United States Patent [19]

Caruel et al.

[11] **3,757,522**

[45] **Sept. 11, 1973**

[54] **DEVICES FOR PRE-VAPORISING LIQUID FUEL**

[75] Inventors: **Jacques Emile Jules Caruel,** Dammarie-les-Lys; **Bernard Andre Cantaloube,** Chennevieres; **Guy Daniel Stora,** Melun; **Jean Robert Bedue,** Creteil; **Philippe Marc Denis Gastebois,** Melun; **Herve Alain Quillevere,** Issy-les-Moulineaux, all of France

[73] Assignee: **Societe Nationale D'Etude et De Construction De Moteurs D'Aviation,** Paris, France

[22] Filed: **July 13, 1972**

[21] Appl. No.: **271,235**

[30] **Foreign Application Priority Data**

July 16, 1971 France 7126107
Apr. 28, 1972 France 7215409

[52] **U.S. Cl.** ..... **60/39.71,** 60/39.74 R, 431/210
[51] **Int. Cl.** **F02g 3/00**
[58] **Field of Search** 60/39.71, 39.74; 431/247, 248, 210

[56] **References Cited**

UNITED STATES PATENTS

3,633,361 1/1972 Bauger et al. 60/39.71
3,626,444 12/1971 Caruel et al. 60/39.74

Primary Examiner—Carlton R. Croyle
Assistant Examiner—Robert E. Garrett
Attorney—Watson, Cole, Grindle & Watson

[57] **ABSTRACT**

A device for pre-vaporising liquid fuel, designed for application for a combustion system comprising a combustion chamber, a liquid fuel source and a source of combustion agent such as air, said pre-vaporisation device comprising, projecting into the combustion chamber, a hollow structure having a general T-shape and made up of a body which constitutes the leg of the T and is connected to said liquid fuel and combustion agent sources, and two transverse arms connected to said body of the hollow structure and terminating, in each case, in a discharge orifice which opens into the combustion chamber and through which, in operation, there escapes a flow made up of a mixture of combustion agent and fuel in an at least partially vaporised state, in which said body of the hollow structure is partially closed off, in the neighbourhood of the armpits where the transverse arms join the body of the hollow structure, by a thin-walled diaphragm in the form of two thin partitions each presenting a sharp edge disposed towards the axis of said body and towards, the similar sharp edge belonging to the particular other partition, said partitions between said mutually opposite edges defining a restricted flow passage through which the body of the hollow structure communicates with each of said transverse arms.

6 Claims, 6 Drawing Figures

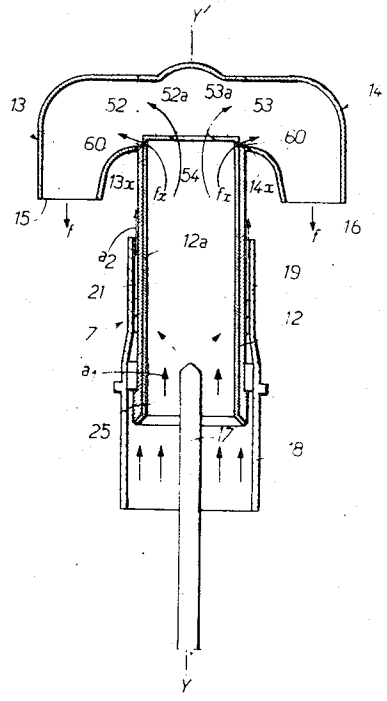


FIG. 1

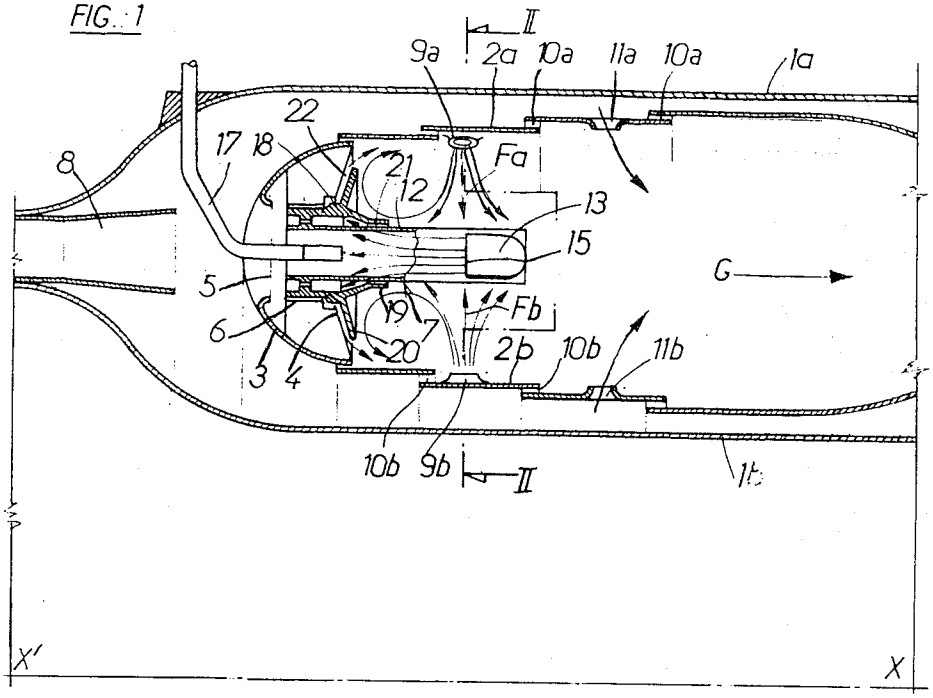

II
9a
2a
10a
11a
10a
1a
22
17
18
21
12
Fa
8
13
15
G
5
19
Fb
6
7
20
2b
10b
11b
3
4
10b
9b
II
1b
X'
X

FIG. 2

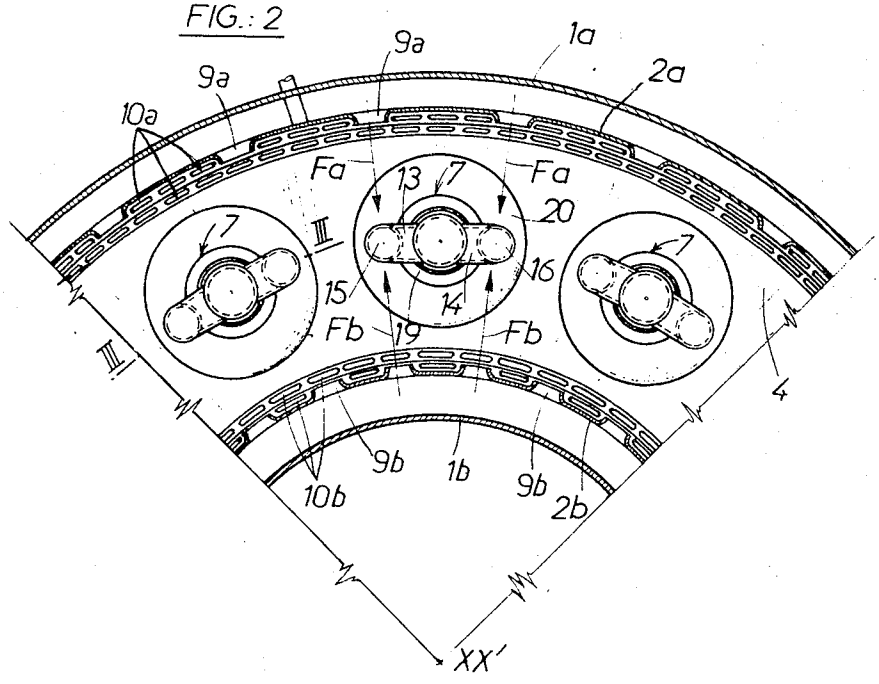

9a
1a
9a
2a
10a
Fa
13
7
Fa
20
7
7
II
16
15
14
Fb
19
Fb
II
4
9b
1b
9b
10b
2b
XX'

FIG.: 3

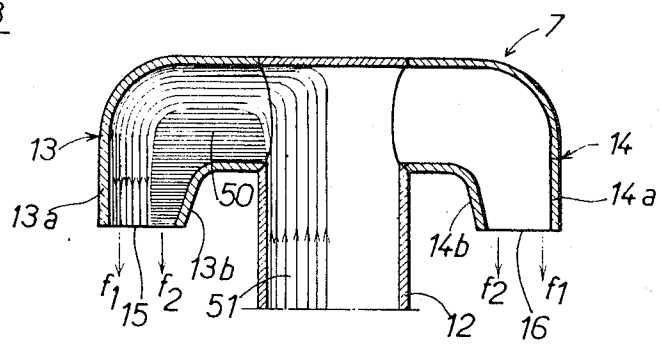


FIG.: 4

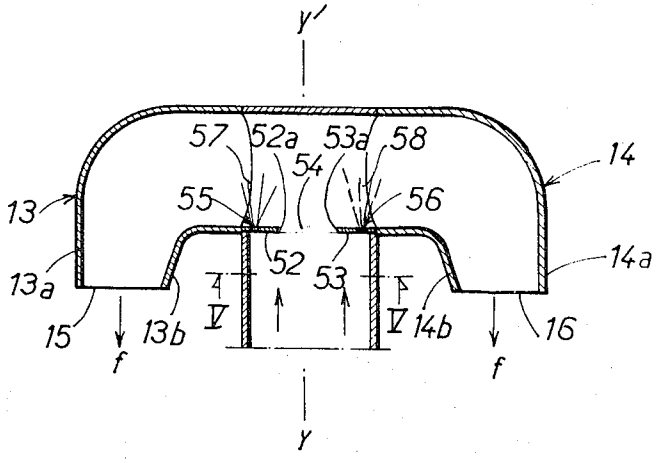


FIG.: 5

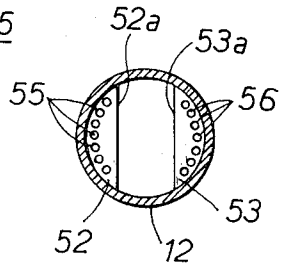
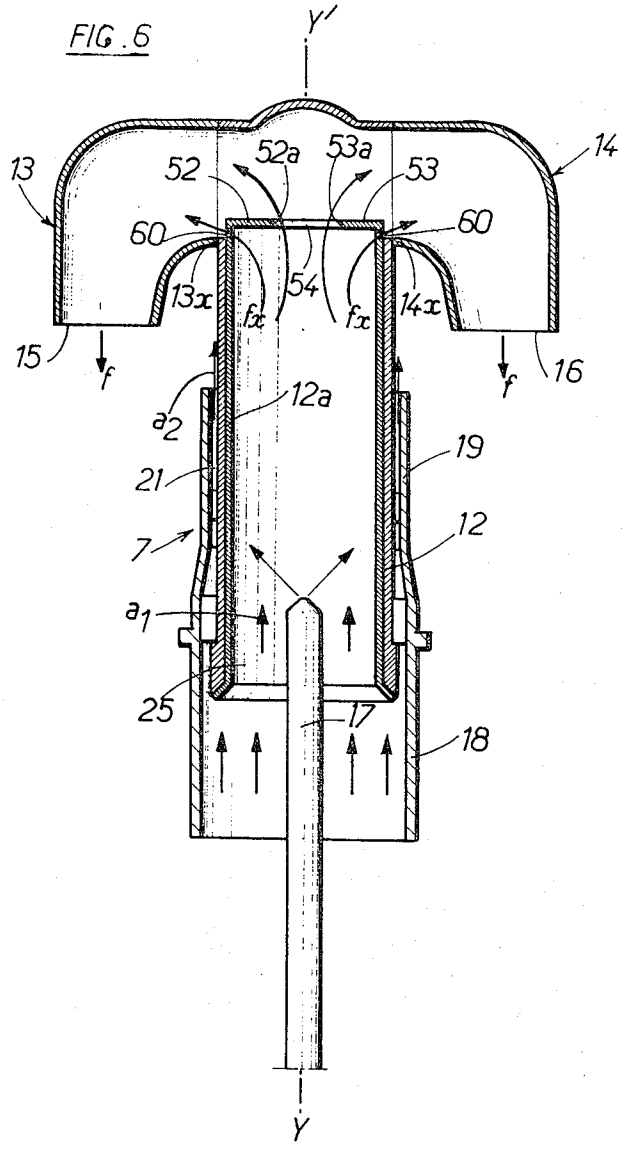


FIG. 6


Y'
13
52
52a
53a
53
14
60
60
13x
fx
54
fx
14x
15
f
f
16
a2
12a
19
21
12
7
a1
25
17
18
Y

DEVICES FOR PRE-VAPORISING LIQUID FUEL

The present invention relates to a device for pre-vaporising liquid fuel, designed for application for a combustion system comprising a combustion chamber, a liquid fuel source and a source of combustion agent such as air, said pre-vaporisation device being of the kind which comprises, projecting into the combustion chamber, a hollow structure having a general T-shape and made up of a body which constitutes the leg of the T and is connected to said liquid fuel and combustion agent sources, and two transverse arms connected to said body of the hollow structure and terminating, in each case, in a discharge orifice which opens into the combustion chamber and through which, in operation, there escapes a flow made up of a mixture of combustion agent and fuel in an at least partially vaporised state.

The combustion installation in question can be designed, in particular, for fitting to a gas-turbine engine such as a turbo-jet engine.

It has been found that in certain conditions of operation of the installation and more especially at low loads, there developed, in the combustion chamber, zones of incomplete combustion of such a nature as to impair the overall efficiency of the overall overall combustion chamber.

It has likewise been observed, under these same conditions, that the arms of the T-shaped hollow structure sometimes experienced local overheating, which affected their service life.

The Applicants have observed that these two conditions could have the same origin, although this was far from obvious, namely a defective process of vaporisation in the injector.

The Applicants have found that at low load, the temperature prevailing inside the hollow structure, although high under certain special conditions, is not always sufficient to enable complete vaporisation of all the fuel introduced into the hollow structure to take place. Part of the fuel therefore stays in the form of large droplets so that the distribution of the fuel in the flow passing through the transverse arms is not as uniform as it would be if all the fuel were vaporised.

The air-fuel mixture which escapes from the hollow structure is therefore non-uniform and this could explain the appearance of the aforesaid zones of incomplete combustion.

As far as the local overheating is concerned, it will be remembered that the cooling effect due to the vaporisation of the fuel in the hollow structure is a prime factor in achieving thermal protection of the walls of the hollow structure which are located in the combustion chamber. It is essential, therefore, for this cooling action to be effective, that all the internal surfaces of the hollow structure should be correctly "wetted" by the air-fuel mixture flowing through the hollow structure. However, because of the changes in direction to which said flow is subjected during its passage through the transverse arms, stratification of this flow takes place in particular due to the action of the centrifugal force. In each arm, the large droplets of fuel, still in the liquid state, are projected onto one of the walls of the particular arm, while the other wall is in contact virtually exclusively with air. The unwetted walls are thus insufficiently cooled and this explains the phenomenon (paradoxical as it may appear at first sight, since it occurs at low load) of the aforesaid local overheating.

In the context of the foregoing, it will be observed, in particular, that the region located near the point where the arms join the body, i.e. the region of the armpits of said arms is particularly difficult to cool.

It is a general object of the present invention to reduce the aforestated drawbacks.

In accordance with the invention, the body of the T-shaped hollow structure is partially closed off, in the neighbourhood of the armpits where the transverse arms join the body of the hollow structure, by a thin-walled diaphragm in the form of two thin partitions each presenting a sharp edge disposed towards the axis of said body and towards the similar sharp edge belonging to the particular other partition, said partitions, between said mutually opposite edges, defining a restricted flow passage through which the body of the hollow structure communicates with each of said transverse arms.

The presence of said thin partitions has two consequences : — first of all, it brings about a local reduction in the cross-sectional area of the body of the hollow structure and therefore a corresponding acceleration in the air flow passing through same, this promoting the pneumatic atomising of the fuel and its intimate mixture with the air;

it also has the effect of producing, at the two sharp edges of said partitions, a mechanical atomising action (by impact effect) on the fuel.

Under the effect of this double atomising the fuel, still in the liquid state, is distributed in a more uniform fashion in the flow passing through the hollow structure downstream of the diaphragm. All the walls of the arms are thus correctly wetted and an air-fuel mixture of substantially uniform richness thus exits from the hollow structure.

Thermal protection of these walls is thus ensured while the efficiency of the combustion chamber is improved.

The thin-walled diaphragm referred to hereinbefore can be located exactly at the level of the armpits where the said transverse arms join the body of the hollow structure, or slightly downstream thereof in relation to the direction of flow of the mixture of fuel and combustion agent passing through the said body.

In accordance with an embodiment applicable to the latter case, the pre-vaporisation device comprises additional passages through which the body of the hollow structure communicates with each of said arms, said additional passages originating in said body, upstream of said thin-walled diaphragm, and opening into said transverse arms directly in the zones of the armpits where said arms join the body. Said supplementary passages can advantageously be aligned in a direction having a component disposed transversely of the axis of the said body.

A certain fraction of the flow of liquid fuel injected into the body of the hollow structure, can thus directly wet the region of the armpits of the transverse arms, and this promotes the cooling of this region and consequently improves the thermal resistance of the overall hollow structure.

In accordance with another disposition of the invention, the aforesaid thin partitions are each pierced by at least one orifice aligned in a direction which has a component parallel to the axis of the body of the hol-

low structure, said orifice or orifices allowing a small fraction of the mixture of fuel and combustion agent to supply the wake zone which forms downstream of said partitions.

Trials carried out on T-shaped pre-vaporising hollow structures, with or without partitions, have shown local temperature differences in the sheet metal, which may amount to as much as several hundreds of degrees, in favour of hollow structures equipped with such partitions.

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

FIG. 1 is an axial half-section of a combustion system equipped with pre-vaporisation devices of the T-shaped hollow structure kind;

FIG. 2 is a partial transverse sectional view, on the lines II—II of FIG. 1, through said system;

FIG. 3 is a section on the line III—III of FIG. 2, on a larger scale, through a T-shaped pre-vaporisation hollow structure, of known kind;

FIG. 4 is a view similar to that of FIG. 3, showing an improved pre-vaporisation hollow structure in accordance with a first embodiment of the invention;

FIG. 5 is a transverse sectional view, on the line V—V, of part of the hollow structure shown in FIG. 4; and

FIG. 6 is a view similar to FIG. 4, showing an improved pre-vaporisation hollow structure in accordance with a second embodiment of the invention.

In FIGS. 1 and 2, the general reference 7 has been used to indicate the liquid fuel pre-vaporisation devices fitted to a combustion system which, in the example, forms part of a gas-turbine engine.

This installation, which is of known kind, comprises for example a combustion chamber on axis X'-X, limited by an external casing 1a and an internal casing 1*b*, which are substantially coaxial with one another. Said two casings together define an annular space inside which two walls 2*a*, 2*b* disposed substantially coaxially with respect to said two casings, delimit an annular flame tube constituting the combustion space proper. This latter is closed, at its upstream part, by an annular wall 3 or dome, inside which an annular support structure 4 is arranged. The dome 3 and the annular structure 4 are pierced by orifices 5–6, uniformly distributed around the axis X'—X of the chamber, each orifice 6 being arranged in extension of an orifice 5. A pre-vaporisation device 7 is inserted, with as easy fit, in each of the holes 6. The combustion chamber is connected at its upstream part to a source of combustion agent, for example compressed air, schematically illustrated by a pipe 8. This air circulates through the annular spaces respectively defined between the casing 1*a* and the wall 2*a*, the casing 1*b* and the wall 2*b*, and enters the combustion space in the form of primary air through orifices 5, and in the form of secondary cooling and dilution air, through orifices 9*a*–9*b*, 10*a*–10*b* and 11*a*–11*b*.

Each pre-vaporisation device 7 comprises, in a manner known per se, a hollow structure of generally T-shaped form, projecting into the combustion chamber from an orifice 6. The leg of the T is constituted by a tubular body 12 coaxial with the orifice 6 and branching to form two transverse arms 13–14 which form the branches of the T. These latter are curved towards the dome 3 and respectively terminate in discharge orifices 15–16, disposed towards the upstream end of the combustion chamber. The body 12 contains an intake orifice communicating with a source of liquid fuel schematically represented by a pipe 17.

The orifice 6 has a larger cross-sectional area than the body 12 in order to enable a sleeve 18, possibly integral with said body, to be arranged round the body. The sleeve 18 extends in the form of two branches 19–20, delimiting two annular passages 21–22 through which, into the combustion space, there is directly admitted a certain fraction of the primary air flow.

In operation, the major fraction of the primary air flow, at the same time as the liquid fuel, penetrates into the pre-vaporisation device or injector 7 whose walls are subjected, on their external surface, to the action of the flame so that the fuel vaporises. The mixture of primary air and vaporised fuel, escapes substantially axially through the orifices 15–16 in the reverse direction to the general direction of flow of the combustion gases which is indicated in FIG. 1 by the arrow G. The smaller fraction of the air flow admitted at 21 around the body 12 serves chiefly to ensure a certain degree of thermal insulation of the upstream part of the pre-vaporisation hollow structure.

The orifices 9*a*–9*b* make it possible to create two sets of jets F*a*–F*b* which are substantially radially disposed and of opposite direction. These jets meet in the neighbourhood of the discharge orifices 15–16. Part of the flow they produce then recirculates towards the upstream end of the chamber, there to form, in the region close to the dome 3, a turbulent zone suitable to promote ignition and sustain combustion, whilst the other part of this flow passes directly downstream in accordance with the arrow G, for example in the direction of a gas turbine, which has not been shown.

As explained hereinbefore, one problem which arises in the operation of a combustion system of the kind described, is that of thermal protection of the walls of the pre-vaporisation hollow structures 7 which, in operation, are subjected to the high temperatures prevailing in the upstream section of the combustion chamber.

This protection is achieved in the upstream section of the hollow structure, to some extent, by an insulating gas barrier formed by that fraction of the air flow passing through the passage 21.

In contrast, as far as the downstream section of the hollow structure is concerned, comprising the arms 13–14 of the T, the walls of which are more exposed to the action of the heat prevailing in the combustion chamber, the only truly effective protection is that which is produced by the cooling of these walls due to vaporisation of the fuel present inside the hollow structure.

It has been observed, nevertheless, that in certain conditions of operation of the system, and in particular at low load, local overheating of the arms 13–14 of the T-shaped hollow structure takes place, in particular in a critical zone located near to the point where the said arms join the leg of the T-shaped structure i.e., near the "armpits" of said arms. This critical zone has been marked 50 in FIG. 3 which latter, on a larger scale, illustrates the downstream section of a T-shaped pre-vaporisation hollow structure of conventional design.

It has been observed, too, that this phenomenon is sometimes accompanied by the development of zones of incomplete combustion in the upstream section of the combustion chamber.

The Applicants have observed that the overheating of these hollow structures and the irregularity in combustion, can both be due to a common cause, at least during low-load operation of the system, namely incomplete vaporisation of the fuel. Part of the latter remains in the form of large droplets whose trajectory has been schematically illustrated by the stream-lines **51**. Due to inertia, and under the effect of centrifugal force, the still-liquid fuel is projected against the walls **13***a*–**14***a* on the arms **13**–**14** while the walls **13***b*–**14***b* of the said arm are virtually unwetted. Because they are insufficiently cooled, these latter may therefore suffer unwanted overheating.

In addition, the flow of the air-fuel mixture escaping through the orifices **15**–**16** is not uniform, one of the fractions f_1 of this flow containing substantially more fuel than the other fraction f_2. The richness of the air-fuel mixture in the upstream part of the combustion chamber is therefore non-uniform and this could explain the irregularities observed in combustion.

In FIGS. **4** and **5**, an improved pre-vaporisation hollow structure has been shown, which reduces the drawbacks which have been mentioned hereinbefore.

The injector **7** is equipped to this end with two thin partitions **52**–**53** extending transversely of the axis y'—y of the tubular body **12** and each presenting a sharp edge **52***a*–**53***a*. These sharp edges are disposed towards one another and determine between each other a restricted passage **54** by which the tubular body **12** communicates with each of the arms **13**–**14** of the injector.

The air flow passing through the hollow structure is subjected, in the neighbourhood of said restricted passage **54**, to a substantial acceleration which, as those skilled in the art will appreciate, promotes the pneumatic atomising of the liquid fuel and its mixture with the air. In addition, the large fuel droplets are mechanically atomised (by impact effect) at the sharp edges **52***a*–**53***a*.

The liquid fuel thus enters the arms **13**–**14** in the form of a mist of fine droplets, which are much lighter and therefore have a much less marked tendency to stratify. The junction or armpit surfaces **13***b*–**14***b* of these arms can then be correctly wetted and are not so likely to overheat. Finally, the flow *f* of air-fuel mixture which escapes through the orifices **15**–**16** is much more uniform than in the case of hollow structures of conventional design, thus making it possible to improve the performances of the combustion chamber. It will be observed, too, that the finally divided condition to which the fuel is reduced by reason of the presence of the thin partitions **52**–**53**, has the effect of accelerating pre-vaporisation.

The efficiency of the device according to the invention can be still further improved if small holes **55**–**56** are formed in the partitions **52**–**53** to enable a small fraction of the mixture of air and fuel to be supplied directly (as schematically illustrated by the jets **57**–**58**) to the wake zone forming downstream of said partitions, thus promoting the establishment of aerodynamically satisfactory flow conditions.

FIG. **6** illustrates another embodiment of a pre-vaporisation hollow structure in accordance with the invention, said hollow structure likewise having the general shape of a T.

The leg of the T is constituted by a tubular body **12** branching to form two transverse arms **13**, **14**, in other words the bar of the T. These arms are curved towards the upstream end of the combustion chamber and respectively terminate in discharge orifices **15**, **16**. The body **12** comprises an intake orifice **25** communicating with the liquid fuel source, schematically illustrated by an injector **17**, and with the air source.

A sleeve **18**–**19** surrounds the tubular body **12** with a certain clearance, in order to define an annular passage **21** communicating, at its upstream end, with the air source and opening, at its downstream end, directly into the combustion space.

In operation, a certain flow of primary air a_1 penetrates along with the liquid fuel, into the pre-vaporisation device or hollow structure **7**, the walls of which, on their external faces, are subject to the action of the flame generated in the combustion space so that the fuel vaporises. The mixture of primary air and vaporised fuel, escapes substantially axially through orifices **15**–**16** (see arrows *f*) in the opposite direction to the general direction of flow of the combustion gases through the combustion chamber. A flow of primary air a_2 penetrates directly, through the annular passage **21**, into the combustion space. This flow, which is weaker than the flow a_1, serves primarily to provide a certain degree of thermal insulation of the upstream part of the pre-vaporisation hollow structure.

The references **13***x* and **14***x* have been used to designate the armpits of the arms **13** and **14**.

The body **12** of the hollow structure is partially closed off, in the neighbourhood of the points **13***x* and **14***x* by a thin-walled diaphragm formed by two thin partitions **52**, **53** each having a sharp edge **52***a*, **53***a*. These edges are disposed towards one another and towards the axis Y—Y' of the body of the injector, and define between one another a restricted passage **54** through which the body of the hollow structure **12** communicates with each of the transverse arms **13**, **14**.

The air flow passing through the hollow structure is subjected, in the neighbourhood of said restricted passage **54**, to a substantial acceleration which, as those skilled in the art will understand, promotes the pneumatic atomising of the liquid fuel and its mixture with the air. In addition, the large fuel droplets are mechanically atomised (by impact effect) at the sharp edges **52***a*–**53***a*.

The liquid fuel thus penetrates into the arms **13**–**14** in the form of a mist of fine droplets, which are much lighter and have therefore a much less marked tendency to stratify. The walls of the arms **13**–**14** are thus fully wetted by a mixture containing at least a certain proportion of fuel which is in the course of vaporisation; they are therefore less likely to overheat. In addition, the flow *f* of air-fuel mixture which escapes through the orifice **15**, **16**, is much more uniform than in the case of conventional types of hollow structures, thus enabling the combustion chamber performance to be improved.

The Applicants have observed that there sometimes develops in the hollow structure, a critical regions which may run the risk of escaping to some extent the cooling action produced by the vaporisation of the fuel contained in the air-fuel mixture flowing through the restricted passage **54**. These regions are constituted by the armpits **13***x*–**14***x* where the arms **13**, **14** join the leg, and by the regions in the vicinity thereof.

Because of sudden changes in direction imposed upon the air-fuel flow in the hollow structure, these re-

gions of the hollow structure may be involved by a turbulent zone where the flow rate is relatively low, so that consequently they are insufficiently wetted by fuel.

In order to at least partially eliminate this drawback, the present invention likewise provides for a modification of the pre-vaporisation hollow structure as described in FIG. **4**, in order to enable more efficient cooling of the aforesaid critical region to be achieved.

In accordance with the invention, the thin-walled diaphragm **52, 53** is offset so that it is located downstream (in relation to the direction of flow of the air-fuel mixture in the body **12** of the hollow structure) of the armpits **13***x*–**14***x* where the arms of the injector join the leg. To this end, the diaphragm **52, 53** is carried by a portion **12***a* of the body **12**, constituted by a sleeve of appropriate length inserted in said body and fixed to it.

Still in accordance with the invention, passages **60** arranged in a direction presenting a component disposed transversely of the axis Y'—Y of the body **12-12***a* of the hollow structure, are formed through the lateral wall of the sleeve **12**a, upstream of the diaphragm **52–53** but slightly downstream of the armpits **13***x*–**14***x*. These passages, which originate in the body **12–12***a*, thus open directly into the aforesaid critical regions.

In operation, a fraction of the air-fuel mixture flowing through the body **12–12***a* of the hollow structure strikes the diaphragm **52–53** and is deflected through the passage **60** to directly supply the regions of the armpits **13***x*–**14***x*. Thus, in these regions, aerodynamically satisfactory flow conditions develop and this facilitates the wetting of the walls of these regions. The thermal integrity of the assembly of the hollow structure is consequently improved.

It goes without saying that the embodiments described are purely examples and could be modified, in particular by the substitution of equivalent techniques, without in so doing departing from the scope of the invention.

We claim:

1. A device for pre-vaporising liquid fuel, designed for application for a combustion system comprising a combustion chamber, a liquid fuel source and a source of combustion agent such as air, said pre-vaporisation device comprising a hollow structure adapted to project into the combustion chamber and having a general T-shape, said hollow structure being made up of a body, which constitutes the leg of the T and is connected to said liquid fuel and combustion agent sources, and two transverse arms connected to said body and terminating, in each case, in a discharge orifice which opens into the combustion chamber and through which, in operation, there escapes a flow made up of a mixture of combustion agent and fuel in an at least partially vaporised state, a thin-walled diaphragm being provided in the neighborhood of the armpits where the transverse arms join the body of the hollow structure to partially close off said body, said diaphragm comprising two thin partitions each presenting a sharp edge disposed toward the axis of said body and toward the similar sharp edge belonging to the particular other partition, said partitions between said mutually opposite edges defining a restricted flow passage through which the body of the hollow structure communicates with each of said transverse arms.

2. A device as claimed in claim **1**, in which said thin-walled diaphragm is located at the level of the armpits where the said transverse arms join the body of the hollow structure.

3. A device as claimed in claim **1**, in which said thin-walled diaphragm is located downstream (considered in relation to the direction of flow of the mixture of combustion agent and fuel through said body of the hollow structure) of the armpits where said transverse arms join said body.

4. A device as defined in claim **3**, in which additional passages are provided through which said body of said hollow structure communicates with each of said arms, said additional passages originating in said body upstream of said thin-walled diaphragm and opening into said transverse arms directly in the zones of the armpits where said arms join the body.

5. A device as claimed in claim **4**, in which said additional passages are aligned in a direction which has a component disposed transversely of the axis of said body of said hollow structure.

6. A device as claimed in claim **1**, in which said thin-walled partitions each contain at least one orifice disposed in a direction having a component parallel to the axis of said body of said hollow structure.

* * * * *