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(54) **ROTARY INTERNAL COMBUSTION ENGINE WITH COOLED INSERT**

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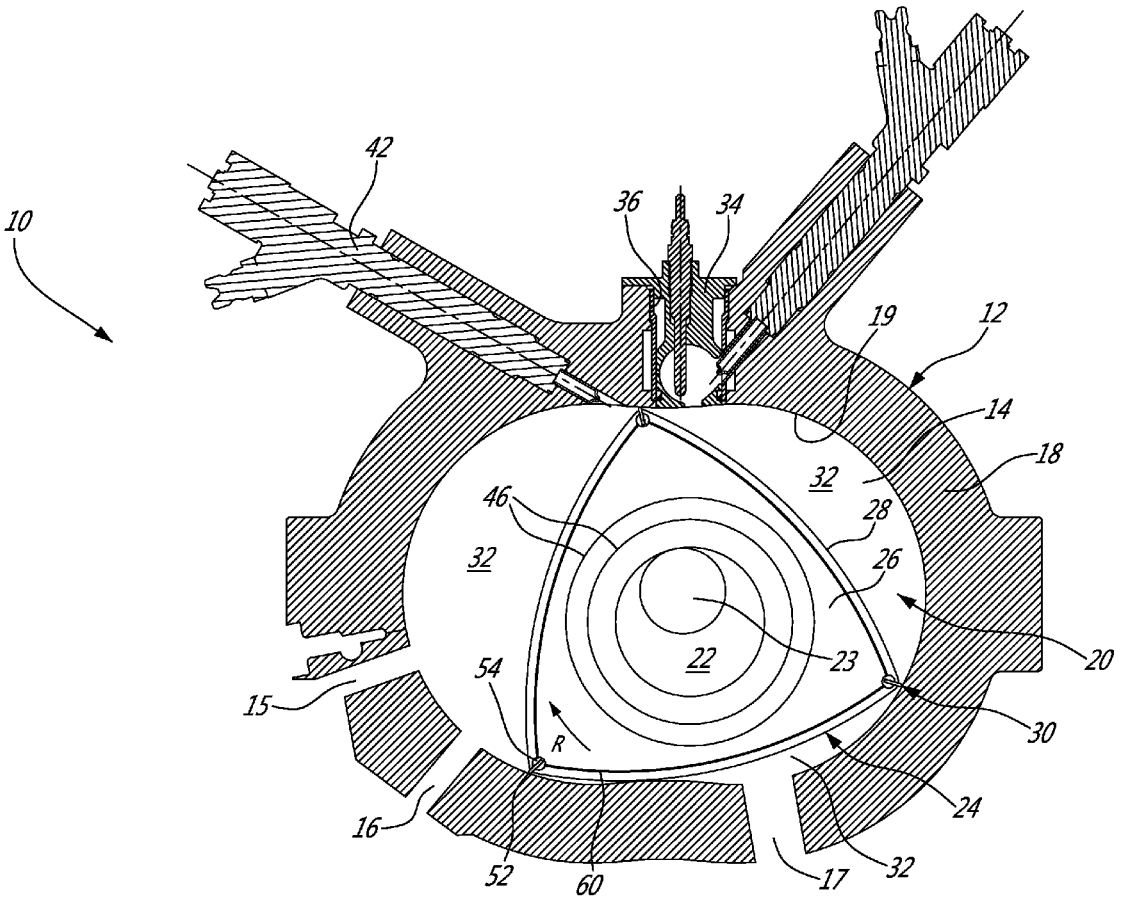
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(57) **ABSTRACT**

A rotary internal combustion engine having an insert opening defined in a hot area of one of the walls of the stator body and in communication with its internal cavity. A cooling jacket is received in and lines the insert opening. An insert is sealingly received in the cooling jacket and made of a material having a greater heat resistance than that of the wall. The cooling jacket extends between the insert and the wall along most of the length of the insert to prevent direct contact between the insert and the wall. A cooling gallery surrounds the cooling jacket and the insert, and is defined at least in part by the cooling jacket such that a coolant circulated therein contacts the cooling jacket. The cooling jacket is located between the cooling gallery and the insert.



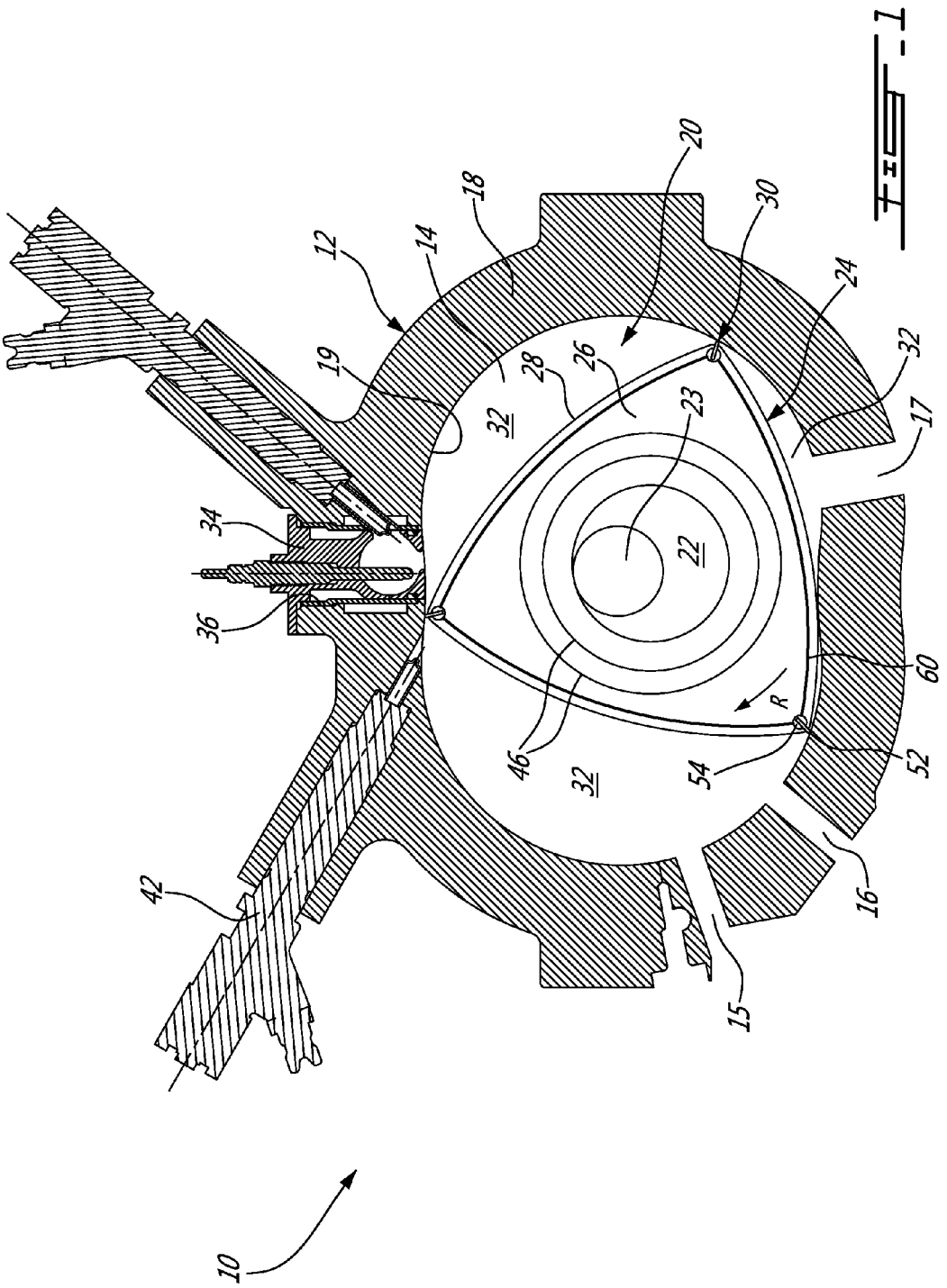


FIG - 1

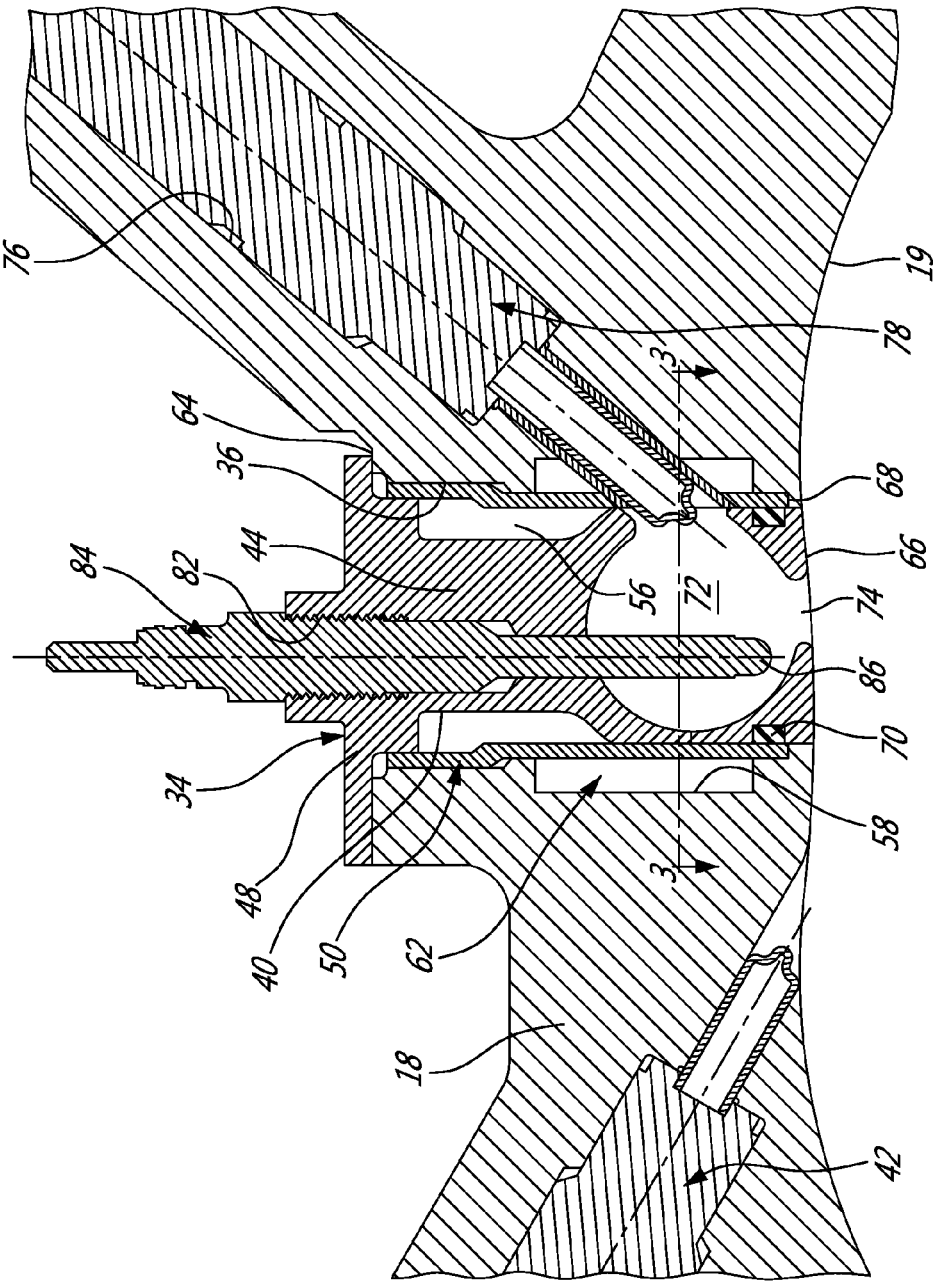


FIG. 2

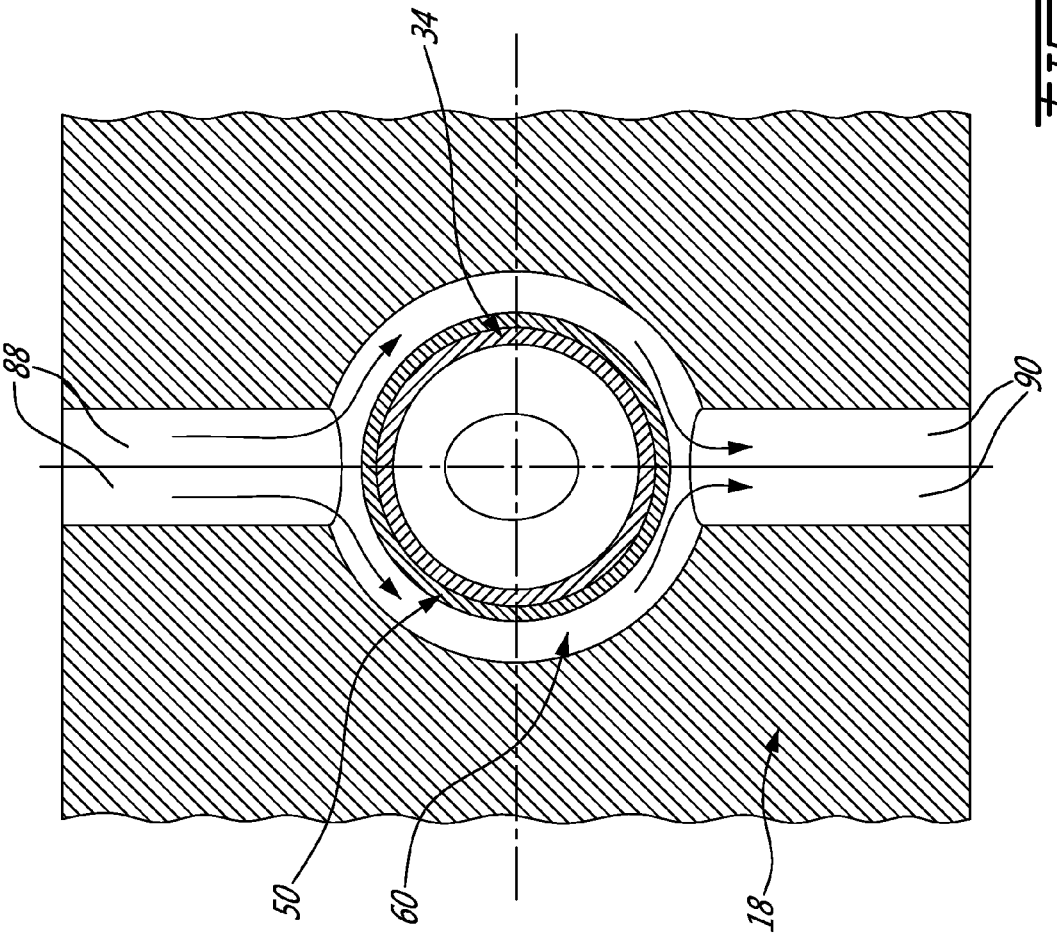


FIG. 3

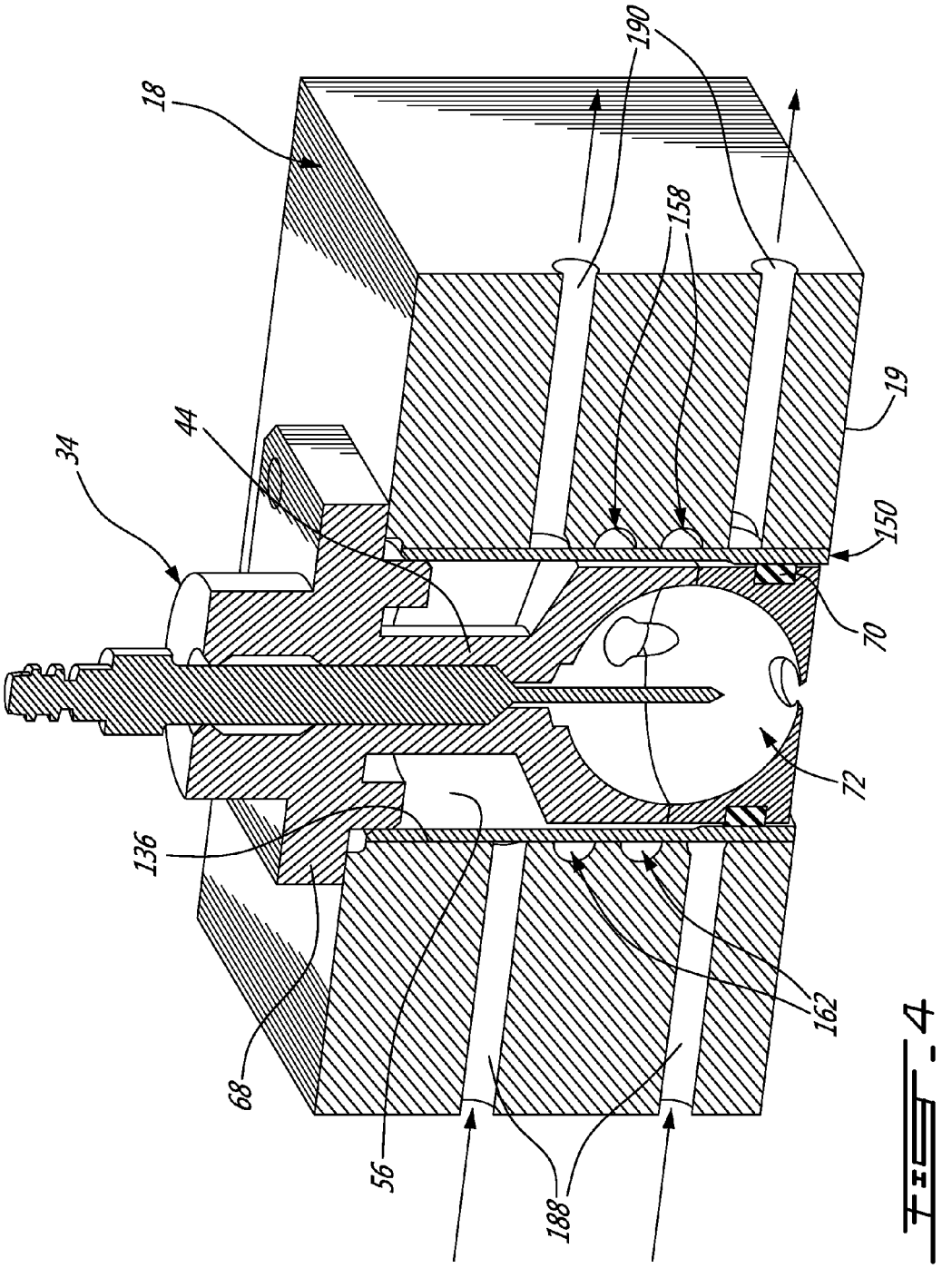


FIG. 4

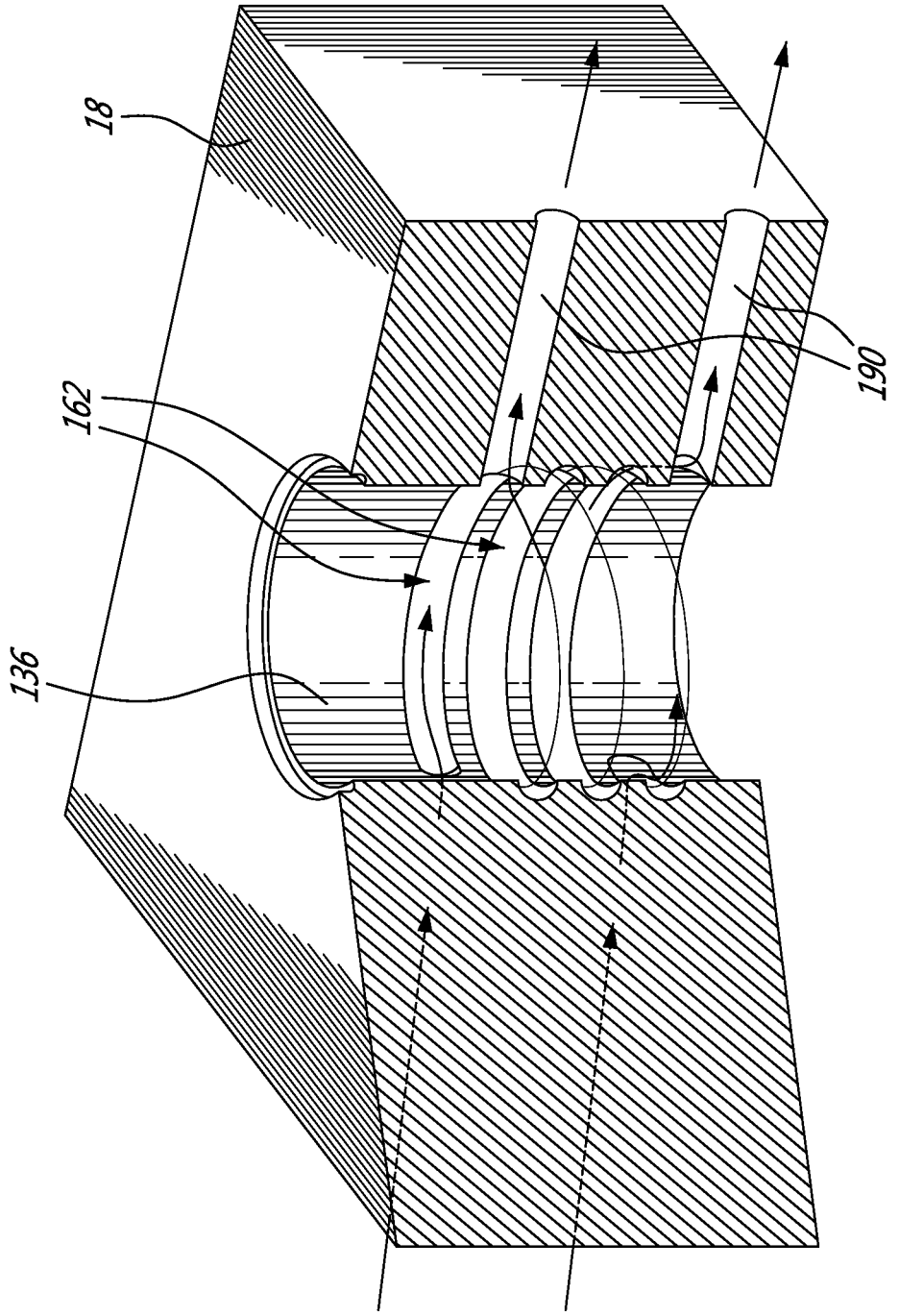


FIG. 5

ROTARY INTERNAL COMBUSTION ENGINE WITH COOLED INSERT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims is a continuation of U.S. application Ser. No. 13/366,458 filed on Feb. 6, 2012, the entire contents of which are incorporated by reference herein.

TECHNICAL FIELD

[0002] The application relates generally to a rotary internal combustion engine, more particularly, to the cooling of an insert in such engines.

BACKGROUND OF THE ART

[0003] Rotary engines, such as for example Wankel engines, use the eccentric rotation of a piston to convert pressure into a rotating motion, instead of using reciprocating pistons. In these engines, the rotor includes a number of apex or seal portions which remain in contact with a peripheral wall of the rotor cavity of the engine throughout the rotational motion of the rotor to create a plurality of rotating chambers when the rotor rotates.

[0004] The stator body of a rotary engine may include high temperature inserts in locally hot areas. Such inserts are typically cooled by providing an air gap around the insert. However in some cases cooling through the surrounding air gap may be insufficient to protect the remainder of the body from the high temperature of the insert.

SUMMARY

[0005] In one aspect, there is provided a rotary internal combustion engine comprising: a stator body having an internal cavity enclosed by a plurality of walls, one of the walls having an insert opening defined across a thickness of the one of the walls in a hot area thereof and in communication with the internal cavity, a rotor body received within the internal cavity and sealingly engaged with the walls to define at least one chamber undergoing intake, compression, expansion and exhaust phases as the movable body moves; a cooling jacket received in and lining the insert opening; an insert sealingly received in the cooling jacket, the insert being made of a material having a greater heat resistance than that of the one of the walls, the insert having a length defined along the thickness of the one of the walls, the cooling jacket extending between the insert and the one of the walls along most of the length of the insert to prevent direct contact between the insert and the one of the walls; and a cooling gallery surrounding the cooling jacket and the insert, the cooling gallery defined at least in part by the cooling jacket such that a coolant circulated therein contacts the cooling jacket, the cooling jacket located between the cooling gallery and the insert.

[0006] In another aspect, there is provided a stator body for a Wankel engine comprising: two axially spaced apart end walls; a peripheral wall extending between the end walls and defining an internal cavity therewith, the cavity having an epitrochoid shape defining two lobes; a cooling jacket lining an opening defined in a hot area of one of the walls of the rotor body, the opening being in communication with the internal cavity; an insert made of a material having a greater heat resistance than that of the walls and sealingly received in the opening with the cooling jacket surrounding the insert, the insert having a length defined along the thickness of the one of the walls, and wherein along most of the length of the insert, the cooling jacket extends between the insert and the one of the walls to prevent direct contact between the insert and the one of the walls; and at least one cooling gallery defined around and bordered by the cooling jacket, the cooling gallery surrounding the insert with the cooling jacket being located between the cooling gallery and the insert.

DESCRIPTION OF THE DRAWINGS

[0007] Reference is now made to the accompanying figures in which:

[0008] FIG. **1** is a schematic cross-sectional view of a rotary internal combustion engine in accordance with a particular embodiment;

[0009] FIG. **2** is a schematic cross-sectional view of an insert and surrounding cooling arrangement of the engine of FIG. **1**;

[0010] FIG. **3** is a schematic cross-sectional view of the insert of FIG. **2** taken along lines **3-3** thereof;

[0011] FIG. **4** is a schematic tridimensional cross-sectional view of an insert and surrounding cooling arrangement according to an alternate embodiment; and

[0012] FIG. **5** is a schematic tridimensional cross-sectional view of the portion of the stator body shown in FIG. **4** with the insert and cooling jacket omitted.

DETAILED DESCRIPTION

[0013] Referring to FIG. **1**, a rotary internal combustion engine **10** known as a Wankel engine is schematically and partially shown. In a particular embodiment, the rotary engine **10** is used in a compound cycle engine system such as described in Lents et al.'s U.S. Pat. No. 7,753,036 issued Jul. 13, 2010 or as described in Julien et al.'s U.S. Pat. No. 7,775,044 issued Aug. 17, 2010, the entire contents of both of which are incorporated by reference herein. The compound cycle engine system may be used as a prime mover engine, such as on an aircraft or other vehicle, or in any other suitable application. In such a system, air is compressed by a compressor before entering the Wankel engine, and the engine drives one or more turbine(s) of the compound engine. In another embodiment, the rotary engine **10** is used without a turbocharger, with air at atmospheric pressure.

[0014] The engine **10** comprises an outer body **12** having axially-spaced end walls **14** with a peripheral wall **18** extending therebetween to form a rotor cavity **20**. The inner surface **19** of the peripheral wall **18** of the cavity **20** has a profile defining two lobes, which is preferably an epitrochoid.

[0015] An inner body or rotor **24** is received within the cavity **20**, with the geometrical axis of the rotor **24** being offset from and parallel to the axis of the outer body **12**. The rotor **24** has axially spaced end faces **26** adjacent to the outer body end walls **14**, and a peripheral face **28** extending therebetween. The peripheral face **28** defines three circumferentially-spaced apex portions **30** and a generally triangular profile with outwardly arched sides. The apex portions **30** are in sealing engagement with the inner surface **19** of the peripheral wall **18** to form three rotating working chambers **32** between the inner rotor **24** and outer body **12**. A recess (not shown) is defined in the peripheral face **28** of the rotor **24** between each pair of adjacent apex portions **30**, to form part of the corresponding chamber **32**.

[0016] The working chambers **32** are sealed. Each rotor apex portion **30** has an apex seal **52** extending from one end

face **26** to the other and protruding radially from the peripheral face **28**. Each apex seal **52** is biased radially outwardly against the peripheral wall **18** through a respective spring. An end seal **54** engages each end of each apex seal **52**, and is biased against the respective end wall **14** through a suitable spring. Each end face **26** of the rotor **24** has at least one arc-shaped face seal **60** running from each apex portion **30** to each adjacent apex portion **30**, adjacent to but inwardly of the rotor periphery throughout its length. A spring urges each face seal **60** axially outwardly so that the face seal **60** projects axially away from the adjacent rotor end face **26** into sealing engagement with the adjacent end wall **14** of the cavity. Each face seal **60** is in sealing engagement with the end seal **54** adjacent each end thereof.

[0017] The rotor **24** is journaled on an eccentric portion **22** of a shaft **23** and includes a phasing gear (not shown) co-axial with the rotor axis, which is meshed with a fixed stator phasing gear secured to the outer body co-axially with the shaft. The shaft rotates the rotor **24** and the meshed gears guide the rotor **24** to perform orbital revolutions within the rotor cavity. The rotor **24** performs three rotations for each orbital revolution. Oil seals **46** are provided around the phasing gear to prevent leakage flow of lubricating oil radially outwardly thereof between the respective rotor end face **26** and outer body end wall **14**.

[0018] At least one intake port **15**, **16** is defined through one of the end walls **14** or the peripheral wall **18** for admitting air (atmospheric or compressed) into one of the working chambers **32**, and at least one exhaust port **17** is defined through one of the end walls **14** or the peripheral wall **18** for discharge of the exhaust gases from the working chambers **32**. For example, in the embodiment shown, a primary intake port **15** and a secondary intake port **16** as well as the exhaust port **17** are all defined through the peripheral wall **18**. The intake and exhaust ports **15**, **16**, **17** are positioned such that during one orbital revolution of the rotor **24**, each chamber **32** moves around the rotor cavity **20** with a variable volume to undergo the four phases of intake, compression, expansion and exhaust, these phases being similar to the strokes in a reciprocating-type internal combustion engine having a four-stroke cycle. The peripheral wall **18** receives a main fuel injector **42** therethrough extending in communication with the rotor cavity **20**.

[0019] A high temperature insert **34** is received in a corresponding opening **36** defined through the peripheral wall **18** of the outer body **12**, the opening **36** being defined in communication with the rotor cavity **20** in a high temperature region of the outer body **12**. In the embodiment shown, the insert **34** defines a subchamber for pilot fuel injection and ignition, and is located forwardly of the main injector **42** with respect to the direction R of the rotor rotation and revolution.

[0020] Referring particularly to FIG. **2**, the insert includes an elongated body **44** extending across a thickness of the peripheral wall **18**. The insert body **44** includes an enlarged flange **48** at its outer end which abuts the outer surface **64** of the peripheral wall **18** and is connected thereto, for example through bolts with appropriate sealing such as a gasket or crush seal (not shown), brazing, etc. The insert body **44** has an inner surface **66** which is aligned with the inner surface **19** of the peripheral wall **18** to define the cavity **20**. The insert body **44** is made of a material having a greater heat resistance (e.g. is able to resist a higher temperature without substantial loss of mechanical properties, has a higher maximum recommended operating temperature) than that of the peripheral wall **18**, which in a particular embodiment is made of aluminium. In a particular embodiment, the insert body **44** is made of an appropriate type of high temperature alloy such as a Nickel based super alloy. In a particular embodiment, the insert body **44** is made of a material which can be used in temperatures of at least 2000° F. (1093° C.). In a particular embodiment, the insert body **44** is made of a material which can be used in temperatures of at least 2200° F. (1204° C.).

[0021] The insert body **44** has a pilot subchamber **72** defined therein in communication with the rotor cavity **20**. In the embodiment shown, the subchamber **72** has a circular cross-section; alternate shapes are also possible. The subchamber **72** communicates with the cavity through at least one opening **74** defined in the inner surface **66**. The subchamber **72** has a shape forming a reduced cross-section adjacent the opening **74**, such that the opening **74** defines a restriction to the flow between the subchamber **72** and the cavity **20**. The opening **74** may have various shapes and/or be defined by a pattern of multiple holes.

[0022] The peripheral wall **18** has a pilot injector elongated hole **76** defined therethrough, at an angle with respect to the insert **34** and in communication with the subchamber **72**. A pilot fuel injector **78** is received and retained within the corresponding hole **76**, with the tip **80** of the pilot injector **78** being received in the subchamber **72**. In a particular embodiment the pilot injector **78** and main injector **42** inject heavy fuel, e.g. diesel, kerosene (jet fuel), equivalent biofuel, etc. into the chambers **32**.

[0023] The insert body **44** also has an ignition element elongated hole **82** defined therein, also in communication with the subchamber **72**. An ignition element **84** is received and retained within the corresponding hole **82**, with the tip **86** of the ignition element **84** being received in the subchamber **72**. In the embodiment shown, the ignition element **84** is a glow plug. Alternate types of ignition elements **84** which may be used include, but are not limited to, plasma ignition, laser ignition, spark plug, microwave, etc.

[0024] In the embodiment shown, the insert body **44** has a circular groove **40** defined in its outer surface between the flange **48** and the subchamber **72**, the purpose of which will be further detailed below. Although the insert body **44** is shown has being made of a single piece, it can alternately include two or more complementary pieces made of the same or different materials.

[0025] An annular cooling jacket **50** lines the insert opening **36** and surrounds the insert **34** across most of the thickness of the peripheral wall **18**. In a particular embodiment, the cooling jacket **50** is made of steel. In the embodiment shown, a wall flange **68** extends in the insert opening **36** adjacent the inner surface **19**, and the cooling jacket **50** abuts the surface of the wall flange **68** opposite the inner surface **19**. The cooling jacket **50** is connected to the peripheral wall **18**, for example by being brazed or welded thereto. The insert **34** is sealingly received within the cooling jacket **50**, and a gasket **70** is provided between the cooling jacket **50** and the insert body **44** adjacent the wall flange **68**. The cooling jacket **50** extends close to the insert outer flange **48**, and as such extends between the peripheral wall **18** and the insert **34** across most of the length of the insert body **44**. The cooling jacket **50** thus helps reduce direct contact between the insert body **44** and the peripheral wall **18**. An annular air gap **56** is formed around the insert body **44** by the cooperation of the circular groove **40** of the insert body **44** and of the cooling jacket **50**.

[0026] The wall of the insert opening **36** also has a circular groove **58** defined therein, aligned with part of the subchamber **72** and extending around the cooling jacket **50**. The circular groove **58** and cooling jacket **50** cooperate to define an annular cooling gallery **62**. In the embodiment shown, the cooling gallery **62** has a rectangular cross-section, but other cross-sectional shapes are also possible. As can be seen from FIG. **3**, the cooling gallery **62** is in communication with one or more coolant inlet channels **88** and one or more coolant outlet channels **90** defined through the peripheral wall **18**. The inlet and outlet channels **88**, **90** may communicate with other coolant channels (not shown) defined through other portions of the engine outer body **12** such as to be part of a same coolant distribution network; alternately, the insert **34** may be independently cooled.

[0027] In use, a flow of coolant circulates within the cooling gallery **62** around the cooling jacket **50** to cool the jacket **50** and limit heat transfer to the engine outer body **12**. In a particular embodiment, the coolant is water. Other adequate types of cooling fluids can alternately be used.

[0028] Referring to FIGS. **4-5**, an insert **34** and cooling arrangement according to an alternate embodiment is shown. The insert **34** is as previously described and as such will not be described further herein. In this embodiment, the wall flange is omitted, and the cooling jacket **150** extends up to the inner surface **19** of the peripheral wall **18**. The wall of the insert opening **136** includes two alternating helical grooves **158** defined around the cooling jacket **150** in alignment with part of the subchamber **72**. The helical grooves **158** and cooling jacket **150** cooperate to define two helical cooling galleries **162** (e.g. configured like a two-start worm screw) around the cooling jacket **150**. In the embodiment shown, the cooling galleries **162** have a semi-circular cross-section, but other cross-sectional shapes are also possible. Each cooling gallery **162** is in communication with a coolant inlet channel **188** and with a coolant outlet channel **190** defined through the peripheral wall **18**, such that coolant flow circulates within each cooling gallery **162** around the cooling jacket **150**. The two coolant inlet channels **188** may be in communication with different cooling fluid source or with a same cooling fluid source.

[0029] Alternate configurations for the cooling gallery(ies) **62**, **162** are also possible, including but not limited to galleries defined by a single helical channel and by multiple annular channels.

[0030] In an alternate embodiment, a similar insert may be used to define another hot area of the stator body **12**, for example the exhaust port **17**. In a particular embodiment, the insert is an annular element with inner walls defining the exhaust port **17**. The insert may be made for example of a high temperature alloy, or may alternately be made of steel if the temperature around the exhaust port **17** is within acceptable limits for the use of steel. The insert is sealingly received in a cooling jacket **50**, **150** as described above, and the cooling jacket is received in a corresponding opening of the engine outer body **12** which communicates with the rotor cavity **20**. The opening may be defined in the peripheral wall **18**, such as for the exhaust port **17** shown in FIG. **1**, or in one of the end walls **14** in the case of an axial exhaust port. The cooling gallery(ies) **62**, **162** may have any appropriate configuration, included but not limited to the configurations shown in FIG. **3** and FIGS. **4-5**.

[0031] In another alternate embodiment, the insert is used to retain an additional ignition element, or the main ignition element in the case of an engine without a pilot subchamber. The insert is shaped to retain the ignition element in a desired orientation and is sealingly received in a cooling jacket **50**, **150** as described above, and the cooling jacket is received in a corresponding opening of the engine outer body **12** which communicates with the rotor cavity **20**. The cooling gallery (ies) **62**, **162** may have any appropriate configuration, included but not limited to the configurations shown in FIG. **3** and FIGS. **4-5**.

[0032] The use of the insert, cooling jacket and cooling gallery(ies) may help to provide a more uniform and efficient cooling system for the high temperature area, which may in turn help improve the durability of the base material of the engine outer body **12**. The more uniform and efficient cooling may also allow for the use of lighter low temperature materials as the base material for the engine outer body **12**. For example, in a particular embodiment where the insert is used to define a pilot subchamber, temperatures within the insert may be about 2300° F. (1260° C.) while temperatures within the engine outer body **12**, for example made of aluminium, may remain below 500° F. (260° C.).

[0033] The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the invention(s) disclosed. For example, the mechanical arrangement of the Wankel engine described above is merely one example of many possible configurations which are suitable for use with the present invention(s). Moreover, the insert, cooling jacket and cooling gallery(ies) may be used in other types of internal combustion engines, including but not limited to other types of rotary engines. The insert, cooling jacket and cooling gallery(ies) may be used in other hot areas of the stator body. Hence, modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

1. A rotary internal combustion engine comprising:

a stator body having an internal cavity enclosed by a plurality of walls, one of the walls having an insert opening defined across a thickness of the one of the walls in a hot area thereof and in communication with the internal cavity,

a rotor body received within the internal cavity and sealingly engaged with the walls to define at least one chamber undergoing intake, compression, expansion and exhaust phases as the movable body moves;

a cooling jacket received in and lining the insert opening;

an insert sealingly received in the cooling jacket, the insert being made of a material having a greater heat resistance than that of the one of the walls, the insert having a length defined along the thickness of the one of the walls, the cooling jacket extending between the insert and the one of the walls along most of the length of the insert to prevent direct contact between the insert and the one of the walls; and

a cooling gallery surrounding the cooling jacket and the insert, the cooling gallery defined at least in part by the cooling jacket such that a coolant circulated therein contacts the cooling jacket, the cooling jacket located between the cooling gallery and the insert.

2. The engine as defined in claim **1**, wherein the one of the walls has at least one coolant inlet channel and at least one

coolant outlet channels defined therethrough in fluid communication with the cooling gallery.

3. The engine as defined in claim **1**, wherein the plurality of walls of the stator body include two axially spaced apart end walls and a peripheral wall extending between the end walls, the internal cavity having an epitrochoid shape defining two lobes, and the rotor body has three circumferentially spaced apex portions, the rotor body being engaged to an eccentric portion of a shaft to rotate and perform orbital revolutions within the cavity with each of the apex portions remaining in sealing engagement with the peripheral wall and separating three rotating chambers of variable volume defined in the cavity around the rotor body.

4. The engine as defined in claim **3**, wherein the insert opening is defined in the peripheral wall.

5. The engine as defined in claim **4**, wherein the insert has a subchamber defined therein and an inner surface bordering the cavity, the subchamber communicating with the cavity through at least one opening defined in the inner surface, the insert receiving a tip of a pilot fuel and of an ignition element within the subchamber, the cooling gallery being defined around the subchamber.

6. The engine as defined in claim **1**, wherein the insert is made of a high temperature metal alloy.

7. The engine as defined in claim **1**, wherein the cooling gallery is annular.

8. The engine as defined in claim **1**, wherein the cooling gallery is helical.

9. The engine as defined in claim **1**, wherein the insert has a groove defined around a perimeter thereof, the cooling jacket cooperating with the groove to define an air channel around the insert and between the insert and the cooling jacket.

10. The engine as defined in claim **1**, wherein the cooling jacket is brazed or welded to the at least one wall within the insert opening.

11. A stator body for a Wankel engine comprising:

two axially spaced apart end walls;

a peripheral wall extending between the end walls and defining an internal cavity therewith, the cavity having an epitrochoid shape defining two lobes;

a cooling jacket lining an opening defined in a hot area of one of the walls of the rotor body, the opening being in communication with the internal cavity;

an insert made of a material having a greater heat resistance than that of the walls and sealingly received in the opening with the cooling jacket surrounding the insert, the insert having a length defined along the thickness of the one of the walls, and wherein along most of the length of the insert, the cooling jacket extends between the insert and the one of the walls to prevent direct contact between the insert and the one of the walls; and

at least one cooling gallery defined around and bordered by the cooling jacket, the cooling gallery surrounding the insert with the cooling jacket being located between the cooling gallery and the insert.

12. The stator body as defined in claim **11**, wherein the stator body includes at least one coolant inlet channel and at least one coolant outlet channel in communication with each cooling gallery.

13. The stator body as defined in claim **11**, wherein the opening is defined in the peripheral wall.

14. The stator body as defined in claim **13**, wherein the insert has a subchamber defined therein and an inner surface bordering the internal cavity, the subchamber communicating with the internal cavity through at least one opening defined in the inner surface, at least one of the insert and the peripheral wall having a pilot fuel injector elongated hole defined therethrough communicating with the subchamber and sized to receive a pilot fuel injector therein, and at least one of the insert and the peripheral wall having an ignition element elongated hole defined therethrough communicating with the subchamber and sized to receive an ignition element therein.

15. The stator body as defined in claim **11**, wherein the insert is made of a high temperature metal alloy.

16. The stator body as defined in claim **11**, wherein the at least one cooling gallery includes an annular cooling gallery surrounding the cooling jacket.

17. The stator body as defined in claim **11**, wherein the at least one cooling gallery includes at least one helical cooling gallery defined around the cooling jacket.

18. The stator body as defined in claim **11**, wherein the insert has a groove defined around a perimeter thereof, the cooling jacket cooperating with the insert groove to define an air channel around the insert and between the insert and the cooling jacket.

19. The stator body as defined in claim **11**, wherein the cooling jacket is brazed or welded to the at least one wall within the opening.

* * * * *