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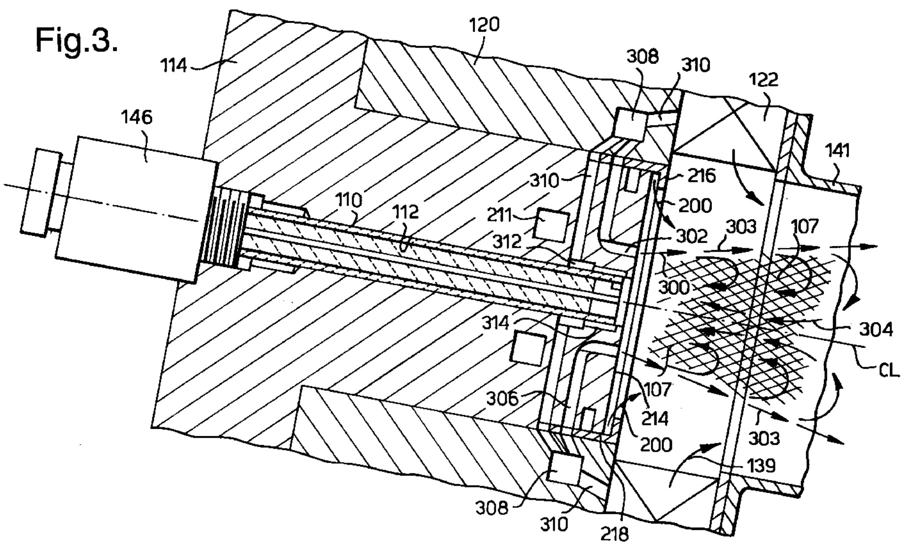
(54) Gas turbine engine combustor

(57) A lean burn combustor for a gas turbine engine has a pilot burner (114) which injects fuel and air separately, the air being injected as a swirling column from a circular slot (302) in the burner head (214) to establish a divergent columnar shear layer (303) in the combustor, and the fuel being injected from a peripheral annular gap in the burner head towards the column of air (300) for mixing with it in the shear layer (303). A main burner (120,122) surrounds the pilot burner and by means of swirler passages (122) injects a fuel-lean main fuel/air mixture into the combustor towards the shear layer (303) for mixing with the pilot fuel and air. The shear layer establishes a sheltered combustion region (107) near the pilot burner and some fuel/air mixture (304) capable of stable combustion in the sheltered region is recirculated from the shear layer into the sheltered region to increase the stability of lean burn combustion in the combustor over a wide range of engine load conditions.

Fig.3.



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Description

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.

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.

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 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.

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.

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 radiallly 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.

It is claimed that the above prior art arrangement enables low Nox 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 undesireable 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.

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 tranferred 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.

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

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.

Also reasons of reduction in cost and complexity, it is further desireable 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.

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.

According to a first aspect of the present invention, a burner for a gas turbine engine combustor (particularly, but not exclusively a pilot burner for a low NOx combustor) has a burner head comprising separate fuel injecting means and air injecting means, wherein the fuel injecting means surrounds the air injecting means and is substantially concentric therewith, the air injecting means being configured to eject a column of air therefrom, the column of air being annular in cross section, the fuel injecting means being configured to inject the fuel towards the column of air for mixing therewith externally of the burner within the combustor.

In most practical circumstances, the column of air will be divergent away from the burner.

Preferably, the air injecting means comprises means defining a circular slot in the burner head, though the circular slot could conceivably be split into a plurality of closely spaced apertures which collectively approximate to a circle, without unduly compromising the circumferential continuity of the column of air. Furthermore, it is highly preferred that the air injecting means comprises means for imparting a swirling flow component to the column of air. Such swirling can be produced by an arrangement in which a plurality of feeder passages feed air to the bottom of a fully circular slot, the feeder passages entering the bottom of the slot obliquely, preferably tangentially with respect to the sides of the slot.

In a preferred form of the fuel injecting means, a circumferentially extending aperture is defined near the periphery of the burner head, the fuel exiting from the burner through said aperture. This aperture may be defined by an annular lip spaced from and covering an outermost peripheral portion of the burner head, the fuel exiting from the burner between the burner head and the lip. Discharge of the fuel may be effected by a circular array of apertures located in the burner head under the lip, the lip acting to deflect fuel emitted by the holes towards the column of air for mixing therewith.

In the preferred embodiment of the invention, the burner is advantageously combined with an igniter, such as an electrical or catalytic igniter, which is contained in an inner burner head region with the air injecting means.

A second aspect of the invention provides a burner arrangement for a gas turbine engine lean burn combustor, the combustor comprising in combustion flow sequence a combustor head incorporating the burner arrangement, a combustion pre-chamber and a main combustion chamber, the prechamber being of substantially smaller cross-sectional area than the main chamber, the burner arrangement comprising:

(a) a pilot burner located in the combustor head for supporting a diffusion type of combustion process in the prechamber; and

(b) a main burner for injecting a fuel-lean fuel/air mixture into the prechamber, the main burner comprising flow swirler means and fuel injection means, the swirler means being disposed outwardly of the pilot burner and downstream thereof, thereby to impart an inward swirling motion to the fuel/air mixture upon injection into the prechamber;

wherein the main burner further comprises a fuel body portion housed in the combustor head, the fuel body portion having fuel supply passages therein for supplying fuel to the swirler's fuel injection means, the swirler being attached to the main burner fuel body portion and forming a periphery of the most upstream part of the prechamber, the pilot burner being nested within the main burner fuel body portion.

A third aspect of the invention provides a lean burn combustor for a gas turbine engine, the combustor having a pilot burner and a main burner for producing a fuel/air mixture for combustion in the combustor, the main burner surrounding the pilot burner and being downstream thereof, wherein the pilot burner is configured to separately and simultaneously inject pilot fuel and air into the combustor for mixing therein, the pilot burner having air injection means for injecting the air into the combustor as a columnar shear layer of annular cross-section surrounding a region adjacent the pilot burner and fuel injection means for injecting 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 into the combustor towards the columnar shear layer, the shear layer establishing a sheltered combustion zone to increase the stability of lean burn combustion in the combustor. Advantageously, the columnar shear layer is divergent away from the pilot burner. Preferably the pilot fuel injecting means surrounds the air injecting means and is substantially concentric therewith. This third aspect of the invention advantageously includes configuring the air injecting means in the pilot burner to impart a swirling flow component to the column of air. It is believed very advantageous if the main burner is also configured to impart a swirling flow component to the main fuel/air mixture, the directions of swirl imparted by the pilot and main burners being mutually opposed.

In a fourth aspect, the invention provides a method of sustaining a lean burn combustion process in a combustor of a gas turbine engine over a range of load conditions of the engine, the method comprising the continuously co-operating steps of;

(a) injecting air into the combustor to establish a columnar shear layer of fluid flow within the combustor, the shear layer being annular in cross section,

(b) injecting pilot fuel substantially uniformly into a circumferential base portion of the shear layer, the fuel being injected from a region surrounding the shear layer, the shear layer carrying the pilot fuel into the combustor for mixing with the air in the shear layer to produce a pilot fuel/air mixture,

(c) injecting a fuel-lean main fuel/air mixture substantially uniformly towards the shear layer from a region surrounding the shear layer but downstream of the region of pilot fuel injection, mixing of the main fuel/air mixture with the pilot fuel/air mixture occurring in the shear layer, the fuel-lean main fuel/air mixture being intended to support a lean-burn combustion process in the combustor at least over a wide range of load conditions of the gas turbine engine,

(d) recirculating some of the fuel/air mixture from the shear layer into a sheltered region surrounded by the shear layer near the circumferential base portion of the shear layer, the sheltered region having substantially lower fluid velocities than neighbouring regions in and beyond the shear layer, and

(e) burning the recirculated fuel/air mixture in the sheltered region, thereby establishing a sheltered combustion zone, the recirculated fuel/air mixture being capable of stable combustion in the sheltered combustion zone, whereby the whole of the combustion process in the combustor is stabilised.

As in the third aspect of the invention, the columnar shear layer should be divergent in the direction of air injection and should have a rotational swirl component of fluid flow about the centre of its annular cross section, the fuel-lean main fuel/air mixture preferably also having a rotational swirl component of fluid flow about the same centre, the directions of swirl in the columnar shear layer and the fuel-lean main fuel/air mixture preferably being mutually opposed.

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.

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 NOx" 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.

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.

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.

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.

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 cross-hatched. 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.

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.

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).

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 Through Each of Total Fuel 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

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.

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.

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.

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.

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 burner (114) for a gas turbine engine combustor, the burner having a burner head (214) comprising fuel injecting means (215,216) and air injecting means (302);

wherein the fuel injecting means surrounds the air injecting means and is substantially concentric therewith, the air injecting means being configured to eject a column of air (300) therefrom, the column of air being annular in cross section, the fuel injecting means being configured to inject the fuel (200) towards the column of air for mixing therewith.

2. A burner according to claim 1, in which the column of air is divergent away from the burner.

3. A burner according to claim 1 or claim 2, in which the air injecting means comprises means defining a circular slot in the burner head.

4. A burner according to any one of claims 1 to 3, in which the air injecting means comprises means for imparting a swirling flow component to the column of air.

5. A burner according to claim 1 or claim 2, in which the air injecting means comprises a circular slot (302) in the burner head (214) and a plurality of feeder passages for feeding air to the bottom of the slot, 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 column of air (300).

6. A burner according to claim 5, in which the feeder passages enter the bottom of the slot tangentially thereof.

7. A burner according to any one of claims 1 to 6, in which the fuel injecting means comprises means (216) defining a circumferentially extending aperture near the periphery of the burner head (214), the fuel exiting from the burner through said aperture.

8. A burner according to claim 7, in which the fuel injecting means comprises an annular lip (216) spaced from and covering an outermost peripheral portion of the burner head (214), the fuel exiting from the burner between the burner head and the lip.

9. A burner according to claim 8, in which the fuel injecting means further comprises a circular array of apertures (215) located in the burner head under the lip (216), the lip acting to deflect fuel emitted by the holes towards the column of air for mixing therewith.

10. A burner according to any one of claims 1 to 9 , the burner having:

(a) an outer burner head region including the fuel injecting means,
(b) an inner burner head region comprising the air injecting means and an ignition source (110) for igniting the fuel and air injected into the combustion chamber by the burner.

11. A burner arrangement (104) for a gas turbine engine lean burn combustor, the combustor comprising in combustion flow sequence a combustor head incorporating the burner arrangement, a combustion pre-chamber (141) and a main combustion chamber (103), the prechamber being of substantially smaller cross-sectional area than the main chamber, the burner arrangement comprising:

(a) a pilot burner (114) located in the combustor head for supporting a diffusion type of combustion process in the pre-chamber; and
(b) a main burner (118) for injecting a fuel-lean fuel/air mixture (139) into the prechamber, the main burner comprising flow swirler means (122) and fuel injection means (136), the swirler means being disposed outwardly of the pilot burner and downstream thereof, thereby to impart an inward swirling motion to the fuel/air mixture (139) upon injection into the prechamber;

wherein the main burner further comprises a fuel body portion (120) housed in the combustor head, the fuel body portion having fuel supply passages (128,130, etc.) therein for supplying fuel to the swirler's fuel injection means, the swirler being attached to the main burner fuel body portion and forming a periphery of the most upstream part of the prechamber (141), the pilot burner being nested within the main burner fuel body portion.

12. A burner arrangement according to claim 11 in which an ignition source is housed in the pilot burner for ignition of the combustion process.

13. A burner arrangement according to claim 11 or claim 12, in which the pilot burner incorporates fuel injecting means and air injecting means, the fuel injecting means surrounding the air injecting means and being substantially concentric therewith, the fuel injecting means being configured to inject the fuel towards the air injecting means for producing a fuel-rich fuel/air mixture within the prechamber externally of the pilot burner.

14. A burner arrangement according to any one of claims 11 to 13, 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.

15. A lean burn combustor (100) for a gas turbine engine, the combustor having a pilot burner (114) and a main burner (118) for producing a fuel/air mixture for combustion in the combustor, the main burner surrounding the pilot burner but injecting fuel into the combustor downstream of the pilot burner;

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 injection means (302) for injecting the air into the combustor as a columnar shear layer (303) of annular cross-section surrounding a region (107) adjacent the pilot burner and fuel injection means (215,216) for injecting 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 a sheltered combustion zone (107) to increase the stability of lean burn combustion in the combustor.

16. A combustor according to claim 15, in which the columnar shear layer is divergent away from the pilot burner.

17. A combustor according to claim 15 or claim 16, in which in the pilot burner the fuel injecting means surrounds the air injecting means and is substantially concentric therewith.

18. A combustor according to claim 17, in which the pilot burner air injecting means is configured to impart a swirling flow component to the column of air.

19. A combustor according to any one of claims 15 to 18, in which the main burner is configured to impart a swirling flow component to the main fuel/air mixture.

20. A combustor according to any one of claims 15 to 17, in which the pilot and main burners are configured to impart swirling flow components to the columnar shear layer and to the main fuel/air mixture respectively, the directions of swirl imparted by the pilot and main burners being mutually opposed.

21. A method of sustaining a lean burn combustion process in a combustor (100) of a gas turbine engine over a range of load conditions of the engine, the method being characterised by the continuously co-operating steps of;

(a) injecting air (300) into the combustor to establish a columnar shear layer (303) of fluid flow within the combustor, the shear layer being annular in cross section,
(b) injecting pilot fuel (200) substantially uniformly into a circumferential base portion of the shear layer, the fuel being injected from a region surrounding the shear layer, the shear layer carrying the pilot fuel into the combustor for mixing with the air in the shear layer to produce a pilot fuel/air mixture,
(c) injecting a fuel-lean main fuel/air mixture (139) substantially uniformly towards the shear layer from a region surrounding the shear layer but downstream of the region of pilot fuel injection, mixing of the main fuel/air mixture with the pilot fuel/air mixture occuring in the shear layer, the fuel-lean main fuel/air mixture being intended to support a lean-burn combustion process in the combustor at least at starting and full load conditions of the gas turbine engine,
(d) recirculating some of the fuel/air mixture (304) from the shear layer into a sheltered region (107) surrounded by the shear layer near the circumferential base portion of the shear layer, the sheltered region having substantially lower fluid velocities than neighbouring regions in and beyond the shear layer,
(e) burning the recirculated fuel/air mixture in the sheltered region, thereby establishing a sheltered combustion zone (107), the recirculated fuel/air mixture being capable of stable combustion in the sheltered combustion zone, whereby the whole of the combustion process in the combustor is stabilised.

22. A combustion process according to claim 21, in which the columnar shear layer is divergent in the direction of air injection.

23. A combustion process according to claim 21 or claim 22, in which the columnar shear layer has a rotational swirl component of fluid flow about the centre of its annular cross section.

24. A combustion process according to any one of claims 21 to 23, in which the fuel-lean main fuel/air mixture has a rotational swirl component of fluid flow about the centre of the annular cross section of the columnar shear layer.

25. A combustion process according to claim 21 or claim 22, in which the columnar shear layer and the fuel-lean main fuel/air mixture have rotational swirl components of fluid flow about the centre (CL) of the annular cross section of the columnar shear layer, the directions of swirl in the columnar shear layer and the fuel-lean main fuel/air mixture being mutually opposed.

26. A combustion process according to any one of claims 21 to 25, in which the relative amounts of air, pilot fuel and main fuel injected into combustion chamber 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 zone is sufficiently fuel-rich to sustain stable combustion for the whole of the combustion process.

27. A combustion process according to claim 26, in which 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, the amount of pilot fuel injected as a proportion of total fuel injected being varied from a minor proportion at start-up to a major proportion at full speed with minimum load to about zero at full speed with full load.

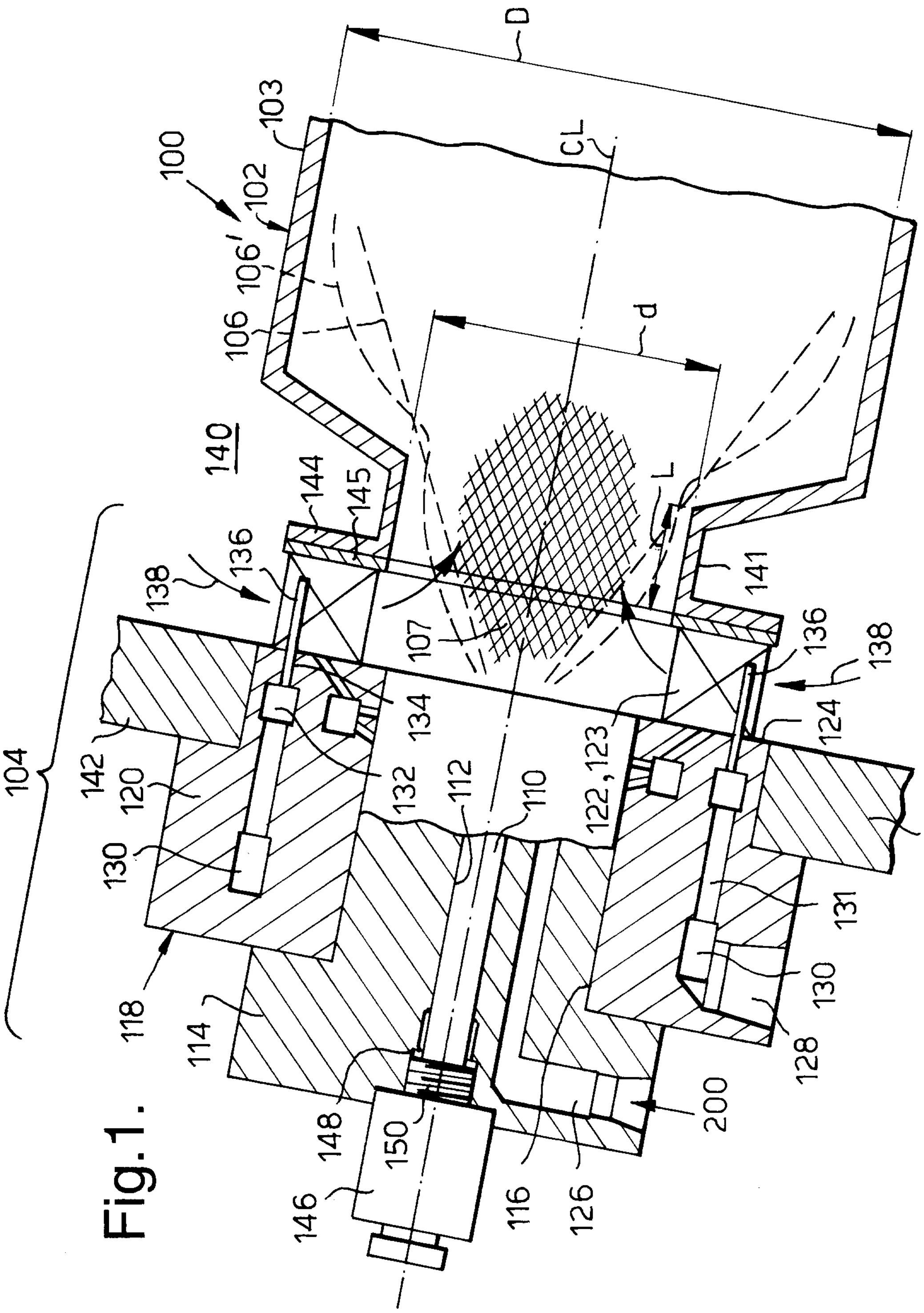
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Fig.1.

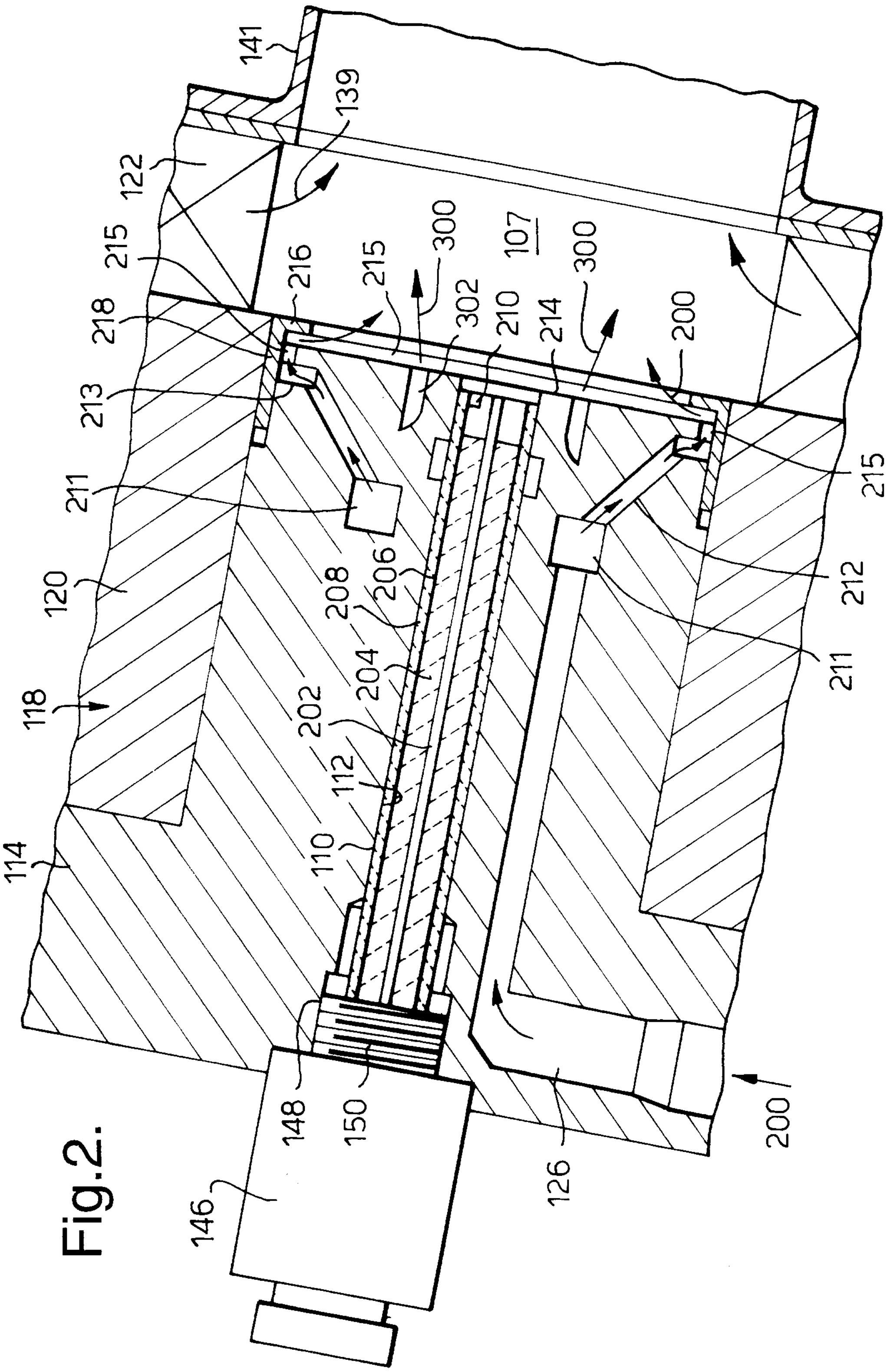

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Fig.2.

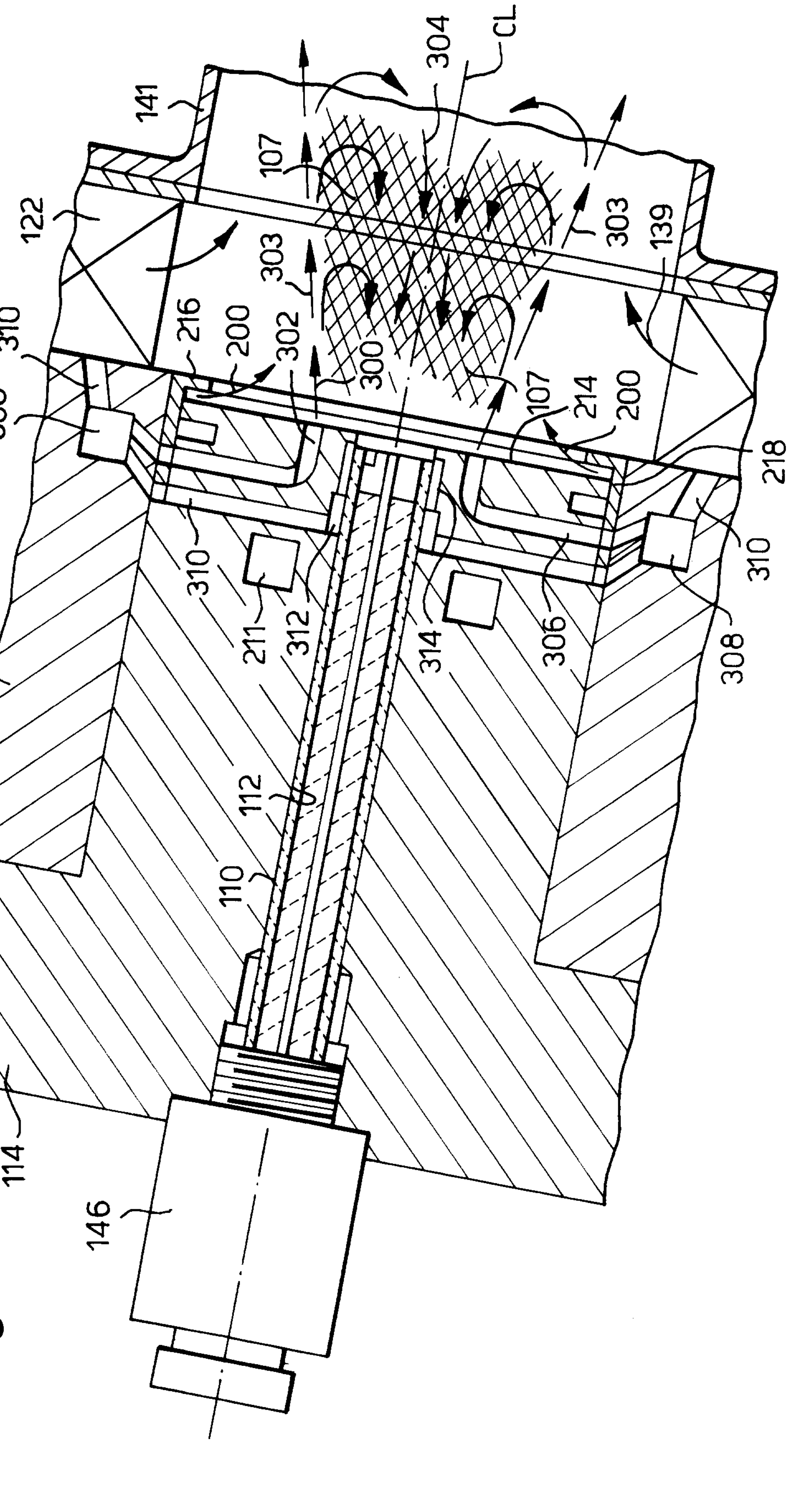
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Fig.3.