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(54) **GAS SEAL ARRANGEMENT FOR ROTARY INTERNAL COMBUSTION ENGINE**

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(51) **Int. Cl.**

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F01C 1/22	(2006.01)
F01C 19/08	(2006.01)
F01C 21/08	(2006.01)

(52) **U.S. Cl.**

CPC ***F01C 19/005*** (2013.01); ***F01C 19/02*** (2013.01); ***F01C 1/22*** (2013.01); ***F01C 19/08*** (2013.01); ***F01C 21/08*** (2013.01); *F04C 2240/80* (2013.01); ***F01C 19/085*** (2013.01)

USPC **418/116**; 123/200; 418/117; 418/119; 418/120; 418/121; 418/141; 418/61.2

(58) **Field of Classification Search**

CPC F01C 19/005; F01C 19/085; F01C 19/02; F01C 1/22; F01C 19/08; F01C 21/08; F04C 2240/80

USPC 123/200; 418/113, 116, 117, 119, 120, 418/121, 123, 124, 142, 141, 61.2; 29/888.012

See application file for complete search history.

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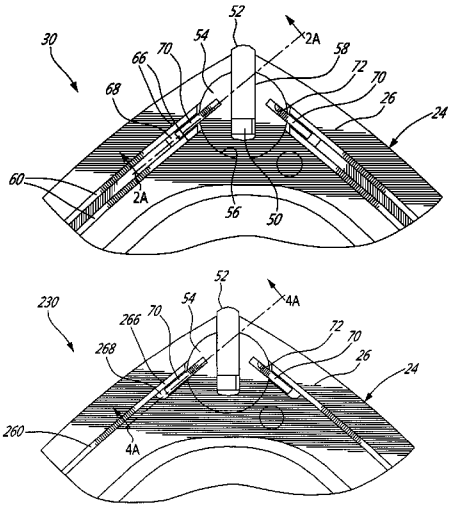
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(57) **ABSTRACT**

A rotor of a rotary internal combustion engine, with each of the end faces having at each of the apex portions a recess defined therein in communication with the at least one apex groove, an end seal received in the recess in sealing engagement with the apex seal of each of the at least one apex groove, a first seal member in sealing engagement with the end seal and with the face seal of the face groove defined between the apex portion and a first one of the adjacent apex portions, and a second seal member in sealing engagement with the end seal and with the face seal of the face groove defined between the apex portion and a second one of the adjacent apex portions.

20 Claims, 4 Drawing Sheets



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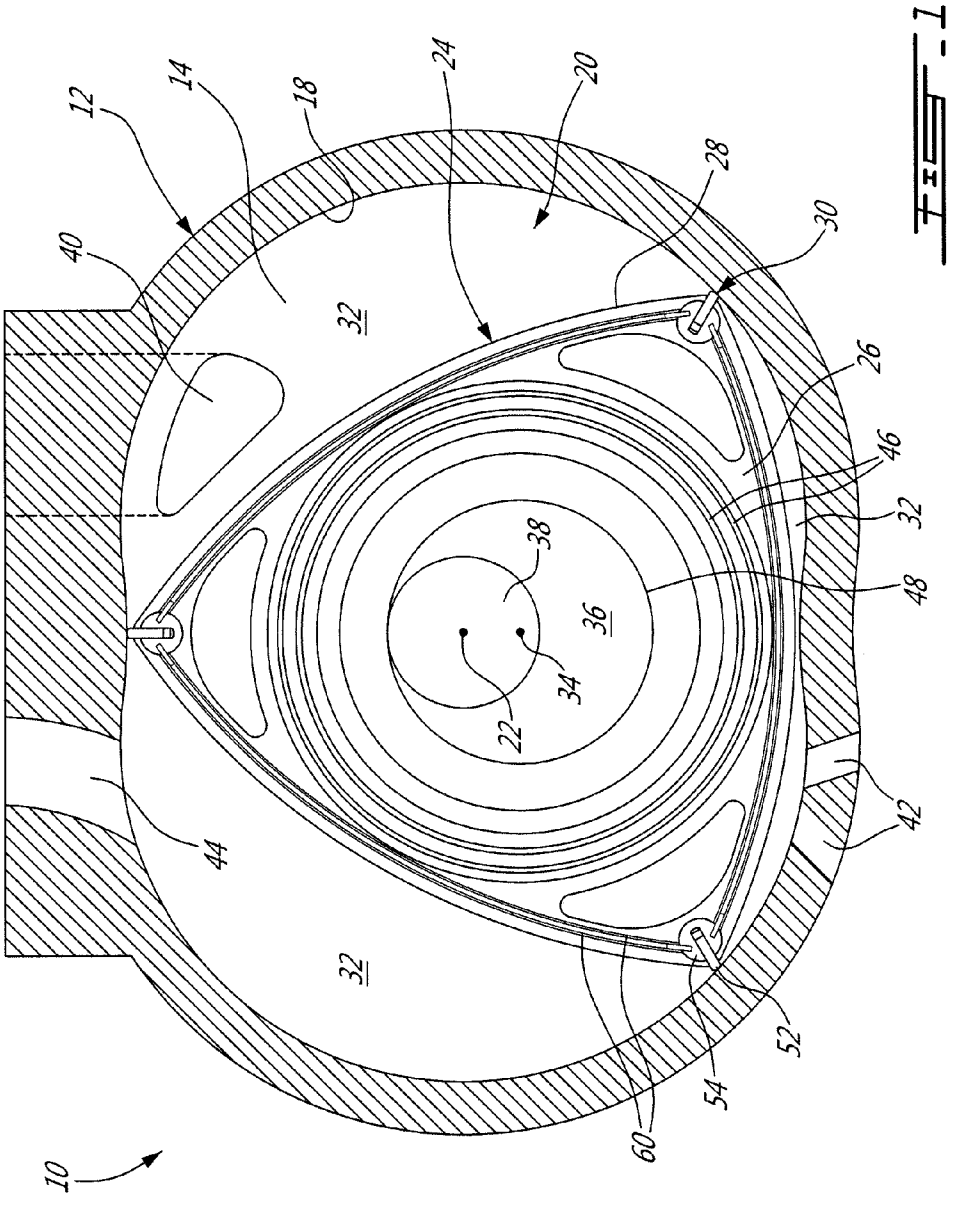


FIG. 1

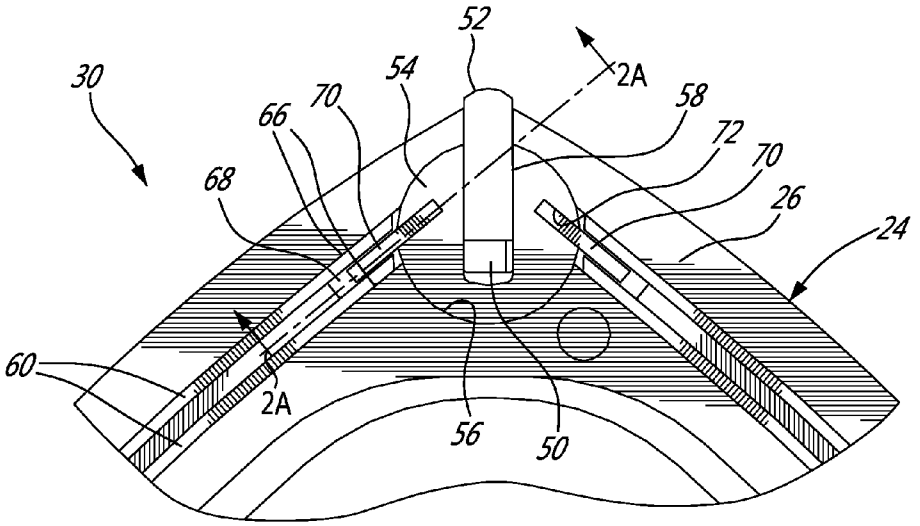


Fig. 2

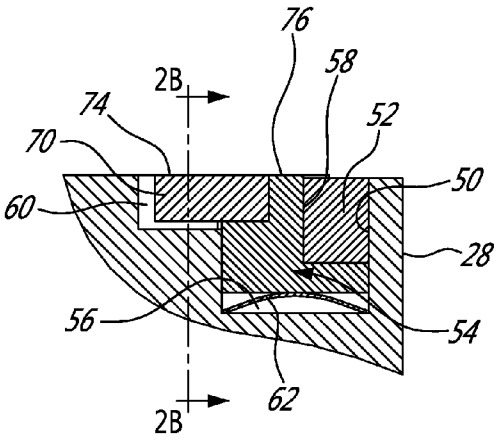


Fig. 2A

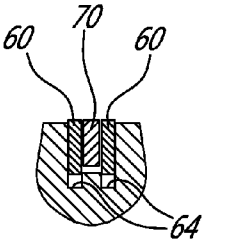


Fig. 2B

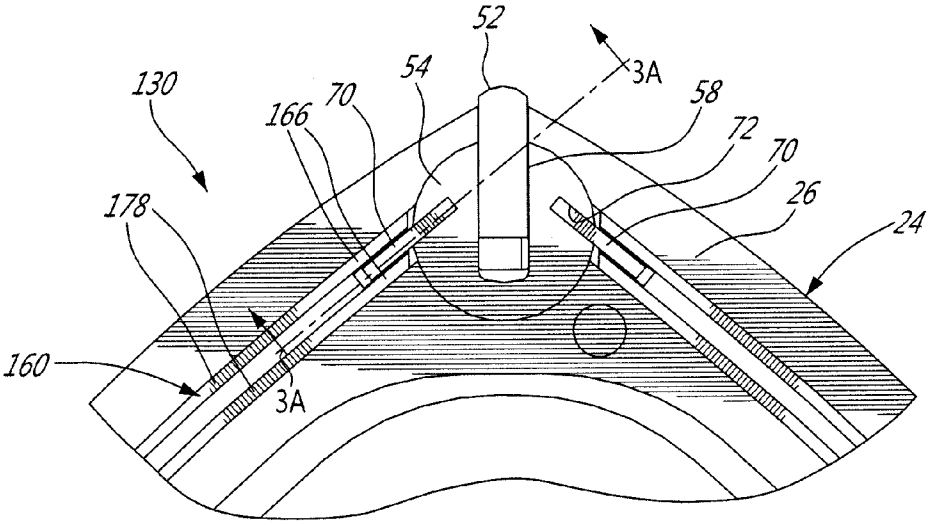


FIG. 3

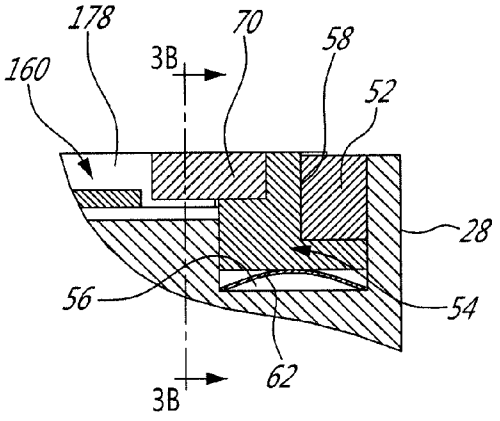


FIG. 3A

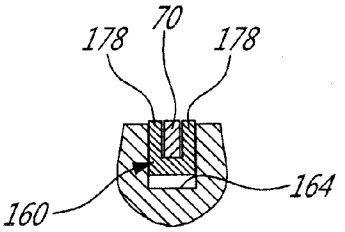


FIG. 3B

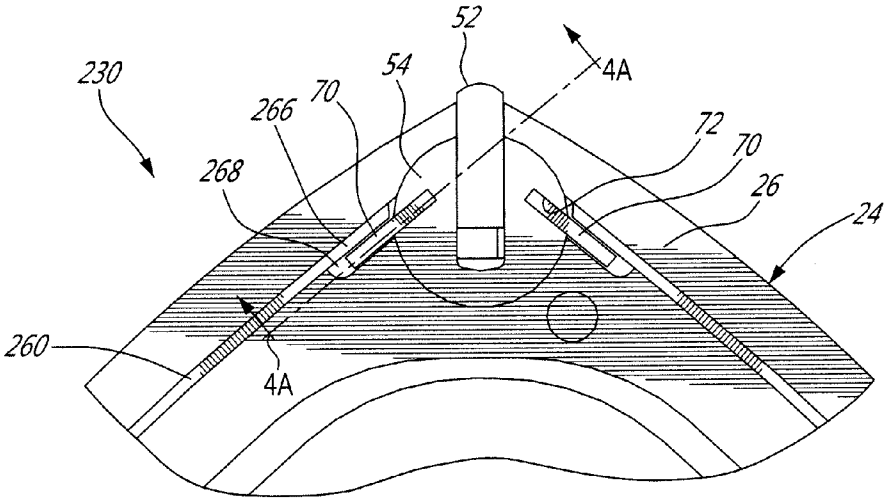


FIG. 4

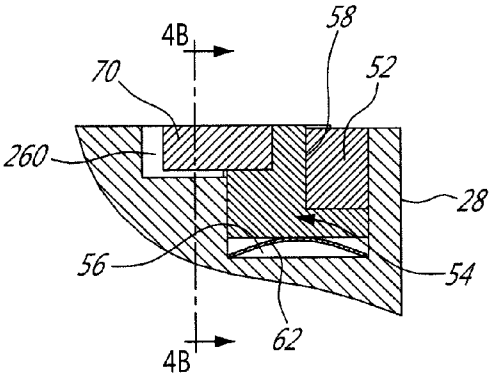


FIG. 4A

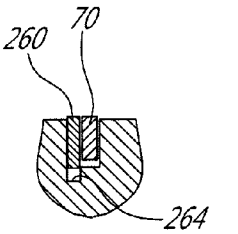


FIG. 4B

GAS SEAL ARRANGEMENT FOR ROTARY INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority on provisional U.S. application No. 61/512,483 filed Jul. 28, 2011, the entire contents of which are incorporated by reference herein.

TECHNICAL FIELD

The application relates generally to an internal combustion engine using a rotary design to convert pressure into a rotating motion, more particularly, to a gas seal arrangement for such an engine.

BACKGROUND OF THE ART

Rotary engines such as the ones known as 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 portions which remain in contact with a peripheral wall of the rotor cavity of the engine throughout the rotational motion of the rotor.

The space around the rotor within the rotor cavity defines a number of working chambers which must be sealed from one another in order for the engine to work efficiently. The working chambers must also be sealed from the oil exposed central portion of the rotor cavity. Prior art sealing arrangements typically have gaps between some of the adjacent seal members, which may be due to manufacturing tolerances and/or differential thermal expansions of the seal elements and rotor.

In particular, it is known to provide apex seals along the apex portions and face seals along end faces of the rotor which are interconnected through intermediate or end seals. However, the manufacturing tolerances of the face seal may result in undesirable gaps at their junction with the end seals.

SUMMARY

In one aspect, there is provided a rotor of a rotary internal combustion engine, the rotor comprising a body having two axially spaced apart end faces, and a peripheral face extending between the end faces and defining three circumferentially spaced apex portions, each of the apex portions having at least one apex groove defined radially inwardly into the rotor body and extending between the end faces, each of the at least one apex groove having an apex seal received therein biased radially away from the peripheral face, each of the end faces having a face groove defined therein between each of the apex portions and each adjacent one of the apex portions, each face groove extending axially inwardly into the rotor body and having a face seal received therein biased axially away from the end face, and each of the end faces having at each of the apex portions a recess defined therein in communication with the at least one apex groove, an end seal received in the recess in sealing engagement with the apex seal of each of the at least one apex groove, a first seal member in sealing engagement with the end seal and with the face seal of the face groove defined between the apex portion and a first one of the adjacent apex portions, and a second seal member in sealing engagement with the end seal and with the face seal of the face groove defined between the apex portion and a second one of the adjacent apex portions.

In another aspect, there is provided a rotary internal combustion engine comprising a stator body having an internal cavity defined by two axially spaced apart end walls and a peripheral wall extending between the end walls, the cavity having an epitrochoid shape defining two lobes, a rotor body having two axially spaced apart end faces each extending in proximity of a respective one of the end walls of the stator body, and a peripheral face extending between the end faces and defining three circumferentially spaced apex portions, the rotor body being engaged to an eccentric shaft to rotate within the cavity with each of the apex portions remaining adjacent the peripheral wall, each of the apex portion having at least one apex seal extending between the end faces and protruding radially from the peripheral face, each apex seal being radially biased against the peripheral surface, each of the end faces having a face seal extending between each of the apex portions and each adjacent one of the apex portions, each face seal protruding axially from the end face and being axially biased against the respective one of the end walls, and each of the end faces having at each of the apex portions an end seal in sealing engagement with the at least one apex seal, a first seal member in sealing engagement with the end seal and with the face seal extending between the apex portion and a first one of the adjacent apex portions, and a second seal member in sealing engagement with the end seal and with the face seal extending between the apex portion and a second one of the adjacent apex portions.

In a further aspect, there is provided a method of sealing a junction between an end seal of an apex portion of a rotor of a Wankel engine and at least one face seal extending from an adjacent apex portion of the rotor, the method comprising connecting a feather seal to one of the end seal and the at least one face seal, and sealingly engaging the feather seal with the other of the end seal and the at least one face seal.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying figures in which:

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

FIG. **2** is a schematic enlarged view of an apex portion of a rotor of the engine of FIG. **1**;

FIG. **2**A is a schematic cross-sectional view taken along line **2**A-**2**A of FIG. **2**;

FIG. **2**B is a schematic cross-sectional view taken along line **2**B-**2**B of FIG. **2**A;

FIG. **3** is a schematic enlarged view of an apex portion of a rotor in accordance with an alternate embodiment;

FIG. **3**A is a schematic cross-sectional view taken along line **3**A-**3**A of FIG. **3**;

FIG. **3**B is a schematic cross-sectional view taken along line **3**B-**3**B of FIG. **3**A;

FIG. **4** is a schematic enlarged view of an apex portion of a rotor in accordance with another alternate embodiment;

FIG. **4**A is a schematic cross-sectional view taken along line **4**A-**4**A of FIG. **4**; and

FIG. **4**B is a schematic cross-sectional view taken along line **4**B-**4**B of FIG. **4**A.

DETAILED DESCRIPTION

Referring to FIG. **1**, a rotary internal combustion engine **10** known as a Wankel engine is schematically shown. The engine **10** comprises an outer body **12** having axially-spaced end walls **14** with a peripheral wall **18** extending therebe-

tween to form a rotor cavity **20**. The inner surface of the peripheral wall **18** of the cavity **20** has a profile defining two lobes, which is preferably an epitrochoid.

An inner body or rotor **24** is received within the cavity **20**. 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. As will be detailed further below, the apex portions **30** are in sealing engagement with the inner surface of peripheral wall **18** to form three working chambers **32** between the inner rotor **24** and outer body **12**. The geometrical axis **34** of the rotor **24** is offset from and parallel to the axis **22** of the outer body **12**.

In the embodiment shown, the outer body **12** is stationary while the rotor **24** is journaled on an eccentric portion **36** of a shaft **38**, the shaft **38** being co-axial with the geometrical axis **22** of the cavity **20**. Upon rotation of the rotor **24** relative to the outer body **12** the working chambers **32** vary in volume. An intake port **40** is provided through one of the end walls **14** for admitting air, or air and fuel, into one of the working chambers **32**. Passages **42** for a spark plug or other ignition mechanism, as well as for one or more fuel injectors (not shown) are provided through the peripheral wall **18**. An exhaust port **44** is also provided through the peripheral wall **18** for discharge of the exhaust gases from the working chambers **32**. Alternately, the exhaust port **44** and/or the passages **42** may be provided through the end wall **14**, and/or the intake port **40** may be provided through the peripheral wall **18**.

During engine operation the working chambers **32** have a cycle of operation including 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.

At least one oil seal ring **46** is disposed in a circular groove in each end face **26** of the rotor between the bearing **48** for the rotor **24** on the shaft eccentric **36** and the face seals. Each oil seal **46** prevents leakage flow of lubricating oil radially outwardly thereof between the respective rotor end face **26** and outer body end wall **14**. Suitable springs (not shown) are provided for urging each oil seal **46** axially into contact with the adjacent end wall **14** of the outer body **12**.

For efficient engine operation the working chambers **32** are sealed by apex seals, face seals and end seals.

Referring to FIGS. **2**-**2**A, each rotor apex portion **30** has a groove **50** defined therein and extending radially inwardly into the rotor body **24**, from one end face **26** to the other. An apex seal **52** is received within each groove **50**, and protrudes radially from the peripheral face **28**. In a particular embodiment, each apex seal **52** extends axially beyond both end faces **26**, and has an axial dimension which is as close as possible to a distance between the two end walls **14** of the cavity **20**, taking into consideration the difference in thermal expansion between the material(s) of the outer body **12** and the material of the apex seal **52**, which in a particular embodiment is made of a suitable type of ceramic. In a particular embodiment, each apex seal **52** is monolithic, i.e. is formed of a single seal member. Alternately, each apex seal **52** may be formed of two or more cooperating seal members. More than one apex seal **52** may also be provided on each apex portion **30**. Each apex seal **52** is biased radially outwardly against the peripheral wall **18** through a respective spring (not shown).

An end seal **54** is received within a respective cylindrical recess **56** defined at each end of the groove **50**. Each end seal **54** has a radial slot **58** defined therein, which receives the respective end of the apex seal **52**. Each end seal **54** is biased against the respective end wall **14** through a suitable spring **62** (FIG. **2**A).

Referring to FIGS. **1**-**2**, each end face **26** of the rotor **24** has two radially spaced apart grooves **64** (FIG. **2**B) defined therein running between each pair of adjacent apex portions **30**, with a face seal **60** being received within each groove **64**. In a particular embodiment, each face seal **60** is monolithic. Each end face groove **64** and corresponding face seal **60** are arc-shaped and disposed adjacent to but inwardly of the rotor periphery throughout their length. A spring (not shown) located behind each face seal **60** urges it 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 **20**.

As can be seen more clearly in FIG. **2**, each face seal **60** extends with each end **66** in close proximity to or in abutment with the adjacent end seal **54**. As such, two face seals **60** extend between each pair of adjacent end seals **54** received on the same end face **26**. The adjacent end face grooves **64** extending between the same apex portions **30** merge together near each recess **56**, forming an opposed enlarged groove **68** in communication with the adjacent recess **56** at each end of the grooves **64**. Each end **66** of each face seal **60** extends into the respective enlarged groove **68** near the corresponding end seal **54**.

As shown in FIGS. **2**-**2**A-**2**B, the junction between the end seal **54** and each pair of adjacent face seals **60** which extend from the same apex portion **30** is sealed by a thin seal member which in the embodiment shown in a feather seal **70**. The feather seal **70** is partly received in a corresponding groove **72** defined in the end seal **54** and extends into the enlarged groove **68**, between the two ends **66** of the adjacent face seals **60**. Each feather seal **70** sealingly engages the end seal **54** and the adjacent face seals **60**. Two feather seals **70** thus extend from each of the end seals **54**, one in direction of each of the adjacent apex portions **30**.

In the embodiment shown, the feather seals **70** are each attached or connected to the end seal **54** and extend freely between the corresponding face seals **60**. In a particular embodiment, the feather seals **70** are permanently connected to the end seal **54**, for example through welding or brazing. Alternately, the feather seals **70** may be attached or connected, for example permanently connected, to one of the face seals **60** and be slidably received within the respective groove **72** of the end seal **54**. The feather seals **70** are machined such as to have an axially outer surface **74** aligned with that of the seal they are attached or connected to (here outer surface **76** of the end seal **54**, see FIG. **2**A).

In a particular embodiment, the feather seals **70**, face seals **60** and end seals **54** are made of a same metal, for example cast iron.

Referring to FIGS. **3**-**3**A-**3**B, an alternate embodiment is shown, where each end face **26** of the rotor **24** has a single groove **164** and face seal **160** extending between each pair of adjacent apex portions **30**. Each face seal **160** has a U-shaped cross section defining two radially spaced knife edges **178** protruding axially from the end face **26**. The feather seals **70** each extend from the corresponding groove **72** of the end seal **54** and between the ends **166** of the two knife edges **178** of the respective face seal **160**. The feather seals **70** may be attached or connected, for example permanently connected through brazing or welding, to the end seal **54** or to one of the knife edges **178** of the respective face seal **160**.

Referring to FIGS. **4**-**4**A-**4**B, an alternate embodiment is shown, where each end face **26** of the rotor **24** has a single groove **264** and face seal **260** extending between each pair of

adjacent apex portions **30**. Each face seal **260** is in the form of a single fin. The feather seals **70** each extend from the corresponding groove **72** of the end seal **54**, into an enlarged portion **268** of the end face groove **264** receiving the end **266** of the face seal **260**, and beyond the end **266** of the respective seal **260**, i.e. in radial overlap therewith. In this embodiment, the feather seals **70** are permanently connected to the end seal **54**, although connection with the respective face seal **260** is alternately possible.

The end seals **54**, face seals **60**, **160**, **260** and feather seals **70** thus cooperate to form a seal against the respective end wall **14** around the perimeter of the rotor **24**. Improved sealing along the end wall **14** reduces leakage of the hot gas into the oil system, which may improve performance of the engine, reduce the oil temperature, and/or reduce the oil contamination by the combustion by-products.

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 disclosed. 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.

The invention claimed is:

1. A rotor of a rotary internal combustion engine, the rotor comprising:

a body having two axially spaced apart end faces, and a peripheral face extending between the end faces and defining three circumferentially spaced apex portions, each of the apex portions having at least one apex groove defined radially inwardly into the rotor body and extending between the end faces, each of the at least one apex groove having an apex seal received therein biased radially away from the peripheral face;

each of the end faces having at least one face groove defined therein between each of the apex portions and each adjacent one of the apex portions, each face groove extending axially inwardly into the rotor body, and a plurality of face seals each received in one of the face grooves and biased axially away from the end face; and

each of the end faces having at each of the apex portions:

a recess defined therein in communication with the at least one apex groove,

an end seal received in the recess in sealing engagement with the apex seal of each of the at least one apex groove,

a first seal member in sealing engagement with and extending from the end seal in a direction of a first one of the adjacent apex portions, the first seal member extending between two ends of at least one of the face seals, and

a second seal member in sealing engagement with and extending from the end seal in a direction of a second one of the adjacent apex portions, the second seal member extending between two ends of at least another one of the face seals.

2. The rotor as defined in claim **1**, wherein the first and second seal members are feather seals.

3. The rotor as defined in claim **1**, wherein each of the first and second seal members is attached to the end seal and free of the face seals.

4. The rotor as defined in claim **1**, wherein the first seal member is attached to the at least one of the face seals, and the second seal member is attached to the at least another one of the face seals.

5. The rotor as defined in claim **1**, wherein the at least one face groove defined between each of the apex portions and each adjacent one of the apex portions includes two radially spaced apart face grooves so that the at least one of the face seals includes two radially spaced apart first face seals and the at least another one of the face seals includes two radially spaced apart second face seals, the first seal member extending between the ends of the two first face seals, and the second seal member extending between the ends of the two second face seals.

6. The rotor as defined in claim **5**, wherein each of the first and second seal members is attached to the end seal and free of the face seals.

7. The rotor as defined in claim **1**, wherein the at least one face groove defined between each of the apex portions and each adjacent one of the apex portions includes a single face groove so that the at least one of the face seals includes one first face seal and the at least another one of the face seals includes one second face seal, each face seal having a U-shaped cross section defining two knife edges protruding axially from the end face and defining the two ends, the first seal extending between the knife edges of the first face seal, and the second seal member extending between the knife edges of the second face seal.

8. The rotor as defined in claim **1**, wherein each end seal has a first groove defined therein receiving an end of the first seal member and a second groove defined therein receiving an end of the second seal member.

9. A rotary internal combustion engine comprising:

a stator body having an internal cavity defined by two axially spaced apart end walls and a peripheral wall extending between the end walls, the cavity having an epitrochoid shape defining two lobes;

a rotor body having two axially spaced apart end faces each extending in proximity of a respective one of the end walls of the stator body, and a peripheral face extending between the end faces and defining three circumferentially spaced apex portions, the rotor body being engaged to an eccentric shaft to rotate within the cavity with each of the apex portions remaining adjacent the peripheral wall;

each of the apex portion having at least one apex seal extending between the end faces and protruding radially from the peripheral face, each apex seal being radially biased against the peripheral surface;

each of the end faces having a plurality of face seals with at least one of the face seals extending between each of the apex portions and each adjacent one of the apex portions, each face seal protruding axially from the end face and being axially biased against the respective one of the end walls; and

each of the end faces having at each of the apex portions:

an end seal in sealing engagement with the at least one apex seal,

a first seal member in sealing engagement with and extending from the end seal in a direction of a first one of the adjacent apex portions, the first seal member extending between two ends of at least one of the face seals, and

a second seal member in sealing engagement with and extending from the end seal in a direction of a second one of the adjacent apex portions, the second seal member extending between two ends of at least a another one of the face seals.

10. The engine as defined in claim **9**, wherein the first and second seal members are feather seals.

11. The engine as defined in claim 9, wherein each of the first and second seal members is attached to the end seal and free of the at least one face seal.

12. The engine as defined in claim 9, wherein the first seal member is attached to the at least one face seals, and the second seal member is attached to the at least another one of the face seals.

13. The engine as defined in claim 9, wherein the face seals include two radially spaced apart face seals extending between each of the apex portions and each adjacent one of the apex portions so that the at least one of the face seals includes two first face seals and the at least another one of the face seals includes two second face seals, the first seal member extending between the ends of the two first face seals, and the second seal member extending between the ends of the two second face seals.

14. The engine as defined in claim 13, wherein each of the first and second seal members is attached to the end seal and free of the first and second face seals.

15. The engine as defined in claim 9, wherein the face seals include a single face seal extending between each of the apex portions and each adjacent one of the apex portions so that the at least one of the face seals includes one first face seal and the at least another one of the face seals includes one second face seal, each face seal having a U-shaped cross section defining two knife edges protruding axially from the end face and defining the two ends, the first seal extending between the knife edges of the first face seal, and the second seal member extending between the knife edges of the second face seal.

16. The engine as defined in claim 9, wherein each end seal has a first groove defined therein receiving an end of the first seal member and a second groove defined therein receiving an end of the second seal member.

17. A method of sealing a junction between an end seal of an apex portion of a rotor of a Wankel engine and at least one face seal extending from an adjacent apex portion of the rotor, the method comprising:

sealingly engaging one end of a feather seal with the end seal;

inserting another end of the feather seal between two ends defined by the at least one face seal; and

connecting the feather seal to one of the end seal and the at least one face seal.

18. The method as defined in claim 17, wherein connecting the feather seal includes welding or brazing the feather seal.

19. The method as defined in claim 17, wherein the junction is defined between an end seal and two face seals extending from the adjacent apex portion, connecting the feather seal includes connecting the one end of the feather seal to the end seal, and the other end of the feather seal is inserted between the two face seals.

20. The method as defined in claim 17, wherein the junction is defined between an end seal and a single faces seal extending from the adjacent apex portion, connecting the feather seal includes connecting the one end of the feather seal to the end seal, and the other end of the feather seal is inserted between two axially extending knife edges of the face seal.

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