Dec. 3, 1963 M. BENTELE 3,112,870

AIR COOLED ROTOR FOR ROTARY MECHANISM

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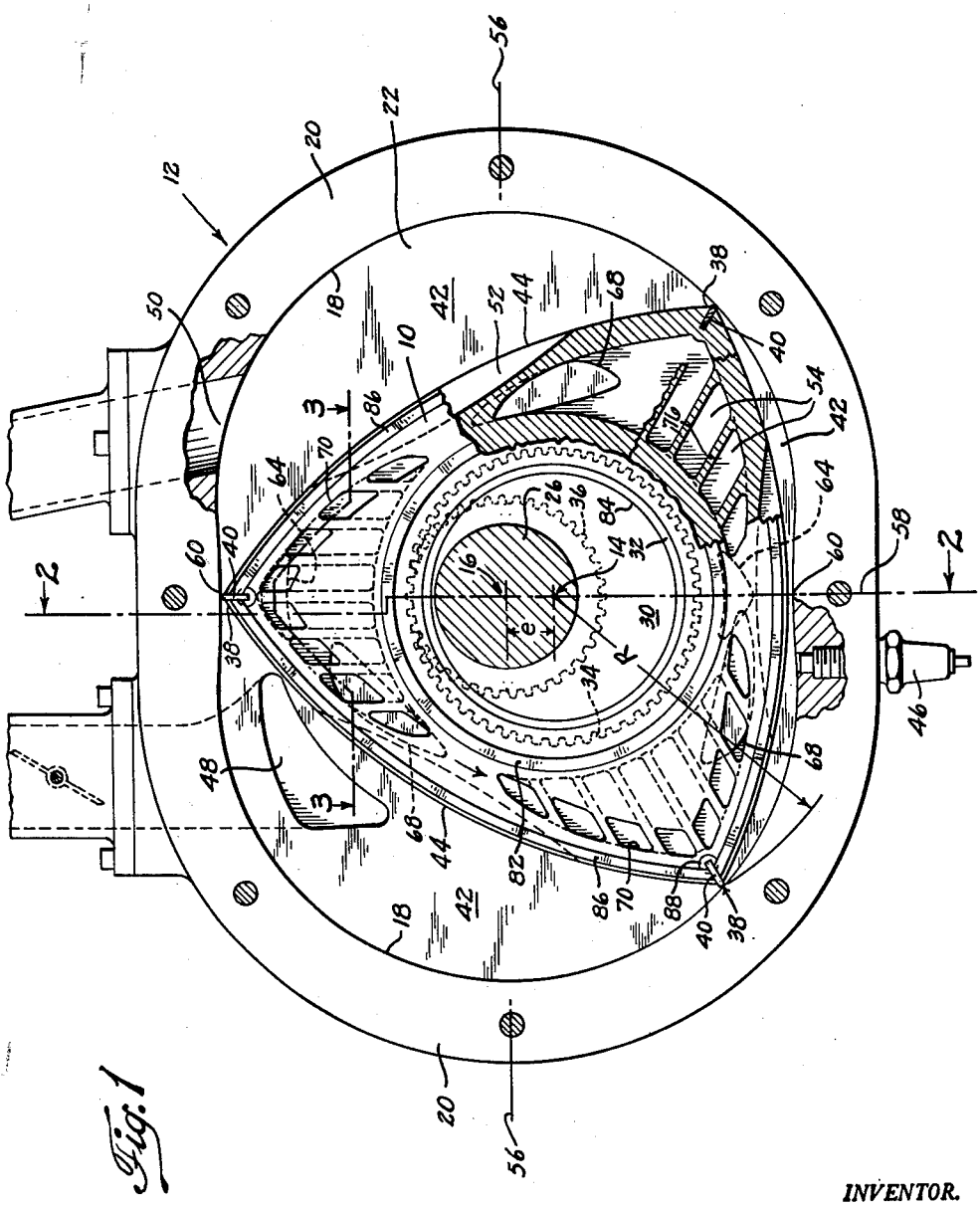


Fig. 1

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Fig. 3

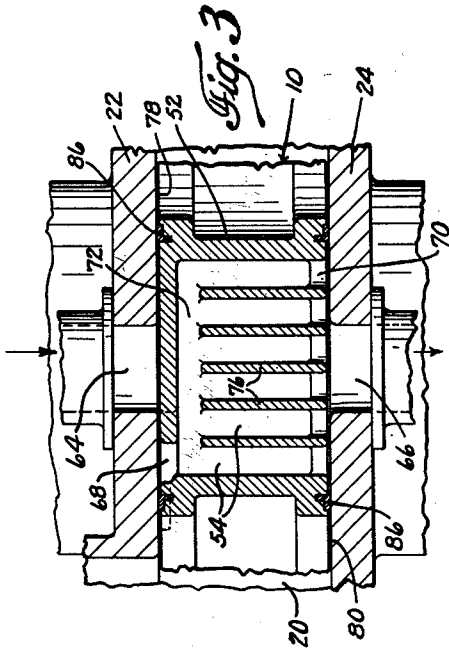
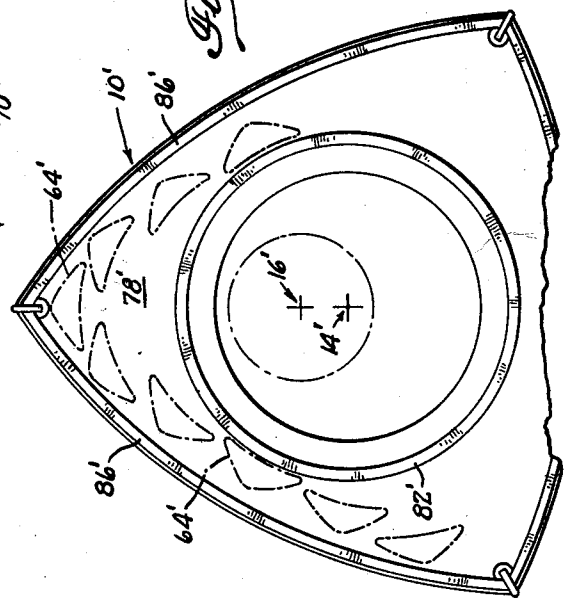


Fig. 4



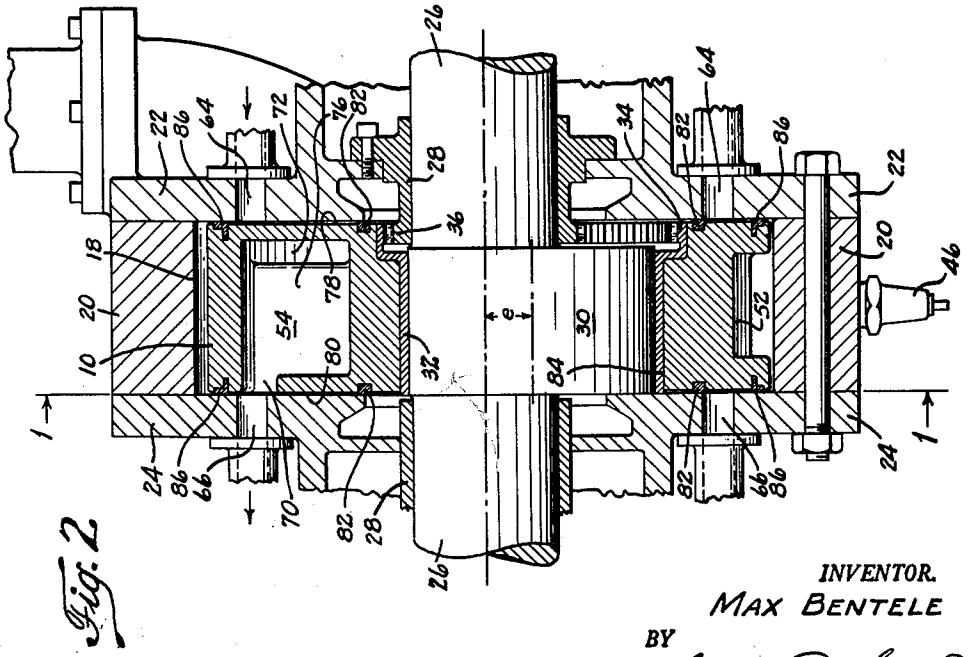


Fig. 2

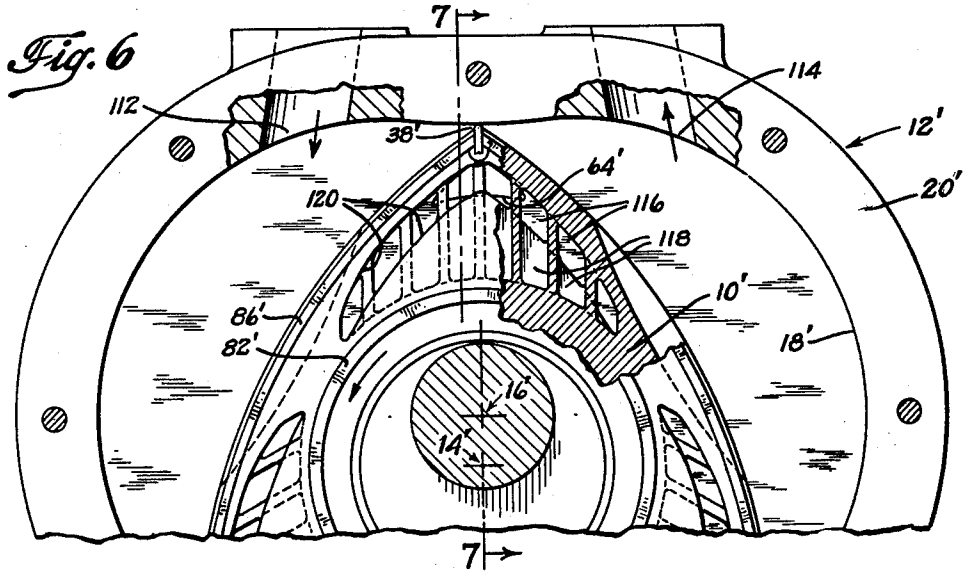
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AIR COOLED ROTOR FOR ROTARY MECHANISM

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Fig. 6



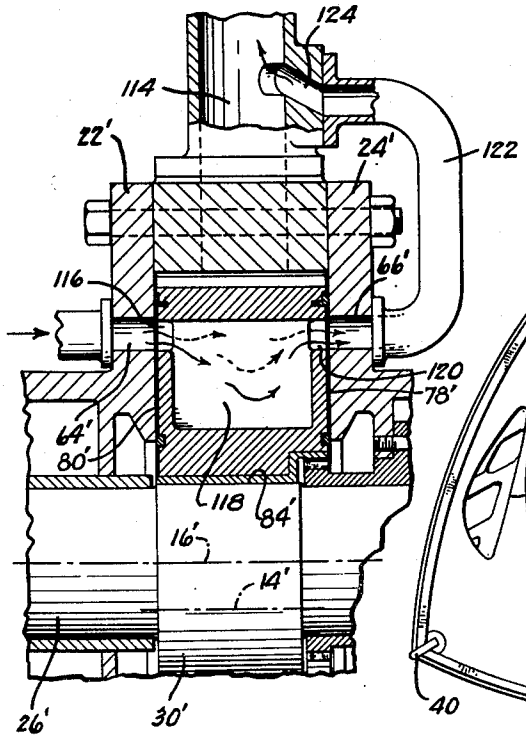
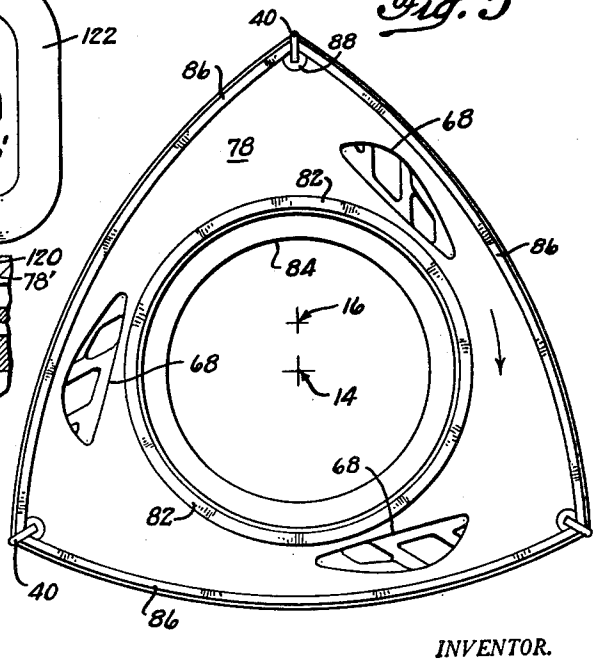


Fig. 7

Fig. 5



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AIR COOLED ROTOR FOR ROTARY MECHANISM

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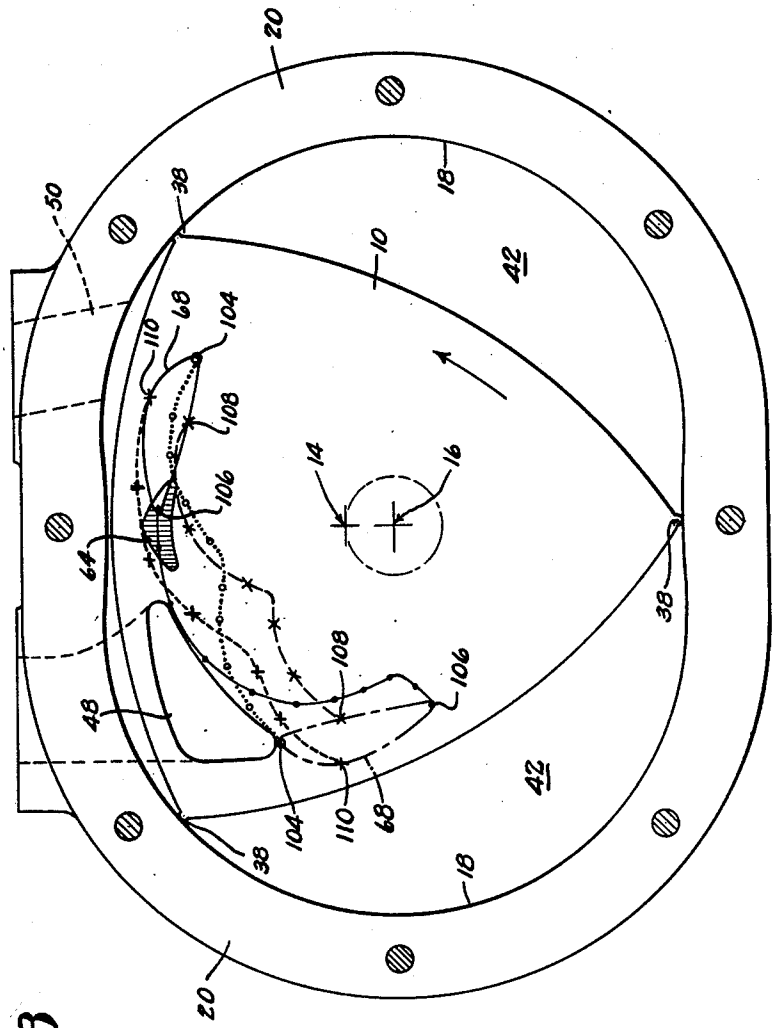


Fig. 8

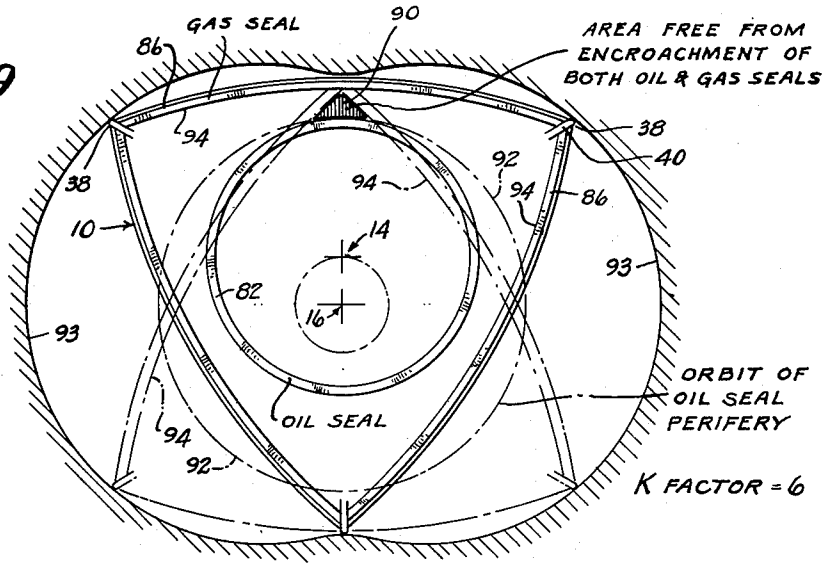
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Fig. 9



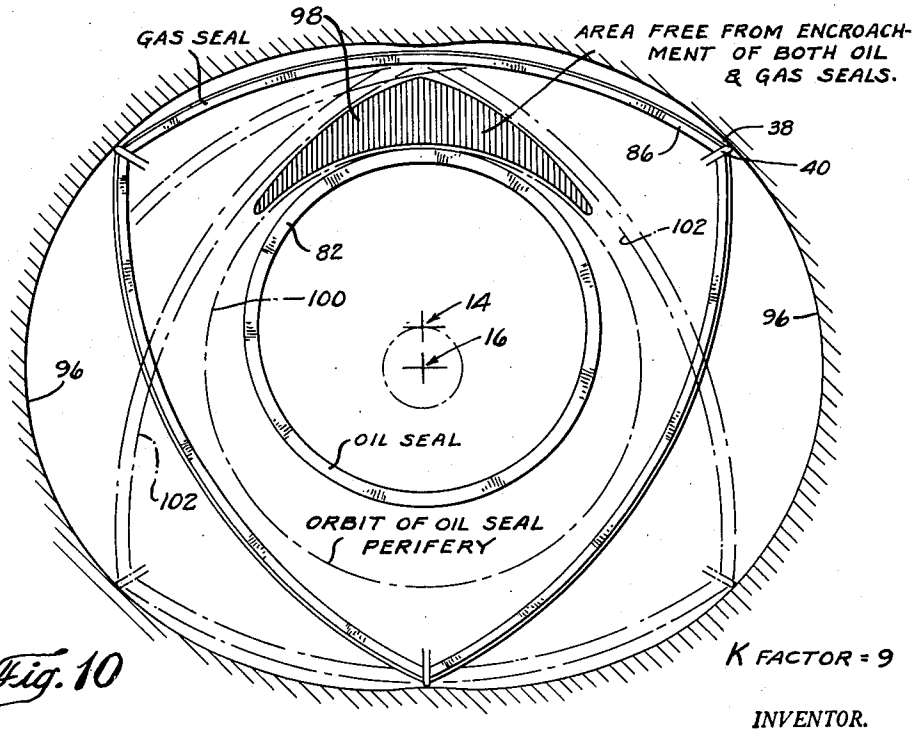


Fig. 10

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AIR COOLED ROTOR FOR ROTARY MECHANISM

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Filed June 6, 1961, Ser. No. 115,195
10 Claims. (Cl. 230—210)

The present invention relates to means for cooling rotary mechanisms, and more particularly to an air cooling system for the inner body or rotor of such mechanisms.

Although this invention is applicable to and useful in almost any type of rotary mechanism which presents a cooling requirement, such as combustion engines, fluid motors, fluid pumps, compressors, and the like, it is particularly useful in rotary combustion engines. To simplify and clarify the explanation of the invention, the description which follows will, for the most part, be restricted to the use of the invention in a rotary combustion engine. It will be apparent from the description, that with slight modifications which would be obvious to a person skilled in the art, the invention is equally applicable to other types of rotary mechanisms.

The present invention is particularly useful in rotary mechanisms of the type that comprise an outer body having an axis, axially-spaced end walls, and a peripheral wall interconnecting the end walls. In such rotary mechanisms the inner surfaces of the peripheral wall and end walls form a cavity, and the mechanism also includes an inner body or rotor that is mounted within the cavity between its end walls.

The axis of the inner body or rotor is eccentric from and parallel to the axis of the cavity of the outer body. The rotor has axially-spaced end faces disposed adjacent to the end walls of the outer body and a plurality of circumferentially-spaced apex portions. The rotor is rotatable relative to the outer body, and its apex portions substantially continuously engage the inner surface of the outer body to form a plurality of working chambers that vary in volume during engine operation, as a result of relative rotation between the rotor and outer body.

The inner surface of the peripheral wall of the outer body has a multi-lobed profile that is preferably an epitrochoid and the number of lobes of this epitrochoid is one less than the number of apex portions of the inner body or rotor.

By suitable arrangement of ports, such rotary mechanisms may be used as fluid motors, compressors, fluid pumps, or internal combustion engines. This invention is of particular importance when employed with a rotary mechanism that is designed for use as a rotary combustion engine, and, accordingly, will be described in combination with such an engine. As the description proceeds, however, it will be apparent that the invention is not limited to this specific application.

When the rotary mechanism is designed for use as a rotary combustion engine, such engines also include an intake passage means for administering a fuel-air mixture to the variable volume working chambers, an exhaust passage means communicating with the working chambers, and suitable ignition means so that during engine operation the working chambers of the engine undergo a cycle of operation which includes the four phases of intake, compression, expansion, and exhaust. This cycle of operation is achieved as a result of the relative rotation of the inner body or rotor and outer body and for this purpose both the inner body or rotor and outer body may rotate at different speeds, but preferably the inner body or rotor rotates while the outer body is stationary. Such an engine could obviously also be operated as a diesel engine.

For efficient operation of the engine, its working chambers should be sealed, and therefore an effective seal is provided between each rotor apex portion and the inner surface of the peripheral wall of the outer body, as well as between the end faces of the rotor and the inner surfaces of the end walls of the outer body.

Between the apex portions of its outer surface the rotor has a contour that permits its rotation relative to the outer body free of mechanical interference with the multi-lobed inner surface of the outer body. The maximum profile which the outer surface of the rotor can have between its apex portions and still be free to rotate without interference is known as the "inner envelope" of the multi-lobed inner surface, and the profile of the rotor that is illustrated in the accompanying drawings approximates this "inner envelope."

For purposes of illustration, the following description will be related to the present preferred embodiment of the engine in which the inner surface of the outer body is basically a two-lobed epitrochoid, and in which the rotor or inner body has three apex portions and is generally triangular in cross-section but has curved or arcuate sides.

It is not intended that the invention be limited, however, to the form in which the inner surface of the outer body approximates a two-lobed epitrochoid and the inner body or rotor has only three apex portions. In other embodiments of the invention the inner surface of the outer body may have a different plural number of lobes with a rotor having one more apex portion than the inner surface of the outer body has lobes.

In a rotary combustion engine of the type described above, as the rotor rotates relative to the outer body, each of its three working faces goes through all four phases of the cycle of operation in succession, i.e., intake, compression, expansion, and exhaust. Accordingly, the total heat input to each face of the rotor during the complete cycle of operation can be substantially high, and this is especially true when the engine is operating at a high number of revolutions per minute.

It has been found desirable to use a rotor fabricated from a light weight metal alloy in many applications of the rotary combustion engine. A light weight metal alloy, such as an aluminum alloy, provides the important benefits and advantages of ensuring a great saving of weight in the principal moving part of the engine, and also provides a rotor having high thermal conductivity. The latter characteristic is particularly beneficial in preventing the formation of hot spots within the rotor, while the former characteristic greatly reduces energy losses that result from inertia forces of the rotor.

A rotor constructed of a light weight metal alloy, however, demands adequate and efficient cooling, as such alloys will fail from overheating at a considerably lower temperature than a material, such as cast iron or steel. Accordingly, although the present invention is not limited to use with light weight metal alloy rotors, it is particularly useful when used with such rotors.

In accordance with the present invention, means are provided for cooling the rotor of a rotary combustion engine during operation, or more particularly, means are provided for cooling the rotor by utilizing a stream of compressed air or other gaseous medium.

In the present preferred embodiment of the invention, the means for cooling the rotor comprises a plurality of sets of cooling passages within the rotor extending from one end face of the rotor to the other and preferably located adjacent to its apex portions. The sets of passages are equally spaced circumferentially about the rotor axis. Within each set of passages, the spacing of the passages is determined by the distribution of heat input to the rotor and stress conditions within the rotor.

The means for cooling the rotor also comprises at least one cooling air supply port formed from an opening in one end wall of the outer body and a corresponding cooling air exhaust port formed from an opening in the other end wall of the outer body. Inserts or deflectors may be used in the interior of the cooling passages in the rotor to direct the cooling air toward the hotter regions of the rotor. This cooling air is supplied to the rotor through ports in the outer body. The cooling air may be forced through the rotor by a fan or by means of an ejector pump operated by the exhaust gases of the engine. When a fan is used to pump the air through the rotor, the exhausing cooling air may also be accelerated by combining it with the exhaust gases from the engine.

In operation, a supply of cooling air is directed into the rotor cooling passages from the supply ports in the outer body. After passing through the rotor cooling passages in direct heat exchange with the rotor, the air is exhausted through the exhaust ports in the other end wall of the outer body.

This invention may be adapted for use with a rotary combustion engine of the peripheral intake port type in which the intake port is located in the peripheral wall of the outer body. It may also be adapted for use with a rotary combustion engine of the side intake port type in which the intake port is located in either one or both of the end walls of the outer body. The invention may also be adapted for use with a rotary combustion engine that uses two side intake ports, or a dual side intake port.

In view of the foregoing, it is a primary object of this invention to provide a novel air cooling system for the rotor of a rotary mechanism.

Another object of the present invention is to provide a novel air cooling system for the rotor of a rotary mechanism that is sufficiently effective and efficient to permit the construction of the rotor from light weight metal alloys, such as aluminum, without danger of overheating and thermal distortion of the rotor.

Another object of the present invention is to provide a novel air cooling system for the rotor in which the coolant passages provide a large and extended heat transfer surface and give maximum heat transfer or maximum heat input into the cooling air stream.

Another object of the instant invention is to provide a novel air cooling system for the rotor of a rotary mechanism that eliminates the energy losses that result from churning and turbulence of cooling fluid when a liquid type coolant is used.

Another object of this invention is to provide a novel air cooling system for the rotor of a rotary mechanism that can be used in combination with or as a supplement to a liquid cooling system for the rotor.

Another object of this invention is to provide a novel air cooling system for the rotor of a rotary mechanism that will permit the configuration of the cooling passages to be adjusted to heat input distribution and to stress conditions within the rotor.

Another object of this invention is to provide a novel air cooling system for the rotor of a rotary mechanism that permits the cooling passages within the rotor to act as vents for any combustion gases that get past the gas side seal of the rotor and become trapped between the gas side seal and the oil seal in the space or clearance that exists between the end face of the rotor and the adjacent end wall of the engine in an engine with a peripheral intake port or on the side of the engine opposite the intake port on a side intake port engine. In a side intake port engine the intake port itself will vent the side of the engine that it is on.

Another object of this invention is to provide a novel air cooling system for the rotor of a rotary mechanism in which the cooling air flow will be a pulsating flow caused by the intermittent opening and shutting off of the cooling air supply and exhaust ports in the outer body end walls of the engine as the rotor rotates. This pulsating air flow provides more efficient heat transfer from the rotor to the cooling air.

Another object of this invention is to provide a novel air cooling system for the rotor that includes a large number of cooling passages within the rotor and yet is relatively inexpensive and easy to fabricate.

Additional objects of the present invention are to provide a novel air cooling system for the rotor of a rotary mechanism that achieves substantial savings in weight, virtually eliminates the problem of leakage or freezing of the cooling medium, and requires very little servicing as compared with a liquid cooling system. The air cooling passages in the rotor permit reduction of its weight without sacrificing its strength, and a further advantage of the air cooling system for the rotor is that it is less expensive to manufacture and produce than a liquid cooling system.

To achieve the foregoing objects, and in accordance with its purpose, this invention provides means which, as embodied and broadly described, comprise air cooling passages within the rotor from one end face of the rotor to the other and located adjacent its apex portions, cooling air supply ports formed from openings in one end wall of the outer body, cooling air exhaust ports formed from openings in the other end wall of the outer body, inlet and outlet ports leading to the air cooling passages within rotor and located in the end faces of the rotor so that they pass over the cooling air supply ports and cooling air exhaust ports in the end walls of the outer body during revolution of the rotor relative to the outer body, means for supplying a continuous stream of compressed air to the cooling air supply ports in the end wall of the outer body, and means for removing heated air from the exhaust ports of the other end wall of the outer body.

Additional objects and advantages of the invention will be set forth in part in the description which follows and in part will be obvious from the description, or may be learned by practice of the invention, the objects and advantages being realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

The invention consists in the novel parts, constructions, arrangements, combinations, and improvements shown and described.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one embodiment of the invention and together with the description serve to explain the principles of the invention.

In the accompanying drawings illustrating the mechanical aspects of the present invention, it is believed that the showing of the fundamental construction, functions, originality and advantages of the invention may be more easily understood when certain details of practical construction are omitted, where these details form no part of the claimable invention, are well-known to those skilled in the art, and could be incorporated in the present invention by any skilled workman. These details may consist of means for lubrication, such as, oil cups, grooves, reservoirs, seals, wipers and O-rings; means for reduction of friction, such as, bushings, ball bearings, and roller bearings; means for sealing off various spaces or areas to confine fluid pressures to their functional locale, such as, packing, packing glands, O-rings, and gaskets; constructional details of fluid conducting means, such as, tube or pipe joints, unions, and elbows including supporting and securing means; and such other comparable means and devices that may be omitted for the sake of clarity.

Of the drawings:

FIG. 1 is a sectional view of the mechanism taken along the line 1—1 of FIG. 2, and is thus a side elevation of the mechanism with the end wall of the outer body removed to show the rotor positioned within the outer body. The

rotor cooling passages are shown in FIG. 1 as they appear when viewed from their exhaust ends;

FIG. 2 is a central vertical section of the mechanism taken along the line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 1 and showing details of the cooling passages within the rotor;

FIG. 4 is a schematic view of the rotor showing a plot of the relative positions that the cooling air supply port assumes relative to the end face of the rotor as the rotor rotates relative to the outer body;

FIG. 5 is a view of a rotor to be used with the present invention in a rotary mechanism having a side intake port. This view shows how the air inlet ports in the rotor are positioned relative to the rotor itself;

FIG. 6 is a view similar to FIG. 1 but showing the rotor adapted for use of the invention with a peripheral intake port rotary mechanism as distinguished from the side intake port rotary mechanism of FIG. 1;

FIG. 7 is a sectional view of the mechanism taken along line 7—7 of FIG. 6. This view shows how the exhausting cooling air may be accelerated by combining it with the exhaust gases from the engine to provide an ejector pump;

FIG. 8 is a schematic view showing how the shape and location of the air inlet port in the rotor for a side intake port rotary mechanism is determined. This view shows how the air inlet port having the shape and location shown, passes over the cooling air supply port that is in the same end wall of the mechanism as the side intake port, but avoids passing over the side intake port itself;

FIG. 9 is a schematic view showing the general configuration of one of the substantially triangular areas that is not swept over or encroached upon by either the gas seal or the oil seal during operation of the rotary mechanism, and which is, therefore, a feasible area for location of the cooling air supply or exhaust ports in each end wall; the configuration shown in FIG. 9 applies to a rotary mechanism having a K factor approximately equal to 6, as will be more fully explained in the description below;

FIG. 10 is a view similar to FIG. 9 showing the configuration of one of the substantially triangular areas for a rotary mechanism having a K factor approximately equal to 9.

It is to be understood that both the foregoing general description and the following detail description are exemplary and explanatory but are not restrictive of the invention.

Reference will now be made in detail to the present preferred embodiment of the invention, an example of which is illustrated in the accompanying drawings.

In accordance with the invention, a rotary combustion engine and a means for air cooling its rotor or inner body are provided. As embodied, and as shown in FIGS. 1 and 2, the present preferred embodiment of the invention includes a rotary combustion engine comprising a generally triangular rotor **10** having arcuate sides which is eccentrically supported for rotation within an outer body **12**.

Although in the illustrative embodiment shown in the drawings the outer body **12** is fixed or stationary, a practical and useful form of the invention may be constructed in which both the outer body and rotor are rotary; in this latter form of the invention, the power shaft is driven directly by rotation of the outer body and the inner body or rotor rotates relative to the outer body.

As shown in FIGS. 1 and 2, and as here preferably embodied, the rotor **10** rotates on an axis **14** that is eccentric from and parallel to the axis **16** of the curved inner surface of the outer body **12**. The distance between the axes **14** and **16** is equal to the effective eccentricity of the engine and is designated *e* in the drawings. The curved inner surface **18** of the outer body **12** has basically the form of an epitrochoid in geometric shape and includes two arched lobe-defining portions or lobes.

As embodied, the generally triangular shape of the rotor **10** corresponds in its configuration to the "inner envelope" or the maximum profile of the rotor which will permit interference free rotation of the rotor **10** within the outer body **12**.

In the form of the invention illustrated, the outer body **12** comprises a peripheral wall **20** that has for its inner surface the curved inner surface **18**, and a pair of axially-spaced end walls **22** and **24** that are disposed on opposite sides of the peripheral wall **20**.

The end walls **22** and **24** support a shaft **26**, the geometric center of which is coincident with the axis **16** of the outer body **12**. This shaft **26** is supported for rotation by the end walls **22** and **24** on bearings **28**. A shaft eccentric **30** is rigidly attached to or forms an integral part of the shaft **26**, and the rotor **10** is supported for rotation or rotatively mounted upon the shaft eccentric **30** by a rotor bearing **32** that is fixed to the rotor.

As shown in FIGS. 1 and 2, an internally-toothed or ring gear **34** is rigidly attached to one end face of the rotor **10**. The ring gear **34** is in mesh with an externally-toothed gear or pinion **36** that is rigidly attached to the stationary end wall **22** of the outer body **12**.

From this construction, it may be observed that the gearing **34** and **36** does not drive or impart torque to the shaft **26** but merely serves to index or register the position of the rotor **10** with respect to the outer body **12** as the rotor rotates relative to the outer body and removes the positioning load that would otherwise be placed upon the apex portions of the rotor **10**.

As shown most clearly in FIG. 1, the rotor **10** includes three apex portions **38** that carry radially movable continuous gas-sealing engagement with the inner surface **18** of the outer body **12** as the rotor **10** rotates within and relative to the outer body **12**.

By means of the rotation of the rotor **10** relative to the outer body **12**, three variable volume working chambers **42** are formed between the peripheral working faces **44** of the rotor **10** and the inner surface **18** of the outer body **12**. As embodied in FIG. 1, the rotation of the rotor relative to the outer body is counterclockwise and is so indicated by an arrow.

A spark plug **46** is mounted in the peripheral wall **20** of the outer body **12**, and at the appropriate time in the engine cycle, the spark plug **46** provides ignition for a compressed combustible mixture which, on expansion, drives the rotor in the direction of the arrow. As previously stated, the rotary combustion engine may also be operated as a diesel, and when it is operated as a diesel, the spark plug **46** is not required, since ignition of the fuel is initiated by the temperature reached through high compression of the working air.

Also as shown in FIG. 1, one lobe of the epitrochoidal surface **18** is provided with an intake port **48**, and the other lobe is provided with an exhaust port **50**. As the rotor **10** rotates, a fresh charge is drawn into the appropriate working chamber **42** through the intake port **48**. This charge is then successively compressed, ignited, expanded, and finally exhausted through the exhaust port **50**.

In the drawings, FIG. 1 illustrates an embodiment of the rotary combustion engine using a side intake port, whereas FIG. 6 illustrates an embodiment of the engine that uses a peripheral intake port. In addition to the peripheral port and side intake port engines it is possible to construct an engine having a double or dual side intake port. There are thus three types of practical engines possible: (1) side intake port; (2) peripheral intake port; and (3) double or dual side intake port. The construction of the cooling system of the present invention will vary somewhat depending upon which of the three types of engines it is to be used with.

All four successive phases of the engine cycle: intake, compression, expansion, and exhaust, take place within each one of the variable volume working chambers **42**

each time the rotor 10 completes one revolution within the outer body, and for each revolution of the rotor, the engine completes a cycle.

The working faces 44 of the rotor 10 are provided with cut-off portions or channels 52 that permit combustion gases to pass freely from one lobe of the epitrochoidal inner surface 18 to the other lobe, when the rotor is at or near the dead center of maximum compression position. Also, a desired compression ratio of the engine may be attained by appropriate proportioning of the volume of the channels 52.

Since the gear ratio between the rotor ring gear 34 and the outer body gear or pinion 36 is 3:2, each time the rotor 10 completes one revolution about its own axis 14, the shaft 26 rotates three times about its axis 16.

In accordance with the invention, means are provided to efficiently cool the rotor by rapidly passing air or an equivalent medium through the rotor. As embodied, the means for cooling the rotor comprises a plurality of sets of cooling passages 54 within the rotor 10. Within each set of passages the arrangement of individual passages and the wall thicknesses between passages are designed to provide the best possible configuration for transferring the heat input to the rotor from the rotor to the cooling air without sacrificing the strength of the rotor to resist the stresses it encounters. These same considerations also govern the spacing of the passages relative to each other.

The sets of passages (in the illustrated embodiment, there will be three sets) are symmetrically arranged about the rotor axis, but the planes of symmetry do not necessarily coincide with the planes of symmetry of the rotor apex portions 38. The embodiment of the invention shown in FIGS. 1 and 2 is an embodiment adapted for use with a rotary mechanism employing a side intake port. With a side intake port mechanism the air inlet ports in the rotor itself are relatively small, therefore, the design of the flow passages within the rotor must be carefully accomplished to achieve the maximum benefit in heat transfer without sacrificing rotor strength.

The inner surface 18 of the peripheral wall 20 is basically an epitrochoid in profile, as shown by the inner surface 18 in FIG. 1. This epitrochoidal inner surface 18 has a major axis 56 and a minor axis 58. The minor axis 58 passes through the point on the inner surface 18 at which its two lobes are joined, or the lobe junctions 60. The lobe junctions 60 are at the point of least radius from the center 16 of the epitrochoidal inner surface 18.

The means for cooling the rotor in the embodiment of FIGS. 1 and 2 also comprises at least one cooling air supply port 64, and as shown in FIGS. 1 and 2, the cooling air supply port 64 is formed in the end wall 22. It would be possible, however, to construct an embodiment of this invention in which the air supply port 64 would be formed in the other end wall 24, since the direction of flow of the cooling air stream may be changed, if appropriate changes are also made in the construction of the rotor. Preferably, however, the air supply port 64 will be located in the same end wall 22 of the rotary mechanism as is the intake port 48, when the intake port is a side intake port, because this arrangement permits the air exit from the rotor to be made larger, and the larger exit results in less power loss.

As embodied in FIGS. 1 and 2, the means for cooling the rotor further comprises a cooling air exhaust port 66 in the other end wall of the mechanism, and the cooling air exhaust port 66 would normally be directly opposite from the cooling air supply port 64. As shown in FIG. 1, the rotor itself is provided with an air inlet port 68, and there is one of these air inlet ports 68 for each apex portion of the rotor. The rotor is also supplied with a series of rotor outlet ports 70, and there is one group or set of these rotor outlet ports for each apex portion of the rotor.

In operation, once air has entered the rotor inlet port from the air supply port in the end wall, it passes into a manifold 72 (FIGS. 2 and 3) that serves to interconnect each individual cooling passage in the series of cooling passages 54 that exist in each rotor apex portion 38. Incoming air entering the rotor is thus distributed by means of the manifold 72 into each of the cooling passages that comprise the series of cooling passages 54.

A series of cooling passages 54 is used rather than one large passage because the walls of metal 76 (FIGS. 1 and 3) between the passages 54 act as cooling fins and help to transfer heat rapidly from the rotor to the cooling air stream by providing a much larger heat exchange area than would be possible if only one or two large passages were used. Further, the walls or fins 76 serve as strengthening members in the apex portions 38 of the rotor to prevent deformation or failure of the rotor.

As shown in FIG. 2, the rotor 10 has two end faces 78 and 80 respectively, which are opposite to the end walls 22 and 24, respectively. Each end face 78 and 80 of the rotor carries an oil seal 82 in the form of a ring substantially surrounding the bearing bore 84 of the rotor. The purpose of the oil seal 82 is to prevent the escape of lubricating fluid in undesirable quantities from its desired location around and adjacent bearing bore 84 of the rotor. Lubricating fluid in this latter area is, of course, necessary to lubricate the main rotor bearing, the shaft bearings 28, and the gears 34 and 36. The oil seal 82 effectively confines the lubricating fluid to this desired area of lubrication.

In addition to the oil seal 82, each end face 78 and 80 of the rotor 10 also carries a gas seal 86. As shown in FIG. 1, the gas seal is approximately parallel to the outer peripheral edge of the rotor end faces 78 and 80. The gas seal 86 is thus a peripheral seal which is very close to the outer peripheral edge or outline of the rotor 10, and with the connecting seal members 88, as shown in FIG. 1, it forms a complete peripheral seal around the end faces 78 and 80 of the rotor 10. The gas seal 86 prevents the escape of gases from the working chambers 42 of the engine across the end faces 78 and 80, when these gases are undergoing compression or expansion during the working cycle of the engine.

From the foregoing description, it will be apparent that if the rotary combustion engine is to function properly, it will not be possible to have a cooling air supply port 64 or a cooling air exhaust port 66 located in an area of the end walls 22 and 24 that form a portion of the working chambers 42 of the engine. The air supply and exhaust ports 64 and 66 must, accordingly, be located radially inward from the radially innermost points of the end wall that are swept by the gas seal 86 during revolution of the rotor 10 within the outer body 12. Location of the cooling air supply and exhaust ports 64 and 66 within or overlapping an area of the working chambers 42, or more specifically in the area radially outward from the inner limit of the plot of the gas seal path (see, e.g., 94 and 102 in FIGS. 9 and 10), would make the engine inoperative.

Similarly, the cooling air supply and exhaust ports 64 and 66 must be located in a portion of the end walls 22 and 24 that is radially outward from the area of the end walls that is swept by the oil seal 82 upon revolution of the rotor 10 within the outer body 12. Neither the path of the gas seal 86 nor the path of the oil seal 82 may thus encroach upon the area of location of the cooling air supply and exhaust ports 64 and 66.

There are two substantially triangular areas on each of the end walls 22 and 24 that are not swept over or encroached upon by either the gas seal 86 or the oil seal 82, and either of these two triangular areas in each end wall forms a suitable and practical location for the cooling air supply and exhaust ports. If the cooling air supply port 64 is placed in one end wall, then the cooling air exhaust port 66 must be placed in the other end wall. Further, since there are two substantially triangular areas that meet the criteria for a satisfactory location of a cooling air supply or exhaust port, it is possible to include two cooling

air supply ports 64 in one end wall and two cooling air exhaust ports 66 in the other end wall, as shown in FIGS. 1 and 2.

In the present preferred embodiment of this invention as shown in FIGS. 1 and 2, virtually the entire triangular area described above is utilized to form both the cooling air supply port 64 and the cooling air exhaust port 66 within each of the end walls 22 and 24. The exact shape of this triangular area will vary slightly, however, with the shape of the epithrochoid that is used to construct the inner surface 18 of the outer body or peripheral wall 20 and the location of the gas and oil seals.

The shape of the epitrochoid profile of the inner surface 18 is determined by the ratio between two variables, R and *e*. R is defined as the distance from the axis or center 14 of the rotor (see FIG. 1), to the point at which a sealing member 40 of the rotor contacts the inner surface 18. The other variable *e* is defined as the eccentricity of the rotor axis 14 from the outer body axis 16, or the distance between the axes 14 and 16. This ratio between R and *e* may conveniently be designated K, or the K factor of the epitrochoid. K may thus be defined by the equation

$$K=\frac{R}{e}$$

It is known that satisfactory rotary combustion engines may be constructed having K factors of various values.

To illustrate how the triangular area described above varies with a change in the K factor, reference should be made to FIGS. 9 and 10.

FIG. 9 shows an epitrochoid 93, having a K factor of about 6, or $K=6$. There are two triangular areas in the epitrochoid of FIG. 9 which are similar to and correspond in shape to the areas of the substantially triangular cooling air supply ports 64 shown in FIGS. 1 and 6. These triangular areas are not swept or encroached upon by either the side gas seal 86 or the oil seal 82, and the triangular area 90 in FIG. 9 delimits the area of the end wall which is not swept by either the side gas seal 86 or the oil seal 82. The outer limit of oil seal eccentric rotation is designated 92 in FIG. 9, and the inner limit of side gas seal travel relative to the end wall is designated 94.

Similarly, FIG. 10 shows an epitrochoid 96, having a K factor of about 9, or $K=9$. The triangular area 98 in FIG. 10 delimits the area of the end wall which is not swept or encroached upon by either the side gas seal 86 or the oil seal 82. In FIG. 10 the outer limit of the path of the oil seal is designated 100, and the inner limit of travel of the side gas seal 86 is designated 102.

From a comparison of the triangular area 90 in FIG. 9, and the triangular area 98 of FIG. 10, it can be readily observed that the substantially triangular area available for use as a cooling air supply or exhaust port in the end walls of the outer body becomes distinctly larger as the K factor of the epitrochoid increases from $K=6$ to $K=9$. FIGS. 9 and 10 thus demonstrate the general principle that for different feasible K factors of the rotary mechanisms the present invention, a useable triangular area exists which becomes larger as the K factor increases. Also, it should be noted that a K factor of 9 is not the upper limit for the design of the rotary combustion engine, but has merely been selected as illustrative of the general principle that the useable area for the cooling air supply and exhaust ports becomes larger as the K factor increases. The K factor could well be larger than 9 in a diesel type rotary combustion engine. Similarly, a K factor of 6 is not the lower limit for a rotary combustion engine, and this invention is applicable to engines having K factors outside the illustrated range of 6 to 9.

In construction of an air cooling system for a rotary combustion engine, it is thus important to exactly determine the roughly triangular areas in the end walls which will be available for use as air supply and exhaust ports according to the K factor of the epitrochoidal inner surface 18 that is used in the engine. Since the area available for the cooling air supply and exhaust ports is not large in relation to the total area of the rotor end faces 78 and 80, the entire available triangular area will normally be utilized.

Also, it should be noted that although the present preferred embodiment of this invention shown in the drawings depicts a practical construction of the invention using a rotary combustion engine having a 3:2 gear ratio, it is in no way intended that this invention be limited to rotary combustion engines having a gear ratio of 3:2, as the invention is applicable to other rotary combustion engines having different gear ratios.

When the air cooling system of the present invention is to be used with an engine having a side intake port, great care must be taken to be certain that the air inlet port 68 (see FIG. 1) in the rotor 10 will not interfere with the intake port 48 used for delivery of the air-fuel mixture that forms the combustible charge for the working cycle of the engine. Obviously, if the air inlet port 68 in the rotor should register with the air-fuel intake port 48 in the end wall 22 at any time, there would be a substantial loss of air-fuel mixture by exhausting directly through the cooling system and a resultant severely deleterious effect on the operation of the engine. At the same time, it is, of course, necessary that the air inlet port 68 in the rotor register as directly and fully as possible with the cooling air supply port 64 in the end wall 22, as the rotor revolves within the outer body 12.

When a side intake port engine, such as shown in FIGS. 1 and 2, is used, the air inlet port 68 to the rotor must fulfill two conditions: (1) It must register with the triangularly shaped cooling air supply port 64 in the end wall 22; and (2) It must not sweep over or register with the intake port 48.

If the air inlet port 68 in the rotor does not conform to both of these criteria, it will not be satisfactory for use.

FIG. 8 shows how a satisfactory location for the air inlet port 68 in the end face 78 of the rotor may be determined. From the preceding description it is apparent that the air inlet ports 68 in the rotor end face 78 must be located in an area of the rotor formed between the side gas seal 86 and the oil seal 82, so this basic requirement determines the general area of possible location. Within this area, however, the two criteria set forth above must also be complied with.

The epitrochoidal inner surface 18, the side intake port 48, and the cooling air supply port 64 are all shown schematically in FIG. 8. Also shown in FIG. 8 are tracks or plots of the paths that four limiting points on the periphery of the air inlet port 68 describe upon the end wall 22 when the rotor 10 rotates one-third of a revolution counterclockwise relative to the outer body 12.

The four limiting points on the periphery of the air inlet port 68 in the rotor as shown in FIG. 8 determine the ultimate shape of a satisfactory air inlet port 68. In FIG. 8 the four limiting points are designated respectively, 104, 106, 108, and 110.

The path described on the end wall 22 of the outer body 12 by the limiting point 104 as the rotor moves through one-third of a revolution relative to the outer body, and as the air inlet port 68 moves past both the cooling air supply port 64 and the intake port 48 of the engine, is shown by a dotted line. Similarly, the path described on the end wall 22 by the limiting point 106 is shown by a solid line in FIG. 8. The paths described on the end wall 22 by the points 108 and 110 are also shown in FIG. 8 as a long dashed line and short dashed line, respectively.

From a study of FIG. 8, it is apparent that an air inlet port having a configuration like the air inlet port 68 in FIG. 8 will be satisfactory as complying with the necessary criteria. FIG. 8 shows that all four of the limiting points 104—110 on the periphery of the air inlet port 68

effectively register with the cooling air supply port 64, and yet all these points also avoid passing over or registering with the side intake port 48. The air inlet port 68 is thus one that satisfies the requirements of the present invention.

The air inlet port as shown in FIG. 8 is also sufficiently close in location to the apex portion 38 of the rotor to provide effective introduction of cooling air into the apex portions, both directly and through the manifold 72 (FIGS. 2 and 3). The major portions of the sets of cooling passages 54 and preferably located in the apex portions of the rotor, since these portions present a greater cooling requirement than the portion of the rotor intermediate the apex portions. The total heat input to the apex portions of the rotor is greater than the heat input to its intermediate portions, and more heat must thus be removed adjacent the apex portions 38 of the rotor than from its intermediate portions. It is an important advantage of the present invention that it provides a means of directly removing heat from the apex portions of the rotor, and this characteristic of the invention materially aids in establishing thermal equilibrium within the rotor.

FIG. 5 clearly illustrates how the air inlet ports 68 appear and are located in the finished rotor design on the end face 78 of the rotor.

If an engine with two side intake ports is used, it is necessary to provide the same configuration for the air outlet port 70 as for the air inlet port 68, because when a dual side intake port engine is used there are two side intake ports 48 of the same configuration, and the same criteria that governed the configuration of the air inlet port 68 then apply to both sides of the engine.

FIG. 6 shows the preferred embodiment for the cooling system of the present invention when the invention is used in a rotary combustion engine having both a peripheral intake port 112 and a peripheral exhaust port 114. From FIG. 6, it can be seen that when a peripheral intake port 112 is used there is no requirement that the air inlet port in the rotor be located so that it will not sweep over the side intake port 48, as shown in FIG. 8.

In the description of the preferred embodiment of the cooling system of this invention for use with a peripheral intake port engine, as shown principally in FIG. 6, the parts of this peripheral intake port embodiment that correspond to the parts of the side intake port embodiment (described earlier, and shown principally in FIGS. 1 and 2), will be designated by the same reference numerals, but these numerals will be primed when they apply to the peripheral intake port engine as distinguished from the side intake port engine.

Accordingly, a series of air inlet ports 116 may be provided in the rotor 10 as shown in FIG. 6, designed to sweep the full area of the cooling air supply port 64'. The design of the series of air inlet ports 116 is determined by the inverse of the method used for the design of the air inlet ports 68 used with the side intake port engine of FIGS. 1 and 8. Since in the peripheral intake port engine of FIG. 6, there is no limitation that prevents use of the full area of registration of the cooling air supply port 64' with the portion of the rotor end face 78' between the gas seal 86' and oil seal 82', the design of the air inlet ports 116 is determined by plotting the location of the cooling air supply port 64' relative to the end face 78' of the rotor 10' as the rotor rotates within the outer body 12' and as shown schematically in FIG. 4. Exactly the same considerations govern the design of the cooling air supply port 64' for the peripheral port engine as govern the design of the cooling air supply port 64 of the side intake port engine. The primary considerations, it will be remembered, are that the substantially triangular shaped area of the cooling air supply port must lie radially inward from the inner limit of travel of the side gas seal 86 and must lie radially outward from the outer limit of travel of the oil seal 82 so that it is in an area of the end wall 22 that is neither swept over nor encroached upon by either the side gas seal 86 or the oil seal 82.

From the design of the location of the cooling air supply port 64, for the side intake port engine, as described previously, it is known that the cooling air supply port 64' for the peripheral port engine will always be covered by that portion of the rotor end face that lies between the inner limit of the side gas seal 86' and the outer limit of the oil seal 82', as shown in FIG. 4. A stroboscopic plot of the triangular-shaped area of the air supply port 64' against the rotor end face in FIG. 4 delimits the area within which the air inlet ports 116 should be placed on the rotor end face 78'.

FIG. 6 shows that the air inlet ports 116 in the rotor end face 78' of the peripheral port engine correspond with the stroboscopic plot of the cooling air supply port 64' against the rotor end face 78', as shown in FIG. 4. Obviously, instead of an individual intake port 116 at each rotor apex portion, as in FIG. 6, a single intake port may extend in a substantially continuous manner around the end face.

FIGS. 1, 2, 6 and 7 show that the cooling passages 54 and 118 adjacent to the apex portions 38, 38' of the rotor 10, 10' are enlarged on the inside of the rotor. This enlargement of the cooling passages 54 and 118 on the inside of the rotor as shown in FIGS. 1, 2, 6 and 7 reduces the weight of the rotor 10, 10'. Inserts may be used in these enlarged cooling passages 54 and 118 to direct the cooling air to hot spots and to increase cooling air velocity.

The porting arrangement for the air outlet ports 120 in the peripheral port engine of FIG. 6 is the same as the arrangement for the air inlet ports 116.

In the side intake port engine of FIGS. 1 and 2, in which only one side intake port 48 is employed, the design and arrangement of the air outlet ports 70 in the rotor 10 are the same as the air outlet ports 120 in the peripheral port engine of FIG. 6. In both embodiments the air outlet ports 70 and 120 are designed to take advantage of a full sweep across the air exhaust port 66, 66'.

As may be ascertained from the foregoing description, the air cooling system of the present invention is better adapted for use with a peripheral port engine than for use with a side intake port engine, although it can be used effectively with both embodiments.

When used with a peripheral intake port engine, the air cooling system of this invention requires less power to drive the cooling air fan, because less cooling air pressure is required to drive the cooling air through the rotor. The total area of the air inlet ports 116 is considerably greater than the area of the air inlet ports 68 in the side intake port engine, and therefore less pressure is required to introduce a given quantity of cooling air into the rotor of the peripheral intake port engine. The advantageous location and increased area of the cooling intake ports 116 in the peripheral intake port engine result in a lower power loss when the cooling air is forced through the rotor.

The better arrangement or location of the air inlet ports 116 obtainable with a peripheral intake port engine also result in better cooling air distribution within the rotor and permit the cooling passages within the rotor to have a configuration that may be adjusted to cause the cooling air flow to conform to the heat input distribution in the rotor subject only to consideration of the stress conditions in the rotor.

In accordance with the invention, means may be provided for accelerating the exhausting cooling air from the engine. As embodied, and as shown in FIG. 7, the means for accelerating the exhausting cooling air in an exhaust gas operated ejector. In the present preferred embodiment, the exhaust gas operated ejector means comprises a conduit 122 connected at one end to the other end of the cooling air exhaust port 66' and at its other

end to an exhaust passage entry port **124**. Although this modification is illustrated in the drawings in combination with a peripheral intake port engine (FIG. 6), it may be used with either the side intake port engine cooling system (FIGS. 1 and 2), or with the peripheral intake port engine cooling system (FIG. 6).

In operation, the exhaust gas operated ejector helps to exhaust cooling air from the rotor by using the fast moving exhaust gases to create suction at the interior end of entry port **124** to accelerate and pull exhausting cooling air from the cooling air exhaust port **66'** at a faster rate and with less power loss than would prevail if the cooling air were merely exhausted to the atmosphere.

In operation, a supply of clean cooling air is directed from the air supply port **64** in the end wall **22** (FIGS. 1 and 2) into the air inlet port **68** in the rotor end face **78**. The cool air after passing through the air inlet port **68** reaches the manifold **72** from which, because of its flow under pressure, it distributes itself through the series of cooling passages **54** within the rotor **10**. While still under some pressure, the cooling air flow leaves the rotor through the rotor outlet ports **70** as these ports pass or sweep over the air exhaust ports **66** in the end wall **24** of the outer body and from the end wall **24** the air is further exhausted to the atmosphere.

When an engine is used having a peripheral intake port (FIG. 6), the only difference in its operation is the design and arrangement of the air inlet ports **116** in the rotor end face **80'**. The operation between the corresponding parts of the two types of engines is virtually identical, only the structure of the air inlet ports **68** and **116** is different.

From the foregoing description of this invention, one may grasp the importance of the discovery of the means by which an efficient and effective air cooling system for a rotary combustion engine or other type of rotary mechanism can be constructed and placed in operation. By using the means of the present invention to achieve an air cooling system, it is possible to effect significant economies in the manufacture and operation of rotary mechanism. The air cooling passages in the rotor lighten the rotor and reduce inertia losses without the accompanying disadvantages that are introduced when a liquid cooling medium is used. When a liquid is directed into the rotor to cool it, problems of churning and turbulence of the liquid are introduced as well as an inertia loss caused by the weight of the liquid itself.

The air cooling system of the present invention is relatively simple, easy and economical to construct and trouble-free in operation. Unlike a liquid cooling system, the air cooling system provided by this invention avoids any necessity for a multiplicity of fittings, conduits, channels, and passages for transferring cooling liquid from one point to another in the system with consequent danger of leakage, breakage, and failure through loss of cooling liquid.

Another advantage of the present invention is that the cooling air flow may be routed through the outer body **12, 12'** of the engine in a manner such that the cooling air will cool the outer body as well as the rotor in the course of its passage through the engine. The arrangement of air cooling passages within the outer body to achieve this object presents no unusually difficult problems to be overcome and is considered to be within the skill of a person trained in the art.

In the foregoing detailed description of the present preferred embodiment, it is apparent that this particular embodiment is restricted to mechanisms in which the outer bodies are stationary and the rotors and eccentrics are rotary, but it is not intended to limit the scope of the invention to such a mechanism. It is apparent that with mechanical changes that would be obvious to a person skilled in the art, alternative embodiments of the invention could be contructed in which both the outer body and rotor are rotary and the eccentric is stationary with the power shaft taken off the outer body.

Accordingly, this invention in its broader aspects is not limited to the specific mechanisms known and described, but also includes within the scope of the accompanying claim any departures made from such mechanisms which do not sacrifice its chief advantages.

What is claimed is:

1. A rotary mechanism comprising a hollow outer body having an axis, axially-spaced end walls and a peripheral wall interconnecting the end walls; a rotor mounted within the outer body for rotation relative to the outer body on an axis eccentric from and parallel to the axis of the outer body; the rotor having end faces disposed adjacent to the end walls of the outer body and a plurality of circumferentially-spaced apex portions in sealing engagement with the inner surface of the peripheral wall to form a plurality of working chambers between the rotor and the peripheral wall that vary in volume upon relative rotation of the rotor within the outer body; the profile of the inner surface of the peripheral wall being a curve that is basically a multi-lobed epitrochoid; the epitrochoidal profile having minor radii connecting the center of the epitrochoid with each point of least distance from the center; each end face of the rotor carrying an oil seal located radially outward from the rotor mounting axis and concentric therewith; each end face of the rotor also carrying a gas seal located adjacent to the outer periphery of the rotor end face; the rotor having a plurality of internal cooling passages for the flow of a cooling medium through the rotor under pressure; the rotor having at least one inlet in one end face to admit the coolant into the rotor passages and at least one outlet in the other end face for exhausting the coolant from the rotor passages, both the inlet and outlet being disposed between the oil seal and the gas seal carried by their respective end faces; one end wall of the outer body having at least one coolant supply port therein in the region of a minor radius for supplying coolant to the rotor inlet; the other end wall of the outer body having at least one coolant exhaust port therein in the region of a minor radius for receiving the coolant from the rotor outlet; the coolant supply port and coolant exhaust port in each end wall being so located that they are at all rotor positions relative to the outer body radially inward of the gas seals and radially outward of the oil seals.

2. The invention as defined in claim 1, in which the coolant supply port and the coolant exhaust port are substantially triangular in shape.

3. The invention as defined in claim 1, in which the rotor passages comprise a plurality of sets of passages, there being one set of passages for each apex portion of the rotor.

4. The invention as defined in claim 1, in which the oil seals are substantially circular and the gas seals are substantially parallel to the periphery of the rotor end faces.

5. The invention as defined in claim 1, in which the rotor has one inlet for each apex portion.

6. The invention as defined in claim 3, in which the rotor has one inlet for each apex portion and a manifold for each apex portion, each manifold connecting the inlet with each passage in the adjacent set of passages within each apex portion.

7. The invention as defined in claim 3, in which the rotor has a plurality of outlets for each apex portion.

8. The invention as defined in claim 3, in which the rotor has a plurality of inlets for each apex portion.

9. The invention as defined in claim 1, in which at least one end wall of the outer body has an intake port for delivery of fluid to the working chambers of the rotary mechanism, and in which the rotor coolant inlet communicates at least intermittently with the coolant supply port in the end wall but does not communicate with the intake port for delivery of fluid to the working

chambers at any rotor position relative to the outer body.

10. The invention as defined in claim 1, wherein the outer body has an intake port for delivery of fluid to the working chambers, and an exhaust port for discharging exhaust from the working chambers; a conduit passage carrying exhaust away from the working chamber exhaust port, and passage means receiving the coolant discharge from the coolant exhaust port and opening into the exhaust conduit passage.

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