Sept. 3, 1963 W. B. GIST ETAL 3,102,516

COOLING SYSTEM FOR ROTARY MECHANISMS

Filed Nov. 14, 1960 5 Sheets-Sheet 1

FIG. 1.

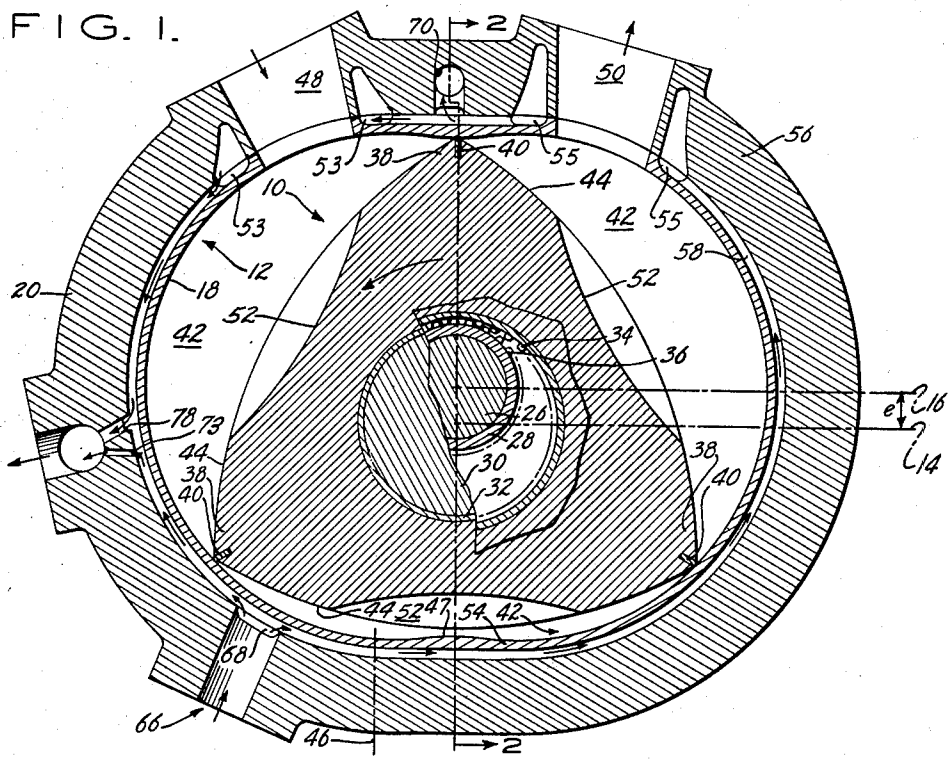
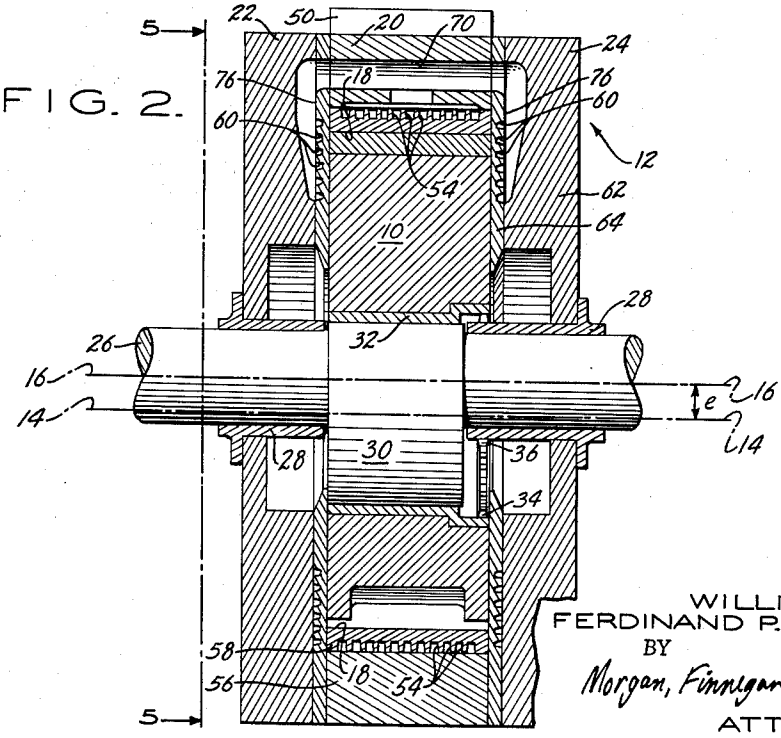


FIG. 2.



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5 Sheets-Sheet 2

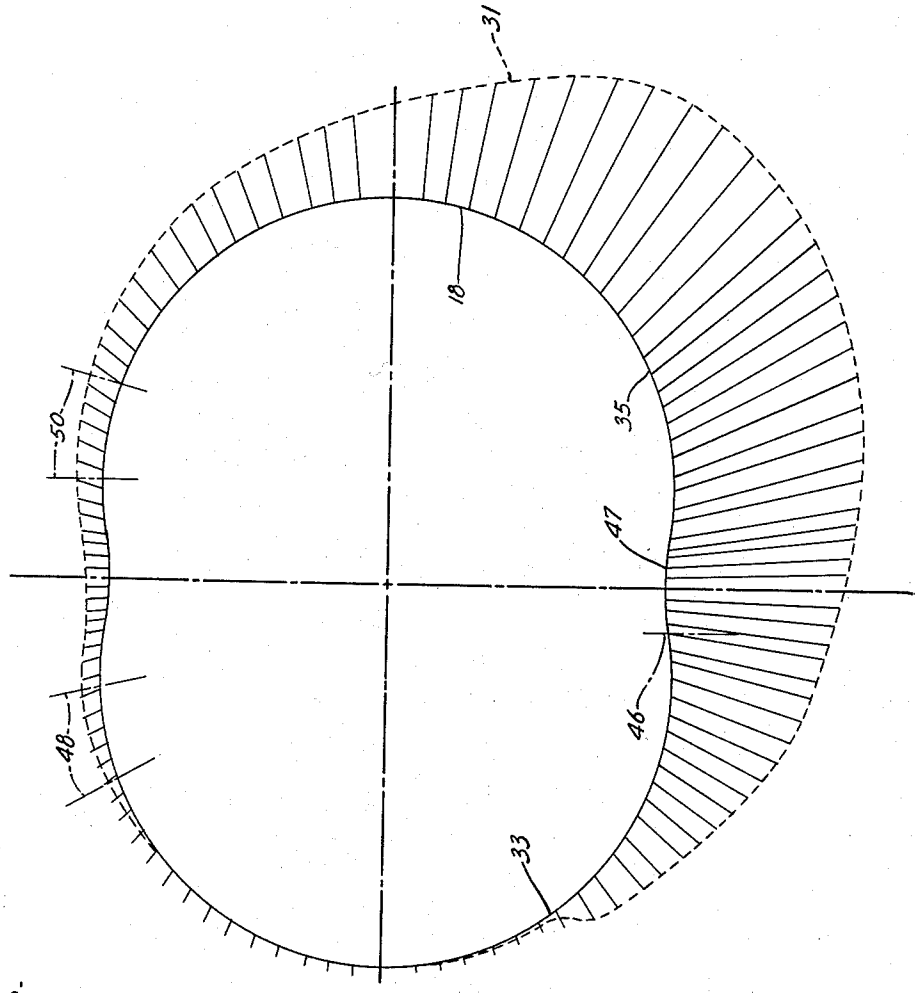


FIG. 3.

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COOLING SYSTEM FOR ROTARY MECHANISMS

Filed Nov. 14, 1960 5 Sheets-Sheet 3

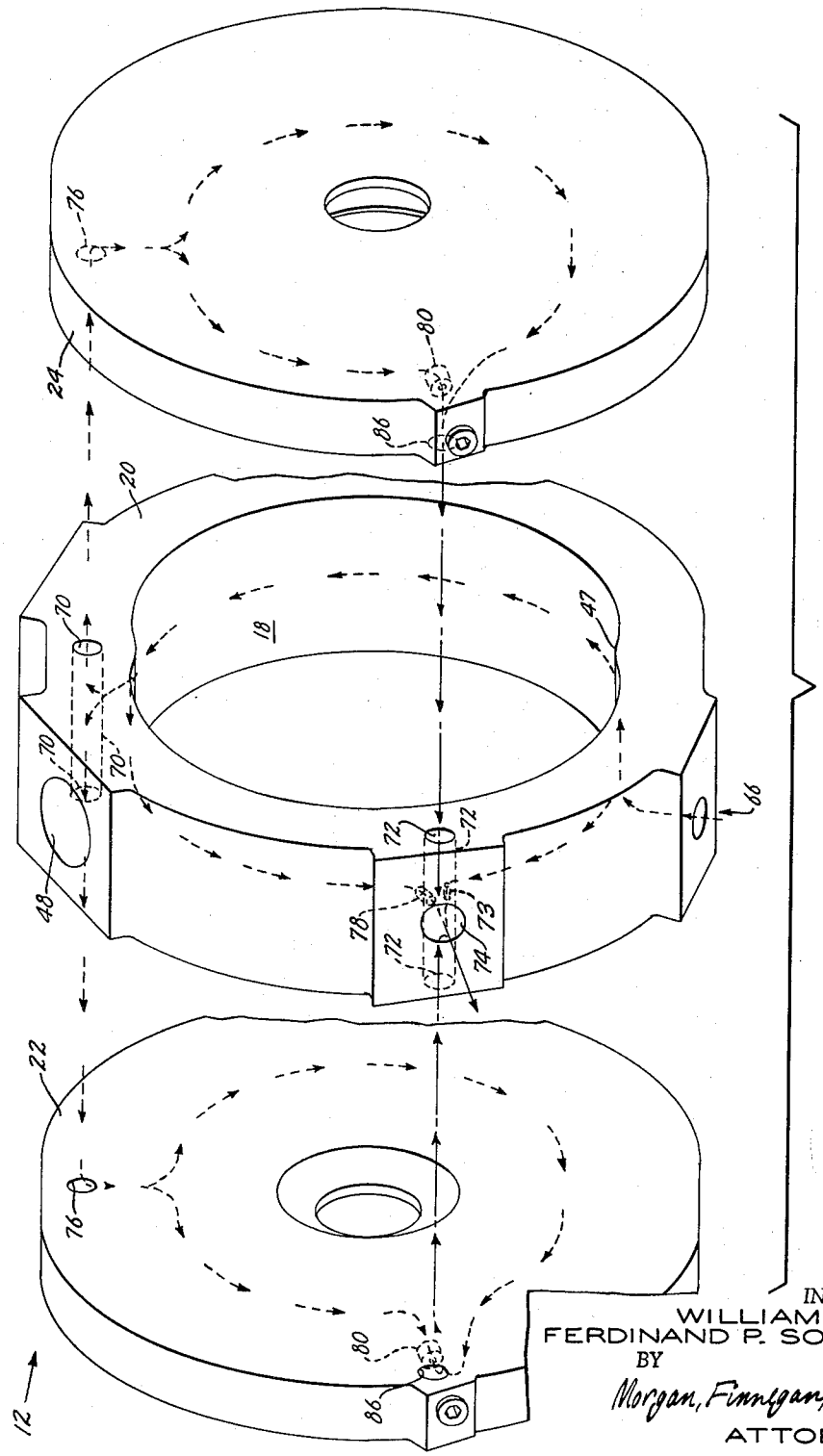


FIG. 4.

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COOLING SYSTEM FOR ROTARY MECHANISMS

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FIG. 5.

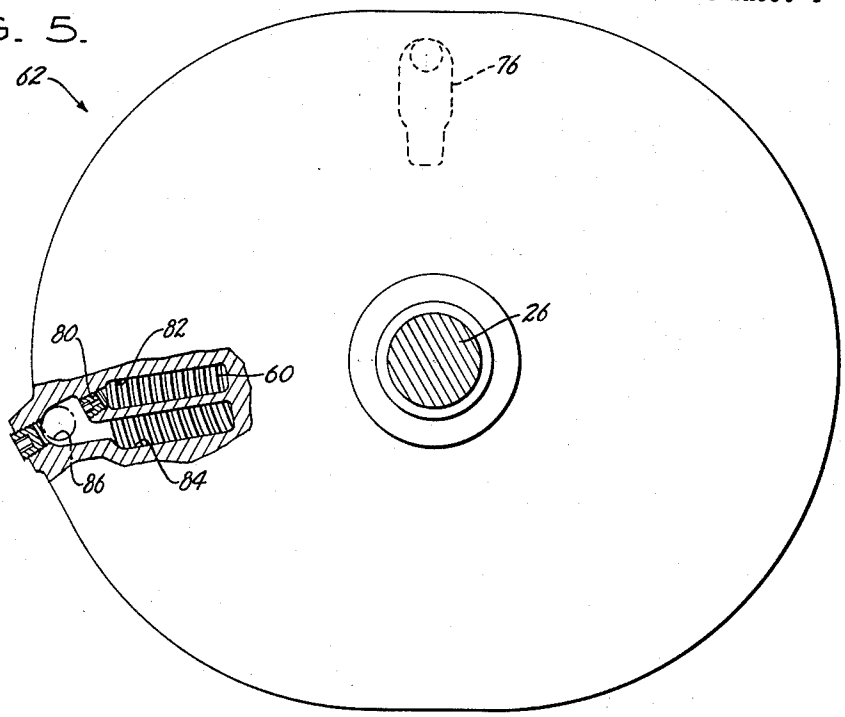
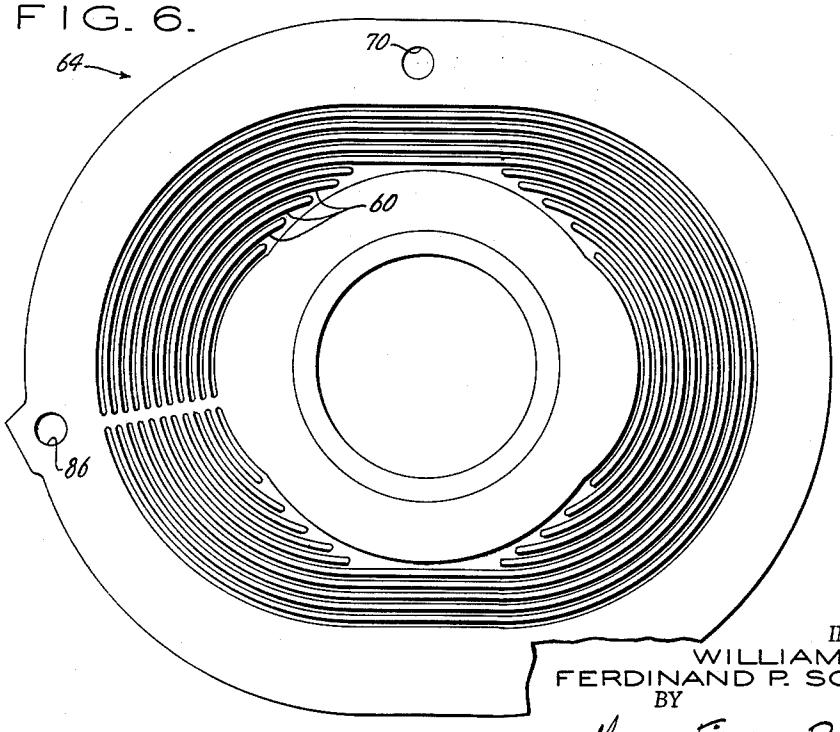


FIG. 6.



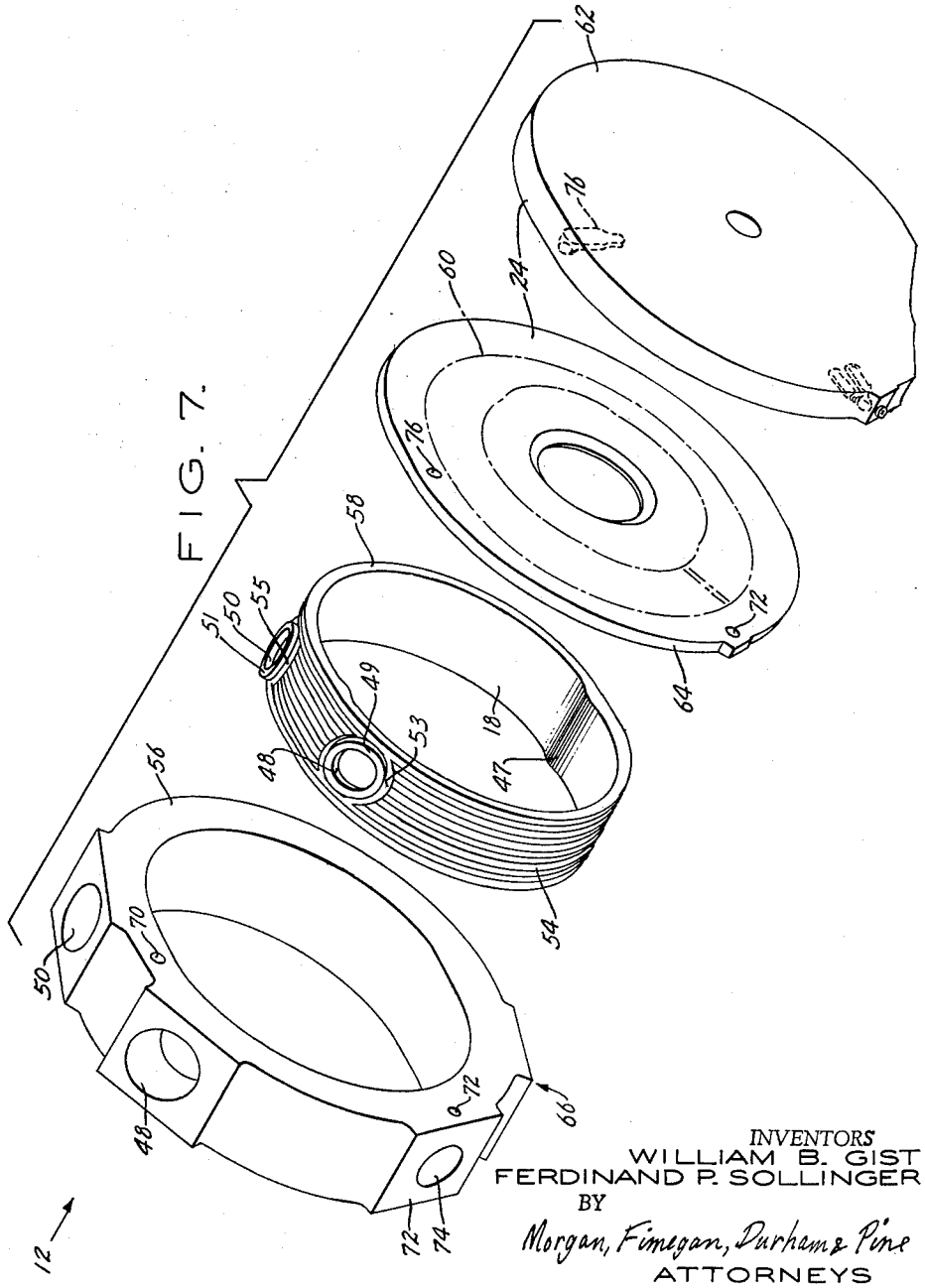
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COOLING SYSTEM FOR ROTARY MECHANISMS

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FIG. 7.



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United States Patent Office 3,102,516 Patented Sept. 3, 1963

3,102,516

COOLING SYSTEM FOR ROTARY MECHANISMS

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Filed Nov. 14, 1960, Ser. No. 69,037
9 Claims. (Cl. 123—8)

The present invention relates to means for cooling rotary mechanisms, and more particularly to a fluid cooling system for the outer body 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 rotating 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 rotating combustion engine. It will be apparent from the description, however, 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 combustion engines of the type that is described in detail in U.S. Patent No. 2,988,065, issued June 13, 1961, and reference may be made to the disclosure of this patent for a detailed description of such a rotary combustion engine.

In a rotating combustion engine of the type described above, the heat input to the outer body resulting from the combustion gas, or working fluid cycle is not uniform around the inner surface of the outer body. This phenomenon occurs because each of the various phases of the engine cycle always takes place adjacent to the same portion of the outer body. As a result, the portion of the engine outer body adjacent to which the combustion phase and expansion phase take place has a much higher heat input rate than other portions of the outer body. Similarly, in other rotary mechanisms, because the phases of the mechanism do not shift in their location relative to the outer body, the heat input to the outer body resulting from the cycle of the working fluid will not be uniform around the inner surface of the outer body.

In accordance with the present invention, means are provided for cooling a rotating combustion engine in operation, or, more particularly, means are provided for cooling the outer body of such an engine. In the present preferred embodiment of the invention, the means for cooling the outer body comprise a multiplicity of circumferential passages in the outer body near its inner surface, a suitable cooling fluid, such as oil, and appropriate means for passing and properly distributing the cooling fluid through the peripheral wall and end walls of the outer body.

In view of the foregoing, it is a primary object of the present invention to provide a novel liquid cooling system for the outer body of a rotary mechanism which, in spite of large variations in the heat input to the outer body around its inner surface, will minimize temperature variations in the outer body around its periphery and will ensure that thermal stresses and distortions set up in the outer body during operation will be kept at a relatively low level.

Another object of the instant invention is to provide a novel fluid cooling system for a rotary mechanism in which the relatively cool incoming coolant fluid initially flows through the regions of high heat input to the outer body in its circulatory path through both the peripheral wall of the outer body and the end walls of the outer body and in which the coolant fluid as it increases in temperature flows through regions of relatively lower heat input until it flows through the regions of lowest heat input just prior to leaving the outer body.

Another object of the present invention is to provide a novel fluid cooling system for the outer body of a rotary mechanism which affords adequate cooling of the outer body with a minimum quantity of fluid coolant and yet utilizes coolant passages having a sufficiently large flow area for ease of fabrication and for minimizing clogging of the passages.

Another object of the instant invention is to provide a cooling system for the outer body which uses coolant flow passages having smooth hydrodynamic contours, i.e., having no abrupt changes in direction or area, particularly in regions of high heat input. This latter provision serves to avoid the presence of dead spots in the coolant flow passages, i.e. spots in the coolant flow passages which have little or no flow velocity of the coolant. When dead spots are eliminated in this manner, any vapor produced in the passages is instantly carried away by the coolant flow and hot spots resulting from vapor accumulation are avoided.

Another object of the present invention is to provide a novel cooling system for the outer body of rotary mechanism which gives adequate cooling capacity with a minimum length cooling circuit. This short cooling circuit is particularly adapted to the use of a combined coolant and lubricant fluid, such as synthetic oil, since the short cooling circuit helps to minimize pressure losses in the flow path and promotes a high velocity flow which permits consequent reduction in the amount of fluid required to yield a specific cooling efficiency. The coolant flow is subdivided in its downstream portion to achieve the advantages of a short cooling circuit without sacrificing the advantages of a complete and continuous flow path for coolant in both the peripheral walls and the end walls.

Another object of the present invention is to provide a novel cooling system for the outer body of a rotary mechanism which includes means for placing the coolant fluid in close proximity to the surface of the outer body into which the principal amount of heat is being rejected.

Another object of the present invention is to provide a novel cooling system for the outer body of a rotary mechanism in which the coolant fluid is first circulated through the high heat rejection portion of the peripheral wall of the outer body and then its major portion is divided and directed into each end wall where it is principally routed to the high heat input areas of the end walls.

It is another object of the instant invention to provide a novel cooling system for the outer body of a rotary mechanism which uses for a coolant the same type of fluid which is used to lubricate the mechanism.

Another object of the present invention is to provide a novel cooling system for the outer body of a rotary mechanism which includes a large number of finned coolant passages within both the peripheral wall and end walls of the outer body and yet is relatively inexpensive and easy to fabricate through manufacturing processes such as machining, casting, and the like.

A further object of the present invention is to provide a novel cooling system for the outer body of a rotary mechanism which uses for the coolant fluid the same fluid which is used to lubricate and cool the bearings and rotor of the rotary mechanism; the achievement of this object permits the realization of the following beneficial and advantageous results:

(1) The conventional water-glycol pump, tank, and lines which are needed in the usual outer body cooling system may be eliminated.

(2) Servicing of the outer body cooling system is simplified, since the problem of filling the coolant reservoir or radiator with exact proportions of water and glycol is eliminated.

(3) The fluid which can be used for both cooling and lubricating is lighter in weight than the glycol-water mixture it replaces.

(4) The probability of leakage in the outer body cooling system is considerably reduced because fewer lines and fittings are needed.

(5) The mean coolant temperature in the outer body cooling system can be raised, which permits consequent weight reduction in the cooling system as a whole.

A still further object of the present invention, attainable because of the weight reduction benefits and advantages just recited, is to provide a novel outer body cooling system which is particularly useful in all applications of the rotary mechanism in which reduction of weight on lightweight construction is a desideratum.

To achieve the foregoing objects, and in accordance with its purpose, the present invention provides means which as embodied and broadly described, comprises fluid coolant passages within both the peripheral wall and the end walls of the outer body of a rotary mechanism, the passages being located close to the hottest metal portions of the peripheral wall and end walls. A suitable coolant fluid, such as oil, is fed into the inlet of the cooling system in the peripheral wall and is forced to circulate through the hottest portions of the peripheral wall; a major portion of the coolant fluid is then divided and circulated through the end walls in appropriate passages, and, finally, all the coolant fluid is fed into an outlet manifold within the peripheral wall and from there is discharged through an outlet.

Since the present invention is particularly useful in the rotating combustion type of rotary mechanism, it will be described with reference to its use in such a rotating combustion engine.

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.

Of the drawings:

FIG. 1 is a sectional view of the mechanism taken along the line 1—1 of FIG. 2 and showing the rotor positioned within the outer body;

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

FIG. 3 is a diagrammatic view and polar-type graph showing the relative rates of heat input to the peripheral wall of the outer body at all points about the periphery of the inner surface of the peripheral wall;

FIG. 4 is an exploded schematic perspective view of the two end walls and the peripheral wall of the outer body of the rotary mechanism; this view schematically shows the flow path of the coolant fluid through the peripheral wall and end walls of the outer body;

FIG. 5 is a plan view partly in section of the outer portion of an end wall of the outer body;

FIG. 6 is a plan view of the inner portion of an end wall of the outer body which shows the finned passages for coolant fluid in the end wall; and

FIG. 7 is an exploded 30° isometric view showing the outer and inner portions of the peripheral wall of the outer body and the outer and inner portions of an end wall of the outer body in their proper relationship to one another but displaced for clarity.

It is to be understood that both the foregoing general description and the following detailed 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 the rotating combustion engine the enclosed combustion gases transmit heat very rapidly to the surrounding metal walls of the outer body. Unless this heat is removed by an appropriate cooling system, the metal temperature will rapidly increase until the metal loses its strength or melts.

Even when the heat is being removed as fast as it is being put into the metal, it is a well known fact that there must be a temperature gradient in the metal in the direction in which the heat is flowing. This gradient has the value:

$$\frac{dt}{dx}=\left(\frac{1}{k}\right)\left(\frac{Q}{A}\right)$$

Where

$$\frac{(dt)}{(dx)}$$

is the temperature drop per unit thickness of the metal,

$$\frac{(Q)}{(A)}$$

is the rate at which the heat is being transferred per unit area perpendicular to the heat flow, and k is the thermal conductivity of the metal. It can thus be seen that a high heat flow per unit area, or a low thermal conductivity, or both of these factors combined will result in a larger temperature drop in the metal if the metal thickness is large.

The cooling system of the present invention is designed to minimize the difference between the coolant temperature and the hottest metal temperature by minimizing the metal thickness between the hot working gases and the coolant.

This desideratum is achieved by placing substantially parallel grooves or cooling passages near the heated surface of the metal. The grooves conduct coolant circumferentially around the peripheral wall of the outer body from the point where the heating begins to be significant to the point where the heat load is negligible, i.e., near the exhaust port of the engine.

At the exhaust port, the flow of coolant divides, a small portion continues circumferentially around the peripheral wall of the outer body to an outlet manifold near the point where the coolant was first admitted to the peripheral wall; this continuous flow around the peripheral wall promotes uniform temperature distribution within this part of the engine. The remaining coolant subdivides into two substantially equal parts, the two parts being directed one to each end wall of the outer body.

Within each end wall the coolant flow again divides; the larger portion flows through finned passages in the most severely heated portion of the end wall, and the remainder, or minor portion, passes around the end wall in the opposite direction, to promote more uniform temperature distribution within the end walls. Each of these portions of coolant flow within each end wall is collected in separate manifolds at a point near the outlet manifold of the peripheral wall. Each of the end wall coolant flows then joins the residual coolant flow which continued around the peripheral wall and the entire coolant flow leaves the peripheral wall through a single outlet.

Control of the flow distribution within the peripheral wall of the outer body is effected by providing a suitably restricted flow passage at the point in the peripheral wall where the residual coolant flow enters the outlet manifold and within each of the end walls at the point where the smaller portion of the end wall coolant flow is collected in

the end wall outlet manifold before admission into the outlet manifold of the peripheral wall.

The actual size and shape of the coolant passages must be designed for each application of the engine; among the factors which must be considered are the type, quantity, initial temperature, and pumping pressure of the coolant fluid; the thermal conductivity and temperature resistance of the metal; and the rate of heating. In general, however, the coolant passages should be as close as is practicable to the heated surface of the metal, and the shape of the metal defining the sides of the coolant passages should have "high fin effectiveness." To achieve high fin effectiveness, the coolant passages must usually be deeper that they are wide and narrower at the bottom, i.e., toward the heat source, than at the top.

In accordance with the invention, a rotating combustion engine and a novel cooling system for the peripheral wall and end walls of its outer body are provided. As embodied, and as shown in FIGS. 1 and 2, the present preferred embodiment includes a rotating 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, but the eccentric is stationary; 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 which 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 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 which has for its inner surface a curved inner surface 18, preferably in the form of an epitrochoid and a pair of axially-spaced end walls 22 and 24 which 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 large and ample 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 which 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 which 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 which 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 which carry radially movable sealing members 40. The sealing members 40 are in substantially 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.

The spark plug 46, as schematically indicated in FIG. 1, 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.

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

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-out portions or channels 52 which permit combustion gases to pass freely from one lobe of the epitrochoidal inner surface 18 to the other lober, when the rotor is at or near the top dead center compression position. Also, the compression ratio of the engine may be controlled by adjusting 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 around its own axis 14, the shaft 26 rotates three times about its axis 16.

As the engine operates, the various phases of the cycle of the engine working fluid in the working chambers 42 take place adjacent to the same portion of the outer body 12. Thus, for each working chamber 42 combustion is initiated by the spark plug 46, which is located adjacent to the lobe junction 47 of the peripheral wall 20 of the outer body.

With the rotor 10 in the position of FIG. 1, the lower working chamber 42 is approximately in a position for initiation of combustion in this chamber, and combustion preferably would be initiated just prior to the chamber 42 having reached this position. Similarly to the spark plug 46, the engine intake port 48 and exhaust port 50 successively serve each of the working chambers 42, and these ports are on the side of the outer body opposite to the spark plug 46. It is apparent, therefore, that as the engine operates, the rate of heat input or rejection to the outer body 12, resulting from the cycle of the gas (working fluid) in the working chambers 42, is not uniform about the outer body and is greatest on the side of the outer body adjacent to the spark plug 46 where combustion is initiated. The actual distribution of the heat input to the outer body peripheral wall 20 is shown by the polar-type curve 31 of FIG. 3, and the magnitude of the rate of heat input per unit area at each point of the inner surface 18 of the peripheral wall 20 is proportional to the radial distance between that point and the curve 31.

As is apparent from the curve 31 of FIG. 3, the rate of heat input per unit surface area to the outer body peripheral wall 20 suddenly begins to increase adjacent to a point 33 on the inner surface 18 of the peripheral wall 20. As is evident from a comparison of FIGS. 1 and 3, this point 33 corresponds approximately to the position of the trailing end of a combustion chamber 42 (clockwise end of the lower combustion chamber in FIG. 1) as combustion is initiated in the chamber. From

the point 33, the heat input to the outer body increases in a counter clockwise direction about the axis 16 of the outer body approximately to a point 35 on the inner surface 18 and then proceeds to fall off so that at the exhaust port 50 the rate of heat input per unit surface area into the outer body peripheral wall 20 is already quite small. From the intake port 48 counter clockwise to the point 33 the heat input to the outer body is a minimum and is negligible.

It should be emphasized that the curve 31 represents the heat input to the outer body peripheral wall 20 per unit surface area of the wall exposed to the working fluid

$$\frac{(Q)}{(A)}$$

and this area is uniform around the peripheral wall except in the vicinity of the intake passage 48 and the exhaust passage 50. In the vicinity of the exhaust passage 50 the total surface area of the outer body peripheral wall 20 exposed to the combustion gases is suddenly increased by virtue of the surface area of the exhaust passage 50 itself. The total heat input rate to the outer body peripheral wall 20 in the vicinity of the exhaust passage 50 thus is much greater than the total heat input rate on either side of the exhaust passage although the heat input per unit surface area (curve 31) remains about the same. It is, therefore, apparent that the cooling requirements of the outer body 12 vary considerably about its periphery.

Since almost no heat rejection takes place in the portion of the outer body which is adjacent to the location where the intake phase occurs, it is desirable to transfer some of the heat from the hotter portions of the engine into the relatively cool portion which exists adjacent to the location where the intake phase takes place to minimize thermal distortions within the outer body.

In accordance with the invention, means are provided to minimize temperature variations in the outer body around its periphery and to insure that thermal stresses and distortions set up in the outer body during operation will be kept at an acceptably low level. In the present preferred embodiment, this means comprises a plurality of fluid coolant passages within both the peripheral wall 20 and the end walls 22 and 24 of the outer body 12 which permit a suitable coolant fluid to circulate progressively from the hotter portions of the peripheral wall to the hotter portions of the end walls and, finally, into the cooler portions of both the peripheral wall and end walls.

As embodied, the fluid coolant passages within the outer body 12 comprise a plurality of parallel passages 54 separated by walls or fins (FIG. 2 and FIG. 7) and these passages 54 are located within the peripheral wall 20 close to the inner surface 18. Also, as embodied, the passages 54 are formed by fabricating the outer body 12 from two parts, an outer portion 56 and an inner portion 58 (FIG. 7). When the outer body 12 is assembled, the inner portion 58 is mated with the outer portion 56 so that the outer portion 56 covers a plurality of slots which have been machined or cast in the inner portion 58, and the slots when thus covered yield the finned passages 54 (see FIG. 2).

As embodied, the fluid coolant passages within the end walls 22 and 24 also comprise a plurality of parallel finned passages 60 within each of the end walls 22 and 24. Similarly to the outer body finned passages 54, the end wall finned passages 60 are formed by the mating together of two parts from which the complete or assembled end wall is constructed. These two parts of each of the end walls 22 and 24 similarly comprise an outer end wall portion 62 and an inner end wall portion 64. A series of slots or grooves are cut in the inner end wall portion 64, as can best be seen in FIG. 6, and when the outer end wall portion 62 is assembled to the inner end wall portion 64, the outer portion 62 covers the slots or grooves to form the complete end wall finned passages 60 (see FIGS. 2, 5, 6 and 7).

In both the peripheral wall 20 and the end walls 22 and 24 the peripheral wall finned passages 54 and the end wall finned passages 60 are preferably machined or cast and assembled in a manner which will insure that the coolant passages have a high finned effectiveness, i.e., the coolant passages are preferably deeper than they are wide and are narrower at the portion toward the heat source than at the portion away from the heat source.

It should be observed that the finned passages 54 in the peripheral wall and the finned passages 60 in the end walls have no abrupt changes in direction or flow area. Because of this smooth hydrodynamic contour of the passages 54 and 60, there are no locations in these passages which have little or no flow velocity of the fluid coolant and, accordingly, any vapor accumulation in these passages is instantly carried away by the coolant flow. This smooth hydrodynamic contour of the liquid coolant passages avoids hot spots that might otherwise be formed in the regions of high heat input to the outer body if vapor were permitted to accumulate at certain spots in these fluid coolant passages.

In accordance with the invention, means are provided for insuring an effective cooling circuit for circulation of the cooling fluid within the outer body 12 which will yield a maximum cooling effectiveness for a given quantity of cooling fluid and which will, at the same time, tend to minimize thermal distortions within the outer body by promoting more uniform temperatures around the periphery of the outer body. As embodied, and as can best be seen depicted schematically in FIG. 4, taken in combination with FIGS. 1 and 5, the means for insuring an efficient cooling circuit comprise a coolant inlet passage 66 in the peripheral wall 20 of the outer body 12. The coolant inlet passage 66 leads into an inlet manifold 68 which distributes the incoming coolant fluid to the peripheral wall finned passages 54.

As shown in FIGS. 1, 4 and 7, the coolant is introduced into the peripheral wall 20 at a point which approximately corresponds to the point 33 on the polar-type heat rejection graph, FIG. 3, at which a substantial quantity of heat begins to be rejected to the peripheral wall at the start of the engine combustion phase. From this point, 33, as can be seen in FIG. 4, the major portion of the fluid pursues a flow path through the finned passages 54 around the hottest part of the peripheral wall 20 (see FIG. 3) and the major portion of the fluid continues this undivided flow until it reaches a point slightly past the exhaust passage 50.

A very minor portion of the fluid flows through the passages 54 in the opposite direction for a short distance around the cooler portion of the peripheral wall 20 and into the outlet manifold 72 through a small passage 73 which is sufficiently restricted to insure that only a very minor portion of the fluid entering the inlet manifold 68 follows this path. The minor flow just described, however, helps to keep the temperature around the peripheral wall 20 as uniform as possible by removing some of the heat being rejected to the peripheral wall 20 in the region of the inlet manifold 68. As shown in FIG. 2, the finned passages 54 are placed as close to the inner surface 18 of the peripheral wall 20 as the strength of the materials will permit.

A flow distribution manifold 70 occurs in the cooling circuit in the present embodiment just slightly past the exhaust passage 50 within the peripheral wall 20. This flow distribution manifold 70 is shown in all figures of the drawings except FIG. 3, but its function can best be grasped by a perusal of FIG. 4. As shown in FIG. 4, the flow distribution manifold 70 divides the main stream of coolant fluid into three separate portions. A residual portion continues the flow path around the peripheral wall outlet manifold 72 from whence it is withdrawn from the outer body by means of an outlet passage 74 in the

peripheral wall 20, and this outlet passage 74 is located adjacent to the coolant inlet passage 66 so that the coolant fluid describes a complete circuit around the peripheral wall.

From the flow distribution manifold 70 the remaining two portions of coolant flow are directed in approximately equal amounts, one portion to each of the end walls 22 and 24. An end wall inlet manifold 76 is provided in each end wall as a continuation of the flow distribution manifold 70 so that the portion of coolant flow in each end wall may be distributed to the end wall finned passages 60. As the coolant fluid enters the end wall finned passages 60 from the inlet manifold 76, which extends across the passages 60, it is again subdivided into two discrete flow paths. The major portion of the fluid describes a flow path through the finned passages 60 which is opposite to the hottest portions of the engine as shown in the polar-type graph FIG. 3, while a lesser portion of the fluid pursues a shorter path in the opposite direction which is adjacent to the cooler portions of the engine, as shown in FIG. 3. The flow paths described by the coolant fluid within the end walls 22 and 24 are clearly depicted in FIG. 4.

In accordance with the invention, means are provided for insuring desired proportional divisions of coolant flow, first, between the residual portion in the peripheral wall 20 and the two portions going to the end walls 22 and 24 and second, within each end wall itself to insure proper proportional division between the major and minor flow paths within the end walls.

As embodied, the means for insuring the proportional division of flow between the residual portion remaining in the peripheral wall 20 and the two portions going to the end walls 22 and 24 comprises a restricted passage 78 on the upstream side of the outlet manifold 72 in the peripheral wall 20. This restricted passage is dimensioned to give the desired distribution of coolant flow between the portion going to the end walls from the manifold 70 and the residual portion remaining within the peripheral wall 20.

Similarly, an end wall restricted passage 80 is placed within each of the end walls 22 and 24 at a point just downstream from a first end wall manifold 82 which acts as a collecting point for the minor portion of the coolant fluid flowing in the end wall (see FIG. 5). A second end wall manifold 84 is provided adjacent to the first end wall manifold 82 and serves as a collecting point for the major portion of the cooling fluid flowing through the end walls. The two manifolds, 82 and 84, meet at a common outlet portion 86 which receives the coolant fluid from both the manifolds 82 and 84 and directs it into the peripheral wall outlet manifold 72.

From the foregoing and from a perusal of FIG. 4, it can be seen that the peripheral wall outlet manifold 72 acts as a collecting point for all of the coolant fluid which flows through both the peripheral wall 20 and the end walls 22 and 24, and the peripheral wall outlet manifold 72 is provided with the previously described outlet passage 74 from which the coolant fluid leaves the outer body 12.

As illustrated in FIG. 7, the fins of the finned passages 54 are cut back adjacent to the interior bosses 49 and 51 of the intake and exhaust passages 48 and 50. The interior bosses 49 and 51 as shown in FIG. 7, are located on the inner portion of the peripheral wall or liner portion 58. The cutting back of the fins of the finned passages 54 forms an annulus to permit the fluid to flow around each of the bosses 49 and 51. When the liner or inner portion 58 is assembled to the outer portion of the perihperal wall 56, a complete annulus 53 is formed which surrounds the intake passage 48 and a similar annulus 55 is formed which surrounds the exhaust passage 50 as close to the working surfaces of these passages as is structurally possible. The annulus 55 surrounding the exhaust passage 50 serves to help cool the exhaust

passage, but the coolant flowing within the annulus 53 surrounding the intake passage 48 serves a different purpose.

The fluid coolant surrounding the intake passage 48 is at a higher temperature than the temperature of the fuel-air charge which enters the engine through the inlet passage. The heated coolant fluid, therefore, serves to heat the incoming charge, and in the case of a fuel-air charge, helps to vaporize the fuel in the charge.

After the coolant fluid has been discharged from the outlet passage 74 of the outer body 12, it is passed through an appropriate cooling radiator to return it to the desired inlet temperature and is then recirculated back to the coolant inlet passage 66. Continuous circulation of the coolant fluid through the cooling circuit is insured by means of an appropriate pump within the circuit.

The invention is also applicable to rotary mechanisms having a general configuration different from that illustrated. For example, the profile of the inner surface of the outer body could be a three-lobed instead of a two-lobed epitrochoid with the inner body having a generally square (as illustrated in U.S. Patent No. 2,988,065, issued June 13, 1961) instead of the generally triangular shape illustrated. In addition, as previously stated, the invention is applicable to rotary mechanisms such as fluid motors and fluid pumps.

From the foregoing description, it will be apparent that the novel cooling system for rotary mechanisms provided by the present invention yields the following positive benefits, advantages, and unexpected results:

(1) The system keeps thermal stresses and distortions set up in the inner surface of the outer body during operation at a relatively low level by minimizing temperature variations in the outer body around the periphery of its inner surface.

(2) The system provides means for directing the relatively cool entering fluid first adjacent to one end of a region of high input from which the fluid flows toward the other of the regions of high heat input and finally into the regions of lowest or negligible heat input just before being withdrawn from the outer body.

(3) The system provides coolant flow passages having smooth hydrodynamic contours and avoids the creation of hot spots within the cooling circuit.

(4) The system includes means for placing the coolant fluid in as close proximity to the inner surface of the outer body as is structurally permissible to withdraw the heat as efficiently as possible from the inner surface into which it is being rejected.

(5) The system permits the use of a coolant fluid which can also be used to lubricate the rotary mechanism.

(6) The system provides for cooling of the outer body wiht a reduced number of parts, a simplified design, less probability of leakage within the system, and very considerable weight reduction than can be achieved with the conventional water and glycol cooling systems.

(7) The system provides for heating of the intake charge within the intake passage to improve vaporization of a fuel-air charge and to promote combustion efficiency.

(8) The system provides a short cooling circuit which minimizes pressure losses in the flow path, promotes a high velocity of flow, and permits a small amount of coolant fluid to provide a high degree of cooling efficiency.

(9) The system achieves the advantages of a short cooling circuit without sacrificing the advantages of a complete and continuous flow path by subdividing the circuit in its downstream portion in the regions of lower heat input to the outer body.

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

What is claimed is:

1. A rotary mechanism employing a working fluid and comprising an outer body having a cavity with spaced

end walls and a peripheral wall interconnecting the end walls; an inner body mounted within the cavity for rotation with respect to the outer body to form working chambers between the inner body and outer body which vary in volume upon relative rotation of the inner body within the outer body so that a relatively high temperature phase of the working fluid cycle always takes place in the working chamber adjacent to a first region of the peripheral wall and a relatively low temperature phase of the working fluid cycle always takes place in the working chamber adjacent to a second region of the peripheral wall; the first region of the peripheral wall being a region of relatively high heat input and the second region of the peripheral wall being a region of relatively low heat input; the outer body having a plurality of peripheral wall passages extending substantially around the peripheral wall for the flow of a coolant liquid through the peripheral wall; an inlet for supplying the coolant liquid to the peripheral wall passages adjacent to the region of relatively high heat input; the outer body also having a plurality of end wall passages extending around each end wall for the flow of a coolant liquid through the end walls of the outer body; a distribution manifold in the peripheral wall downstream from the inlet for connecting the end wall passages to the peripheral wall passages; an outlet manifold in the peripheral wall, the end wall passages being connected to the outlet manifold; a restricted passage providing communication between the downstream ends of the peripheral wall passages and the outlet manifold; and at least a portion of the coolant liquid flowing from the inlet along a relatively high heat input region around the peripheral wall to the distribution manifold from which at least a portion of the liquid is supplied to the end walls and the remaining portion proceeds in the original direction around the peripheral wall to the outlet manifold.

2. The invention as defined in claim 1, in which the end wall passages include a first portion about a relatively high temperature region of the end wall adjacent to the relatively high heat input region of the peripheral wall; a second portion about a relatively low temperature region of the end wall adjacent to the relatively low heat input region of the peripheral wall; a first end wall outlet manifold for the first portion of the end wall passages; and a second end wall outlet manifold for the second portion of the end wall passages.

3. The invention as defined in claim 2, which includes means for restricting flow through the second portion of the end wall passages for insuring that a major portion of the coolant liquid directed to each end wall flows through the first portion of the end wall passages.

4. The invention as defined in claim 2, in which the first and second end wall outlet manifolds are connected to the peripheral wall outlet manifold.

5. A rotary mechanism as defined in claim 1, in which the rotary mechanism is an internal combustion engine having ignition means disposed in a working chamber in the region of relatively high heat input and including an intake passage for the delivery of a combustible charge to the working chambers of the mechanism, the intake passage having its discharge portion disposed in heat exchange relation with the coolant liquid.

6. The invention as defined in claim 5, which also includes an exhaust passage for the removal of burned gases from the working chambers of the mechanism, the exhaust passage having its inner end disposed in heat exchange relation with the coolant liquid.

7. The invention as defined in claim 5, which includes an annular passage surrounding the periphery of the intake passage adjacent to its discharge end, the annular passage being connected to the peripheral wall passages.

8. The invention as defined in claim 6, which includes an annular passage surrounding the periphery of the exhaust passage at its interior end, the annular passage being connected to the peripheral wall passages.

9. A rotary mechanism employing a working fluid and comprising an outer body having a cavity with spaced end walls and a peripheral wall interconnecting the end walls; an inner body mounted within the cavity for rotation with respect to the outer body to form working chambers between the inner body and outer body which vary in volume upon relative rotation of the inner body within the outer body so that a relatively high temperature phase of the working fluid cycle always takes place in the working chambers adjacent to a first region of the peripheral wall and a relatively low temperature phase of the working fluid cycle always takes place in the working chambers adjacent to a second region of the peripheral wall; the first region of the peripheral wall being a region of relatively high heat input and the second region of the peripheral wall being a region of relatively low heat input; the outer body having a plurality of peripheral wall passages extending substantially around the peripheral wall for the flow of a coolant liquid through the peripheral wall; an inlet for supplying a coolant liquid to the peripheral wall passages adjacent to one end of the region of relatively high heat input; the outer body also having a plurality of end wall passages extending around each end wall for the flow of a coolant liquid through the end walls of the outer body; a distribution manifold in the peripheral wall downstream from the inlet for connecting the end wall passages to the peripheral wall passages; the end wall passages being subdivided into a major portion and a minor portion within the end wall, the major portion being located about a region of relative high heat input to the end wall adjacent to the relatively high heat input region of the peripheral wall.

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