Oct. 27, 1970 R. J. SNEEDEN ET AL 3,535,875

ANNULAR FUEL VAPORIZER TYPE COMBUSTOR

Filed Nov. 27, 1968 4 Sheets-Sheet 1

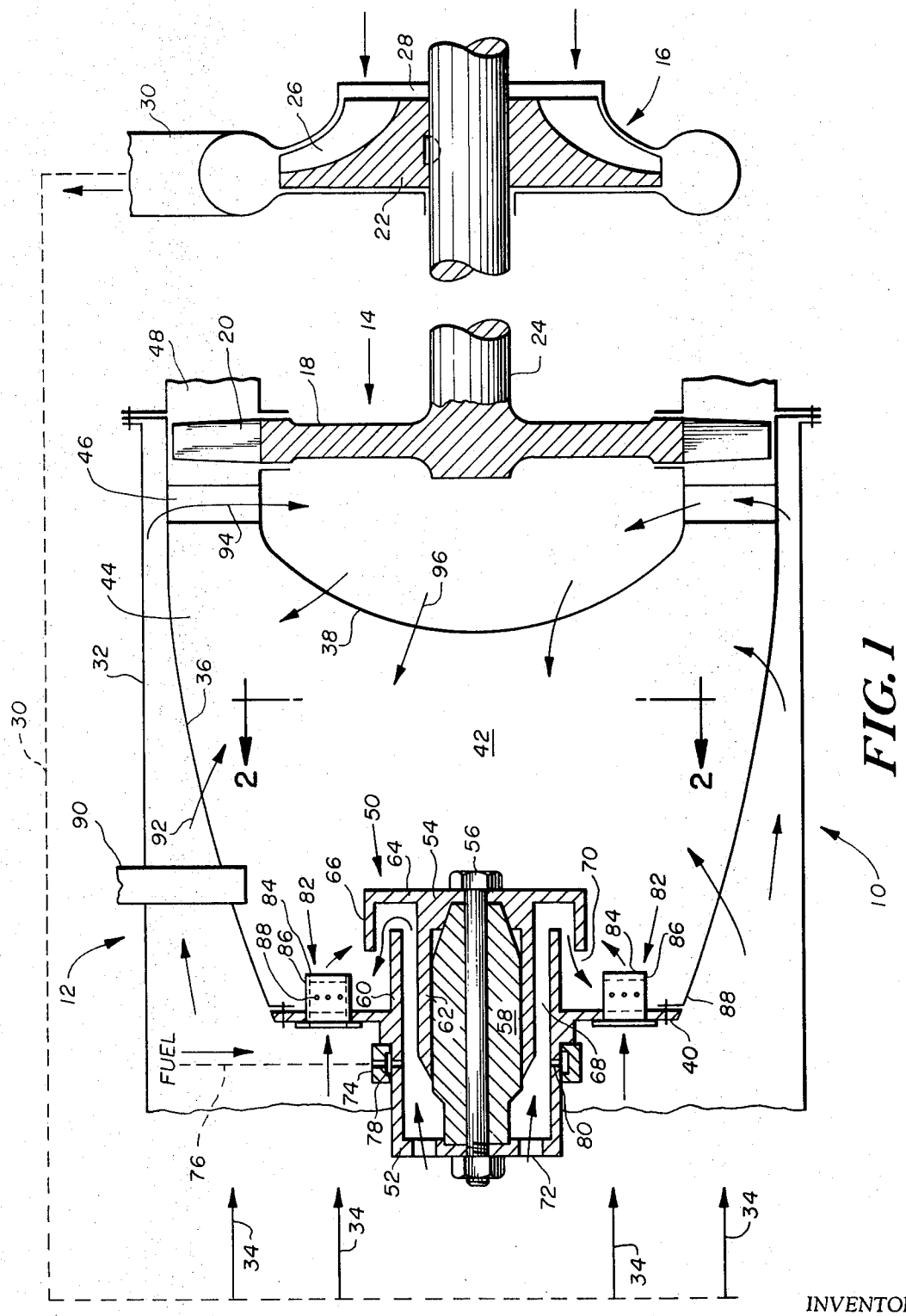


FIG. 1

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ANNULAR FUEL VAPORIZER TYPE COMBUSTOR

Filed Nov. 27, 1968 4 Sheets-Sheet 2

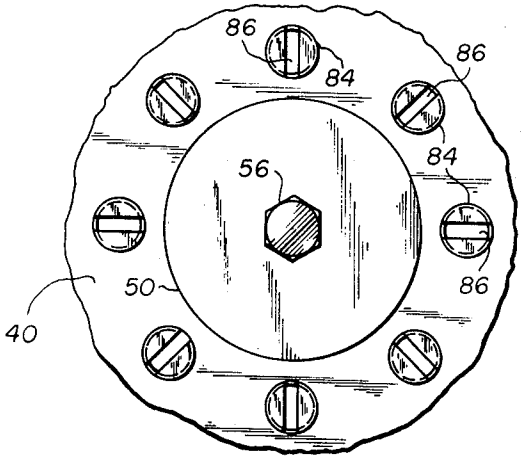


FIG.2

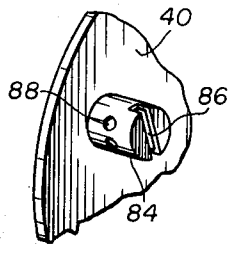


FIG.2A

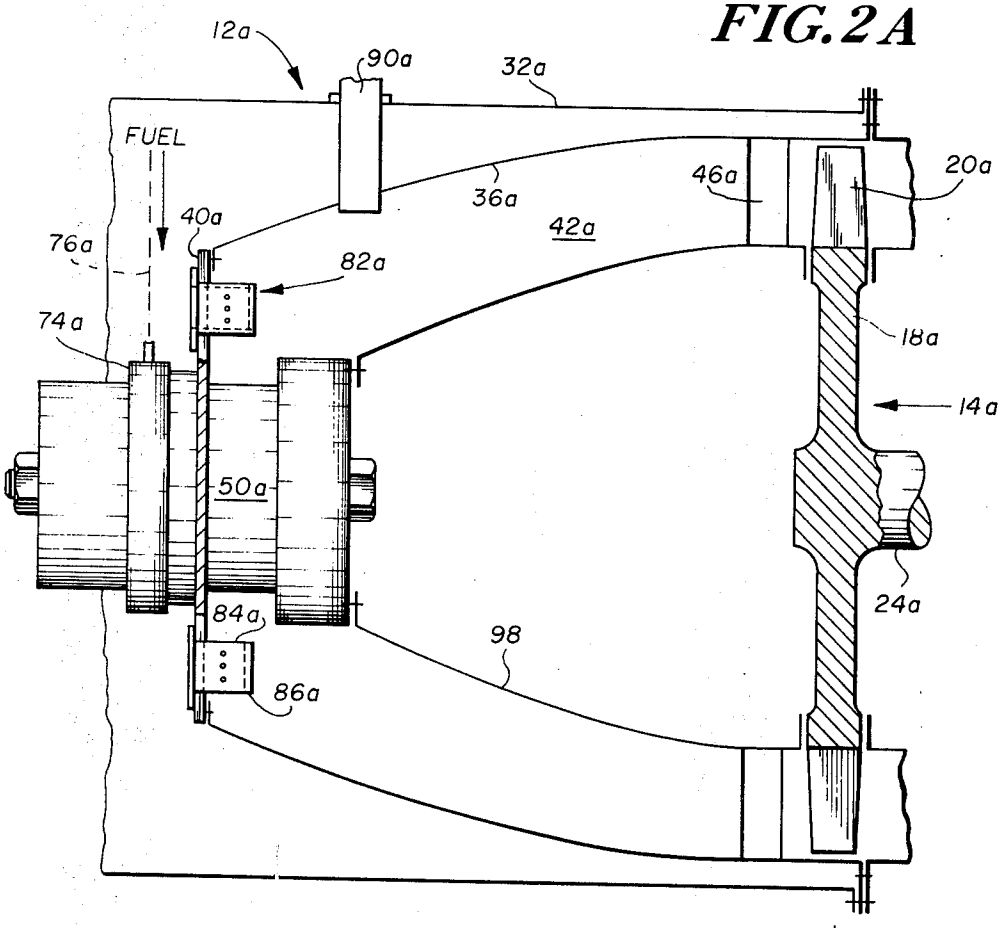


FIG.3

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ANNULAR FUEL VAPORIZER TYPE COMBUSTOR

Filed Nov. 27, 1968 4 Sheets-Sheet 3

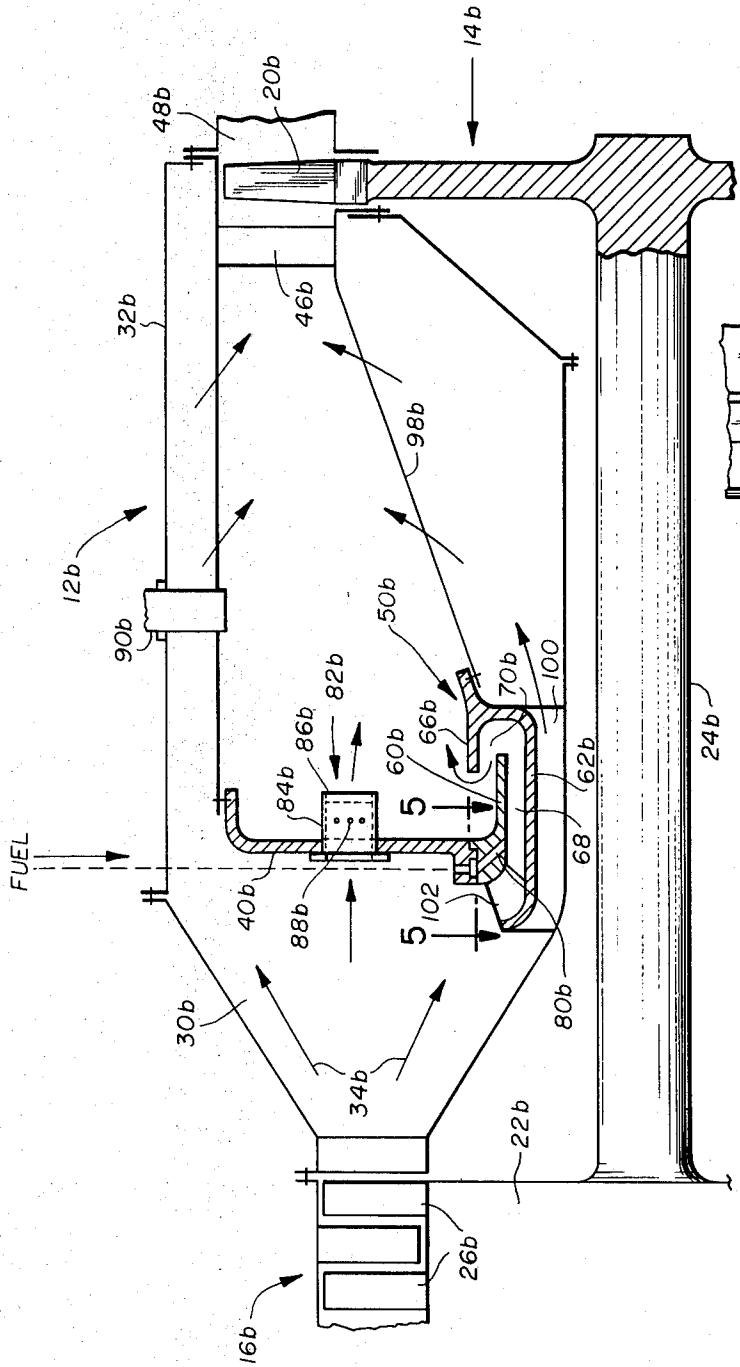


FIG. 4

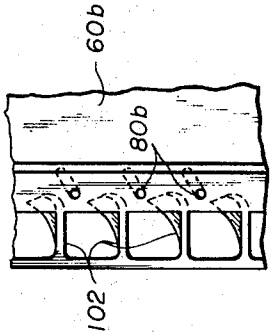


FIG. 5

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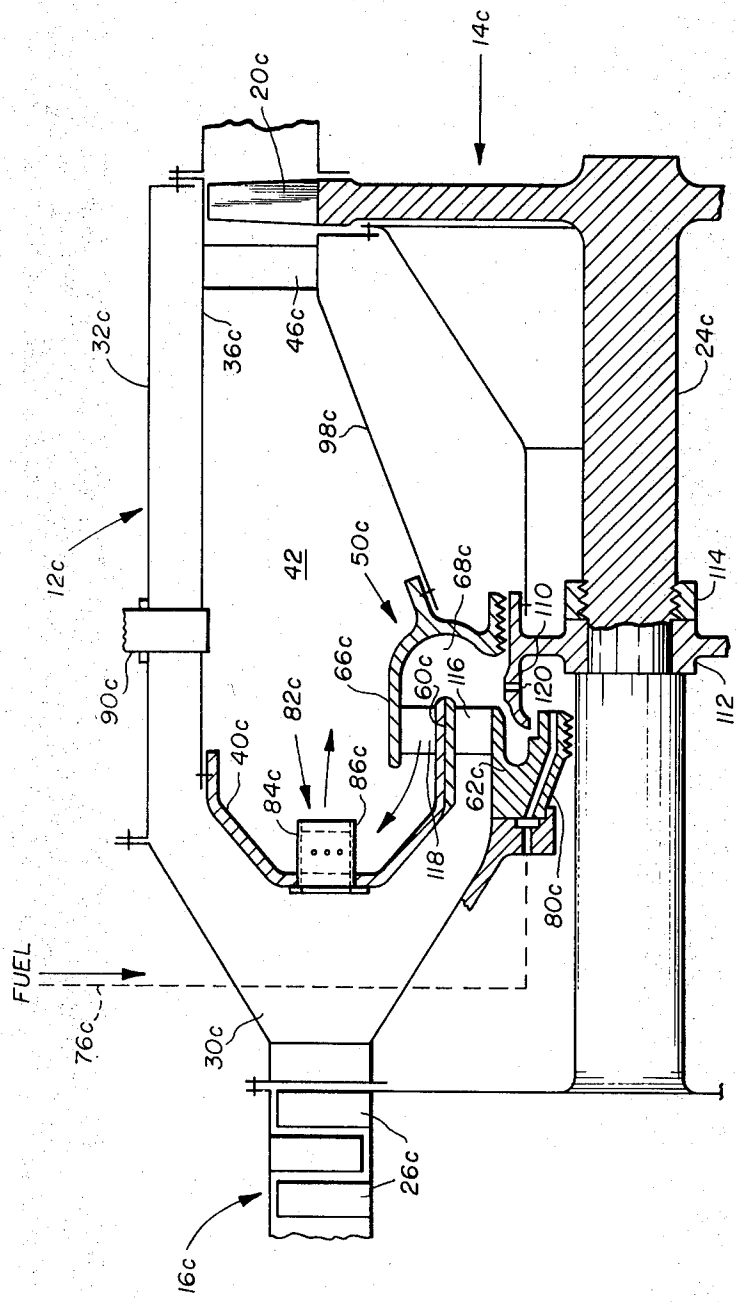


FIG. 6

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ANNULAR FUEL VAPORIZER TYPE COMBUSTOR

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Int. Cl. F02c 3/22

U.S. Cl. 60—39.71 3 Claims

ABSTRACT OF THE DISCLOSURE

Combustion apparatus of the fuel vaporizer type having a single fuel vaporizing unit coaxial with the combustion chamber, said unit providing an annular air-fuel passage which extends downstream into the combustion chamber and then turns radially outwardly and finally back on itself so that its annular discharge end faces toward the upstream end of the combustion chamber.

BACKGROUND OF THE INVENTION

The invention relates to combustion apparatus and is particularly directed to improved combustion apparatus for gas turbine engines.

The invention concerns combustion apparatus of the fuel vaporizer type, such as disclosed in U.S. Pat. No. 3,276,676. This prior art patent discloses a plurality of fuel vaporizer units spaced circumferentially about the axis of a combustion chamber, as well as being spaced radially across said chamber. This prior patent utilizes such a plurality of fuel vaporizer units in order to achieve substantially uniform combustion gas temperatures across the combustion chamber. In accordance with the present invention, these results are achieved with a novel and simple combustion apparatus having but a single fuel vaporizing unit disposed on the axis of the combustion chamber with this single vaporizing unit having an annular fuel-air path compared to the tubular fuel-air path of the vaporizing units of said prior patent.

SUMMARY

An object of this invention comprises the provision of a novel and simple combustion apparatus of the fuel vaporizer type. More particularly, it is an object of this invention to provide novel and simple combustion apparatus having only a single fuel vaporizer unit on the axis of the combustion chamber with said unit having an annular fuel-air path.

In accordance with the invention, the fuel vaporizer unit is coaxially supported adjacent to the upstream wall of a combustion chamber. This fuel vaporizer unit has radially-spaced inner and outer annular walls extending through said upstream wall into the combustion chamber and forming an annular air-fuel passage between said walls. The inner annular wall of said passage extends axially downstream beyond the annular outer wall of said passage and turns radially outwardly beyond said outer wall and then reverses and turns in an upstream direction radially outwardly of said outer wall to overlap said outer wall so that the annular passage first extends downstream and then turns radially outwardly and finally turns back on itself such that its annular discharge opening faces in an upstream direction toward the upstream wall of said chamber.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic view in axial section of a gas turbine engine having a combustion unit embodying the invention;

FIG. 2 is a view taken along line 2—2 of FIG. 1;

FIG. 2A is a perspective view of a portion of FIG. 2;

FIG. 3 is a partial view similar to FIG. 1 but illustrating combustion apparatus having an annular combustion chamber instead of the cannular chamber of FIG. 1;

FIG. 4 is a diagrammatic view similar to FIG. 3 but illustrating a gas turbine engine in which the combustion chamber is annular and surrounds the turbine shaft;

FIG. 5 is a developed sectional view taken on line 5—5 of FIG. 4; and

FIG. 6 is a view similar to FIG. 5 but in which fuel is discharged into the annular passage of the fuel vaporizer unit by means of a rotating slinger arrangement.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIGS. 1 and 2 of the drawing, a gas turbine engine, schematically indicated by reference numeral **10**, comprises a combustor unit **12**, a turbine unit **14** and a compressor unit **16**. The turbine unit **14** consists of a turbine rotor **18** having a plurality of circumferentially-spaced blades **20** extending radially therefrom. The turbine rotor is driveably connected to the rotor **22** of the compressor unit **16** by a shaft **24**, as well as to the other apparatus (not shown) to be driven by the turbine engine. The compressor rotor **22** has a plurality of circumferentially-spaced blades **26** which, upon being driven by the turbine rotor **18**, draw air into the compressor from the compressor intake **28** and discharge compressed air into its output passage, schematically indicated at **30**. The compressor output passage **30** supplies compressed air to the upstream end of the combustor unit **12**.

The combustor unit **12** consists of an outer annular housing **32** and the arrows **34** represent compressed air being supplied to the upstream end of this housing for combustion therein with fuel so as to supply the combustion gases for reaction with the turbine blades **20** so as to drive the turbine rotor. The structure of the drawing so far described is conventional and forms no part of the present invention.

The combustor housing **32** is coaxial with the turbine rotor **18** and has a coaxial annular liner **36** and a dome-like liner or cap **38** over the upstream end of the turbine rotor **18**. A wall **40** is disposed across the upstream end of the annular liner **36** so that the liner **36**, cap **38** and wall **40** form a combustion chamber **42** therebetween. The downstream end of the chamber **42** has a coaxial annular discharge passage **44** having circumferentially-spaced guide or nozzle vanes **46** extending radially thereacross for directing the combustion gases toward the turbine blades **20** for driving the turbine. The combustion gases exhaust from the turbine through a duct **48** and thence in the case of a turbojet engine through a nozzle for providing the engine with forward thrust.

A fuel vaporizer unit **50** is coaxially supported at the upstream end of the combustion chamber **42** by its up-

stream wall or head plate **40**. As illustrated, the fuel vaporizer unit **50** has a multi-part construction comprising first and second hollow cylindrical members **52** and **54** coaxially secured together by a bolt **56** and an inner core and spacer element **58**. As shown, the first cylindrical member **52** is formed integral with the upstream wall **40** of the combustion chamber **42**, whereby the entire fuel vaporizer unit **50** is supported by this wall. The core **58** also serve to position the hollow cylindrical members **52** and **54** in axial and radial spaced relation relative to each other.

The first and second hollow cylindrical members **52** and **54** have axially extending coaxial annular walls **60** and **62**, respectively, said annular walls extending downstream from the combustion chamber upstream wall or head plate **40** in a downstream direction into the combustion chamber **42**. As illustrated, the annular wall **60** is radially spaced outwardly of the wall **62**. The inner annular wall **62** extends downstream beyond the outer annular wall **60** and at its downstream end has a portion **64** which turns radially outwardly beyond the wall **62** and then has an annular portion **66** which turns back on itself and overlaps the annular wall **60**. With this construction, the hollow cylindrical members **52** and **54** with their axially extending radially-spaced walls **60** and **62** form an annular passage **68** therebetween which extends through and downstream beyond the combustion chamber wall **40** and then at its downstream end turns radially outwardly and finally turns in an axial upstream direction so that its annular discharge end **70** faces toward the upstream wall **40** of the combustion chamber **42**.

The upstream wall of the hollow member **52** has a plurality of circumferentially-spaced openings **72** for admitting compressed air into the annular passage **68**. That is, a portion of the compressed air supplied to the combustion unit, as diagrammatically indicated by the arrows **34**, flows through the openings **72** into the annular passage **68** of the fuel vaporizer unit **50**.

A ring **74** is mounted about the annular wall **60**. Fuel for combustion in the combustion chamber **42** is supplied to the ring **74** by a fuel supply line schematically indicated at **76**. The fuel supply line terminates in an annular channel **78** on the inner surface of the ring **74**. The wall **60** has a plurality of circumferentially-spaced passages **80** therethrough communicating with the annular channel **78**, whereby fuel is discharged into the annular passage **68** from the passages **80**.

The upstream wall **40** of the combustion chamber **42** also has a plurality of circumferentially-spaced air passages **82** therethrough lying on a circle which is coaxial with and is disposed about the fuel vaporizer unit **50**. Each of the air passages **82** consists of a cup-shaped member **84**, the open end of which faces in an upstream direction through the wall **40**, each said cup-shaped member being supported by said wall. The circle on which the circumferentially-spaced, cup-shaped members lie is sufficiently greater in diameter than the outer diameter of the annular discharge opening **70** of the passage **68** so that each cup-shaped member **84** is entirely disposed radially outwardly of said outer diameter of the annular discharge opening **70**.

As best seen in FIG. 2A, each cup-shaped member **84** has a slot **86** across the bottom end of said member through which slot air discharges into the combustion chamber **42**. Each slot **86** preferably is disposed radial relative to the combustion chamber axis, as illustrated in FIG. 2, and extends through the bottom wall of its cup-shaped member **84** and also through diametrically opposed portions of the side wall of said cup-shaped member, thereby providing said member with air flow openings in both its bottom and side walls. Each cup-shaped member **84** may also have a plurality of circumferentially-spaced openings **88** in its side wall for additional lateral air flow therethrough.

The air supplied through the annular passage **68** and that supplied through the passages **82** provided by the cup-shaped member **84** is the primary air for combustion of the fuel in the combustion chamber **42**. The combustion chamber head plate or upstream wall **40** in effect provides a baffle which prevents compressed air from discharging directly into the combustion chamber other than through the annular passage **68** of the fuel vaporizer unit **50** and through the air passages **82**.

The fuel supplied to the annular passage **68** is carried along said passage by the air flow therethrough. The resulting air-fuel mixture in the passage **68** is fuel rich and discharges from the discharge end **70** of said passage toward the upstream wall **40** of the combustion chamber. The wall **40** turns this fuel-air mixture radially outwardly for mixture with the remaining primary air supplied through the passages **82** provided by the cup-shaped members **84**. This fuel-air mixture is ignited by a suitable igniter, schematically indicated at **90**, for combustion within the combustion chamber **42**. The heat of combustion in the chamber **42** serves to pre-heat and vaporize the fuel in the annular passage **68** as it is carried along this passage by the air flow therethrough, whereby the fuel is pre-heated, vaporized and thoroughly mixed with the air in this passage before it is discharged from the passage end **70** into the combustion chamber **42**.

In order to ensure good mixture of the fuel-air mixture discharging from the annular passage **68** with the remaining primary air discharging from the cup-shaped members **84**, the downstream end of each cup-shaped member **84** preferably, as illustrated, is disposed upstream of the discharge end **70** of the annular passage **68**. Since the discharge slots **86** across the bottom ends of the cup-shaped members **84** are radially disposed relative to the axis of the vaporizer unit **50**, the air discharging from these slots comprises radially-oriented, fan-shaped streams of air discharging from the cup-shaped members **84**. As a result, there is a circumferentially-spaced plurality of fan-shaped jets of air surrounding the vaporizer unit **50**. These fan-shaped jets entrain the fuel rich mixture discharging from the end **70** of the vaporizer unit passage **68** with the result that combustion occurs along the edges of said fan-shaped jets. Since the fuel mixture flowing through the vaporizer unit passage **68** is pre-heated, vaporized and thoroughly mixed with the air flowing through this passage before it discharges from the end **70** of this passage, ignition delay time in the combustion chamber **42** is substantially reduced. This reduction in ignition delay time minimizes the length of time the fuel-air mixture must remain in the combustion chamber **42** for combustion to be complete. Hence, the present invention also minimizes the required length of the combustion chamber for complete combustion.

In order to cool the combustion chamber annular liner **36** and cap liner **38** and to cool the combustion gases themselves, secondary air is introduced into the combustion chamber **42** through said liners, as indicated by the arrows **92, 94** and **96**. For this purpose, said liners may be made of porous or perforated material to permit such air flow therethrough. In addition, the turbine nozzle vanes **46** are made hollow to provide air flow therethrough into the space between the cap liner **38** and the turbine rotor **18**. In this way, the combustion chamber **42** is provided with secondary air for cooling the combustion gases and for cooling the annular liner **36** and cap liner **38**. The detailed constructions of the liners **36** and **38** form no part of the present invention. These liners may have a multi-part, perforated construction similar to the construction of the combustion chamber liners in aforementioned U.S. Pat. No. 3,376,676.

The embodiment of FIGS. 1 and 2 provides a combustion chamber **42** of a cannular configuration. FIG. 3 is a partial view similar to FIG. 1 but showing a modification in which the combustion chamber has an annular configuration. The embodiment of FIG. 3 is otherwise

like that of FIGS. 1 and 2 and, for ease of understanding, those parts of FIG. 3 corresponding to parts of FIGS. 1 and 2 have been indicated by like reference numerals but with a subscript *a* added.

In FIG. 3 the cap liner **38** of FIG. 1 has been replaced by an inner annular liner **98**, the upstream end of which is connected to the outer downstream edge of the fuel vaporizer unit **50***a*. This gives the combustion chamber **42***a* an annular configuration instead of the cannular configuration of FIG. 1. The remaining structure of FIG. 3 is like that of FIG. 1 and therefore no further description of FIG. 3 appears necessary, its operation being essentially the same as FIG. 1.

FIGS. 4 and 5 illustrate a further embodiment in which the combustor unit surrounds the turbine shaft. The embodiment of FIGS. 4 and 5 is otherwise generally similar to FIG. 3 and, for ease of understanding, those parts of FIGS. 4 and 5 corresponding to parts of FIG. 3 have been indicated by like reference numerals but with a subscript *b* added.

In FIG. 4 the combustion chamber **42***b* is annular as in FIG. 3 but in FIG. 4 this chamber surrounds the turbine shaft **24***b*. In addition, the shaft **24***b* is connected to the rotor **22***b* of an axial flow-type compressor instead of the centrifugal-type compressor of FIGS. 1 and 3.

The fuel vaporizer unit **50***b* in FIG. 4 differs from that of FIGS. 1 and 3 in that the turbine shaft **24***b* passes through the unit **50***b*. The inner annular wall **62***b* of the annular fuel-air passage **68***b* surrounds the shaft **24***b* in radially-spaced relation so as to provide an annular passage **100** therebetween. With this arrangement, secondary air is supplied inwardly of the combustion chamber liner **98***b* through said annular passage **100**. Accordingly, with the arrangement of FIG. 4, the turbine nozzle vanes **46***b* need not be hollow to provide secondary air to the inner side of the liner **98***b*, as is necessary in FIGS. 1 and 3.

In FIG. 4 circumferentially-spaced vanes **102** are provided across the upstream end of the annular fuel-air passage **68***b*. These vanes preferably have a helical orientation about the axis of the passage **68***b*, as best indicated in FIG. 5, so as to impart a swirl component to the air entering the passage **68***b* about the axis of said passage. In addition, the fuel passages **80***b* preferably are also inclined relative to the axis of the passage **68***b* so as to impart a swirl component to the fuel about the axis of said passage in the same direction as the air swirl component. This inclination of the fuel passages **80***b* is also best seen in FIG. 5. The swirling motion of the fuel and air as it flows through the passage **68***b* promotes more thorough mixing of the fuel and air flowing therethrough. Obviously, similar means may be provided in FIG. 1 to provide for a swirling flow component for the fuel and air in the passage **68** about the axis of said passage and such means may also be included in FIG. 3.

Except for the swirling flow motion of the fuel and air in the passage **68***b* about the axis of said passage, the operation of FIGS. 4 and 5 is essentially that of FIGS. 1 and 3 and therefore no further description of FIGS. 4 and 5 is necessary.

Reference is now made to FIG. 6. This embodiment is like that of FIG. 4 in that the combustion chamber surrounds the turbine shaft and the turbine shaft extends coaxially through the fuel vaporizer unit. For ease of understanding, the parts of FIG. 6 corresponding to parts of FIG. 4 have been indicated by the same reference numerals but with a subscript *c* added.

FIG. 6 differs primarily from FIG. 4 in that the downstream end of the inner annular wall **62***c* of the annular passage **68***c* of the vaporizer unit **50***c* is formed by a rotating annular wall portion or slinger **110**. The slinger **110** has a hub portion secured to the turbine shaft **24***c* as by a nut **114**. Also, for structural reasons, the wall portions **60***c*, **62***c* and **66***c* are interconnected by a plurality of circumferentially-speced ribs **116** and **118**. These ribs may have a helical orientation like the vanes **102** of FIG. 4 for imparting a swirl component to the air-fuel mixture flowing through the passage **68***c*. Also, for fabrication reasons, the wall portion **60***c* has a multi-part construction, as illustrated.

The annular slinger **110** has a concave profile on its inner side facing the shaft **24***b*. The fuel passage or passages **80***c* are disposed to discharge fuel into the space between this concave side of the slinger **110** into shaft **24***b*. As a result of rotation of the slinger and the resulting centrifugal forces, the fuel collects in an annulus on the inner concave side of the slinger. A plurality of circumferentially-spaced holes **120** are provided radially through the slinger **110** so that this fuel discharges radially outwardly therethrough into the passage **68***c*, said fuel discharging through said holes under the action of the centrifugal forces acting thereon. In this way the fuel is discharged in a plurality of fine spray jets into the passage **68***c* where it is promptly vaporized by heat from combustion in the combustion chamber **42***c*.

It should be noted that the portion of the slinger **110** having the holes **120** in effect forms a downstream portion of the inner wall **62***c* of the annular passage **68***c*. Also, in FIG. 6, the vanes **46***c* are made hollow, as in FIGS. 1 and 3, in order that secondary air be supplied therethrough to the inner side of the inner annular combustion chamber liner **98***c*.

Except for the manner in which fuel is discharged into the annular passage **68***c*, the operation of the combustion structure of FIG. 6 is essentially like that of FIG. 4. Hence, no further description of FIG. 6 is necessary.

While we have described our invention in detail in its present preferred embodiments, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. We aim, in the appended claims, to cover all such modifications.

What is claimed is:

1. Combustion structure comprising:

(a) a casing forming a combustion chamber having an annular discharge opening at its downstream end and having a wall coaxial with said opening disposed across the upstream end of said chamber;

(b) means providing an annular air passage extending through said wall for supplying air therethrough, said annular air passage being coaxially disposed relative to said chamber discharge opening with the inner wall of said passage extending axially in a downstream direction beyond its outer wall and turning radially outwardly and then reversing in an upstream direction radially outwardly of said outer wall to overlap at least a portion of said outer wall so that said annular passage first extends downstream and then turns radially outwardly and back on itself, whereby its annular discharge opening faces in an upstream direction toward said upstream chamber wall;

(c) means for introducing fuel into the downstream extending portion of said annular air passage so that fuel discharges from said annular passage in an upstream direction toward said wall for combustion in said chamber with air also discharging from said passage;

(d) said wall having a plurality of air opening means for providing additional air for combustion with said fuel, said air opening means being circumferentially spaced about said annular passage on a circle which is coaxial with said passage and which has a diameter greater than the outer diameter of the annular discharge opening of said passage;

(e) each of said air opening means comprising a cup-shaped member having its mouth end opening through said wall and in which the sides and bottom of each cup-shaped member have openings for air

to discharge therethrough, the bottom of each cup-shaped member being disposed closer to said wall than the discharge end of said annular passage;

(f) the circle on which the centers of the cup-shaped members lie being sufficiently greater in diameter than the outer diameter of the discharge opening of the annular passage so that each cup-shaped member is entirely disposed radially outwardly of said outer diameter of said annular discharge opening.

2. Combustion structure as defined in claim 1 for a turbine engine having a shaft coaxial with said annular air passage, at least a portion of the inner wall of said annular air passage being rotatably connected to said shaft, said portion being concave on its inner surface and having a plurality of radial holes therethrough, said concave portion having a lip at its upstream end extending radially inward, the fuel supplied to said annular passage being supplied to the inner side of said concave wall portion for discharge through said holes into said passage by centrifugal action.

3. Combustion structure as recited in claim 1 and in which each cup-shaped member has a slot-like opening across its bottom and is disposed generally radial to the circle on which the cup-shaped members are disposed.

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U.S. Cl. X.R.

60—39.65, 39.74