des revendications 1 à 3, dans lequel les moyens d'injection d'air sont configurés pour éjecter une colonne tourbillonnante divergente d'air loin du brûleur pilote dans la pré-chambre, la colonne d'air étant annulaire en termes de section transversale.
5. Système de combustion à mélange pauvre selon la revendication 1, dans lequel le brûleur pilote est configuré pour injecter séparément et simultanément le combustible pilote (200) et l'air (300) dans le système de combustion pour y être mélangés, le brûleur pilote ayant des moyens d'injection d'air (302) pour injecter l'air dans le système de combustion sous la forme d'une couche de cisaillement (303) en forme de colonne de section transversale annulaire entourant une région de combustion centrale (107) adjacente au brûleur pilote, les moyens d'injection de combustible pilote (215, 216) étant conçus pour injecter le combustible pilote vers la couche de cisaillement en forme de colonne pour y être mélangé avec l'air, le brûleur principal étant configuré pour injecter un mélange combustible principal/air pauvre en combustible (139) dans le système de combustion vers la couche de cisaillement en forme de colonne, la couche de cisaillement établissant la région centrale (107) comme zone de combustion protégée pour augmenter la stabilité de la combustion pauvre dans le système de combustion.
6. Système de combustion à mélange pauvre selon la revendication 5, dans lequel la couche de cisaillement en forme de colonne est divergente par rapport au brûleur pilote.
7. Système de combustion à mélange pauvre selon la revendication 5 ou 6, dans lequel, dans le brûleur pilote, les moyens d'injection de combustible pilote entourent les moyens d'injection d'air et sont sensiblement concentriques avec eux.
8. Système de combustion à mélange pauvre selon la revendication 7, dans lequel les moyens d'injection d'air du brûleur pilote sont configurés pour impartir une composante d'écoulement tourbillonnante à la colonne d'air.
9. Système de combustion à mélange pauvre selon la revendication 8, dans lequel les directions de tourbillonnement

imparties par les brûleurs pilote et principal sont mutuellement opposées.

- 5 10. Système de combustion à mélange pauvre selon l'une quelconque des revendications 3 à 9, dans lequel les moyens d'injection d'air comprennent des moyens définissant une fente circulaire (302) dans le corps combustible intérieur.
- 10 11. Système de combustion à mélange pauvre selon la revendication 10, dans lequel les moyens d'injection d'air comportent en outre une pluralité de passages d'alimentation pour alimenter l'air vers la partie inférieure de la fente (302), les passages d'alimentation (306) pénétrant dans la partie inférieure de la fente de manière oblique par rapport aux côtés de la fente, une composante d'écoulement tourbillonnante étant impartie à l'air (300) sortant de la fente.
- 15 12. Système de combustion à mélange pauvre selon la revendication 11, dans lequel les passages d'alimentation pénètrent dans la partie inférieure de la fente tangentiellement.
- 20 13. Système de combustion à mélange pauvre selon l'une quelconque des revendications 1 à 12, dans lequel les moyens d'injection de combustible pilote comprennent des moyens (216) définissant une ouverture s'étendant circonférentiellement à proximité de la périphérie du corps combustible intérieur (214), le combustible quittant le brûleur pilote à travers ladite ouverture.
- 25 14. Système de combustion à mélange pauvre selon la revendication 13, dans lequel les moyens d'injection de combustible pilote comprennent une lèvre annulaire (216) espacée d'une partie périphérique la plus extérieure du corps combustible intérieur (214) et recouvrant celle-ci, le combustible quittant le brûleur pilote entre le corps combustible intérieur et la lèvre.
- 30 15. Système de combustion à mélange pauvre selon la revendication 14, dans lequel les moyens d'injection de combustible pilote comportent en outre un réseau circulaire d'ouvertures (215) situées dans le corps combustible intérieur sous la lèvre (216).

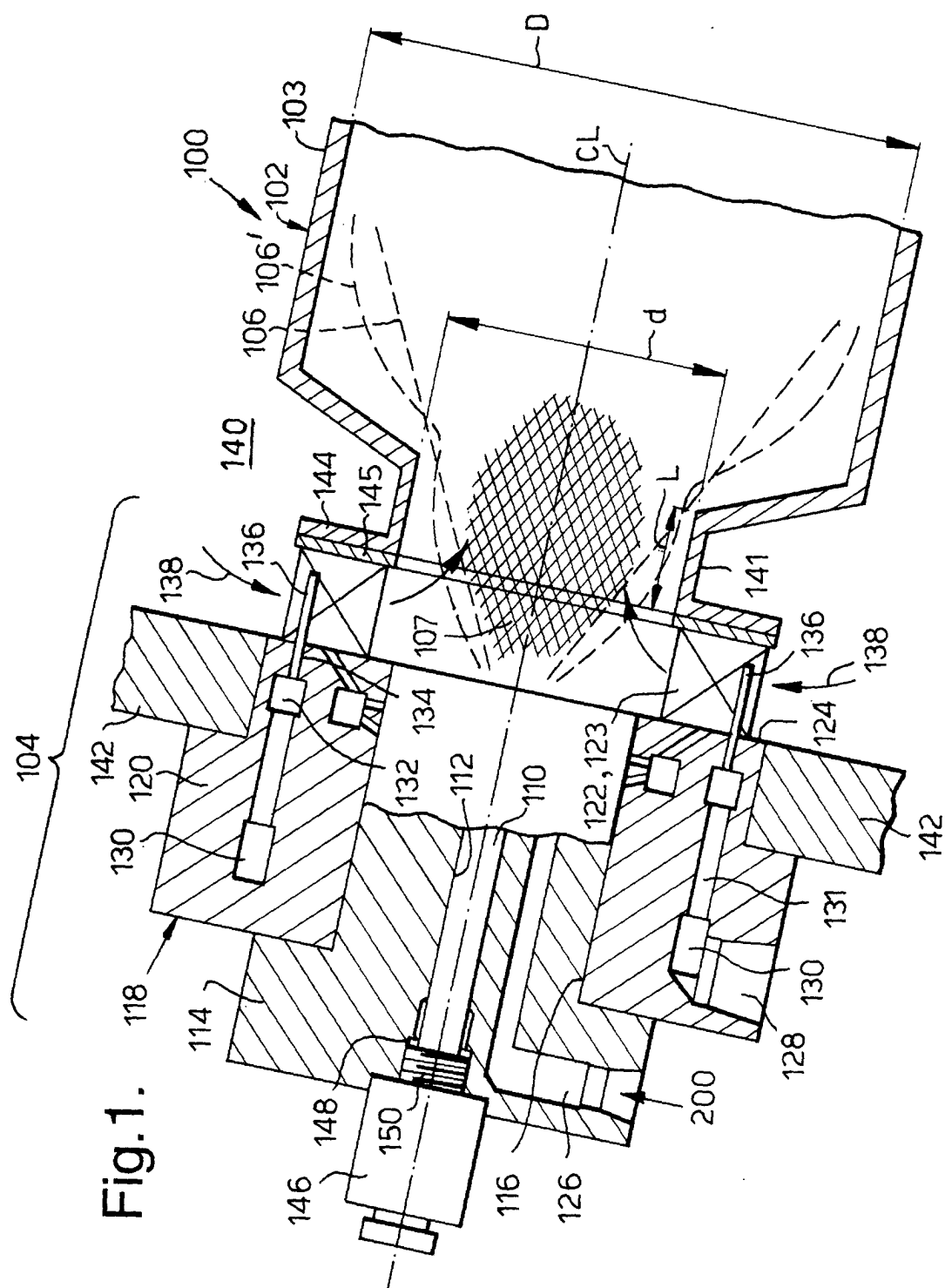


Fig. 1.

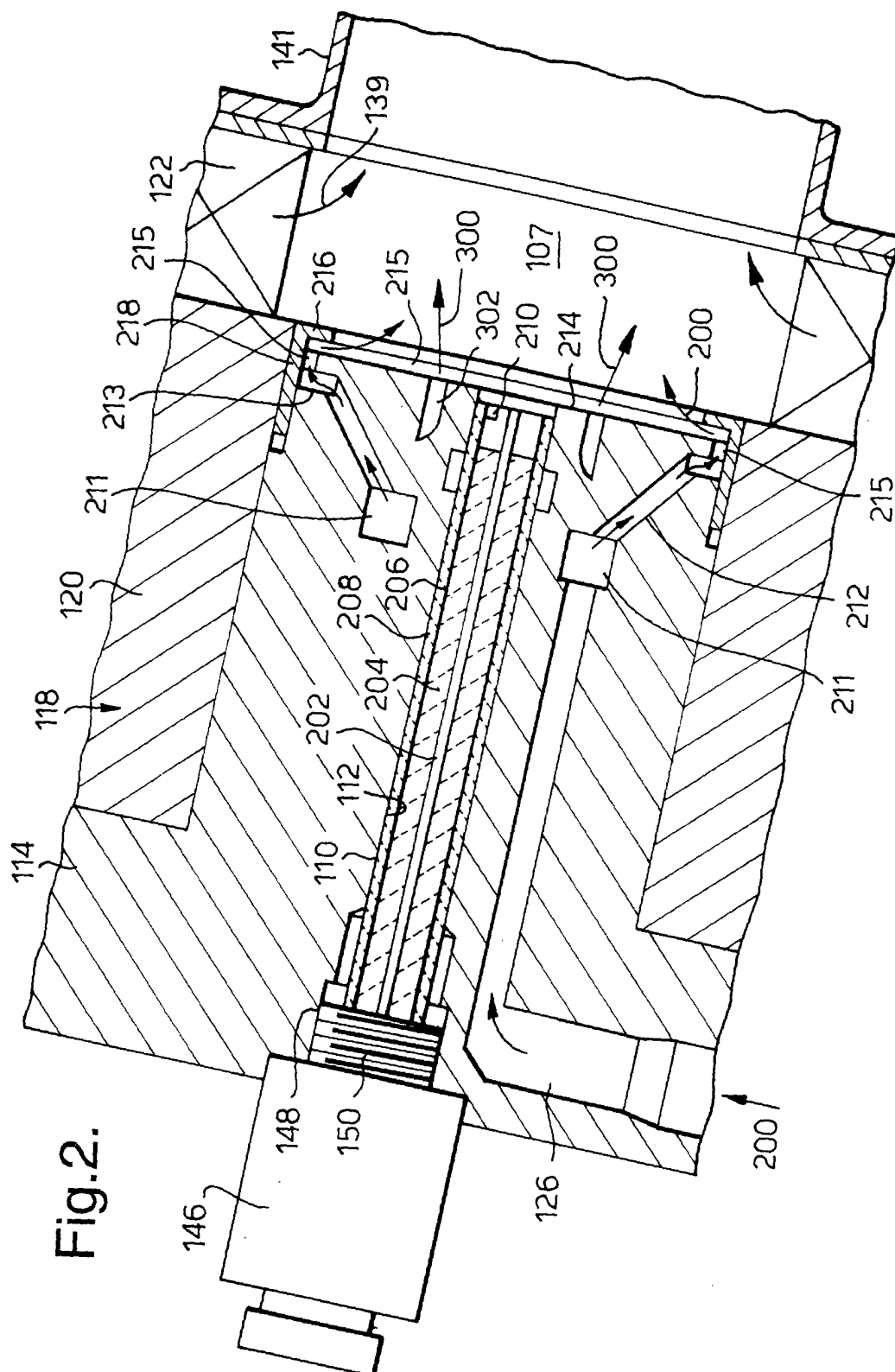


Fig. 2.

