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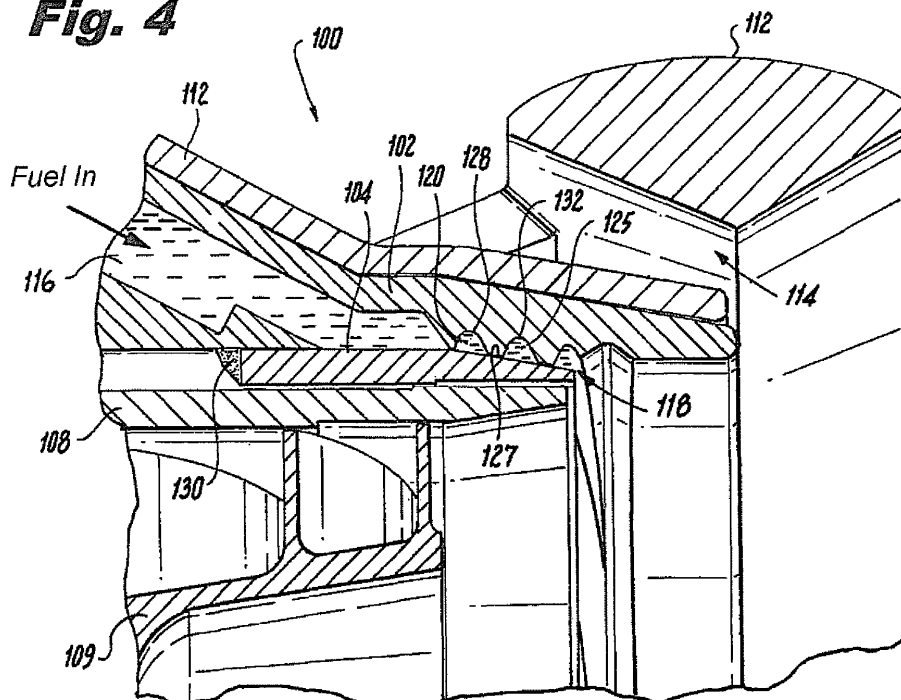
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(54) **Airblast injectors for multipoint injection and methods of assembly**

(57) A method of assembling an airblast injector (100) includes forming a fluid passage (128) on an internal conical surface (127) of a first nozzle component (102) and/or on an outer conical surface of a second nozzle component (104) configured and adapted to mate with the first nozzle component to form at least a portion

of a fluid circuit (120) therebetween. The fluid passage is configured and adapted to provide passage for fluid in the fluid circuit between the first and second nozzle components. The method also includes joining the first and second nozzle components together by engaging the second nozzle component within the first nozzle component.

Fig. 4



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Description

DEVELOPMENT

[0001] This invention was made with government support under contract number NNC11CA15C awarded by NASA. The government has certain rights in the invention.

CROSS-REFERENCE TO RELATED APPLICATIONS

[0002] This application claims priority to U.S. Provisional Patent Application No. 61/555,363 filed November 3, 2011 which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0003] The present invention relates to airblast injection nozzles, and more particularly, to systems and methods for assembling components of airblast injection nozzles for multipoint injection.

2. Description of Related Art

[0004] Multipoint lean direct injection (LDI) for gas turbine engines is well known in the art. Multipoint refers to the use of a large number of small airblast injector nozzles to introduce the fuel and air into the combustor. By using many very small airblast injector nozzles there is a reduction of the flow to individual nozzles, therein reducing the diameter of the nozzle. The volume of recirculation zone downstream of the nozzle is thought to be a controlling parameter for the quantity of NO_x produced in a typical combustor. If the recirculation volume is proportional to the cube of the diameter of the mixer, and if the NO_x produced is proportional to the recirculation volume, and the fuel flow is taken to be proportional to the square of the diameter of the mixer, then a larger nozzle will produce greater fuel flow, but also a greater emission index of NO_x (EINO_x).

[0005] In addition, conventional construction of small sized injectors, nozzles, atomizers and the like, includes components bonding together with braze. The components have milled slots or drilled holes to control the flow of fuel and prepare the fuel for atomization. The components are typically nested within one another and form a narrow diametric gap which is filled with a braze alloy. The braze alloy is applied as a braze paste, wire ring, or as a thin sheet shim on the external surfaces or within pockets inside the assembly. The assembly is then heated and the braze alloy melts and flows into the narrow diametric gap and securely bonds the components together upon cooling.

[0006] Such conventional methods and systems generally have been considered satisfactory for their intended

purpose. However, when using traditional brazing techniques, the braze alloy must flow from a ring or pocket to the braze area. In doing so, it is prone to flow imprecisely when melted. It is also not uncommon for braze fillets to be formed on or in certain features. In some instances intricate or narrow passages can become plugged if too much braze is used. These fillets and plugs can negatively affect nozzle performance. There is higher chance fillet formation of and plugs as the nozzle components become smaller, as in multipoint applications. The difficulties in controlling braze flow employing traditional brazing techniques is a limiting factor in the design of fuel and air flow passages. That is, the shape and size of the passages is limited by the ability to control the flow of braze.

[0007] There remains a need in the art for a method and system of assembling nozzles that will eliminate or greatly reduce fillet formation and/or plugging and allow for formation of intricate internal fuel and air flow passages. There also remains a need in the art for such a method and system that are easy and inexpensive to make and use. The present invention provides a solution for these problems.

SUMMARY OF THE INVENTION

[0008] The subject invention is directed to a new and useful method of assembling an airblast injector. The method includes forming a fluid passage on an internal conical surface of a first nozzle component and/or on an outer conical surface of a second nozzle component configured and adapted to mate with the first nozzle component to form at least a portion of a fluid circuit therebetween. The fluid passage is configured and adapted to provide passage for fluid in the fluid circuit between the first and second nozzle components. The method further includes joining the first and second nozzle components together by engaging the second nozzle component within the first nozzle component.

[0009] The step of joining can include engaging the second nozzle component into the first nozzle component in an interference fit. It is also possible for the step of forming a fluid passage to include forming a thread around at least a portion the internal conical surface of the first nozzle component and/or the outer conical surface of the second nozzle component. In addition, the step of forming a fluid passage can include forming a multiple-start thread around at least a portion of the internal conical surface of the first nozzle component and/or the outer conical surface of the second nozzle component for providing multiple individual outlets for the fluid circuit. It is also possible for the method to include a step of applying braze directly to the joint location on at least one of the first and second nozzle components. The method can also include a step of applying heat to the braze to form a braze joint at the joint location. The method can also include a step of welding the first and second nozzle components together at the joint location

to form a weld joint.

[0010] The invention also provides an injector comprising a fuel distributor with a fluid inlet, and a fluid outlet. A fluid circuit is provided for fluid communication between the fluid inlet and the fluid outlet and includes a passage defined along a cone.

[0011] The fuel distributor can include an outer distributor ring and an inner distributor ring mounted within the outer distributor ring. The fluid circuit can be formed between the inner and outer distributor rings. It is possible for the outer distributor ring to include an internal conical surface with a helically threaded fluid passage defined therein. The fluid circuit can be defined between the helically threaded fluid passage of the internal conical surface of the outer distributor ring and an outer conical surface of the inner distributor ring. The internal conical surface of the outer distributor ring can include a multiple-start helically threaded fluid passage defined therein, wherein the fluid circuit is defined between the multiple-start helically threaded fluid passage of the internal conical surface of the outer distributor ring and an outer conical surface of the inner distributor ring.

[0012] The fuel distributor can also include a braze or a weld joint mounting the inner and outer distributor rings together. The braze or weld joint bounds the fluid circuit for confining fluid flowing therethrough.

[0013] The invention also provides an injector for use in a multipoint fuel injection system. The injector includes first and second nozzle components, assembled as described above, to form a fuel distributor. The injector includes an inner heat shield mounted inboard of the second nozzle component for thermal isolation of fuel in the fuel distributor from compressor discharge air inboard of the inner heat shield. The injector further includes a core air swirler mounted inboard of the inner heat shield for swirling compressor discharge air inboard of the fuel distributor for atomizing fuel issued from the fuel distributor. In addition, the injector includes an outer heat shield assembly mounted outboard of the first nozzle component for thermal isolation of fuel in the fuel distributor from compressor discharge air outboard of the fuel distributor.

[0014] The outer heat shield assembly can define an outer air circuit configured and adapted to issue compressor discharge air outboard of fuel issued from the fuel distributor. The outer air circuit can be configured and adapted to issue a swirl-free flow of air therethrough. It is also contemplated that, the outer air circuit can be configured and adapted to issue a converging flow of air therethrough to enhance swirl imparted on a flow of compressor discharge air issued from the core air swirler.

[0015] These and other features of the systems and methods of the subject invention will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] So that those skilled in the art to which the subject invention appertains will readily understand how to make and use the devices and methods of the subject invention without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

Fig. 1 is a perspective view of an exemplary embodiment of an airblast injector constructed in accordance with the present invention;

Fig. 2 is an exploded perspective view of the airblast injector of Fig. 1, showing how the fuel distributor constructed in accordance with the present invention can be assembled;

Fig. 3 is a cross-sectional side elevation view of the airblast injector of Fig. 1, showing components of the fuel distributor mounted together at a braze joint; and

Fig. 4 is an enlarged cross-section side elevation view of a portion of the airblast injector of Fig. 1, showing a fluid circuit between an internal conical surface of an outer distributor ring and an outer conical surface of an inner distributor ring.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject invention. For purposes of explanation and illustration, and not limitation, a partial view of an exemplary embodiment of the airblast injectors for multipoint injection in accordance with the invention is shown in Fig. 1 and is designated generally by reference character 100. Other embodiments of the airblast injectors for multipoint injection in accordance with the invention, or aspects thereof, are provided in Figs. 2-4, as will be described. Airblast injector is adapted and configured for delivering fuel to the combustion chamber of a gas turbine engine.

[0018] Nozzles used in conventional multipoint LDI configurations were pressure atomizing air assist nozzles. The conventional pressure atomizing air assist nozzles were generally inexpensive and light weight. In such conventional LDI configurations, it was found that the air assist nozzles had to be very small in order to allow a very large number of nozzles, for example nozzles in excess of 1000, in order to achieve the target low NO_x emissions.

[0019] Conventional pressure atomizing air assist nozzle systems generally have been considered satisfactory for their intended purpose, however it is desired to reduce cost, complexity and poor low power operability since the fuel had to be divided among so many nozzles. The air blast nozzle approach is advantageous in multipoint applications because of its ability to mix fuel and air more efficiently, permitting the use of larger nozzles. Fewer air

blast nozzles are required than with the pressure atomizing types while still achieving low NO_x. This contravenes the idea that larger nozzles produce higher NO_x emissions index (EINO_x). However it was found that continuing to increase the diameter of the conventional air blast nozzles in order to reduce the total number, again caused higher NO_x emissions. This means that there is an optimum size associated with nozzles to reduce emissions and that air blast nozzles have had an advantage over conventional pressure atomizing air assist permitting fewer nozzles.

[0020] One source of difficulty associated with conventional air blast nozzles is the way fuel is distributed. Fuel cannot be exposed to excessive heat, for example wall temperatures exceeding 400° F, without destabilizing and depositing coke in the channel. Coke can block the channel and impede nozzle performance of the nozzle. In conventional pressure atomizing air assist nozzles, as discussed above, fuel emanates from a small centrally located hole. The channels feeding the hole are usually located in a symmetrical, location which is easily insulated from heat. In conventional air blast nozzles, fuel is distributed over a large diameter near the exit of the nozzle. The fuel feed channels in conventional air blast nozzles tend to be much larger than in the conventional pressure atomizing air assist nozzles and they are generally adjacent to substantial hot air channels which heat the nozzle. Keeping the fuel cool in conventional air blast nozzles requires the use of substantial amounts of heat shielding which adds to the cost and weight. In addition, the necessity of flowing air through the core of the nozzle requires an asymmetric fuel feed channel be utilized which adds additional complexity. In general, in order to increase the ultimate mixing rate with air at the exit, the spread of fuel flow segregated from air within the geometry of the conventional air blast nozzle makes the nozzle much more vulnerable to fuel overheating and coke contamination. It is desired to reduce complexity of manufacture, weight, cost and coke contamination of conventional air blast nozzles.

[0021] With reference to Figs. 1 and 2, the invention provides an injector 100 for use in a multipoint fuel injection system. Injector 100 includes first and second nozzle components, shown as outer and inner distributor rings 102 and 104, respectively, to form a fuel distributor 106. Injector 100 includes an inner heat shield 108 mounted inboard of inner distributor ring 104 for thermal isolation of fuel, as shown in Fig. 4, in fuel distributor 106 from compressor discharge air inboard of inner heat shield 108. Injector 100 further includes a core air swirler 109 mounted inboard of inner heat shield 108 for swirling compressor discharge air inboard of fuel distributor 106 for atomizing fuel issued from fuel distributor 106. In addition, injector 100 includes an outer heat shield assembly 112 mounted outboard of first nozzle component 102 for thermal isolation of fuel in fuel distributor 106 from compressor discharge air outboard of fuel distributor 106. Those having skill in the art will readily appreciate that

the spherical shape of outer heat shield assembly 112 allows injector 100 to be rotated to avoid spraying fluid on adjacent walls while still permitting sealing thereof within a cylindrical sealing feature to permit axial travel during thermal growth and contraction of the combustor.

[0022] With reference now to Fig. 3, outer heat shield assembly 112 defines an outer air circuit 114 configured and adapted to issue compressor discharge air outboard of fuel issued from fuel distributor 106. Outer air circuit 114 is configured and adapted to issue a swirl-free flow of air therethrough. Since outer air circuit 114 converges toward the central axis, outer air circuit 114 issues a converging flow of air therethrough to enhance swirl imparted on a flow of compressor discharge air issued from core air swirler 109.

[0023] With reference now Figs. 3 and 4, fuel distributor 106 includes a fluid inlet 116, and fluid outlet 118, and a fluid circuit 120. Fluid circuit 120 is for fluid communication between fluid inlet 116 and fluid outlet 118 and includes a three-start helically threaded fluid passage 128, defined along a cone, i.e. internal conical surface 125 of outer distributor ring 102. Fluid circuit 120 is defined between three-start helically threaded fluid passage 128 of internal conical surface 125 of outer distributor ring 102 and an outer conical surface 127 of inner distributor ring 104. Although shown and described herein as a three-start helically threaded fluid passage, those skilled in the art will readily appreciate that the passage can be any suitable number of starts for a given application. Typically, it is contemplated that one start should be provided for every 1-inch (2.54 cm) or circumference of the passage, however, any other suitable spacing can be used without departing from the scope of the invention. Those having skill in the art will readily appreciate that the multiple-start thread and multiple individual outlets provide enhanced performance when operating at low pressure, for example, the multiple-starts and multiple outlets of thread allow for even fuel distribution.

[0024] In addition, the circumferential distribution of the fuel was aided by the use multiple-start threaded passages 128 because their inherent flow resistance divided very small quantities of fuel uniformly between fluid circuit 120. Therein, the velocity of the fuel through fluid circuit 120 was substantially higher than it would be in a conventional airblast nozzle without threads 132. High velocity and fluid friction increase fuel cooling ability and helps to keep the metallic walls temperature adjacent to threads 132 cool without overheating the fuel. Therefore, permitting the multiple-start threaded passages 128 maintain an extremely small wetted surface area of the nozzle as compared to conventional airblast nozzles. The smaller the wetted surface of the nozzle, the less coke contamination occurs. In addition, the use of the multiple-start threaded passage along a conical surface, i.e. internal conical surface 125 and/or outer conical surface 127, reduces the profile of wetted components and thus permits more space for air through the interior of the nozzle.

[0025] Further, the geometry of the multiple-start threaded passages 128 inherently imparts high degrees of swirl to the exiting fuel. The fuel flows nearly circumferentially at the exit 118 of the threads 132 and forms a uniform film on a short downstream lip of the nozzle. Intensely co-swirling air helps distribute the fuel circumferentially while it progresses to the final exit. Those having skill in the art would readily appreciate that the fuel film helps keep the short filming lip cool as it intervenes between the lip and the hot core air.

[0026] Now referring to Fig. 4, fuel distributor 106 also includes a braze joint 130 mounting together inner and outer distributor rings, 104 and 102. Braze joint 130 bounds fluid circuit 120 for confining fluid flowing there-through. Since distributor 106 includes multiple-start helically threaded fluid passages 128, braze joint 130 bounds fluid circuit 120 for confining fluid flowing there-through.

[0027] With reference now to Fig. 2, a method of assembling an airblast injector, i.e. injector 100, is described. The method includes forming a fluid passage, i.e. multiple start helically threaded fluid passage 128, on an at least one of an internal conical surface, i.e. internal conical surface 125, of a first nozzle component, i.e. outer distributor ring 102, and an outer conical surface, i.e. outer conical surface 127, of a second nozzle component, i.e. inner distributor ring 104. While shown herein in the exemplary context of fluid passage 128 formed on internal conical surface 125 of outer distributor ring 102, those skilled in the art will readily appreciate that fluid passage 128, e.g. including a multiple-start thread as described above, in addition or instead, can be formed on outer conical surface 127 of inner distributor ring 104. The inner distributor ring is configured and adapted to mate with the outer distributor ring to form at least a portion of a fluid circuit, i.e. fluid circuit 120, therebetween. The fluid passage is configured and adapted to provide passage for fluid in the fluid circuit between the outer and inner distributor rings.

[0028] With continued reference to Fig. 2, the method further includes joining the outer and inner distributor rings together by engaging the inner distributor ring within first the nozzle component. Joining inner and outer distributor rings together also includes engaging the inner distributor ring into the outer distributor ring in an interference fit. The inner distributor ring can be engaged in an interference fit with the outer distributor ring by forcefully pulling the inner distributor ring towards the outlet of the outer distributor ring. Those skilled in the art will readily appreciate that due to the conical surfaces involved joining the outer and inner distributor rings together, an interference fit is not required, for example, the inner distributor ring can be disposed within the outer distributor ring and fixed with a weld or braze at joint 130. Those skilled in the art will readily appreciate that without the inner and outer rings joined together in an interference fit, fuel will still follow the helically threaded fluid passage 128 due to the pressure differential between the

inlet 116 and outlet 118. In addition, those having skill in the art will readily appreciate that due to the conical surfaces involved joining the outer and inner distributor rings together does not require thermal resizing to tightly fit the inner distributor ring over the threads to seal the fuel, thereby permitting more efficient and cost effective manufacture and assembly.

[0029] With reference now to Fig. 2 and 3, inner distributor ring can be employed to form the inner wetted surface. It can be easily slid into position from the upstream end of the nozzle. The threads are cut on an adjacent conical surface, i.e. internal conical surface 125 of outer distributor ring 102, which provides a stop for the inner distributor ring. Once the inner distributor ring is in position, it can be tacked into place at a joint location, i.e. joint location 130, while pressing against the threads. The upstream end at the joint location is then brazed or welded to keep the ring in position and to seal the fluid circuit. Those having skill in the art will readily appreciate that this permits a purely mechanical placement.

[0030] In addition, those having skill in the art will appreciate that because the inner distributor ring is so short, it minimizes weight it is effectively cooled by fuel. Reducing or minimizing the wetted surface of the nozzle reduces the length of the heat shield, i.e. inner or outer heat shields 108 and 112, respectively, required to keep the wetted surface carrying components cool. It can also be appreciated that the heat shielding was functionally integrated into the components of injector 100. Inner heat shield 108 forms the shroud for inner air swirler 109 into which swirler 109 could be brazed or welded. It also forms the inside of the heat shield for the feed tube of fuel circuit 120.

[0031] In reference to Figs. 1 and 2, outer heat shield 112 can form the inner air shroud for outer air circuit 114. Both inner and outer heat shields, 108 and 112, can be configured to attach together at the back of injector 100 where an air sealing weld or braze could be located. Once attached, the heat shields, 108 and 112, thermally encapsulate inner and outer distributor rings 104 and 102, allowing them to remain at around fuel temperature even if the air is at a much higher temperature as it arrives from the compressor. Gaps between adjacent shells permit the hot components to grow radially and axially unimpeded by the cold components. Zones where hot air can touch the fuel conveying components are reduced to an absolute minimum. By keeping injector 100 components small, the heat shielding is kept at a reduced weight as compared to conventional injectors. Combining functionality of heat shields 108 and 112 keep cost of the components to a minimum.

[0032] Now with reference to Fig. 3, the method also includes applying braze directly to the joint location on at least one of the outer and inner distributor rings. The braze is applied over tack beads between the outer and inner distributor rings at the braze location, i.e. braze joint 130. Heat is then applied to the braze to form a braze joint at the joint location. Those having skill in the art will

readily appreciate that by applying braze directly to the braze joint, there is less chance for the braze to form fillets on or in certain features, for example, the fluid circuit.

[0033] While shown and described in the exemplary context of multipoint injection for gas turbine engines, those skilled in the art will readily appreciate that the apparatus and method described herein can be used for any other suitable application. Moreover, while the apparatus is shown in the exemplary process described herein, those skilled in the art will readily appreciate that it can be made by any other suitable process or processes without departing from the scope of the invention.

[0034] The methods and systems of the present invention, as described above and shown in the drawings, provide for systems and methods for assembling components of airblast injection nozzles for multipoint injection with superior properties including reduced formation of fillets and plugs during brazing. While the apparatus and methods of the subject invention have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the scope of the subject invention.

Claims

1. A method of assembling an airblast injector comprising:

forming a fluid passage on an at least one of:

an internal conical surface of a first nozzle component, and
an outer conical surface of a second nozzle component configured and adapted to mate with the first nozzle component to form at least a portion of a fluid circuit therebetween,

wherein the fluid passage is configured and adapted to provide passage for fluid in the fluid circuit between the first and second nozzle components; and
joining the first and second nozzle components together by engaging the second nozzle component within the first nozzle component.

2. A method of assembling an airblast injector as recited in claim 1, wherein the step of joining includes engaging the second nozzle component into the first nozzle component in an interference fit.
3. A method of assembling an airblast injector as recited in claim 1, wherein the step of forming a fluid passage includes forming a thread around at least a portion of one of the internal conical surface of the

first nozzle component and the outer conical surface of the second nozzle component.

4. A method of assembling an airblast injector as recited in claim 1, wherein the step of forming a fluid passage includes forming a multiple-start thread around at least a portion of one of the internal conical surface of the first nozzle component and the outer conical surface of the second nozzle component for providing multiple individual outlets for the fluid circuit.
5. A method of assembling an airblast injector as recited in claim 1, wherein the step of forming a fluid passage includes forming a thread around at least a portion of the internal conical surface of the first nozzle component.
6. A method of assembling an airblast injector as recited in claim 1, wherein the step of forming a fluid passage includes forming a multiple-start thread around the internal conical surface of the first nozzle component for providing multiple individual outlets for the fluid circuit.
7. A method of assembling an airblast injector as recited in claim 1, further comprising:

applying braze directly to the joint location on at least one of the first and second nozzle components; and
applying heat to the braze to form a braze joint at the joint location.

8. A method of assembling an airblast injector as recited in claim 1, further comprising:

welding the first and second nozzle components together at the joint location to form a weld joint.

9. An injector comprising:

a fuel distributor with a fluid inlet, and fluid outlet, and a fluid circuit for fluid communication between the fluid inlet and the fluid outlet, wherein the fluid circuit includes a passage defined along a cone.

10. An injector as recited in claim 9, wherein the fuel distributor includes an outer distributor ring and an inner distributor ring mounted within the outer distributor ring, wherein the fluid circuit is formed between the inner and outer distributor rings.

11. An injector as recited in claim 10, wherein at least one of a) or b):-

a) the outer distributor ring includes an internal

conical surface with a helically threaded fluid passage defined therein, and wherein the fluid circuit is defined between the helically threaded fluid passage of the internal conical surface of the outer distributor ring and an outer conical surface of the inner distributor ring; 5

b) the injector further comprises a braze joint mounting the inner and outer distributor rings together, wherein the braze joint bounds the fluid circuit for confining fluid flowing therethrough. 10

12. An injector as recited in claim 10, wherein at least one of a) or b):-

a) the outer distributor ring includes an internal conical surface with a multiple-start helically threaded fluid passage defined therein, and wherein the fluid circuit is defined between the multiple-start helically threaded fluid passage of the internal conical surface of the outer distributor ring and an outer conical surface of the inner distributor ring; 15 20

b) the injector further comprises a weld joint mounting the inner and outer distributor rings together, wherein the weld joint bounds the fluid circuit for confining fluid flowing therethrough. 25

13. An injector for use in a multipoint fuel injection system comprising:

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first and second nozzle components assembled as recited in claim 1 to form a fuel distributor; an inner heat shield mounted inboard of the second nozzle component for thermal isolation of fuel in the fuel distributor from compressor discharge air inboard of the inner heat shield; 35

a core air swirler mounted inboard of the inner heat shield for swirling compressor discharge air inboard of the fuel distributor for atomizing fuel issued from the fuel distributor; and 40

an outer heat shield assembly mounted outboard of the first nozzle component for thermal isolation of fuel in the fuel distributor from compressor discharge air outboard of the fuel distributor. 45

14. An injector as recited in claim 13, wherein the outer heat shield assembly defines an outer air circuit configured and adapted to issue compressor discharge air outboard of fuel issued from the fuel distributor. 50

15. An injector as recited in claim 14, wherein at least one of a) or b):-

a) the outer air circuit is configured and adapted to issue a swirl-free flow of air therethrough; 55

b) the outer air circuit is configured and adapted to issue a converging flow of air therethrough to

enhance swirl imparted on a flow of compressor discharge air issued from the core air swirler.

Fig. 1

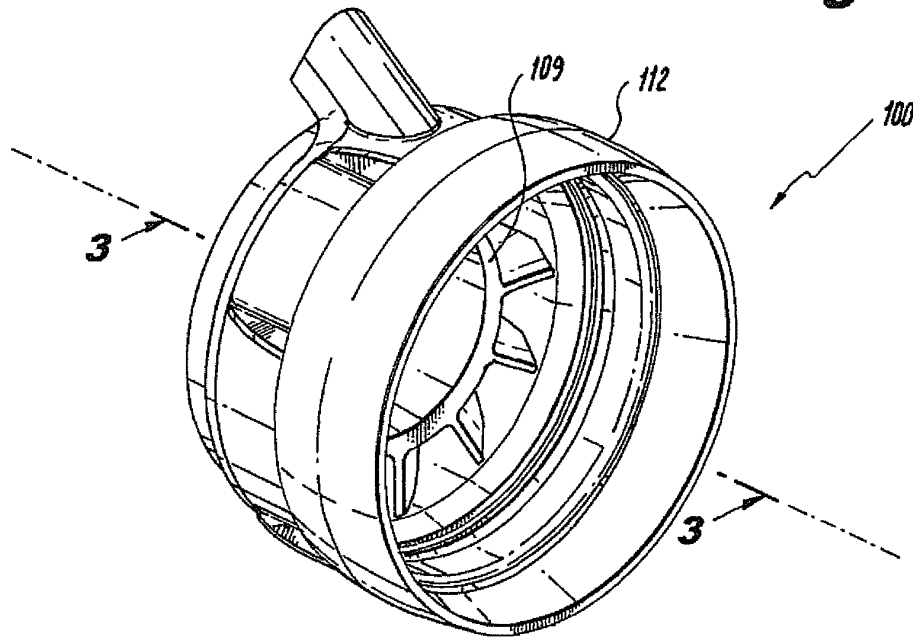


Fig. 4

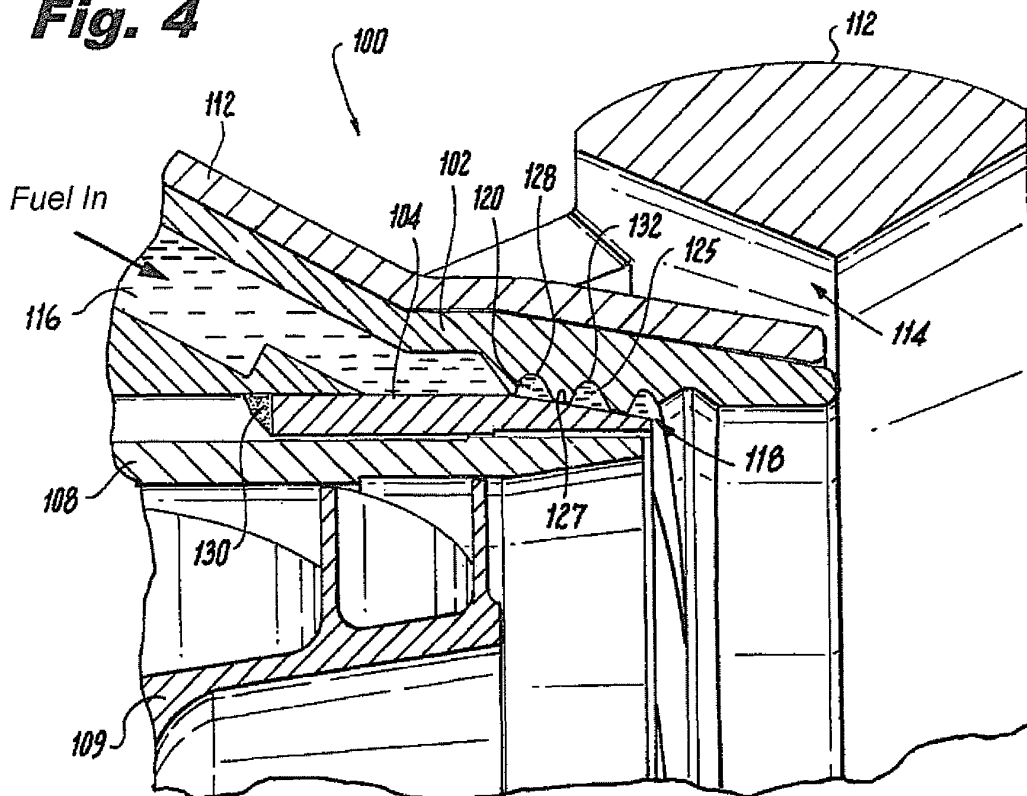
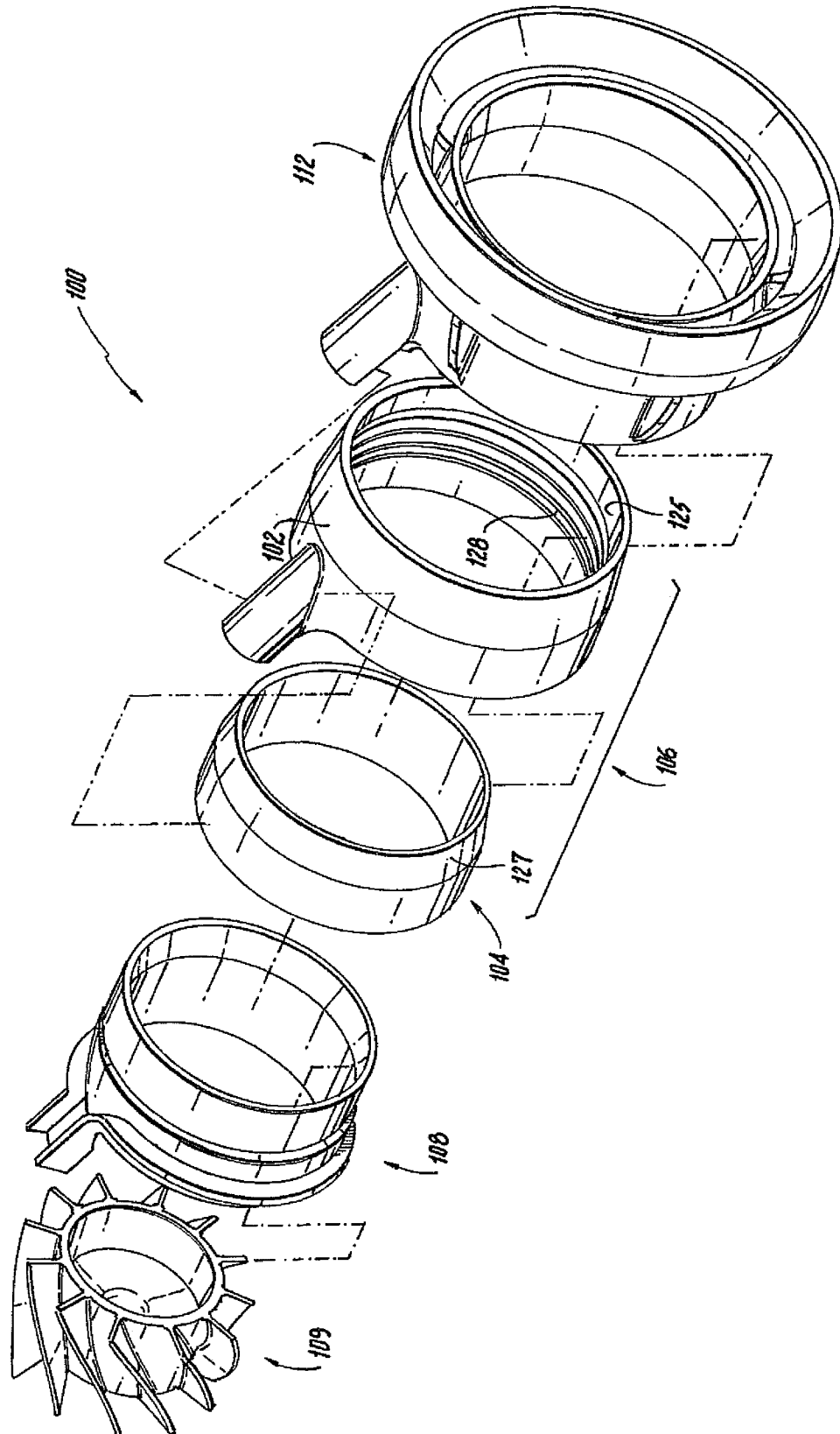


Fig. 2



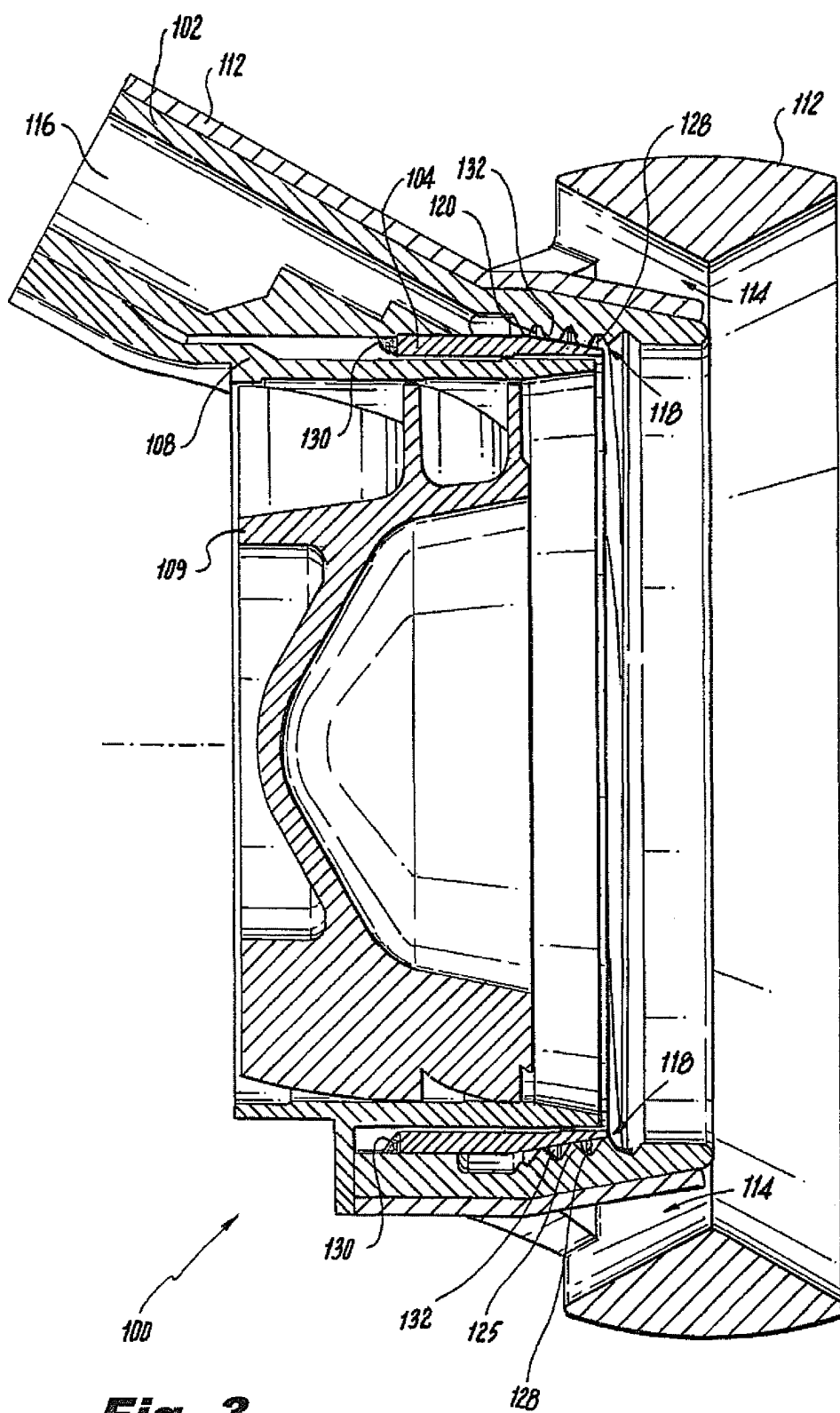


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 61555363 A [0002]