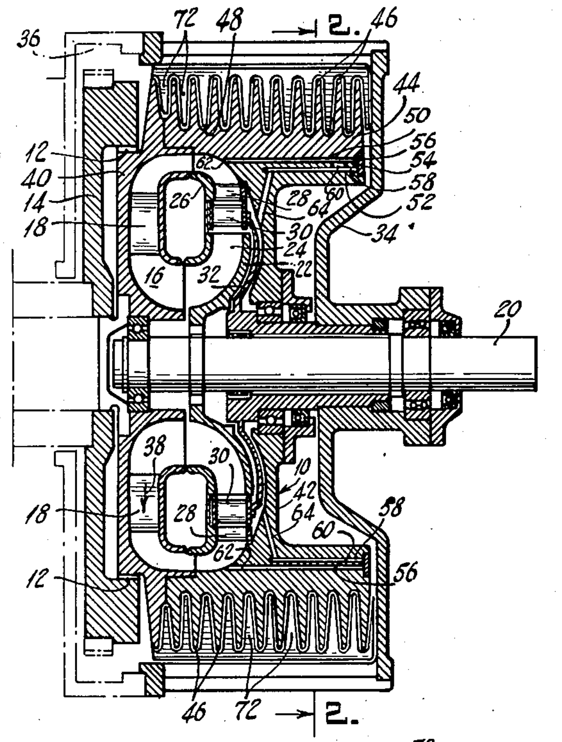
Sept. 23, 1952 K. G. ÅHLÉN ET AL 2,611,248

MEANS FOR EFFECTING HEAT EXCHANGE BETWEEN A ROTATING SOLID BODY AND A GASEOUS MEDIUM, PARTICULARLY FOR COOLING FLUID TRANSMISSIONS WITH ROTATING CASINGS

Filed May 16, 1951 4 Sheets-Sheet 1

Fig. 1.



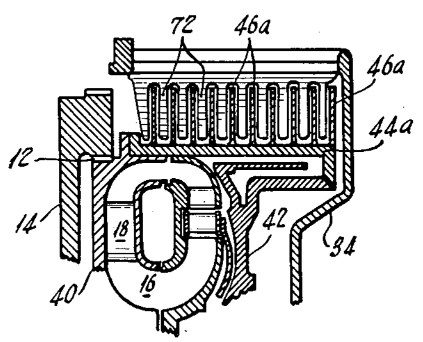


Fig. 3.

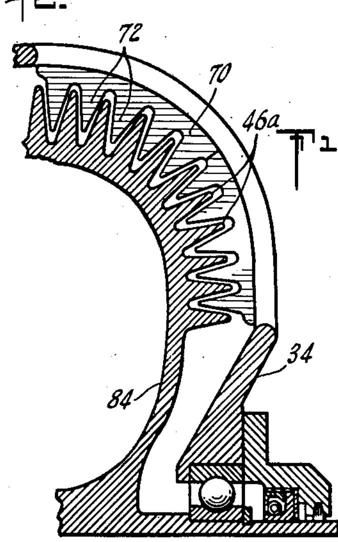


Fig. 4.

INVENTORS
Karl Gustav Åhlén
Tor Axel Ödman
BY
Jarvis C. Marble
their ATTORNEY

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Fig. 5. Fig. 5a. Fig. 5b.

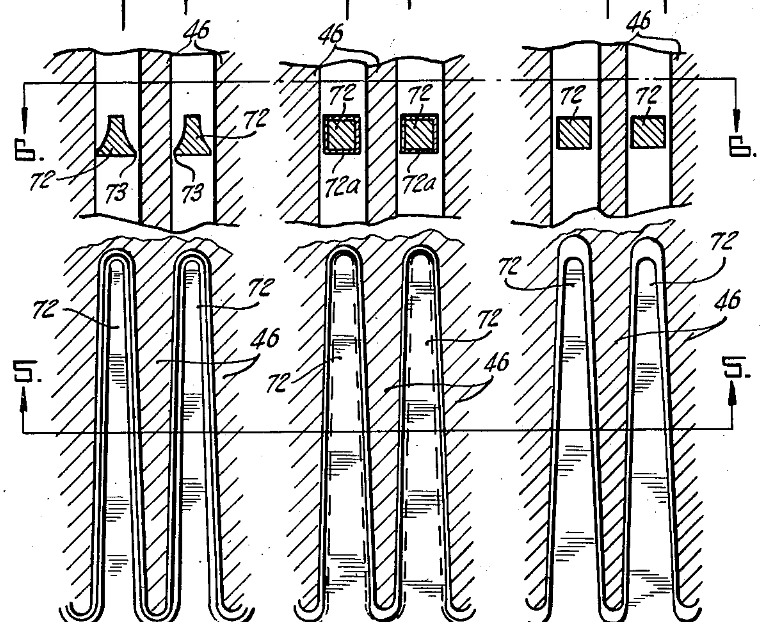
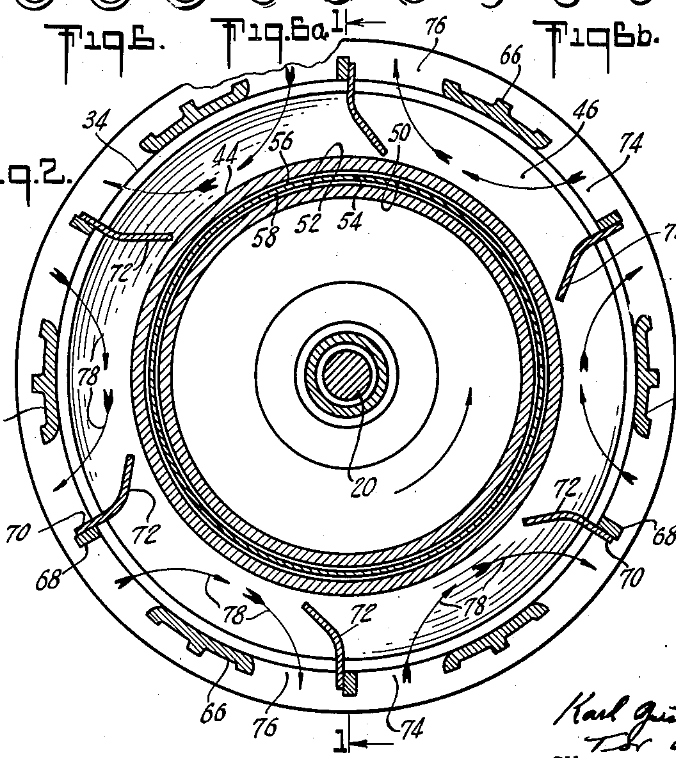


Fig. 6. Fig. 6a. Fig. 6b.

Fig. 2.



Karl Gustav Åhlén
Tor Axel Edman
INVENTORS
BY Darvie, Marble
their ATTORNEY

Sept. 23, 1952 K. G. ÅHLÉN ET AL 2,611,248

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Fig. 9.

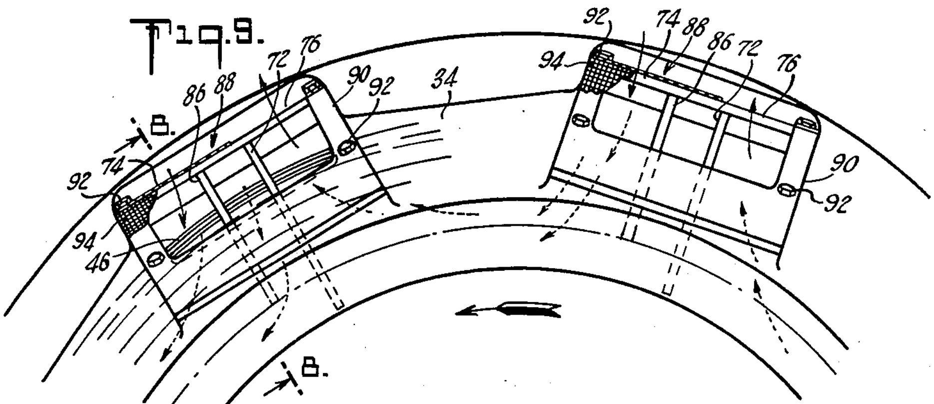


Fig. 8.

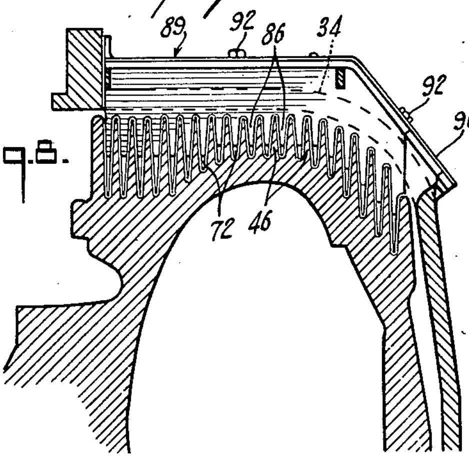
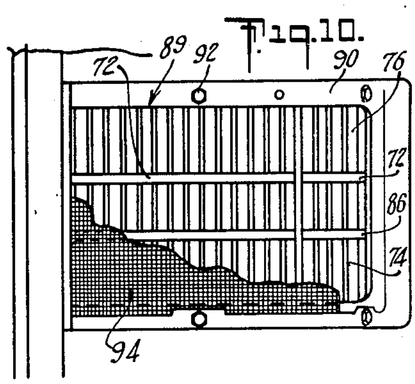


Fig. 10.



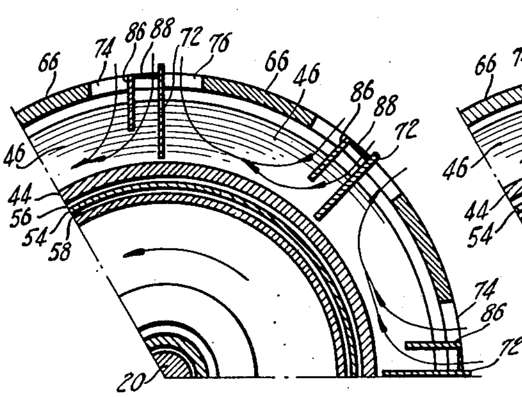


Fig. 7.

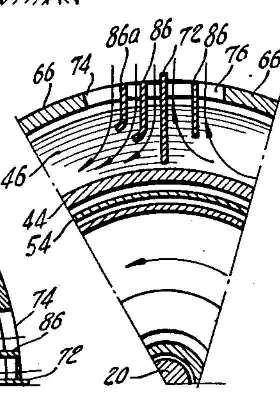


Fig. 7a.

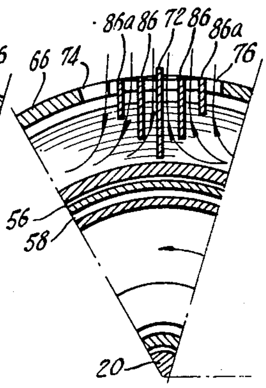


Fig. 7b.

INVENTORS
Karl Gustav Åhlén
Tor Axel Adman
BY Jarvis C. Marble
their ATTORNEY

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Fig. 12.

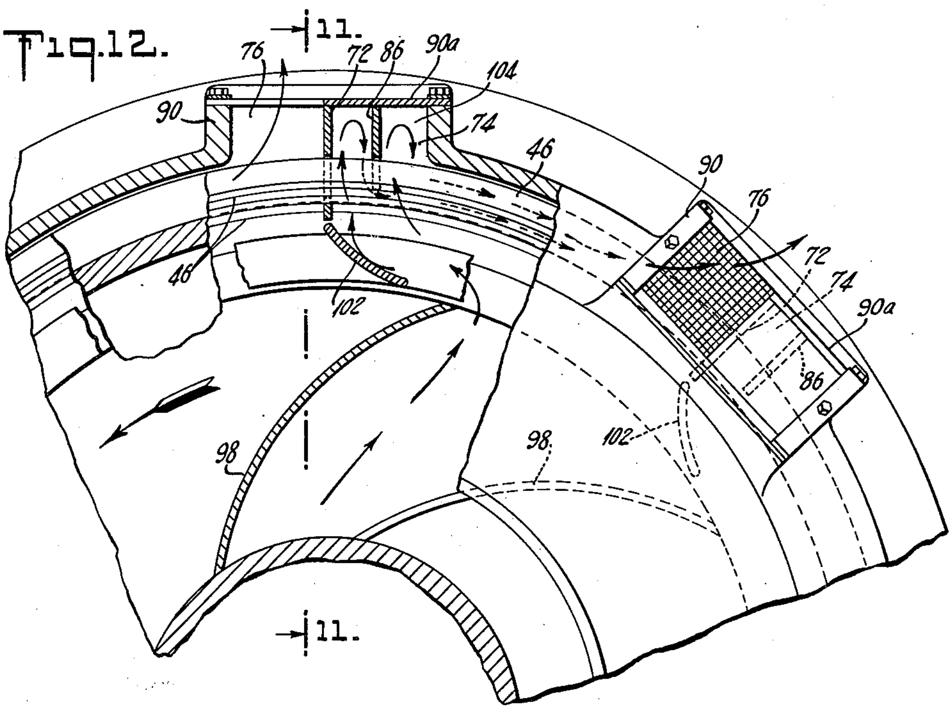
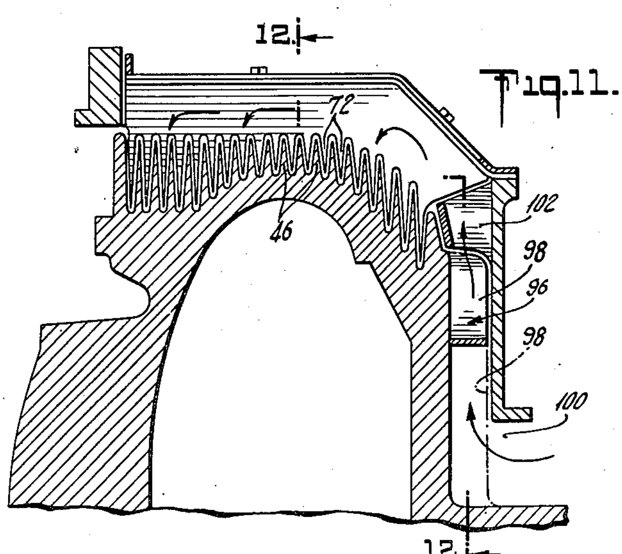


Fig. 11.



INVENTORS
Karl Gustav Åhlén
Tor Axel Öhman
BY
Darvial, Marble & Thiele
ATTORNEY.

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UNITED STATES PATENT OFFICE

2,611,248

MEANS FOR EFFECTING HEAT EXCHANGE BETWEEN A ROTATING SOLID BODY AND A GASEOUS MEDIUM, PARTICULARLY FOR COOLING FLUID TRANSMISSIONS WITH ROTATING CASINGS

Karl Gustav Åhlén, Stockholm, and Tor Axel Ödman, Saltsjo-Duvnas, Sweden, assignors to Svenska Rotor Maskiner Aktiebolag, a corporation of Sweden

Application May 16, 1951, Serial No. 226,581
In Sweden June 11, 1947

30 Claims. (Cl. 60—54)

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This application is a continuation in part replacing our copending application Serial No. 760,616, filed July 12, 1947, and relates back thereto for all common subject matter.

The invention relates to heat transfer between solid and gaseous bodies and has particular reference to such transfer between a rotating solid body and a gaseous medium. Still more particularly the invention relates to the cooling by air or other gaseous medium of rotating bodies which are heated as a result of their normal operation and which require cooling during such operation in order to dissipate excess heat and limit the working temperature of the body to an acceptable value.

In its broader aspects the invention is applicable to a wide variety of structures and uses in which heat may be absorbed from or imparted to the solid body, but for the purpose of explaining the principles of the invention it will hereinafter be described as applied to the air cooling of a heated rotating body. Specifically it will be described by way of example as applied to the air cooling of a hydrodynamic torque converter of the rotating casing type, since such a structure necessarily generates considerable heat in normal operation and is particularly well adapted to have the principles of the invention applied thereto, it being understood, however, that the invention is not limited by the example chosen for disclosure but embraces all forms of apparatus cooled or heated in accordance with the invention, the scope of which is defined in the appended claims.

The general purpose of the invention is to provide improved heat transfer by maintaining both high relative velocity and relatively high temperature difference between the heat exchanging bodies so that a high coefficient of heat transfer is obtained, and to effect the high rates of heat transfer in a novel manner requiring the minimum of power absorption for the heat transfer function.

The manner in which the above and other purposes are achieved, together with more detailed objects hereinafter appearing and also an understanding of the manner in which the principles of the invention may be applied to many varied forms of apparatus, may best be realized from a consideration of the ensuing portion of this specification, taken in conjunction with the accompanying drawings forming a part hereof, in which:

Fig. 1 is a central longitudinal section showing the invention applied to a hydraulic torque converter, the section being taken on the line 1—1 of Fig. 2;

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Fig. 2 is a section taken on the line 2—2 of Fig. 1;

Figs. 3 and 4 are fragmentary views similar to Fig. 1 showing different forms of housing structures of the hydraulic apparatus;

Figs. 5, 5*a* and 5*b*, taken on line 5—5 of Figs. 6, 6*a* and 6*b*, are sectional views on enlarged scale of different embodiments of baffle or guide elements contemplated by the invention;

Figs. 6, 6*a* and 6*b* are elevations of the structures shown respectively in Figs. 5, 5*a* and 5*b* taken on the line 6—6 of the latter figures;

Figs. 7, 7*a* and 7*b* are fragmentary sections similar to Fig. 2 showing different forms of apparatus embodying the invention;

Fig. 8, taken on line 8—8 of Fig. 9, is a fragmentary section similar to Fig. 1 showing another form of the structure embodying the invention;

Fig. 9 is a fragmentary elevation looking from the right of Fig. 8;

Fig. 10 is a fragmentary plan view as seen from above Fig. 9;

Fig. 11, taken on line 11—11 of Fig. 12, is a fragmentary section similar to Fig. 1 of still another embodiment of the invention, and

Fig. 12 is a fragmentary transverse view, partly in elevation and partly in section taken on line 12—12 of Fig. 11.

Referring now more particularly to the embodiment shown in Fig. 1, the apparatus illustrated is a hydraulic torque converter of the hydrodynamic type incorporating the invention. In the apparatus shown, a rotatably mounted casing, indicated generally at 10, is provided with a toothed driving connection 12 through which it is driven at engine speed from an engine flywheel 14. The casing 10 provides a toric chamber 16 for circulation of the power transmitting liquid. In the embodiment shown, the casing 10 carries the pump or impeller blades 18 and in effect constitutes the pump or driving member of the apparatus. A rotatably mounted driven member 20 provides a turbine wheel 22 which in the present instance carries a ring of turbine blades 24 and, indirectly through a part of the torus ring 26, a second ring of turbine blades 28. Between the rings of turbine blades 28 and 24, a ring of guide or reaction blades 30 is carried by the wheel part of a rotationally fixed reaction member 32 secured to an outer stationary housing member 34 fixed to a stationary part of the engine structure indicated at 36.

The structure thus far described is of more or less conventional known form, providing what is ordinarily termed a two-stage converter, through which power is transmitted by circulation of the power transmitting liquid through the pump, turbine and reaction blading in the direction indicated by arrow 38. Insofar as the present invention is concerned, the specific nature of the hydraulic circuit is immaterial and may embody any desired number of stages for converter operation or only pump and turbine members for coupling operation. Also insofar as this invention is concerned, the rotating casing may carry the turbine blades rather than the pump blades, which is a well known form of construction, but for reasons hereinafter pointed out a construction in which the rotating casing carries the pump blades may in many cases be preferable.

Referring now more particularly to the casing 10, the example illustrated is of built up construction comprising a wheel element 40 carrying the pump blades 18 and forming the forward wall of chamber 16, a second element 42 forming the rear wall of the chamber and an annular ring like element 44 joining the other two elements. The element 44 is provided externally with a series of radially extending flanges in the form of ribs or fins 46 separated by intervening grooves 48, these ribs and grooves being concentric with respect to the axis of rotation of the casing. The internal surface 50 of element 44 is cylindrical and radially spaced from a similar outer surface 52 on element 42. Between these surfaces a cylindrical baffle plate or drum 54 is located in radially spaced relation to both surfaces to provide annular channels 56 and 58 which communicate with each other through ports 60 in the baffle 54. Channel 56 is in communication with the radially outer port of chamber 16 by way of a series of peripherally spaced bores 62, while channel 58 communicates through bores 64 with chamber 16 at a place radially inwardly of the place of communication established by bores 62. Since the pressure of the working fluid in chamber 16 during operation of the apparatus is greater at the inlet of bores 62 than at the outlet of bores 64, the differential pressure will result in circulation of a part of the working fluid through the bores and passages 62, 56, 58 and 64 in the order named, which may be said to constitute an internal cooling circuit in the casing.

As will readily be apparent, heat generated in the hydraulic working circuit will be dissipated by direct conduction through the casing to the cooling ribs 46 from chamber 16 and also from the fluid circulated through the cooling circuit.

Owing to the high rate of circulation of the working liquid in the chamber 16 during operation of the converter, and particularly under certain conditions of power transmission through the converter, a very high rate of heat transfer from the liquid to the casing is secured. Under certain conditions of operation, when the converter may not be working at its best efficiency, a relatively high percentage of the power supplied to the converter may have to be dissipated in the form of heat. While in order to dissipate the relatively large amount of heat under such circumstances, the rate of heat transmission from the liquid to the casing may be adequate, the rate of heat transmission from the cooling ribs to the ambient atmosphere, when they are utilized in accordance with usual practice, is not sufficient to dissipate the heat that can be transmitted from the liquid to the casing when the amount of cooling surface is limited to the area dictated by practical considerations such as space limitations. Such constructions are further impractical since they would result under certain conditions which occur during normal operation, in overheating of the apparatus and the body of power transmitting liquid. To overcome this deficiency, cooling of the power transmitting liquid by circulation of all or a part of the liquid through some external extended surface cooler such as a radiator has been employed in most cases. Such arrangements necessitate the undesirable use of separate outside cooling devices which involve both extra weight and cost and also require the further undesirable use of outside conduits and connections which are subject to fluid pressure and are a source of possible trouble due to leakage or breakage.

To avoid the undesirable features of such cooling systems, direct air cooling has been resorted to in certain instances, employing extended heat dissipating surface on the casing. In such cases, however, the required rate of heat transfer for adequate cooling has been secured only by the employment of means for producing high velocity forced draft air to flow over the cooling surface, and the requisite cooling effect has been obtained with such arrangements only at the expense of the expenditure of a very considerable amount of power for supplying the cooling air.

In accordance with the present invention the above noted deficiencies in the cooling of apparatus of the kind discussed by way of illustration are overcome and the transfer of heat from or to rotating bodies at high rate is accomplished by providing a controlled air flow relative to the heat exchange surface of the rotating body which operates to maintain at all times and over substantially the entire area of the heat exchange surface a high relative velocity between the rotating surface and the heat exchanging gaseous medium.

This high rate of heat transfer is further obtained in accordance with the invention with the minimum expenditure of energy for causing the required circulation of the gaseous medium in heat exchange relation with the rotating body and in a great many cases adequate heat exchange at relatively high rate is obtainable without the necessity for fans or other like apparatus, the rotation of the rotating body itself being utilized in a manner which makes possible the high rate of exchange that is obtained.

In those cases where an extraordinarily high rate of heat transfer is required the principles of the invention may be employed in conjunction with apparatus providing for circulation of the gaseous medium by means such as a fan separate from or carried by the rotating body, but even in such cases the utilization of the principles of the invention, enable the desired extremely high rate of heat transfer to be obtained with a minimum expenditure of power.

The improved results flowing from the invention are achieved not only by the utilization of controlled streams of gaseous medium but also by so relating the flow of such streams to the rotating body that relatively high velocity is maintained between the two bodies in heat exchange relation, while at the same time the maximum absolute velocity of the gaseous medium is maintained at a relatively low value, so that the energy required to accelerate and decelerate the mass of gaseous medium used for heat exchange purposes is relatively very low.

Further, the improved results are obtained by so relating the flow of the gaseous medium in heat exchange relation with the rotating body that any given quantity of the gaseous medium is in heat exchange relation with the rotating body for only a relatively short period of time, so that the average temperature difference between the two heat exchanging bodies is much higher than in previous forms of heat exchange arrangements of the kind under consideration.

Additionally, the controlled flow of gaseous medium is, in accordance with the principles of the invention, so related to the rotating body that minimum resistance and power loss is obtained because of the substantial absence of highly turbulent flow, which has heretofore often been resorted to in order to obtain high rates of heat exchange but only with correspondingly high power requirements for effecting the desired function of the apparatus.

The principles of the invention as above discussed are embodied in the example shown in Figs. 1 and 2 by the structure now to be described.

The outer stationary housing **34** comprises a wall portion encircling the ribs **46** on the rotating casing and forms cover means for the grooves or channels **48**. This wall portion is interrupted at peripherally spaced places by openings providing communication between the channels and ambient atmosphere, as will be seen more clearly in Fig. 2. As shown in this figure, the cover portions of the wall are provided by peripherally spaced web portions **66** and in the openings between adjacent web portions axially extending ribs **68** serve to support baffle members **70**. Each of these baffle members comprises a series of obturating baffles in the form of vanes or fingers **72** which extend inwardly into and substantially fill the cross sections of the channels in the casing.

In the present embodiment six such baffle members equidistantly spaced around the periphery are employed. Depending upon the design factors of the individual case the number of these baffles may vary and may be less than the number shown, or more. Generally speaking however, the greater the number of baffles, within reasonable limits, the more effective the heat transfer.

The spaced baffles serve to sub-divide the channels into a plurality of sections and the supporting ribs **68** and baffle members **70** divide each of the openings in the wall of the housing into two openings or ports, one on each side of each baffle member. These ports are located at the ends of the several sections and provide for each section an inlet port **74** and an outlet port **76** for flow of air through each of the sections in the direction of rotation of the casing as indicated by the arrows **78**. Flow of air in the present instance is effected by rotation of the casing which acts to draw air into the channel sections in the manner shown, from which it is ejected through the several outlet openings by the action of the obturating baffles.

The air entering the channel sections from the relatively static ambient atmosphere will have maximum relative velocity with respect to the heat dissipating ribs on the casing and as it enters there will be maximum temperature difference between the air and the ribs. Consequently, the rate of heat transfer per unit area of rib will be very high. The air in the channels is accelerated in the direction of rotation of the casing by friction and while it remains in the channels the relative velocity between the air and the ribs progressively decreases, as does also the temperature difference between the air and the ribs. Consequently, the rate of heat transfer becomes progressively less the longer the air remains in the channels and for that reason, in accordance with the principles of the present invention, the air is ejected from the channels after a relatively short path of travel and before its velocity and temperature have increased to such extent as to seriously reduce the heat transfer coefficient. Since the rate of rotation of the casing, relative smoothness or roughness of the surfaces of the ribs, and the normal maximum desired temperature of the ribs all affect the rate of acceleration of the air and the temperature difference, it will be evident that the length of the channel sections in individual cases will be governed by the specific specification for the individual case and this in turn will govern the number of baffles placed in each channel.

In order to obtain optimum results, that is, to secure the maximum rate of heat transfer per unit area with minimum power consumption and with the minimum space requirement, the grooves or channels should be relatively deep and narrow. The ratio may be in the order of 10 to 1 or even more.

With relatively deep and narrow channels the relative velocity between the air and the walls of the channels produces turbulence of a rotary nature of the boundary layers at the sides of the individual air streams. This insures a displacement of the air in the channels such that substantially all of the air is brought into contact with the walls in even a short path of travel. On the other hand, with a short path of travel the air is not forced to a rotary tumbling movement of the air stream in the plane of rotation. This kind of turbulence should be avoided since it decreases the rate of heat transfer per unit area. Preferably, but without limitation, the length of the channels is chosen, giving effect to the particular conditions of the individual case, so that the flow of air in the channels may be said to be generally laminar.

By way of example, it has been found from actual test that a torque converter for ordinary automotive use having a power absorbing capacity up to approximately 150 H. P., and a rotating casing the diameter of which provides a peripheral speed at the mean diameter of the grooves of approximately 45 meters per second at 1800 R. P. M., can be cooled adequately by apparatus of the kind described having an area of cooling surface area of approximately two square meters and providing a minimum relative air velocity of approximately 30 meters per second, when the converter is operating under conditions requiring the dissipation of the heat equivalent of approximately 35 H. P. This relative velocity may be obtained by structure such as that illustrated and since under the conditions stated the cooling air is accelerated only to the relatively low average absolute velocity of around ten meters per second, the power consumption is small, amounting to materially less than one-quarter of a horsepower.

In the embodiment shown in Fig. 1, the outer element of the rotating casing has been shown as being of cast or forged form of one-piece integral construction including the cooling fins. Forged construction is relatively expensive and cast construction, particularly if relatively weak metals such as aluminum and the like are employed, may be subjected to undesirably high centrifugal stresses for such materials if used in high speed applications. Cast or forged construction is, however, not required, and in Fig. 3 there is illustrated an alternative form in which a structure built up of stampings may be used. Referring now to this figure the construction illustrated is generally similar to that previously described, corresponding parts being correspondingly numbered, and detailed description is accordingly not required. In the present instance the outer or ring element **44***a* of the casing is made in the form of a stamping to which the cooling fins **46***a* of sheet metal are attached in any suitable fashion, as by welding, brazing or other methods giving good heat conduction to the fins.

In the embodiments heretofore described the cooling fins have been shown as extending radially from the outer surface of a cylindrical drum-like ring element forming a part of a casing which further provides an internal cooling circuit for working liquid in addition to the working circuit. The invention is, however, not limited to this form of construction since effective cooling can be obtained with cooling fins positioned differently and in certain cases, more particularly with couplings, the separate internal cooling circuit may be dispensed with.

By way of illustration of such variation there is shown in Fig. 4 a different form of casing which may be utilized as a part of a coupling or converter, the pump and turbine parts being omitted from the drawing. In this construction the rotating casing **84** which may be either driving or driven is provided with a series of external circular cooling fins **46***a* concentric about the axis of rotation of the casing but following the contour of the casing which defines the working chamber **16** of the device. As in the previous forms of construction the outer stationary housing **34** is provided with baffle members **70**, the arrangement being similar to that illustrated in Fig. 2. In this form of construction the heat is dissipated by direct conduction through the wall of the casing through the working chamber to the cooling fins.

The form of the obturating baffle fingers may vary and as will be seen from Fig. 2 these fingers may be bent forwardly against the direction of rotation of the casing to form scoops for ejecting the air from the channel sections. More important, however, is the cross sectional form of the fingers and different suitable embodiments of fingers are illustrated in Figs. 5, 5*a* and 5*b*.

To obtain optimum results, reasonably close clearance should be maintained between the fingers and the walls of the channels. Generally speaking the less the clearance the better the results. The clearance employed however must be governed by manufacturing considerations, bearing in mind the fact that the fingers are carried by a stationary housing while the ribs are carried by a rotating casing and that it may not be possible to maintain absolute axial location of the rotating casing relative to the stationary housing. Differential expansion due to temperature differences and the use of different materials must also be taken into consideration. Fingers **72** of the form shown in Figs. 5 and 6 are advantageously employed. As will be seen from Fig. 5, the fingers are tapered in the plane of rotation so that the clearance between the walls of the ribs **46** and the fingers is established by relatively sharp edges **73**, which, should the clearance be lost for any reason, are easily worn off without damage to the parts. Obviously such

sealing edges may be obtained with other specific configurations and while it is preferable for the edges to face the direction of rotation of the casing as indicated by the arrow in the Fig. 2, this is not essential.

Alternatively, the fingers may be formed as shown in Figs. 5*a* and 6*a*, in which the fingers are plated to provide a coating **72***a* of relatively porous material that is readily worn off in case of unintended contact between the parts. While desirable, special forms of section of the baffles is not essential and in Figs. 5*b* and 6*b* fingers of rectangular section and of conventional material such as precision cast iron are indicated.

As previously mentioned, best results are obtained with channels that are relatively deep and narrow and test experience has shown that with such channels optimum results are obtained by utilizing guide baffles in addition to the obturating baffles **72**, such an arrangement as shown in Fig. 7. In this construction guide baffles **86**, which terminate materially short of the bottoms of the channels formed between the ribs **46**, serve to subdivide and guide the air streams entering the inlet ports **74**, to insure immediate flow of the incoming air to the bottoms of the relatively deep channels. The guide baffles may be supported in any suitable fashion from the housing. In the present embodiment such support is indicated by thin peripherally spaced cross members **88** between which the entering air flows as indicated by the arrows in the figure.

As between inlet and outlet ports, guide baffles at the inlet ports are more effective than at the outlet ports but the baffle arrangement shown in Fig. 7 may be varied as indicated in Figs. 7*a* and 7*b*. In Fig. 7*a* guide baffles **86** are provided to guide both inlet and outlet flow, and as may sometimes be desirable in the case of very deep channels, auxiliary guide baffles such as shown at **86***a* may be employed. The arrangement shown in Fig. 7*b* differs from that of 7*a* only by the inclusion of auxiliary guide baffles **86***a* for guiding outflowing air as well as incoming air. Also it has been found that improved results are obtained if the inlet ports **74** are larger than the outlet ports **76**, this being accomplished by making the inlet ports of greater peripheral extent than the outlet ports, as shown in Figs. 7–7*b*. The use of inlet ports of greater area than the outlet ports is beneficial regardless of whether or not guide baffles are employed.

The embodiments previously described have been shown more or less in diagrammatic fashion and in Figs. 8–10 inclusive a commercial embodiment of the invention as applied to a torque converter for a bus transmission transmitting power from an engine of approximately 150 H. P. is shown. In Fig. 8 the internal elements of the converter have been omitted but may be assumed to be of any conventional form such as illustrated in Fig. 1. The rotating casing with integral cast ribs **46** is encircled by the stationary outer housing **34** which is provided with a series of peripherally spaced openings, indicated generally at **89**. In the present case eight such openings are provided. For each of these openings a closure member **90** is provided which is removably secured to the housing **34** by studs **92**. These closure members are in the form of frames to which are secured the obturating baffles **72** which in the embodiment illustrated are in the form of comb-like members which are advantageously and economically made by precision casting. The closure members also carry the guide baffles 86 which advantageously may be of the same general form and construction as the obturating baffles 72. As will be seen very clearly from Figs. 9 and 10 the obturating baffle members serve to divide the openings 89 in the housing 34 into inlet ports 74 and outlet ports 76 when the closures are in place, the flow of air being as indicated by the arrows in Fig. 9.

The closure members 90 also provide means whereby the grooves or channels may be protected from damage due to solid bodies which otherwise might be thrown into the grooves through the ports when the apparatus is used in many usual locations in automotive use. This protection is readily accomplished by the employment of suitable screens 94 carried by the closure members and covering the ports. It will be noted that in this embodiment as well as that shown in Figs. 7–7b the obturating baffles are so located on the closure members that when the latter are in place the inlet ports 74 have materially greater area than the outlet ports 76.

In the embodiments heretofore described the flow of cooling air is induced by friction generated through rotation of the rotating casing. For most automotive applications, adequate cooling is obtainable with flow of air induced in this manner and from the standpoint of simplicity and cost it is to be preferred where it is adequate. In certain special applications, however, ordinarily in other fields of application but also in certain heavy duty vehicle applications, an even higher rate of heat transfer than can be obtained by friction induced circulation may be required.

For such applications an extremely high rate of heat transfer can be obtained by employing the basic principles of the invention in structures basically the same as those already described, but with the addition of means such as a fan or the like for producing a forced circulation of air which is forced through the channel sections in a direction counter to the direction of rotation of the casing.

An arrangement of this kind, as applied to a hydraulic torque converter similar to those previously described, is illustrated in Figs. 11 and 12, those parts of the converter not required for an understanding of the cooling arrangement being omitted from the figures.

In this embodiment, the rotating casing is similar to that shown in Fig. 8 and is provided with cooling ribs 46 cast integrally therewith. The rotating casing also carries a centrifugal fan indicated generally at 96 and having impeller blades 98 which draw air through the inlet opening 100 and discharge it radially past diffuser guide vanes 102 to chambers 104 from which the air flows through inlet ports 74 into the channel sections, to flow through the sections counter to the direction of rotation of the casing, as indicated by the arrows in Fig. 12.

The construction of the stationary casing is in general similar to that described in connection with Figs. 8 to 10, but in the present instance the closure members 90 are formed with solid covers *90a*, covering inlet ports 74 so as to provide the chambers 104 into which the air is delivered from the fan.

So far as the present invention is concerned, the supply of forced draft air for circulation counter to the direction of rotation of the housing may be accomplished in many different ways and from sources other than fans forming a part of the apparatus cooled.

Superficially, it might appear that forced circulation of the kind described is at variance with the basic principles of the invention, but such is not the case.

With forced circulation of the kind described a very high rate of heat transfer is obtained but it is obtained without the necessity for providing a high absolute velocity of the air circulated. Because of this fact not only is power consumption relatively low in comparison with the rate of heat transfer obtained, but also the undesirable uncontrolled flow of air may be avoided since the latter condition is induced by high absolute velocities, which are not necessary, rather than by the high relative velocity which is obtained for heat transfer purposes.

As in the case of friction induced circulation, the same advantages accrue from the sectionalizing of the channels to provide relatively short paths of flow for the air before it is ejected from the apparatus. With the forced circulation as well as with the friction induced circulation a high average temperature difference is maintained between the air and the surfaces to be cooled, and with the maintenance of a high average relative velocity, a very high rate of heat transfer results.

From the foregoing it will be evident that the invention may be advantageously employed in many different kinds of apparatus employing rotating bodies requiring heat exchange between them and a gaseous heat exchanging medium, and that the invention may be embodied in many different specific forms of construction. It is accordingly to be understood that the invention embraces all forms of apparatus falling within the scope of the appended claims.

What is claimed:

1. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing carrying a plurality of external circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing providing cover means for said channels, a plurality of rotationally stationary peripherally spaced obturating baffles extending into said channels for subdividing the same into a plurality of sections and ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffles for flow of gaseous cooling fluid into and out of each of said sections.

2. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing carrying a plurality of external circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing providing cover means for said channels, a series of equidistantly spaced rotationally stationary baffle members providing obturating baffles extending into said channels for subdividing the same into a plurality of sections each having a length constituting only a minor portion of the circumference of the channels, and ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members for flow of gaseous cooling fluid into and out of each of said sections.

3. A hydraulic power transmission comprising

a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing including wall structure encircling the open faces of said channels adjacent thereto for providing cover means for the channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections, and ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members for flow of gaseous cooling fluid into and out of each of said sections.

4. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing including wall structure encircling the open faces of said channels adjacent thereto for providing cover means for the channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections, ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members for flow of gaseous cooling fluid into and out of each of said sections, and guide baffles extending into said channels from certain of said ports and terminating short of the bottoms of the channels for guiding flow of fluid passing through said certain ports.

5. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing including wall structure encircling the open faces of said channels adjacent thereto for providing cover means for the channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for sub-dividing the same into a plurality of sections, ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members, said ports providing an inlet port and an outlet port for each of said sections, and guide baffles extending into said channels and terminating short of the bottoms thereof for guiding flow of fluid entering said channels through said inlet ports.

6. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing including wall structure encircling the open faces of said channels adjacent thereto for providing cover means for the channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for sub-dividing the same into a plurality of sections, and ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members to provide an inlet port and an outlet port for each of said sections, said inlet ports having greater area for flow for fluid than said outlet ports.

7. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing carrying a plurality of external circular open channels concentric with the axis of rotation of the casing, a stationary outer housing around said casing including a wall encircling the open faces of said channels, said wall having a plurality of peripherally spaced openings therein providing communication with said channels, a plurality of closure members removably secured to said housing, each of said closure members carrying a baffle member comprising a plurality of obturating baffles extending into said channels when said closure member is in place, said baffles constituting obturating elements for subdividing said channels into a plurality of sections and said baffle members dividing the several openings into ports on the opposite sides thereof and each communicating with a different one of said sections.

8. Apparatus as defined in claim 7 in which said baffle member is offset so that the port on one side thereof is larger than the port on the other side.

9. Apparatus as set forth in claim 8 in which said closure member carries a guide baffle member providing guide baffles shorter than said obturating baffles, said guide baffle member being located to divide said larger port.

10. Apparatus as defined in claim 7 in which said closure members are provided with screens covering said ports when said members are in place.

11. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing carrying a plurality of external circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing including a wall encircling said channels adjacent to the open faces thereof, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections, ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members to provide an inlet port and an outlet port for each of said sections, and means for forcing cooling air through said inlet ports to flow through said sections in a direction counter to the direction of rotation of said casing.

12. A hydraulic power transmission comprising a rotating casing providing a working chamber for circulation of power transmitting liquid required to be cooled during normal operation of the apparatus, said casing carrying a plurality of external circular open channels concentric with the axis of rotation of the casing, a rotationally stationary housing around said casing including a wall encircling said channels adjacent to the

open faces thereof, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing same into a plurality of sections, ports in said stationary housing opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle members to provide an inlet port and an outlet port for each of said sections, a fan carried by said rotating casing and means providing passages for connecting the discharge side of said fan with said inlet ports for forcing cooling air to flow through the sections of said channels in a direction counter to the direction of rotation of said casing.

13. Apparatus comprising a rotatably mounted body having a plurality of circular open channels concentric with the axis of rotation of the body, rotationally stationary structure providing cover means for said channels, a plurality of peripherally spaced rotationally stationary baffle means extending into said channels for sub-dividing the same into a plurality of sections, and ports in said cover means opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle means for flow of fluid into and out of each of said sections.

14. Apparatus comprising a rotatably mounted body having a plurality of circular open channels concentric with the axis of rotation of the body, rotationally stationary structure providing cover means for said channels, a series of peripherally spaced rotationally stationary baffle means extending into said channels for subdividing the same into a series of sections each having a length constituting a minor portion of the circumference of the channel, and ports in said cover means opening into said channels adjacent to and on the peripherally opposite sides of each of said baffle means for flow of fluid into and out of each of said sections.

15. Apparatus comprising a rotatably mounted body having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the body, rotationally stationary structure providing cover means for said channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections, ports in said cover means opening into said channels adjacent to and on the peripherally opposite sides of each of said baffles and guide baffles extending into said channels and terminating short of the bottoms thereof for guiding fluid flowing through at least certain of said ports.

16. Apparatus comprising a rotatably mounted body having a plurality of relatively deep and narrow circular open channels concentric with the axis of the rotation of the body, a rotationally stationary wall structure providing cover means of said channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections, ports opening through said wall structure adjacent to and on the peripherally opposite sides of each of said obturating baffles for providing communication between each of said sections and the ambient atmosphere, whereby to cause air to be drawn by rotation of the body into each of said sections through one of the ports communicating with the section and constituting an inlet port and guide baffles extending into said sections and terminating short of the bottoms of the channels for guiding air drawn into said channels through said inlet ports.

17. Apparatus comprising a rotatably mounted body having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the body, rotationally stationary wall structure providing cover means for said channels, a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections and ports opening through said wall structure to provide communication between the end portions of each of said sections and the ambient atmosphere, whereby to cause air to be drawn into each of said sections through one of said ports and ejected from the section through the other of said ports by rotation of said body.

18. Apparatus comprising a rotatably mounted body having a plurality of circular open channels concentric with the axis of rotation of the body, rotationally stationary structure providing cover means for said channels, rotationally stationary obturating baffles extending into said channels, ports in said stationary housing opening into said channels adjacent to and on the opposite sides of each of said baffles for flow of fluid into and out of each of said channels, and means for forcing fluid through certain of said ports to flow through said channels in the direction counter to the direction of rotation of said body.

19. Apparatus comprising a rotatably mounted body having a plurality of relatively deep and narrow circular open channels concentric with the axis of rotation of the body, a rotationally stationary wall structure providing cover means for said channels, and a plurality of peripherally spaced rotationally stationary obturating baffles extending into said channels for subdividing the same into a plurality of sections, openings in said cover means providing inlet and outlet ports for each of said sections at the respective ends thereof, a fan, and conduit means for connecting the discharge side of said fan with each of said inlet ports.

20. Apparatus as defined in claim 19 in which said inlet ports are located to cause fluid entering said sections to flow counter to the direction of rotation of said rotating body.

21. Apparatus comprising a rotatably mounted body having a plurality of external substantially radial and relatively narrow and deep open channels concentric with the axis of the rotation of the body, a rotationally stationary housing encircling said body and providing a cover wall closely adjacent to the outer periphery of said channels, a plurality of peripherally spaced openings in said housing providing communication with said channels and frame members removably secured to said housing at said openings, each of said members carrying an obturating baffle comprising a plurality of fingers located to extend into said channels when the member is in assembled position and said baffle being located with respect to the perimeter of the frame to provide a port communicating with said channels on each side of the baffle member.

22. The combination, with a rotating body having a circular channel concentric with the axis of rotation of the body, of rotationally stationary peripherally spaced obutrating baffles extending into said channel and providing between them a channel section, a rotationally stationary wall for covering the central portion of the length

of said section, said wall terminating peripherally short of each of said baffles to provide an inlet port and an outlet port communicating respectively with the opposite ends of said section, and a guide baffle projecting into said section and terminating short of the bottom of the channel for guiding fluid flowing through one of said ports.

23. The combination, with a rotating body having a circular channel concentric with the axis of rotation of the body, of rotationally stationary peripherally spaced obturating baffles extending into said channel and providing between them a channel section, a rotationally stationary wall for covering the central portion of the length of said section, said wall terminating peripherally short of each of said baffles to provide an inlet port and an outlet port communicating respectively with the opposite ends of said section, and a plurality of peripherally spaced guide baffles projecting into said section and terminating short of the bottom of the channel for guiding fluid flowing through one of said ports.

24. The combination, with a rotating body having a circular channel concentric with the axis of the rotation of the body, of rotationally stationary peripherally spaced obturating baffles extending into said channel and providing between them a channel section, a rotationally stationary wall for covering the central portion of the length of said section, said wall terminating short of each of said baffles to provide an inlet port and an outlet port communicating respectively with the opposite ends of said section, and a plurality of peripherally spaced guide baffles projecting into said section and terminating short of the bottom of the channel for guiding fluid flowing through one of said ports, said guide baffles being of different length and the baffle most remote from said obturating baffle being shorter than a baffle more closely adjacent to said obturating baffle.

25. A hydraulic power transmission comprising a rotating casing structure providing a working chamber for circulation of power transmitting fluid, said casing having a plurality of external circular cooling fins and grooves concentric with the axis of rotation of the casing, and means for creating flow of gaseous cooling fluid in said grooves comprising a plurality of elements extending into each groove at peripherally spaced places and mounted to have relative rotation with respect to said fins for interrupting continuous rotary flow of the cooling fluid within the grooves and forcing the fluid at the places of interruption out of the grooves, whereby to create a plurality of separate streams of cooling fluid flowing into and out of each groove, each of said streams being confined to a portion of the circumference of the groove.

26. Apparatus comprising a rotatably mounted body having a plurality of circular open channels concentric with the axis of rotation of the body, rotationally stationary structure providing cover means for said channels, rotationally stationary baffle means extending into said channels to provide obstructions therein and port openings in said structure communicating with the open faces of said channels adjacent to and on the opposite sides of said baffle means for flow of fluid into said channels on one side of said baffle means and out of said channels on the other side of said baffle means.

27. Apparatus comprising a rotatably mounted body having a plurality of circular open channels concentric with the axis of rotation of the body, a plurality of rotationally stationary baffle means located in peripherally spaced relation and each comprising a plurality of fingers extending into and substantially filling the cross sections of said channels to provide obstructions therein dividing the channels into a plurality of sector-like parts, and rotationally stationary structure providing cover means for each of said parts, said cover means being spaced peripherally from said baffle means to provide inlet and outlet ports communicating with the open faces of said channels at the respective ends of each of said sector-like parts.

28. Apparatus comprising a rotatably mounted casing having a plurality of external closely spaced circular ribs and intervening open grooves concentric with the axis of rotation of the casing, a rotationally stationary outer housing having a wall portion encircling said ribs and providing cover means overlying the open faces of said grooves, a plurality of baffle means carried by said housing at peripherally spaced places thereon, each of said baffle means comprising a plurality of fingers extending into said grooves to divide the grooves into sector-like parts and ports in said wall portion on each side of each of said baffle means to provide communication between the grooves and the ambient atmosphere at each end of each of said sector-like parts.

29. A hydraulic power transmission comprising a rotating casing containing working fluid requiring to be cooled during the normal operation of the transmission, said casing including a plurality of external circular fins and open grooves concentric with the axis of rotation of the casing and having a depth at least several times their width, an outer rotationally stationary housing having a wall portion concentrically encircling said grooves and providing cover means therefor, and a plurality of baffle means carried by said housing in peripherally spaced relation, each of said baffle means comprising a plurality of elongated fingers extending into said grooves to substantially fill the cross sections thereof and provide obstructions dividing the several grooves into sector-like parts, the cover means for each of said parts being peripherally spaced from each of said baffle means to provide inlet and outlet ports through said wall adjacent to the baffle means for flow of cooling air from the ambient atmosphere in separate streams through each of the sector-like passages formed by the walls of the grooves and said cover means.

30. A structure as defined in claim 29 in which said fingers are of scoop-like form pointing in the direction opposite that of the direction of rotation of said casing.

KARL GUSTAV ÅHLÉN.
TOR AXEL ÖDMAN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,906,520	Bode	May 2, 1933
2,088,967	Main	Aug. 3, 1937
2,197,232	Wood	Apr. 16, 1940
2,253,877	Watterson	Aug. 26, 1941

FOREIGN PATENTS

Number	Country	Date
744,956	France	Jan. 21, 1933