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(54) Title: REHEAT BURNER INJECTION SYSTEM

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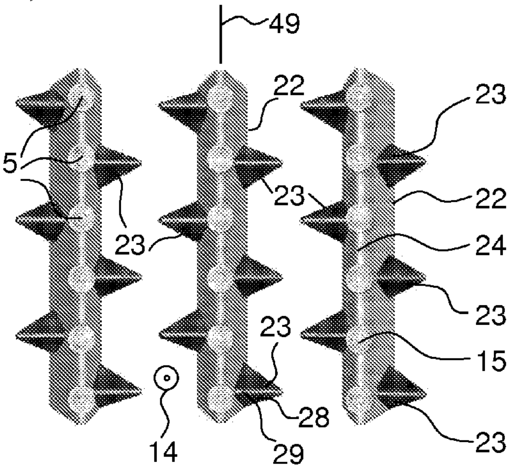

FIG. 5

(57) **Abstract**: The disclosure relates to a burner (1), preferably for a secondary combustion chamber of a gas turbine with sequential combustion having a first and a second combustion chamber, with an injection device (7) for the introduction of at least one gaseous fuel into the burner (1). According to the invention, the injection device (7) has at least one body (22) which is arranged in the burner (1) with at least one nozzle (15) for introducing the at least one gaseous fuel into the burner (1), the at least one body being configured as a streamlined body (22) which has a streamlined cross-sectional profile (48) and which extends with a longitudinal direction (49) perpendicularly or at an inclination to a main flow direction (14) prevailing in the burner (1), the at least one nozzle (15) having its outlet orifice at or in a trailing edge (24) of the streamlined body (22), wherein the body (22) has two lateral surfaces (33) essentially parallel to the main flow direction (14), and wherein upstream of the at least one nozzle (15) on at least one lateral surface (33) there is located at least one vortex generator (23).

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REHEAT BURNER INJECTION SYSTEM

TECHNICAL FIELD

The present invention relates to a burner for a secondary combustion chamber of a gas turbine with sequential combustion having a first and a secondary combustion chamber, with an injection device for the introduction of at least one gaseous fuel into the burner.

PRIOR ART

In order to achieve a high efficiency, a high turbine inlet temperature is required in standard gas turbines. As a result, there arise high NOx emission levels and higher life cycle costs. These problems can be mitigated with a sequential combustion cycle, wherein the compressor delivers nearly double the pressure ratio of a conventional one. The main flow passes the first combustion chamber (e.g. using a burner of the general type as disclosed in EP 1 257 809 or as in US 4,932,861, also called EV combustor, where the EV stands for environmental), wherein a part of the fuel is combusted. After expanding at the high-pressure turbine stage, the remaining fuel is added and combusted (e.g. using a burner of the type as disclosed in US 5,431,018 or US 5,626,017 or in US 2002/0187448, also called SEV combustor, where the S stands for sequential). Both combustors contain premixing burners, as low NOx emissions require high mixing quality of the fuel and the oxidizer.

Since the second combustor is fed by expanded exhaust gas of the first combustor, the operating conditions allow self ignition (spontaneous ignition) of the fuel air mixture without additional energy being supplied to the mixture. To prevent ignition of the fuel air mixture in the mixing region, the residence time therein must not exceed the auto ignition delay time. This criterion ensures flame-free zones inside the burner. This criterion poses challenges in obtaining appropriate distribution of the fuel across the burner exit area.

SEV-burners are currently designed for operation on natural gas and oil only. Therefore, the momentum flux of the fuel is adjusted relative to the momentum flux of the main flow so as to penetrate in to the vortices. The subsequent mixing of the fuel and the oxidizer at the exit of the mixing zone is just sufficient to allow low NOx emissions (mixing quality) and avoid flashback (residence time), which may be caused by auto ignition of the fuel air mixture in the mixing zone.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved burner in particular for high reactivity conditions, i.e. either for a situation where the inlet temperature of a secondary burner is higher than reference, and/or for a situation where high reactivity fuels, specifically MBtu fuels, shall be burned in such a secondary burner.

This object is achieved by providing a burner, in particular for a secondary combustion chamber of a gas turbine with sequential combustion having a first and a second combustion chamber, with an injection device for the introduction of at least one gaseous fuel into the burner, wherein the injection device of this burner has at least one body or lance which is arranged in the burner and wherein this body has at least one nozzle for introducing the at least one gaseous fuel into the burner. The at least one body is configured as a streamlined body which has a streamlined cross-sectional profile and which extends with a longitudinal direction perpendicularly to or at an inclination to a main flow direction prevailing in the burner, the at least one nozzle having its outlet orifice at or in a trailing edge of the streamlined body. The body in accordance with the invention has two lateral surfaces (normally at least for one central body essentially parallel to the main flow direction and converging, i.e. inclined for the others), and upstream of the at least one nozzle on at least one lateral surface there is located at least one vortex generator.

The gist of the invention is to merge the vortex generator aspect and the fuel injection device as conventionally used according to the state-of-the-art as a separate elements (separate structural vortex generator element upstream of separate fuel injection device) into one single combined vortex generation and fuel injection device. By doing this, mixing of fuels with oxidation air and vortex generation take place in very close spatial vicinity and very efficiently, such that more rapid mixing is possible and the length of the mixing zone can be reduced. It is even possible in some cases, by corresponding design and orientation of the body in the oxidising air path, to omit the flow conditioning elements (turbine outlet guide vanes) as the body may also take over the flow conditioning. All this is possible without severe pressure drop along the injection device such that the overall efficiency of the process can be maintained.

In one burner at least one such injection device is located, preferably at least two such injection devices are located within one burner, even more preferably three such injection devices or flutes are located within one burner.

Upstream of the body and downstream of the row of rotating blades, or, in case of several rows, of the last row of rotating blades, of the high-pressure turbine there are typically no additional vortex generators, and preferably also no additional flow conditioning elements.

According to one preferred embodiment of the invention, downstream of said body or lance a mixing zone is located, and wherein at and/or downstream of said body the cross-section of said mixing zone is reduced (normally by conical convergence). Preferably this reduction in cross-section is at least 10%, more preferably at least 20%, or even at least 30% or at least 40%, compared to the flow cross-section upstream of said body. By having such a reduced cross-section the main flow velocity is increased making it possible to use high reactivity fuels or to apply high inlet temperatures as the residence time in the mixing section is substantially reduced.

In order to have a sufficiently efficient vortex generation to produce higher circulation rates at a minimum pressure drop, preferentially the vortex generator has an attack angle in the range of 15-20° and/or a sweep angle in the range of 55-65°.

Generally speaking, vortex generators as they are disclosed in US 5,80,360 to as well as in US 5,423,608 can be used in the present context, the disclosure of these two documents being specifically incorporated into this disclosure.

At least two nozzles (typically at least four, or six) are arranged at different positions along said trailing edge (in a row with spacings in between), wherein upstream of each of these nozzles at least one vortex generator is located.

It is possible to have two vortex generators on opposite sides of the body for one nozzle or for a pair of nozzles.

Generally "upstream" in the context of the vortex generators relative to the nozzles is intending to mean that the vortex generator generates a vortex at the position of the nozzle.

The vortex generators may also be upstream facing in order to bring the vortices closer to the fuel injection location.

Preferably vortex generators to adjacent nozzles (along the row) are located at opposite lateral surfaces of the body. Even more preferably more than three, most preferably at least four, nozzles are arranged along said trailing edge and vortex generators are alternatingly located at the two lateral surfaces.

On the one hand it is possible to have at least one nozzle injecting fuel and/or carrier gas parallel to the main flow direction. This allows to have higher reactivity conditions as the fuel is carried downstream very rapidly and it in addition to that allows to use low pressure carrier gas.

It is also possible that at least one nozzle injects fuel and/or carrier gas at an inclination angle between 0-30° with respect to the main flow direction.

Preferentially, downstream of each vortex generator there are located at least two nozzles for fuel injection at the trailing edge.

A further preferred embodiment is characterised in that the streamlined body extends across the entire flow cross section between opposite walls of the burner.

The burner can be an annular burner arranged circumferentially with respect to a turbine axis. In this case between 10-100 such streamlined bodies for combined vortex generation and fuel injection, preferably between 40-80 streamlined bodies can be arranged around the circumference of the annular combustion chamber, preferably all of them being equally distributed along the circumference of the combustion chamber.

The profile of the streamlined body can be parallel to the main flow direction. It can however also be inclined with respect to the main flow direction at least over a certain part of its longitudinal extension wherein for example the profile of the streamlined body can be rotated or twisted, for example in opposing directions relative to the longitudinal axis on both sides of a longitudinal midpoint, in order to impose a mild swirl on the main flow.

The vortex generator(s) can also be provided with cooling elements, wherein preferably these cooling elements are effusion/film cooling holes provided in at least one of the surfaces (also possible is internal cooling such as impingement cooling) of the vortex generator. The film cooling holes can be fed with air from the carrier gas feed also used for the fuel injection to simplify the setup. Due to the in-line injection of the fuel, lower pressure carrier gas can be used, so the same gas supply can be used for fuel injection and cooling.

Also the body can be provided with cooling elements, wherein preferably these cooling elements are given by internal circulation of cooling medium along the sidewalls (also possible is impingement cooling) of the body and/or by film cooling holes, preferably located near the trailing edge. Again the cooling elements can be fed with air from the carrier gas feed also used for the fuel injection.

As mentioned above, normally the fuel is injected from the nozzle together with a carrier gas stream (typically the fuel is injected centrally and a carrier gas circumferentially encloses the fuel jet), wherein the carrier gas air is low pressure air with a pressure in the range of 10-20 bar, preferably in the range of 16-20 bar. As in-line injection is used, a lower pressure can be used for the carrier gas.

The streamlined body can have a symmetric cross-sectional profile, i.e. one which is mirror symmetric with respect to the central plane of the body.

The streamlined body can also be arranged centrally in the burner with respect to a width of a flow cross section.

The streamlined body can be arranged in the burner such that a straight line connecting the trailing edge to a leading edge extends parallel to the main flow direction of the burner.

A plurality of separate outlet orifices of a plurality of nozzles can be arranged next to one another and arranged at the trailing edge.

At least one slit-shaped outlet orifice can be, in the sense of a nozzle, arranged at the trailing edge.

Furthermore the present invention relates to the use of a burner as defined above for the combustion under high reactivity conditions, preferably for the combustion at high burner inlet temperatures and/or for the combustion of MBtu fuel, normally with a calorific value of 5000-20,000 kJ/kg, preferably 7000-17,000 kJ/kg, more preferably 10,000-15,000 kJ/kg, most preferably such a fuel comprising hydrogen gas.

Further embodiments of the invention are laid down in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described in the following with reference to the drawings, which are for the purpose of illustrating the present preferred embodiments of the invention and not for the purpose of limiting the same. In the drawings,

Fig. 1 shows a secondary burner located downstream of the high-pressure turbine together with the fuel mass fraction contour (left side) at the exit of the burner;

Fig. 2 shows a secondary burner fuel lance in a view opposite to the direction of the flow of oxidising medium in a) and the fuel mass fraction contour using such a fuel lance at the exit of the burner in b);

Fig. 3 shows a secondary burner located downstream of the high-pressure turbine with reduced exit cross-section area;

Fig. 4 shows in a) a schematic representation of a burner according to the invention with contours indicating burner residence times, in b) the injection devices for the burner according to a) in a view opposite to the direction of the flow of oxidising medium, in c) a schematic representation of a burner with a fuel lance with shadings indicating burner residence times, and in d) the fuel lance in a view opposite to the direction of the flow of oxidising medium for the burner according to c),

Fig. 5 shows in a) the streamlined body in a view opposite to the direction of the flow of oxidising medium with fuel injection parallel to the flow of oxidising medium, in b) a side view onto such a streamlined body, in c) a cut perpendicular to the central plane of the streamlined body in d) the corresponding fuel mast fraction contour at the exit of the burner, in e) a schematic sketch how the attack angle and a sweep angle of the vortex generator are defined, , wherein in the upper representation a side elevation view is given, and in the lower representation a view onto the vortex generator in a direction perpendicular to the plane on which the vortex generator is mounted are given, in f) a perspective view onto a body and its interior structure, and in g) in a cut perpendicular to the longitudinal axis;

Fig. 6 shows in a) the streamlined body in a view opposite to the direction of the flow of oxidising medium with fuel injection inclined to the flow of oxidising medium, in b) a side view onto such a streamlined body, in c) a cut perpendicular to the central plane of the streamlined body,

Fig. 7 shows in a) a side view onto a streamlined body with inverted vortex generators , in b) a cut perpendicular to the central plane of the streamlined body,

Fig. 8 shows a radial view onto a row of streamlined bodies where the central plane of the streamlined bodies is inclined with respect to the flow direction of oxidising medium;

Fig. 9 shows a comparison of unmixedness values for the investigated concepts,

Fig. 10 shows a comparison of burner pressure drop for the setup according to figure 2 and the setup according to figure 5.

DESCRIPTION OF PREFERRED EMBODIMENTS

Several design modifications to the existing secondary burner (SEV) designs are proposed to introduce a low pressure drop complemented by rapid mixing for highly reactive fuels and operating conditions. This invention targets towards accomplishing fuel-air mixing within short burner-mixing lengths. The concept includes aerodynamically facilitated axial fuel injection with mixing promoted by small sized vortex generators. Further performance benefit is achieved with elimination/replacement of high-pressure and more expensive carrier air with low pressure carrier air. As a result, the burner is designed to operate at increased SEV inlet temperature or fuel flexibility without suffering on high NOx emissions or flashback.

The key advantages can be summarised as follows:

- Higher burner velocities to accommodate highly reactive fuels
- Lower burner pressure drop for similar mixing levels achieved with current designs
- SEV operable at higher inlet temperatures
- Possibility to remove or replace high-pressure carrier air with low pressure carrier air

With respect to performing a reasonable fuel air mixing, the following components of current burner systems are of interest:

- At the entrance of the SEV combustor, the main flow must be conditioned in order to guarantee uniform inflow conditions independent of the upstream disturbances, e.g. caused by the high-pressure turbine stage.
- Then, the flow must pass four vortex generators.
- For the injection of gaseous and liquid fuels into the vortices, fuel lances are used, which extend into the mixing section of the burner and inject the fuel(s) into the vortices of the air flowing around the fuel lance.

To this end figure 1 shows a conventional secondary burner 1. The burner, which is an annular burner, is bordered by opposite walls 3. These opposite walls 3 define the flow space for the flow 14 of oxidizing medium. This flow enters as a main flow 8 from the high pressure turbine, i.e. behind the last row of rotating blades of the high pressure turbine which is located downstream of the first combustor. This main flow 8 enters the burner at the inlet side 6. First this main flow 8 passes flow conditioning elements 9, which are typically turbine outlet guide vanes which are stationary and bring the flow into the proper orientation. Downstream of these flow conditioning elements 9 vortex generators 10 are located in order to prepare for the subsequent mixing step. Downstream of the vortex generators 10 there is provided an injection device or fuel lance 7 which typically comprises a stem or foot 16 and an axial shaft 17. At the most downstream portion of the shaft 17 fuel injection takes place, in this case fuel injection takes place via orifices which inject the fuel in a direction perpendicular to flow direction 14 (cross flow injection).

Downstream of the fuel lance 7 there is the mixing zone 2, in which the air, bordered by the two walls 3, mixes with the fuel and then at the outlet side 5 exits into the combustion chamber or combustion space 4 where self-ignition takes place.

At the transition between the mixing zone 2 to the combustion space 4 there is typically a transition 13, which may be in the form of a step, or as indicated here, may be provided with round edges and also with stall elements for the flow. The combustion space is bordered by the combustion chamber wall 12.

This leads to a fuel mass fraction contour 11 at the burner exit 5 as indicated on the right side of figure 1.

In figure 2 a second fuel injection is illustrated, here the fuel lance 7 is not provided with conventional injection orifices but in addition to their positioning at specific axial and circumferential positions has circular sleeves protruding from the cylindrical outer surface of the shaft 17 such that the injection of the fuel along injection direction 26 is more efficient as the fuel is more efficiently directed into the vortices generated by the vortex generators 10.

Using a set up according to figure 2a the fuel mass fraction contour according to figure 2b results.

SEV-burners are currently designed for operation on natural gas and oil only. Therefore, the momentum of the fuel is adjusted relative to the momentum of the main flow so as to penetrate in to the vortices. The subsequent mixing of the fuel and the oxidizer at the exit of the mixing zone is just sufficient to allow low NOx emissions (mixing quality) and avoid flashback (residence time), which may be caused by auto ignition of the fuel air mixture in the mixing zone.

The present invention relates to burning of fuel air mixtures with a reduced ignition delay time. This is achieved by an integrated approach, which allows higher velocities of the main flow and in turn, a lower residence time of the fuel air mixture in the mixing zone. The challenge regarding the fuel injection is twofold with respect to the use of hydrogen rich fuels and fuel air mixtures with high temperatures:

- Hydrogen rich fuels may change the penetration behavior of the fuel jets. The penetration is determined by the cross section areas of the burner and the fuel injection holes, respectively.

- The second problem is that depending on the type of fuel or the temperature of the fuel air mixture, the reactivity, which can be defined as $t_{ign,ref}/t_{ign}$, i.e. as the ratio of the ignition time of reference natural gas to the ignition time as actually valid, of the fuel air mixture changes.

The conditions which the presented invention wants to address are those where the reactivity as defined above is above 1 and the flames are auto igniting, the invention is however not limited to these conditions.

For each temperature and mixture composition the laminar flame speed and the ignition delay time change. As a result, hardware configurations must be provided offering a suitable operation window. For each hardware configuration, the upper limit regarding the fuel air reactivity is given by the flashback safety.

In the framework of an SEV burner the flashback risk is increased, as the residence time in the mixing zone exceeds the ignition delay time of the fuel air. Mitigation can be achieved in several different ways:

- The inclination angle of the fuel can be adjusted to decrease the residence time of the fuel. Herein, various possibilities regarding the design may be considered, e.g. inline fuel injection, i.e. essentially parallel to the oxidizing airflow, a conical lance shape or a horny lance design.
- The reactivity can be slowed down by diluting the fuel air mixture with nitrogen or steam, respectively.
- De-rating of the first stage can lead to less aggressive inlet conditions for the SEV burner in case of highly reactive fuels. In turn, the efficiency of the overall gas turbine may decrease.
- The length of the mixing zone can be kept constant, if in turn the main flow velocity is increased. However, then normally a penalty on the pressure drop must be taken.
- By implementing more rapid mixing of the fuel and the oxidizer, the length of the mixing zone can be reduced while maintaining the main flow velocity.

The main goal of this patent is to evolve an improved burner configuration, wherein the latter two points are addressed, which however can be combined also with the upper three points.

In order to allow capability for highly reactive fuels, the injector is designed to perform

- flow conditioning (at least partial),

- injection and
- mixing

simultaneously. As a result, the injector can save burner pressure loss, which is currently utilized in the various devices along the flow path. If the combination of flow conditioning device, vortex generator and injector is replaced by the proposed invention, the velocity of the main flow can be increased in order to achieve a short residence time of the fuel air mixture in the mixing zone.

Figure 3 shows a set-up, where the proposed burner area is reduced considerably. The higher burner velocities help in operating the burner safely at highly reactive conditions. In figure 3 a proposed burner is shown with reduced exit cross-section area. In this case downstream of the inlet side 6 of the burner there is located a flow conditioning element or a row of flow conditioning elements 9 but in this case not followed by vortex generators but then directly followed with a fuel injection device according to the invention, which is given as a streamlined body 22 extending with its longitudinal direction across the two opposite walls 3 of the burner. At the position where the streamlined body 22 is located the two walls 3 converge in a converging portion 18 and narrow down to a reduced burner cross-sectional area 19. This defines the mixing space 2 which ends at the outlet side 5 where the mixture of fuel and air enters the combustion chamber or combustion space 4 which is delimited by walls 12.

Figure 4 shows the typical residence times for the inline injection concept (in a using a device according to b) lowered by 40% when compared to the current cross flow injection concept (in c using a device according to d, i.e. according to figure 2). Indeed the residence time t in case of the setup according to the invention of (a) is much smaller than according to the setup according to c and d.

Several more specific embodiments of the inline injection with flute/VG concept shall be presented below.

Embodiment 1:

The first embodiment to this concept is to stagger the vortex generators 23 embedded on the bodies or flutes 22 as shown in Figure 5. The vortex generators 23 are located sufficiently upstream of the fuel injection location to avoid flow recirculations. The vortex generator attack and sweep angles are chosen to produce highest circulation rates at a minimum pressure drop.

Normally such vortex generators have an attack angle α in the range of 15-20° and/or a sweep angle β in the range of 55-65°, for a definition of these angles reference is made to Fig. 5e), where for an orientation of the vortex generator in the air flow 14 as given in figure 5 a) the definition of the attack angle α is given in the upper representation which is an elevation view, and the definition of the sweep angle β is given in the lower representation, which is a top view onto the vortex generator.

As illustrated the body 22 is defined by two lateral surfaces 33 joined in a smooth round transition at the leading edge 25 and ending at a small radius/sharp angle at the trailing edge 24 defining the cross-sectional profile 48. Upstream of trailing edge the vortex generators 23 are located. The vortex generators are of triangular shape with a triangular lateral surface 27 converging with the lateral surface 33 upstream of the vortex generator, and two side surfaces 28 essentially perpendicular to a central plane 35 of the body 22. The two side's surfaces 28 converge at a trailing edge 29 of the vortex generator 23, and this trailing edge is typically just upstream of the corresponding nozzle 15.

The lateral surfaces 27 but also the side surfaces 28 maybe provided with effusion/film cooling holes 32.

The whole body 22 is arranged between and bridging opposite the two walls 3 of the combustor, so along a longitudinal axis 49 essentially perpendicular to the walls 3. Parallel to this longitudinal axis there is, according to this embodiment, the leading edge 25 and the trailing edge 24. It is however also possible that the leading edge 25 and/or the trailing edge are not linear but are rounded.

At the trailing edge the nozzles 15 for fuel injection are located. In this case fuel injection takes place along the injection direction 35 which is parallel to the central plane 35 of the body 22. Fuel as well as carrier air are transported to the nozzles 15 as schematically illustrated by arrows 30 and 31, respectively. Typically the fuel supply is provided by a central tubing, while the carrier air is provided in a flow adjacent to the walls 33 to also provide internal cooling of the structures 22. The carrier airflow is also used for supply of the cooling holes 23. Fuel is injected by generating a central fuel jet along direction 34 enclosed circumferentially by a sleeve of carrier air.

The staggering of vortex generators 23 helps in avoiding merging of vortices resulting in preserving very high net longitudinal vorticity. The local conditioning of fuel air mixture with vortex generators close to respective fuel jets improves the mixing. The overall burner pressure drop is significantly lower for this concept. The respective vortex generators produce counter rotating vortices which at a specified location pick up the axially spreading fuel jet.

In somewhat more detail three bodies 22 according to a modification of this first embodiment arranged within an annular secondary combustion chamber are given in perspective view in figure 5f, wherein the bodies are cut perpendicularly to the longitudinal axis 49 to show their interior structure, and in a cut perpendicular to the longitudinal axis in figure 5g.

In the cavity formed by the outer wall 59 of each body on the trailing side thereof there is located the longitudinal inner fuel tubing 57. It is distanced from the outer wall 59, wherein this distance is maintained by distance keeping elements 53 provided on the inner surface of the outer wall 59.

From this inner fuel tubing 57 the branching off tubing extends towards the trailing edge 29 of the body 22. The outer walls 59 at the position of these branching off tubings is shaped such as to receive and enclose these branching off tubings forming the actual fuel nozzles with orifices located downstream of the trailing edge 29.

In the essentially cylindrically shaped interior of the branching off tubings there is located a cylindrical central element 50 which leads to an annular stream of fuel gas. As between the wall of the branching off tubings and the outer walls 59 at this position there is also an essentially annular interspace, this annular stream of fuel gas at the exit of the nozzle is enclosed by an essentially annular carrier gas stream.

Towards the leading edge of the body 22 in the cavity formed by the outer wall 59 of the body in this embodiment there is located a carrier air tubing channel 51 extending essentially parallel to the longitudinal inner fuel tubing channel 57. Between the two channels 57 and 51 there is an interspace 55. The walls of the carrier air tubing channel 51 facing the outer walls 59 of the body 22 run essentially parallel thereto again distanced therefrom by distancing elements 53. In the walls of the carrier air tubing channel 51 there are located cooling holes 56 through which carrier air travelling through channel 51 can penetrate. Air penetrating through these holes 56 impinges onto the inner side of the walls 59 leading to impingement cooling in addition to the convective cooling of the outer walls 59 in this region.

Within the walls 59 there are provided the vortex generators 23 in a manner such that within the vortex generators cavities 54 are formed which are fluidly connected to the carrier air feed. From this cavity the effusion/film cooling holes 32 are branching off for the cooling of the vortex generators 23. Depending on the exit point of these holes 32 they are inclined with respect to the plane of the surface at the point of exit in order to allow efficient film cooling effects.

Embodiment 2:

Another embodiment of this concept as shown below in Figure 6, is to direct the fuel at a certain angle (can be increased up to 90°). In this case, the fuel is directed into the vortices and this has shown to improve mixing even further as shown in Figure 7.

More specifically in this case there are, along the row of nozzles 15, a first set of three nozzles 15, which are directing the fuel jet 34 out of plane 35 at one side of plane 35, and the second set of nozzles 15' directing the corresponding fuel jet out of plane at the other side of plane 35. The more the fuel jets 34 are directed into the vortices the more efficient the mixing takes place.

Embodiment 3:

Another embodiment of this concept is to invert the vortex generators (facing upstream) as shown in figure 7. This helps in bringing the vortices closer to the fuel injection location with out producing adverse flow recirculations. The fuel injection locations can be varied with the vortex generator locations to improve the interaction of vortices with the fuel jet.

Embodiment 4:

Another embodiment of inline injection will involve providing 2 fuel jets (injected at an angle) per VG. This would improve the mixing further since each fuel jet is conditioned by the surrounding vortex.

Embodiment 5:

Another embodiment involves increasing the number of flutes 22 and completely replaces the current outlet guide vanes of the high-pressure turbine. This provides better mixing and arrest adverse flow variations arising from the high-pressure turbine.

Embodiment 6:

Another embodiment shown in Fig. 8, and which involves providing inclined bodies 22 (or high-pressure turbine outlet guide vanes) based on the inlet swirl angle exiting the high-pressure turbine. This decreases the pressure drop needed to straighten the high-pressure turbine flow. Specifically, the rotating high-pressure turbine blades 37 induce a general flow direction 14 which is not axial and the bodies 22 are at least over a part of their longitudinal length not parallel to this direction 14.

Figure 9, a comparison of unmixedness values for the investigated concepts, shows the fuel air mixing performance of several injection concepts. The mixing improvement obtained from coflow injection with vortex generators is very much comparable with best available cross fuel injection lances as given for example in figure 2. However the severe disadvantage is the high-pressure loss associated with the fuel injection according to figure 2. Indeed figure 10, a comparison of burner pressure drop for a setup according to figure 2 and concepts according to the invention, shows the burner total pressure drop for the invention and the one according to figure 2. The low-pressure drop obtained with the inline injection concept according to the invention can be utilized for operating at highly reactive conditions.

In summary, at least the following advantages of the injection concept according to the invention when compared with the current concepts can be given:

- Inline injection according to the invention offers better mixing performance at very low burner pressure drops. The mixing performance for the system according to figure 2 is achievable only with increased burner pressure drops (see figure 9, 10).
- Performance benefit due to removal or replacement of high-pressure carrier air with low pressure carrier air.
- Savings in the burner pressure drop obtained with the proposed inline injection allows to burn highly reactive fuels and operating conditions. The existing designs pose operational issues at higher SEV inlet temperatures or highly reactive fuels
- Inline injection provides better control of fuel residing close to the burner walls when compared to the cross flow injection concepts. This can provide higher flashback margin for the inline injection design.
- Reduced burner length results in reduction in cooling requirements. Possibility to replace burner effusion cooling air with TBC coated burner.
- Opportunity to mitigate thermo acoustic pulsations due to increased fuel-air mixture asymmetry at the burner exit. Increased number of vortices when compared to 4 vortices in the existing designs.
- Sufficiently high burner velocities in the entire burner length to avoid flame holding due to fuel/air mixture residing in recirculation regions.
- In the inline injection, outlet guide vanes of the high-pressure turbine can act as flow conditioners and fuel injectors instead of outlet guide vanes acting as flow conditioners in the existing designs.

LIST OF REFERENCE SIGNS

1	burner
2	mixing space, mixing zone
3	burner wall
4	combustion space
5	outlet side, burner exit
6	inlet side
7	injection device, fuel lance
8	main flow from high-pressure turbine
9	flow conditioning, turbine outlet guide vanes
10	vortex generators
11	fuel mass fraction contour at burner exit 5
12	combustion chamber wall
13	transition between 3 and 12
14	flow of oxidising medium
15	fuel nozzle
16	foot of 7
17	shaft of 7
18	converging portion of 3
19	reduced burner cross-sectional area
20	reduction in cross section
21	entrance section of 3
22	streamlined body, flute
23	vortex generator on 22
24	trailing edge of 22
25	leading edge of 22
26	injection direction
27	lateral surface of 23
28	side surface of 23
29	trailing edge of 23
30	fuel gas feed
31	carrier gas feed
32	effusion/film cooling holes
33	lateral surface of 22
34	ejection direction of fuel/carrier gas mixture
35	central plane of 22
36	leading edge of 23
37	high-pressure turbine rotating blade
38	value for the setup according to figure 1
39	value for the setup according to figure 2
40	value for the setup according to figure 5
41	value for the setup according to figure 6
42	value for the setup according to figure 7
43	position upstream of streamlined body
44	injection for setup according to figures 2
45	injection for setup according to figure 5
46	pressure curve for setup according to figure 2
47	pressure curve for setup

	according to figure 5
48	cross-sectional profile of 22
49	longitudinal axis of 22
50	central element
51	carrier air channel
52	interspace between 37 and 51
53	distance keeping elements
54	cavity within 23
55	interspace between 51 and 36
56	cooling holes
57	inner fuel tubing, longitudinal part
58	branching off tubing of inner fuel tubing
59	outer wall of 22

CLAIMS

1. Burner (1) for a combustion chamber of a gas turbine, with an injection device (7) for the introduction of at least one gaseous fuel into the burner (1), wherein the injection device (7) has at least one body (22) which is arranged in the burner (1) with at least one nozzle (15) for introducing the at least one gaseous fuel into the burner (1), the at least one body being configured as a streamlined body (22) which has a streamlined cross-sectional profile (48) and which extends with a longitudinal direction (49) perpendicularly or at an inclination to a main flow direction (14) prevailing in the burner (1), the at least one nozzle (15) having its outlet orifice at or in a trailing edge (24) of the streamlined body (22), wherein the body (22) has two lateral surfaces (33), and wherein upstream of the at least one nozzle (15) on at least one lateral surface (33) there is located at least one vortex generator (23).

2. Burner (1) according to claim 1, wherein downstream of said body (22) a mixing zone (2) is located, and wherein at and/or downstream of said body (22) the cross-section of said mixing zone (2) is reduced, wherein preferably this reduction is at least 10%, more preferably at least 20%, even more preferably at least 30%, compared to the flow cross-section upstream of said body (22).

3. Burner (1) according to any of the preceding claims, wherein the vortex generator (23) has an attack angle in the range of 15-20° and/or a sweep angle in the range of 45-75°, preferably of 55-65°.

4. Burner (1) according to any of the preceding claims, wherein at least two nozzles (15) are arranged at different positions along said trailing edge (24), wherein upstream of each of these nozzles (15) at least one vortex generator (23) is located, and wherein preferably vortex generators (23) to adjacent nozzles (15) are located at opposite lateral surfaces (33), and wherein even more preferably more than three, most preferably at least four, nozzles (15) are arranged along said trailing edge (24) and vortex generators (23) alternatingly located at the two

lateral surfaces (33).

5. Burner (1) according to any of the preceding claims, wherein at least one nozzle (15) injects fuel and/or carrier gas parallel to the main flow direction (14).

6. Burner (1) according to any of the preceding claims, wherein at least one nozzle (15) injects fuel and/or carrier gas at an inclination angle between 0-30° with respect to the main flow direction (14).

7. Burner (1) according to any of the preceding claims, wherein downstream of each vortex generator (23) there are located at least two nozzles (15).

8. Burner (1) according to any of the preceding claims, wherein the streamlined body (22) extends across the entire flow cross section between opposite walls (3) of the burner (1), wherein preferably the burner is an annular burner arranged circumferentially with respect to a turbine axis, and wherein between 10-100 streamlined bodies, preferably between 40-80 streamlined bodies are arranged around the circumference, more preferably all of them being equally distributed along the circumference.

9. Burner (1) as claimed in any of the preceding claims, wherein the profile of the streamlined body (22) inclined with respect to the main flow direction (14) at least over a certain part of its longitudinal extension wherein preferably the profile of the streamlined body (22) is rotated or twisted in opposing directions relative to the longitudinal axis on both sides of a longitudinal midpoint, in order to impose a mild swirl on the main flow.

10. Burner (1) according to any of the preceding claims, wherein the vortex generator (23) is provided with cooling elements (32), wherein preferably these cooling elements (32) are film cooling holes provided in at least one of the surfaces (27, 28) of the vortex generator (23), and wherein even more preferably the film cooling holes (32) are fed with air from the carrier gas feed (31) also used for the fuel injection.

11. Burner (1) according to any of the preceding claims, wherein the body (22) is provided with cooling elements, wherein preferably these cooling elements are given by internal circulation of cooling medium along the sidewalls (33) of the body (22) and/or by film cooling holes, preferably located near the trailing edge (24), and wherein most preferably the cooling elements are fed with air from the carrier gas feed (31) also used for the fuel injection.

12. Burner (1) according to any of the preceding claims, wherein upstream of the body (22) and downstream of the last row of rotating blades (37) of the high-pressure turbine there are no additional vortex generators, and preferably also no additional flow conditioning elements.

13. Burner (1) according to any of the preceding claims, wherein the fuel is injected from the nozzle (15) together with a carrier gas stream, and wherein the carrier gas air is low pressure air with a pressure in the range of 10-25 bar, preferably in the range of 16-20 bar.

14. The burner as claimed in one of the preceding claims, wherein the streamlined body (22) has a cross-sectional profile (48) which is mirror symmetric with respect to the central plane (35) of the body (22).

15. Use of a burner (1) according to any of the preceding claims for the combustion under a high reactivity conditions, preferably for the combustion at high burner inlet temperatures and/or for the combustion of MBtu fuel.

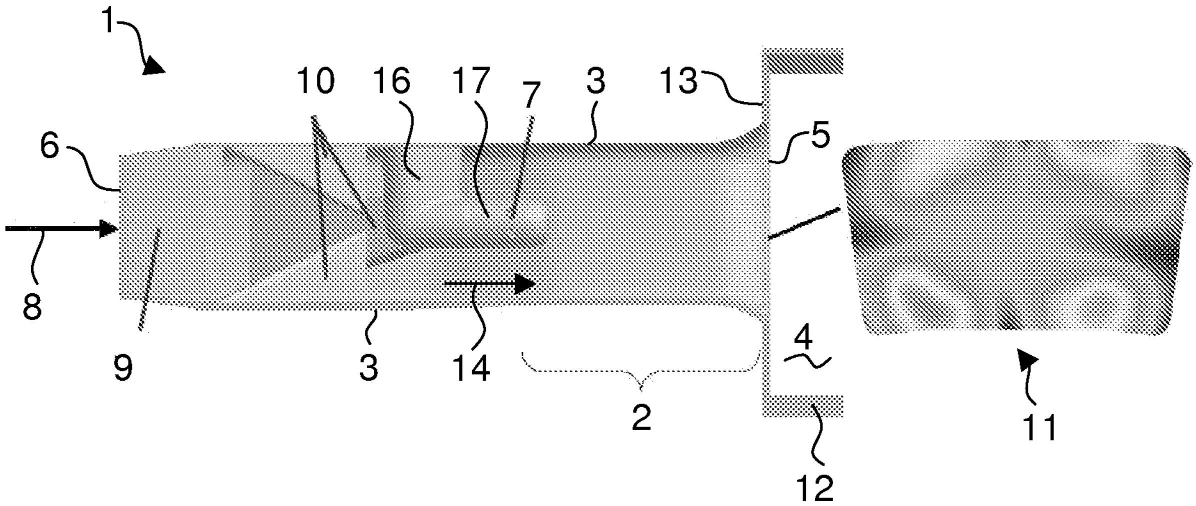


FIG. 1

a) b)

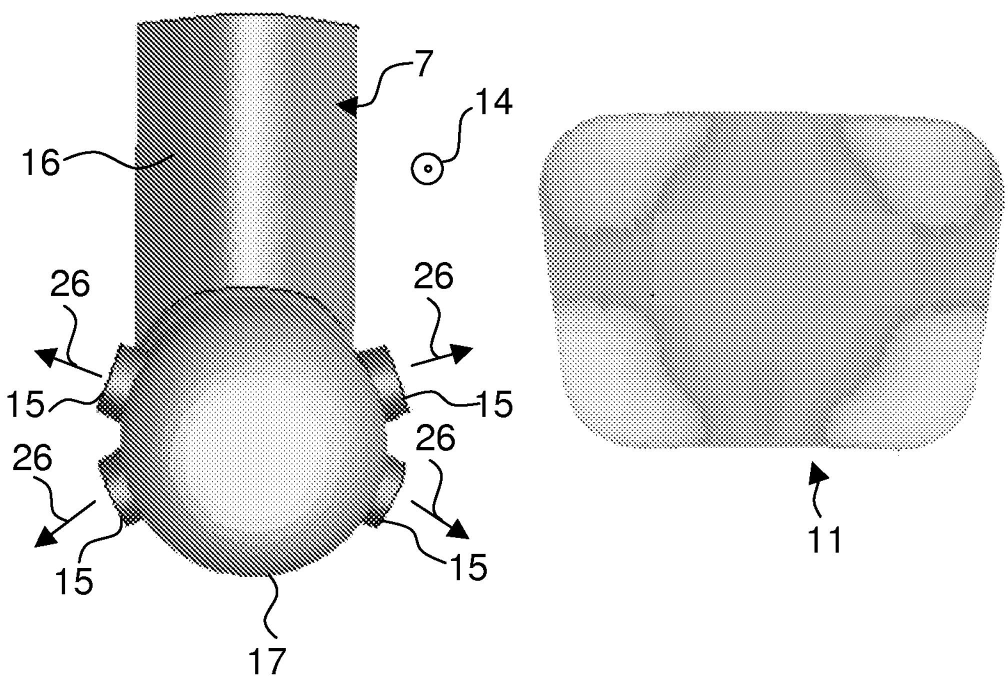


FIG. 2

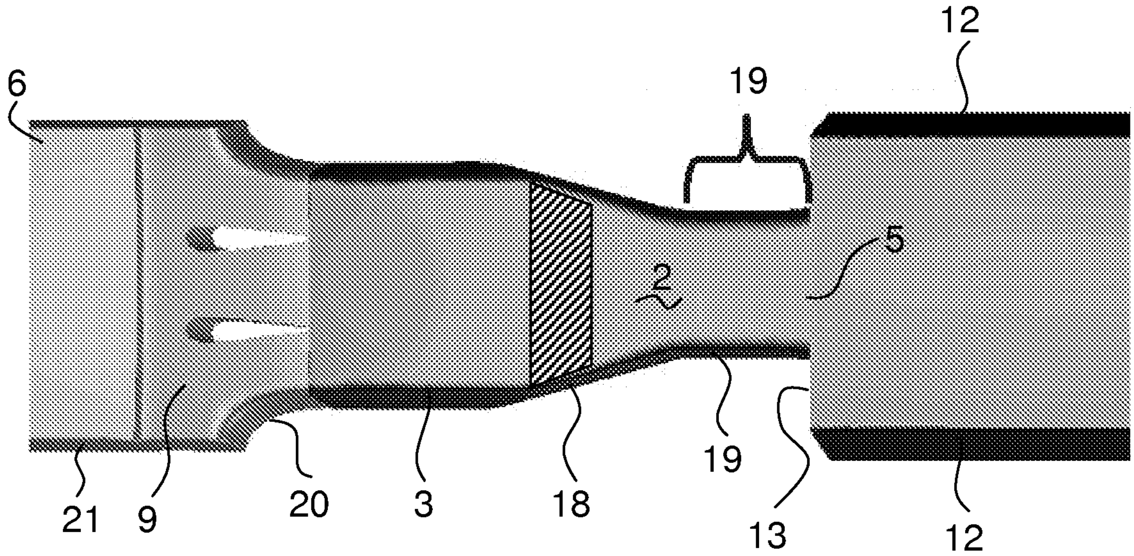

6
19
12
5
2
21
9
20
3
18
19
13
12

FIG. 3

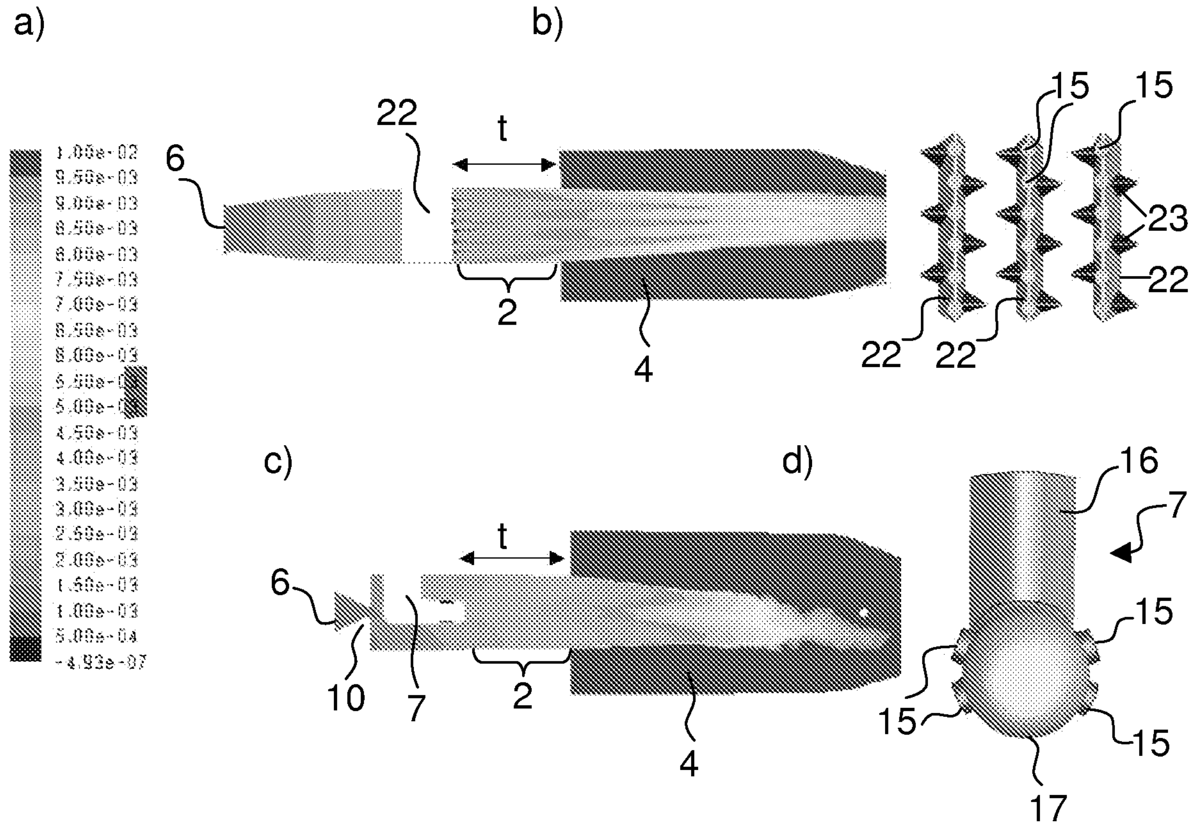

a)
b)
6
22
t
2
4
15
15
23
22
22
22
c)
d)
16
7
6
10
7
t
2
4
15
15
15
17

FIG. 4

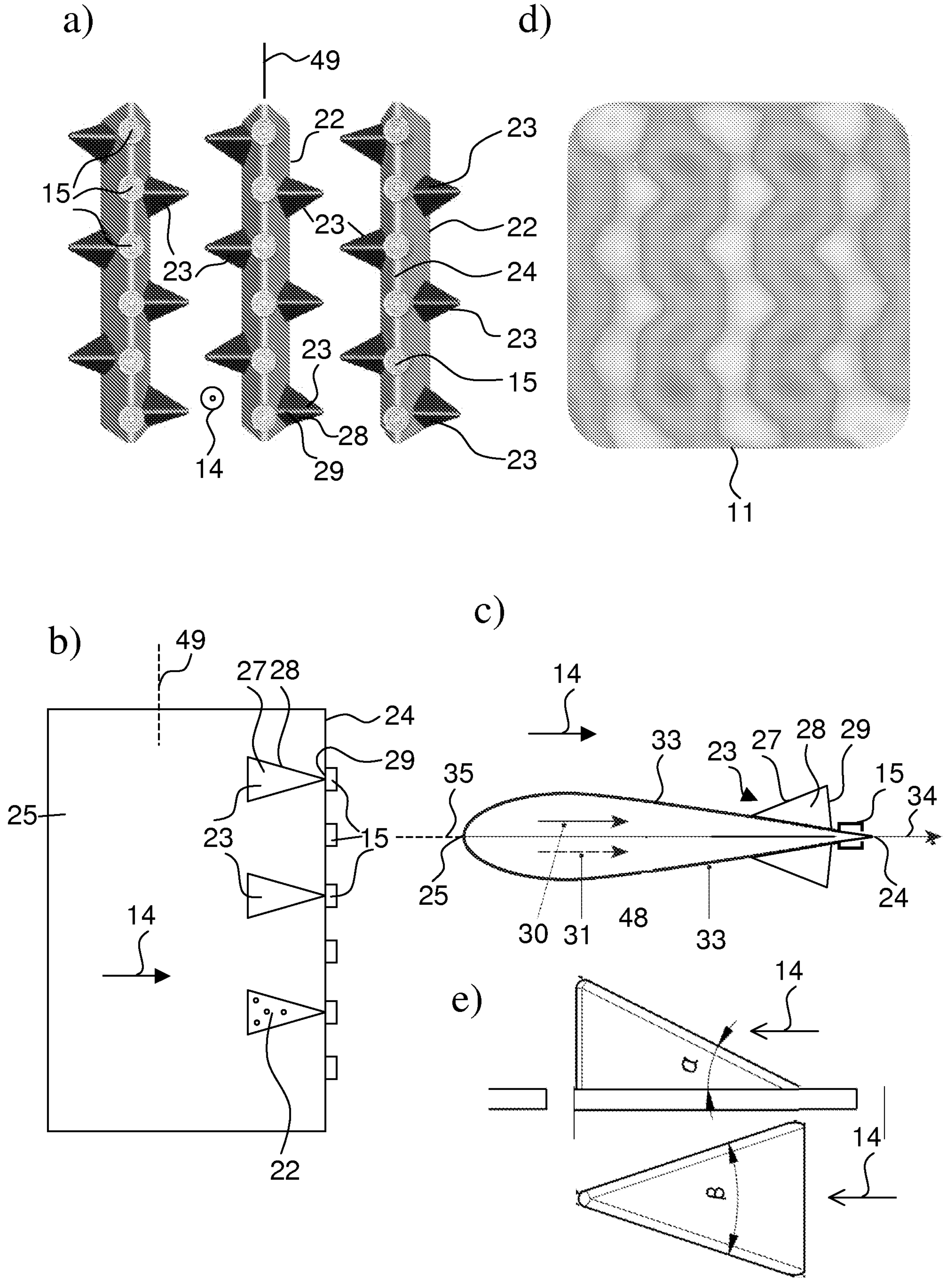
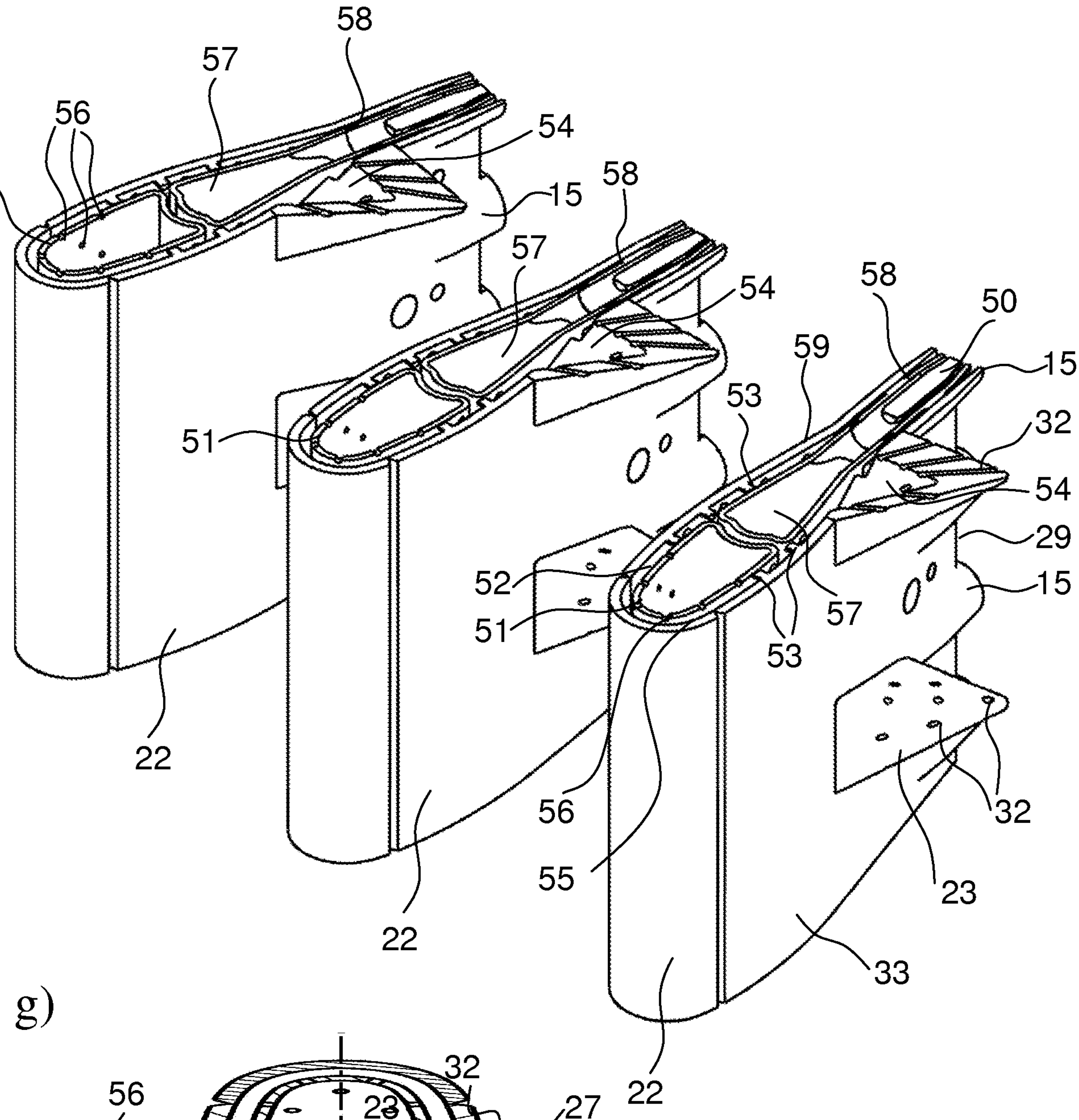


FIG. 5

f)


58
57
56
51
54
15
58
57
54
51
58
50
59
15
53
32
54
29
52
51
57
15
53
56
32
55
23
22
22
33
22

g)

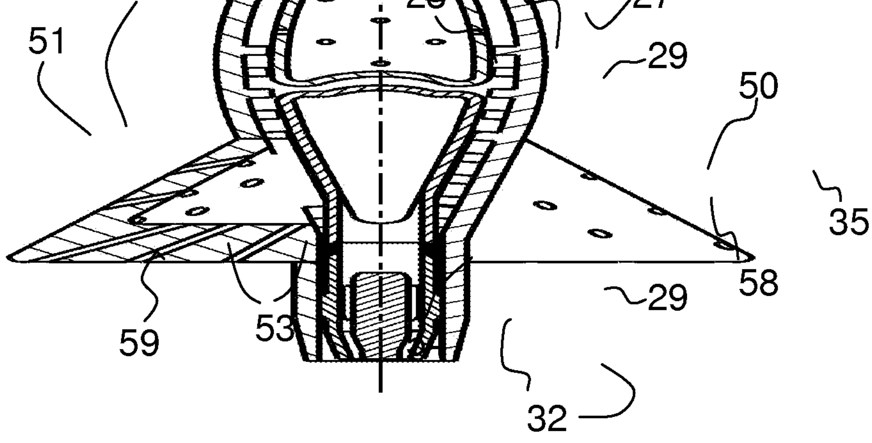

32
56
23
27
51
29
50
35
58
29
59
53
32

FIG. 5

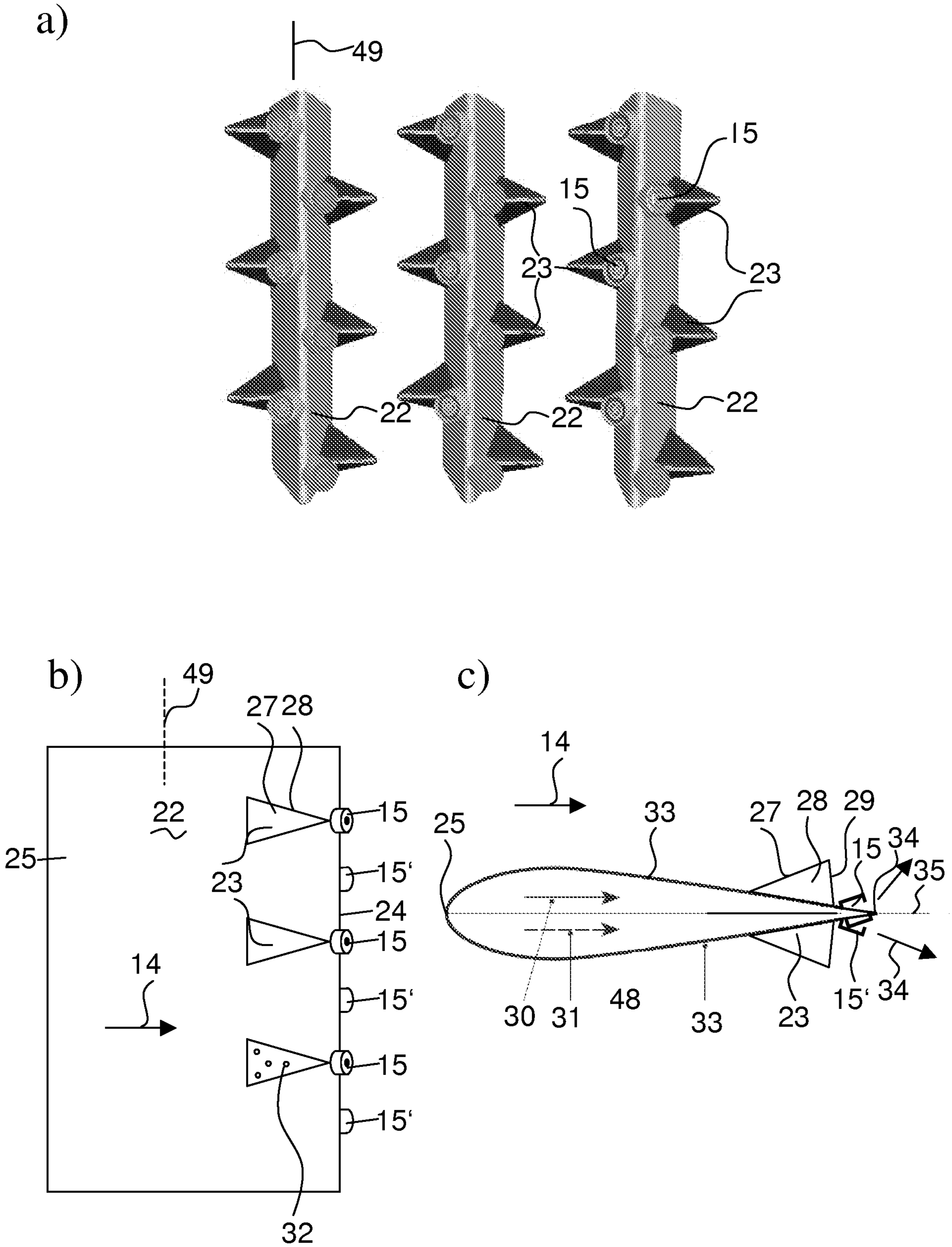

a)
49
15
15
23
23
23
22
22
22
b)
49
27
28
22
15
25
15‘
23
24
15
14
15‘
15
15‘
32
c)
14
33
27
28
29
25
15
34
35
30
31
48
33
23
15‘
34

FIG. 6

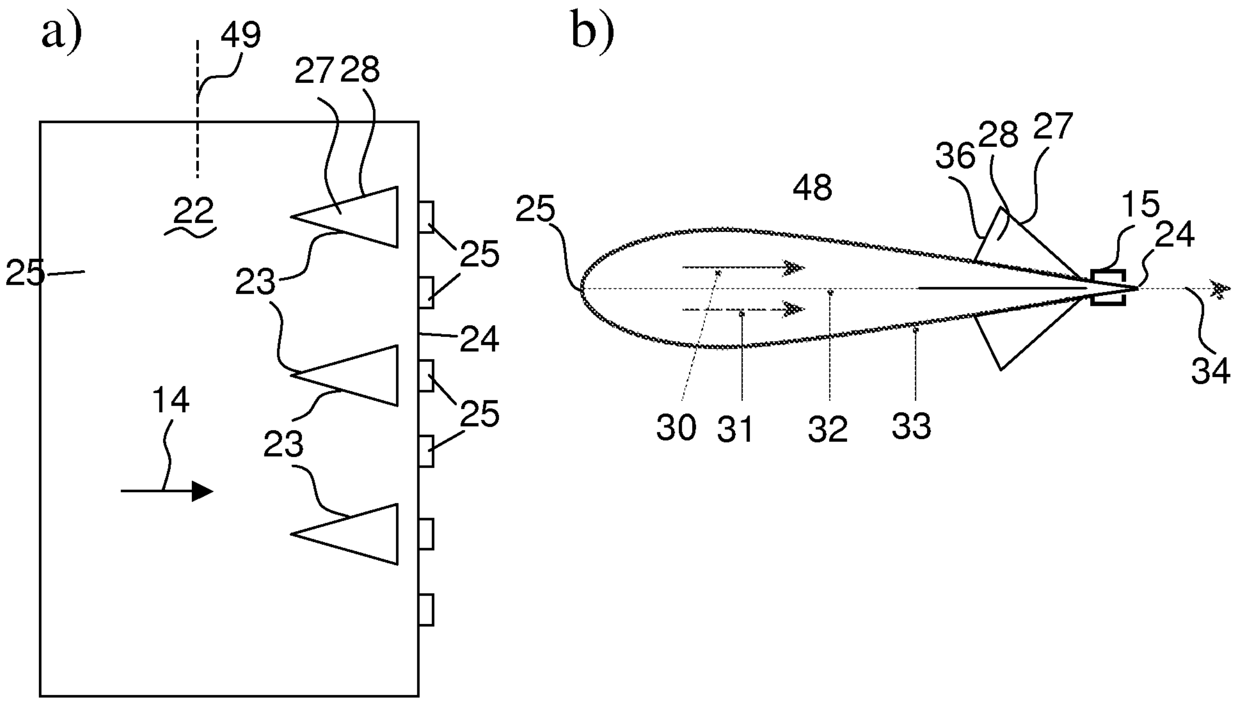

a)
49
27
28
22
25
23
25
24
23
25
14
23
b)
36
28
27
48
25
15
24
30
31
32
33
34

FIG. 7

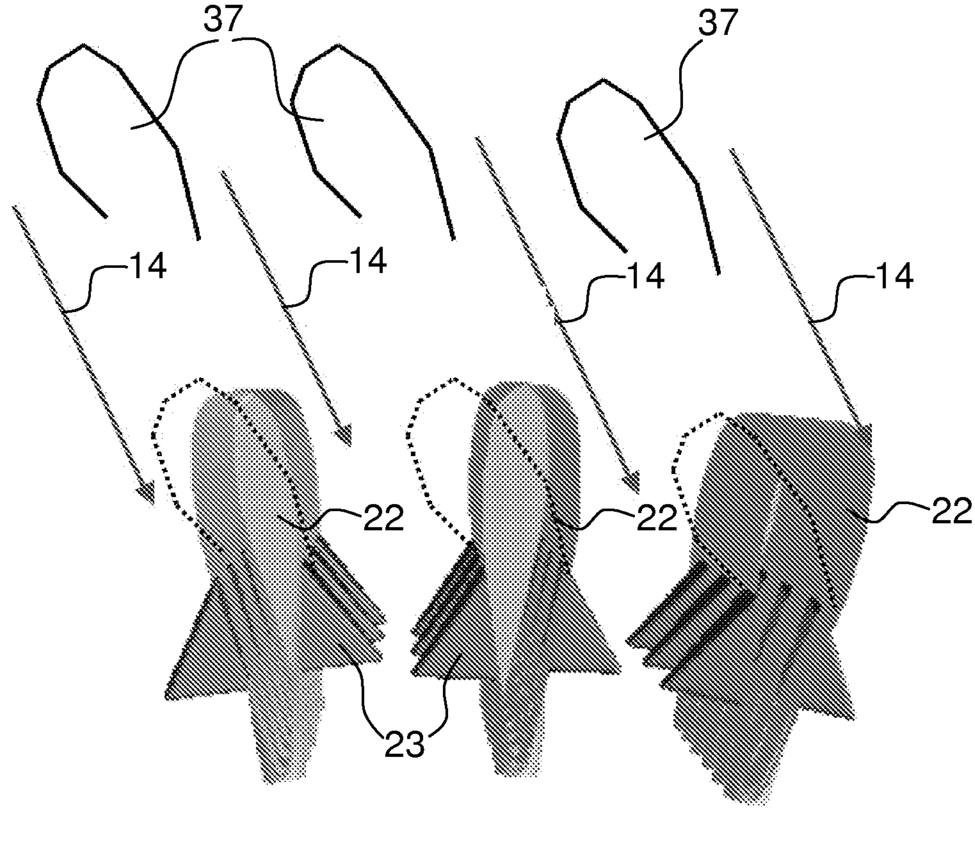

37
37
14
14
14
14
22
22
22
23

FIG. 8

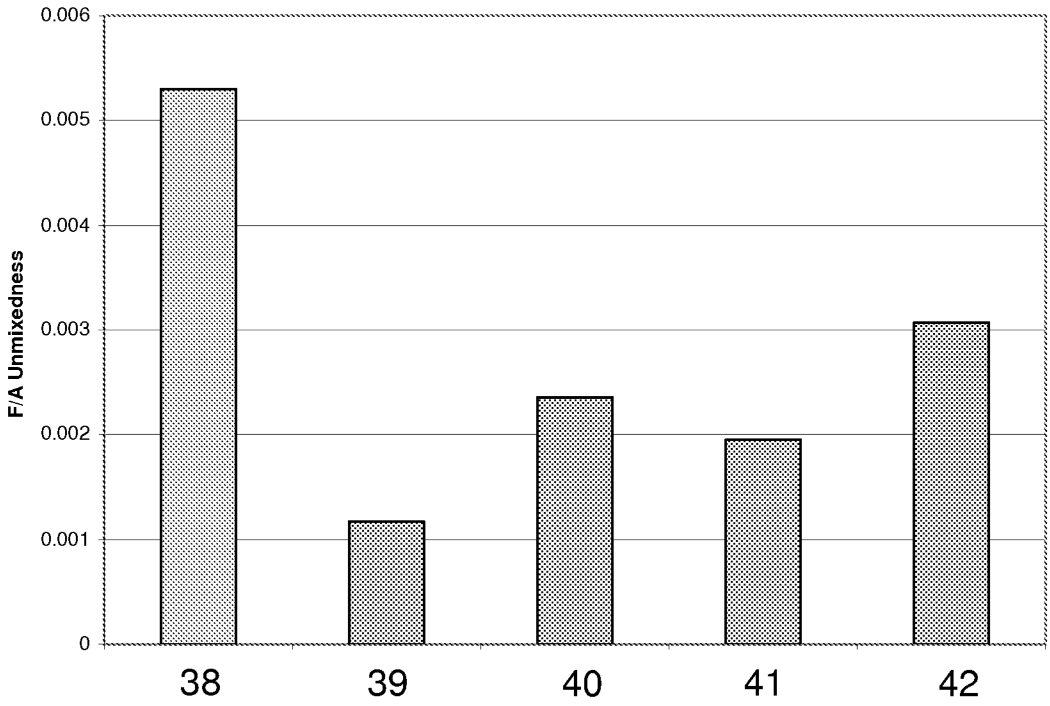

0.006
0.005
0.004
0.003
0.002
0.001
0
F/A Unmixedness
38
39
40
41
42

FIG. 9

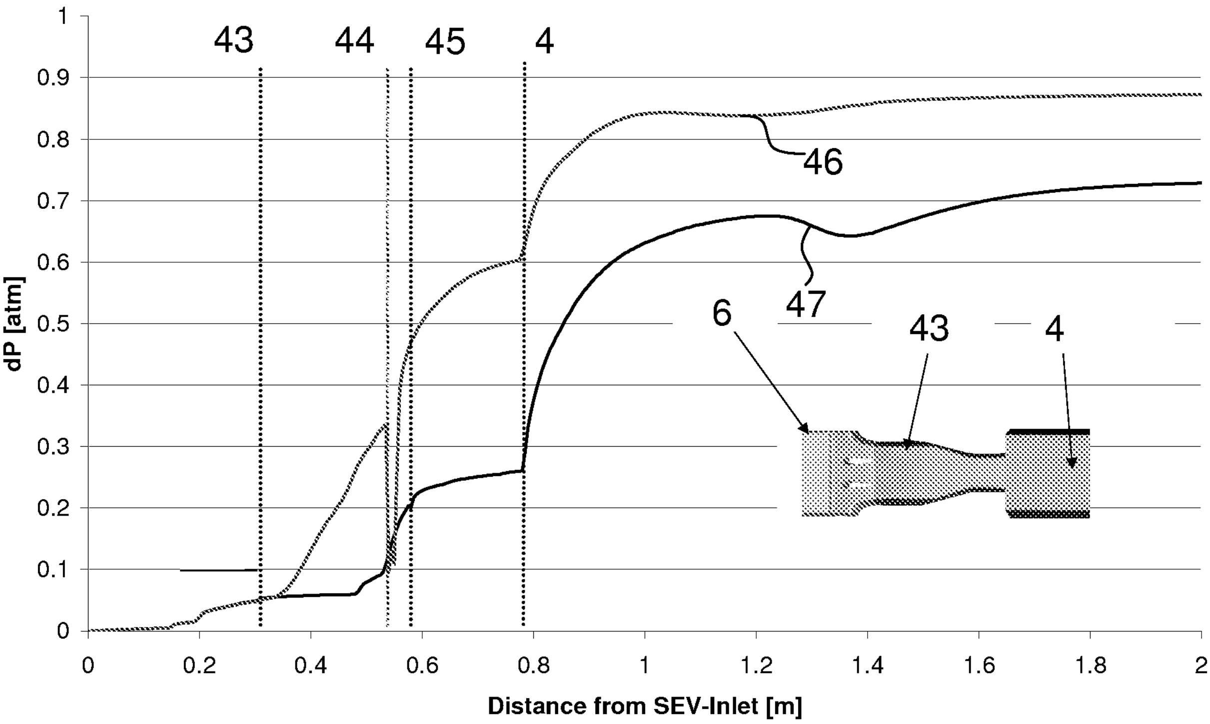

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
dP [atm]
43
44
45
4
46
47
6
43
4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Distance from SEV-Inlet [m]

FIG. 10