June 7, 1966 N. LAING 3,254,706

MACHINE COOLING

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Fig. 1.

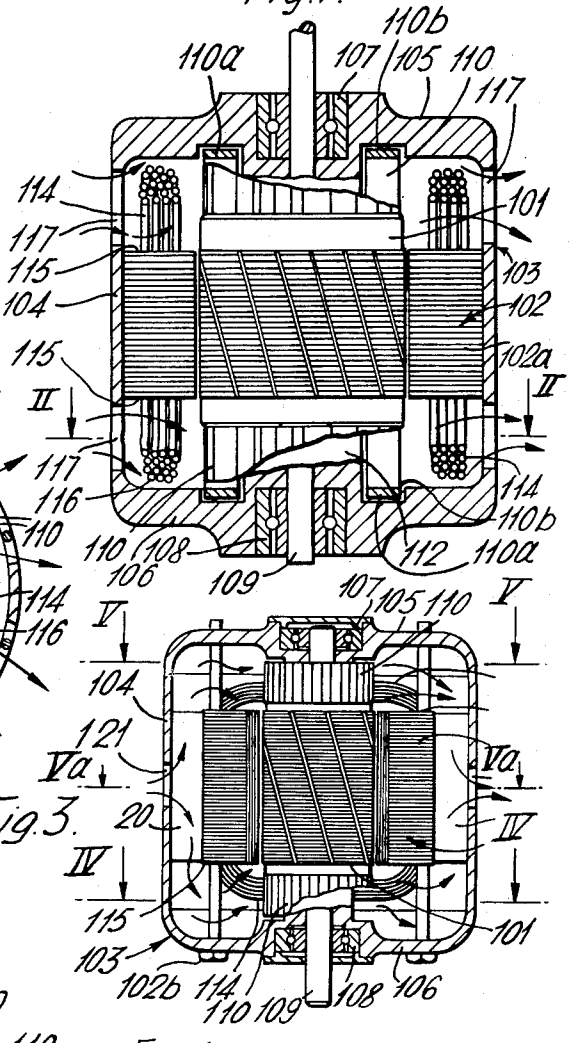


Fig. 2.

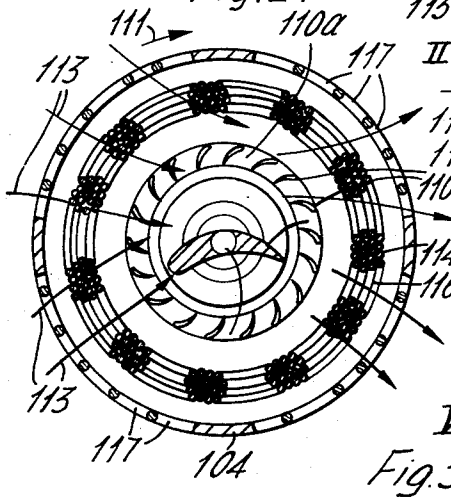


Fig. 3.

Fig. 5.

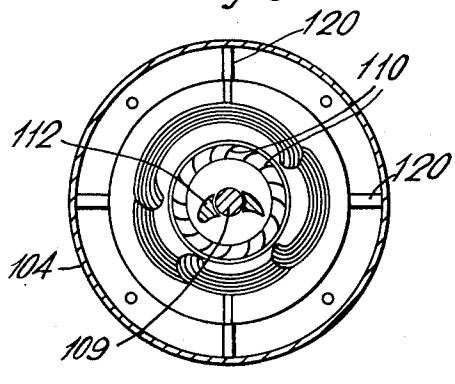
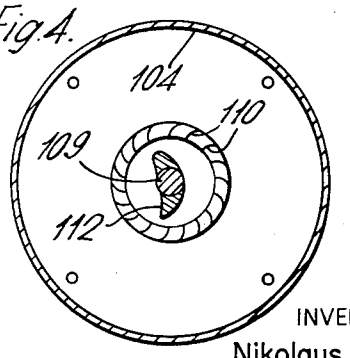


Fig. 4.



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MACHINE COOLING

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Fig. 5a.

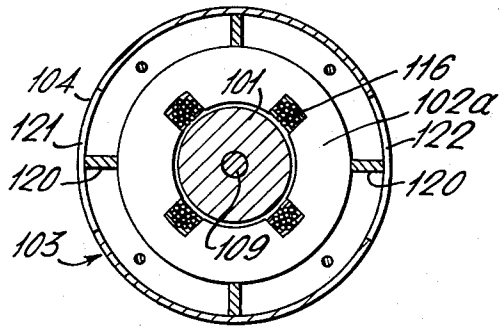
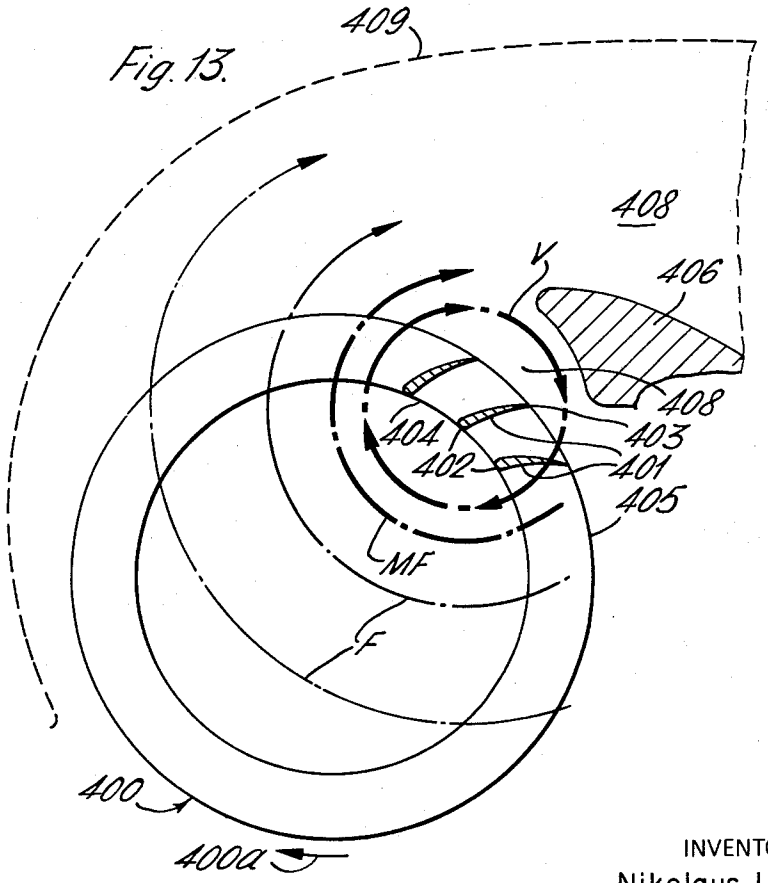


Fig. 13.



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MACHINE COOLING

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Fig. 9.

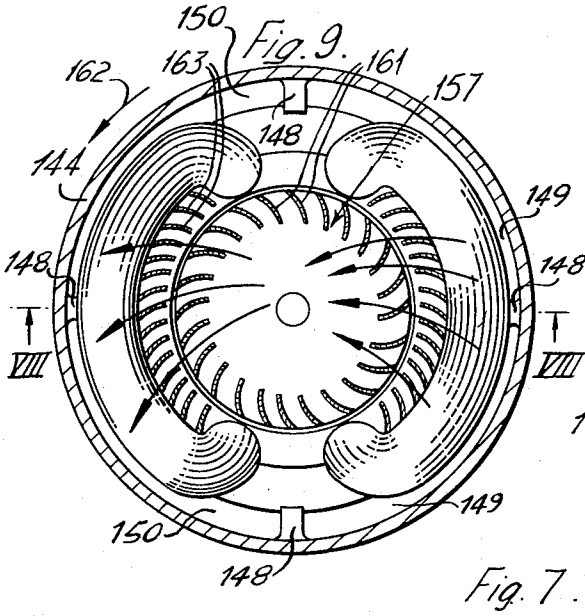


Fig. 6.

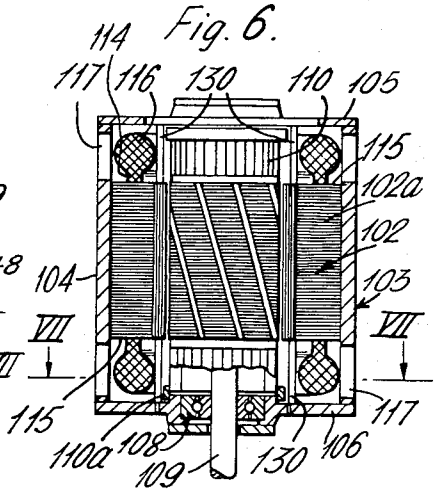


Fig. 7.

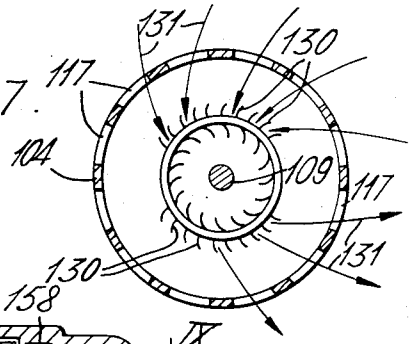
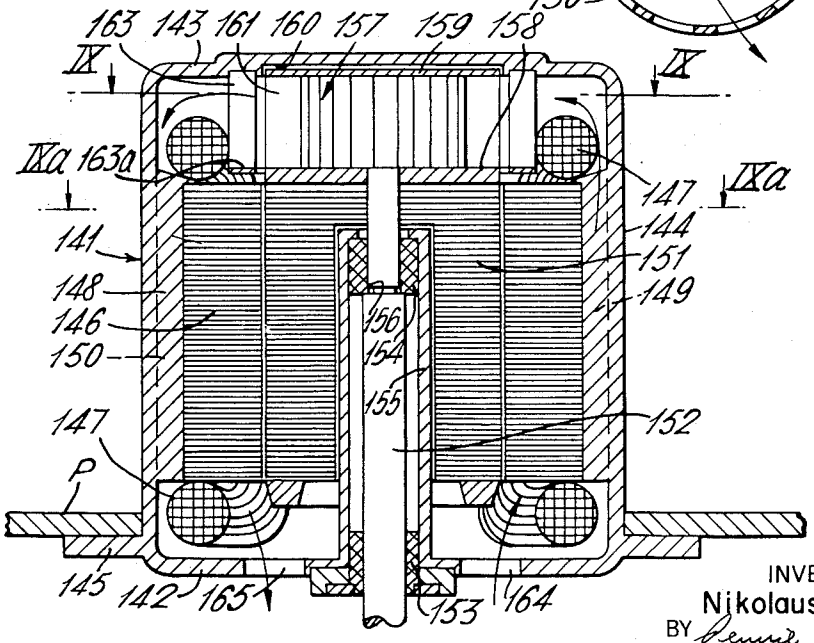


Fig. 8.



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MACHINE COOLING

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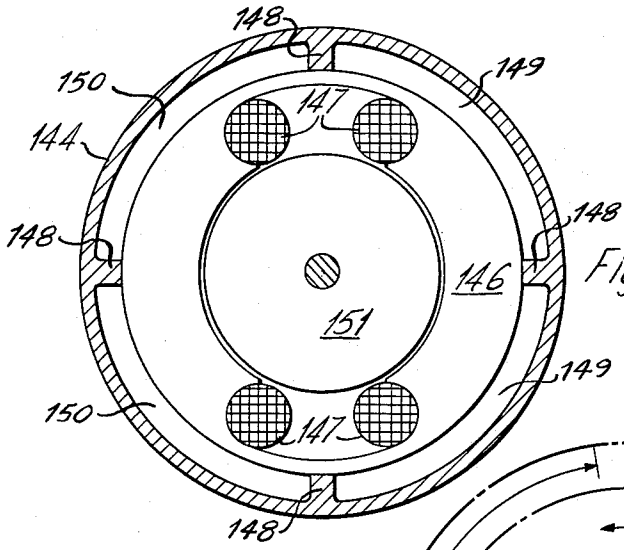


Fig. 9a.

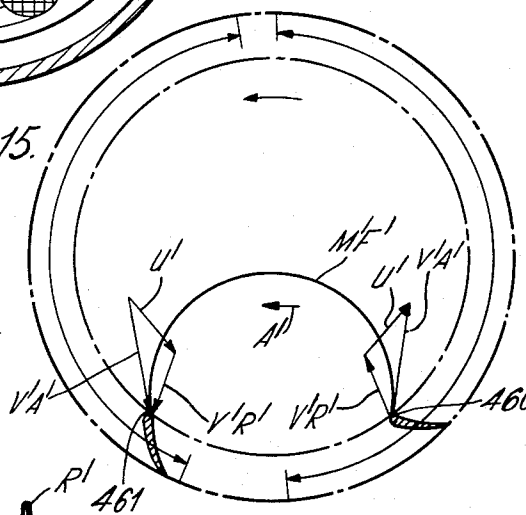
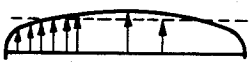


Fig. 15.

Fig. 16b



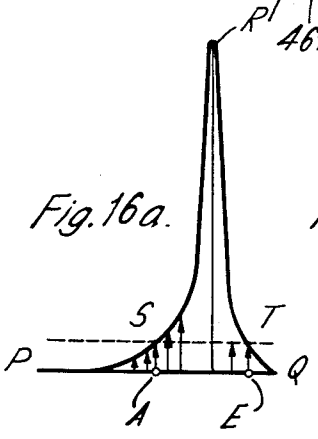


Fig. 16a.

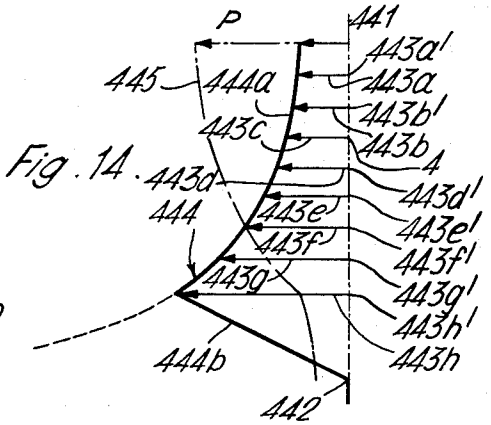


Fig. 14.

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Fig. 10.

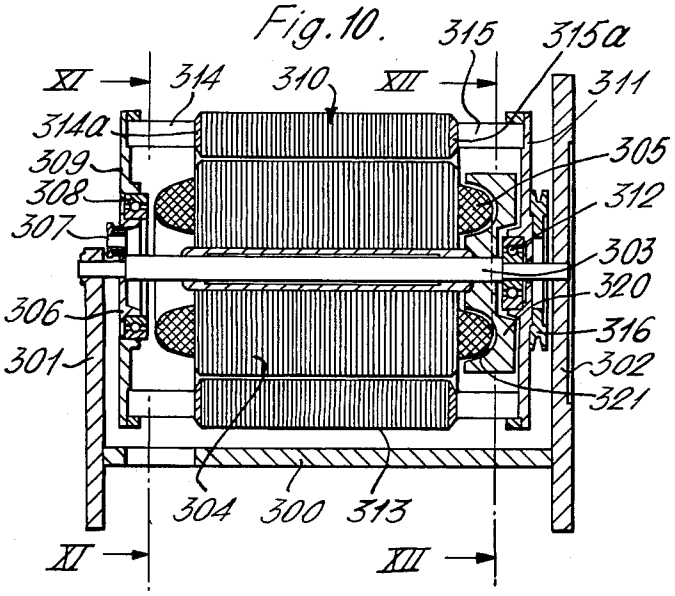


Fig. 11.

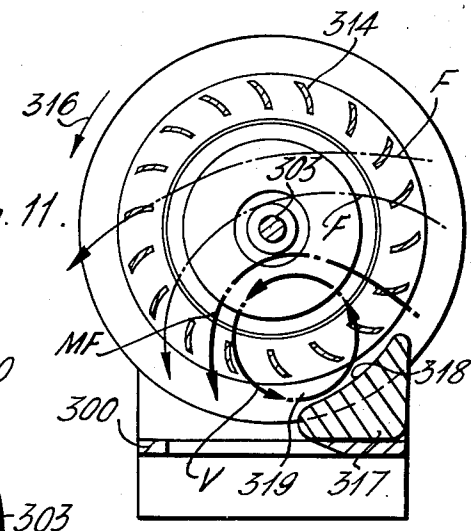
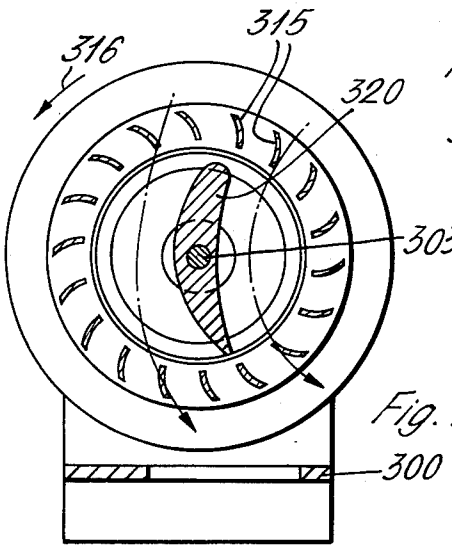


Fig. 12.



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United States Patent Office

3,254,706

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3,254,706

MACHINE COOLING

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Filed Jan. 2, 1963, Ser. No. 249,065
Claims priority, application Germany, Dec. 7, 1956, L 26,392; Dec. 31, 1956, L 26,544
4 Claims. (Cl. 165—86)

This invention relates to the cooling of machine parts and is a continuation-in-part of my application No. 701,600 dated Dec. 9, 1957.

Many types of rotational apparatus generate heat in operation, which has to be got rid of. Examples of such apparatus are brakes, and electric motors and generators. In other types of apparatus, such as furnaces, it may be necessary to rotate some part having a high temperature, and means are required to stop undue heat flow along the shaft or other rotating means to the drive mechanism.

The general object of the invention is to provide improved cooling means for apparatus such as above mentioned which dissipates heat therefrom into a fluid stream.

According to one aspect of the invention, apparatus having a heat-conducting rotating part liable to become hot is provided with fluid impeller blades of heat-conducting material which are connected in heat-transmitting relation with said part so that in operation unwanted heat is conducted from the rotating part to the blades and thence dissipated to the fluid stream which they set up. It is strongly preferred to arrange the blades generally parallel to the rotational axis and in a ring thereabout and to provide guide means co-operating with the blades to induce a flow of fluid from a suction region through the path of the rotating blades into the inferior space defined by the blades and thence again through the path of the rotating blades to a pressure region. In this way the fluid flows over each blade first in one direction (in its first passage through the path of the blades) and then in the other direction (in its second passage through the path of the blades), this reversal occurring twice in every revolution of the rotor. The reversal of flow over the blades has been discovered substantially to reduce the stagnant boundary layer of fluid that would otherwise build up on the blades and effectively insulate them against efficient dissipation of heat into the fluid stream.

In certain cases it is possible to do without the guide means referred to and rely on free vortex formation, as will be mentioned later, to provide the required flow over the blades. Normally however guide means are employed, as explained, and may be such as to co-operate with the blades to set up and stabilize a vortex of Rankine type having a core region interpenetrating the path of the rotating blades. Guide means such as just referred to will preferably lie outside the blades, the interior space within which is obstructed as little as possible. The Rankine vortex flow referred to has been found to be exceptionally efficient, and inter alia has the advantage that throttling of the flow reduces the power requirement of the blades, and so enables power to be taken only when cooling is required, in apparatus where the waste heat appears only intermittently.

However the guide means may also take the form of one or more guide bodies of airfoil profile in cross-section located in the interior space defined by the blades: this arrangement can be used with advantage where a shaft or some other object (axial-type comutator brushes for example) would otherwise seriously obstruct flow through this space, since such object can conveniently be accommodated in the profile of the guide body or bodies.

Another form of guide means comprises two sets of stationary guide vanes disposed close about the envelope of the fluid impeller blades over two opposed arcs.

The exceptional freedom of design brought about by the wide range of combinations of impeller blades and guide means which are possible on the lines indicated enables the invention to be applied to a wide variety of apparatus, as will be understood from what follows.

Further features and advantages of the invention will appear from the following description of various embodiments thereof, given by way of example with reference to the accompanying drawings, in which:

FIGURES 1 and 2 are respectively a longitudinal and a transverse section of an induction motor, the section plane for FIGURE 2 being indicated at II—II in FIGURE 1;

FIGURES 3 and 4 are views similar to FIGURES 1 and 2 of a second induction motor, the section plane of FIGURE 4 being indicated at IV—IV in FIGURE 3;

FIGURES 5 and 5*a* are further transverse sections of the second motor taken on planes indicated at V—V and V*a*—V*a* in FIGURE 3;

FIGURES 6 and 7 are views similar to FIGURES 1 and 2 of a third induction motor, the section line of FIGURE 7 being indicated at VII—VII in FIGURE 6;

FIGURES 8 and 9 are views similar to FIGURES 1 and 2 of a fourth induction motor, the section line of FIGURE 9 being indicated at IX—IX in FIGURE 8;

FIGURE 9*a* is a section of the fourth motor of FIGURES 8 and 9 being indicated at IX*a*—IX*a* in FIGURE 8;

FIGURE 10 is an axial section of an external-rotor motor having a different cooling arrangement at each end; and

FIGURES 11 and 12 are transverse sections of the FIGURE 10 motor, on the lines XI—XI, XII—XII therein each figure showing one cooling arrangement;

FIGURE 13 is a transverse section of a blower illustrating a preferred vortex flow arrangement in a somewhat idealized manner;

FIGURE 14 is a diagram explanatory of the vortex flow of FIGURE 13;

FIGURE 15 is a diagrammatic cross-section of the rotor forming part of the FIGURE 13 blower tracing a flow tube therethrough and showing velocity diagrams thereof; and,

FIGURES 16*a* and 16*b* show velocity profiles, the first illustrating the functioning of the FIGURE 13 blower and the second the conceptions of the prior art.

FIGURES 1 and 2 show an induction motor having a rotor **101** and a stator **102** mounted in a casing designated generally **103** and comprising a cylindrical portion **104** carried by end portions **105, 106** which support bearings **107, 108** for the rotor shaft **109** which runs the whole length of the casing. The rotor **101** has profiled blades **110** longitudinally extending from each end and terminating just short of the corresponding casing end portion **105, 106**. The free ends of the blades **110** are connected to a ring **110***a* received in a recess **110***b* in the casing end portion **105, 106**. The blades **110** are arranged in a ring about the rotor axis, and are concave facing the direction of rotation (indicated by the arrow **111**) with their outer edges leading. The blades **110** are of metal and in heat conducting relation with the body of the rotor **101** so that heat generated therein is conducted into the blades. The casing end portions **105, 106** carry similar guide bodies **112** in the form of integral projections of air-foil cross-section through which the rotor shaft **109** extends. At each end of the rotor the blades **110** and guide body **112** constitute a cross-flow blower and co-operate in operation to set up a stream of air through the blades as indicated by the arrows **113**, and as described more fully hereinafter. Heat conducted from the rotor into the blades **110** is dissipated therefrom into the air stream.

The stator **102** includes windings **114** which are brought out beyond the ends **115** of the stator body **102***a* to form loops **116** through which the air stream passes. The loops **116** turn opposite the outer end portions of the blades **110** but are spaced somewhat from the casing end portions **105, 106.** The cylindrical casing portion **104** is apertured at **117** between the ends **115** of the stator body **102***a* and the casing end portions **105, 106.** Thus at each end of the motor air passes into the casing **103,** through the blades **110** and out of the casing, and in passing through the casing flows twice over the windings **114** so as to extract heat directly from them. The air passes mostly through the loops **116,** but a minor proportion of the flow takes place around the ends of the loops. The turns of the loops **116** are located to cause some deflection of the air stream out of the radial planes which it would follow but for the windings.

It will be seen in FIGURE 2 that the lower arrows **113** are bolder than the upper arrows, by way of indication where the flow is stronger as will be understood from later description. Conduction of heat through the windings will tend to equalize the temperatures therein, but as an aid to such equalization the guide body **112** at the end of the motor not shown in FIGURE 2 is oriented at 90° to that shown in FIGURE 2.

Constructional details which have nothing to do with the invention are shown only summarily in the figures. Thus the casing **103** is shown as a single piece, while in practice it may be made of die-cast end portions **5, 6** and a sheet metal central part **4** located on the end portions as by some kind of spigot arrangement, the whole assembly being held together by bolts extending from end to end of the casing.

FIGURES 3 to 5*a* show a second motor where parts similar to those described above are given the same reference numbers and will not need further description. The chief differences between the second motor and the first are that in the former:

(1) The stator winding loops **116** are much closer to the ends **115** of the stator body **102***a,* and opposite the inner end portions of the blades **110,** so that most of the air flow takes place around the ends of the loops and only a minor proportion through them.

(2) The stator body **102***a* is supported in spaced relation to the interior of the cylindrical portion **104** with the aid of four walls **120***a,* **120***b,* **120***c,* **120***d* extending in diametral planes at right angles, and is held in place by four bolts **102***b* extending through the casing **103** and secured to the end portions **105, 106** thereof. In place of the end apertures **117,** the casing portion **104** is formed with opposite apertures **121, 122** half-way along its length. Instead of having the guide bodies **112** oriented at 90° they have a similar orientation, which is such that the diametral plane nearest approaching the airfoil chord intersects the apertures. An opposed pair of walls **120***a,* **120***c* lie in this plane; they extend only over the length of the stator body **102***a* and divide each of the apertures **121, 122** into two equal parts. The other walls **120***b,* **120***d* extend the length of the casing **103,** and between the ends **115** of the stator body and the casing end portions **105, 106** extend into close proximity to the rotor blades **110,** being notched at **120***e* to accommodate the stator windings. By this division of the space within the casing the air is forced to enter the casing centrally at one side through aperture **121,** flow to either end of the casing, pass through the respective rotor blades **110,** and finally, flow out through apertures **122.** In this way air flows over the whole of the exterior of the stator body **102***a,* as well as past the windings at the ends of the body.

In the second motor the stator cooling is better, and the casing will be cooler, other things being equal. A greater pressure drop between inlet and outlet is to be expected.

The guide bodies **112,** for both motors, may be cast integrally with the casing end portions **105, 106,** and

there may be at least two such bodies for each ring of blades in larger constructions, if desired.

A third motor, shown in FIGURES 6 and 7 generally resembles the second: similar parts are given the same reference numerals and once again will need no further description. The third motor differs from that of FIGURES 3 to 5 chiefly in that at each end the guide means is not an interior body **112** but a series of guide blades **130** disposed in two arcs close to and outside the blades **110** on the rotor **101.** In addition, the flow is taken through the casing **103** at apertures **117** at the ends of the portion **104,** as in FIGURE 8. The pattern of flow is as shown in FIGURE 2 by the arrows **131:** air passes around and between the windings **114** on the stator **102** which however are not shown in FIGURE 7. The guide blades **130** of FIGURES 6 and 7 are more fully described later.

The motor shown in FIGURES 8, 9 comprises a casing designated generally **141** having two end walls **142, 143** interconnected by a generally cylindrical wall **144.** A flange **145** on the cylindrical wall **144** just inward of the end wall **142** allows the motor to be fixed to a panel P about an aperture therein through which the major part of the motor projects.

The motor includes a stator **146** having windings **147** and being supported in the casing **141** by four thin longitudinal ribs **148** integral with and projecting inwardly from the casing wall **144** at 90° spacing, and defining two pairs of passages **149, 150** between them. The motor further includes a rotor **151** mounted within the stator **146** upon a shaft **152** carried in axially spaced bearings **153, 154** of the sintered type. The bearings **153, 154** are mounted within a tube **155** integral with and projecting inwardly from the end wall **142** to a point near the further end of the rotor **151,** the rotor having a bore to accommodate the tube with clearance. One bearing **153,** is secured adjacent the end wall **142** so as effectively to be supported thereon, while the other bearing, **154,** lies at the further end of the tube **155.** For convenience of endwise location the rotor shaft **152** is of reduced diameter where it extends through the bearing **154** and the rotor **151** beyond the tube, the shoulder **156** thus formed abutting an end of the bearing **154.**

The extreme end of the shaft **152** projecting beyond the tube **155** carries an impeller designated generally **157** and comprising an end disc **158** secured at the end of the shaft, a coaxial parallel end disc **159** received in a recess **160** in the end wall **143** so as to present an inner surface flush with that of the wall **143** and blades **161** arranged in a ring and supported between the end discs. The blades **161** are concave facing the direction of rotation indicated by the arrow **162,** with their outer edges leading. The impeller **157** co-operates with guide means in the form of metal stator blades **163** arranged over two arcs close outside the impeller and secured in heat-transmitting relation between the end wall **143** and a mounting ring **163***a* on the adjacent end of the stator **146.** The impeller **157** and stator blades **163** combine to form a blower producing an air flow as indicated in FIGURE 9, in operation of the motor. The blades **163** will be further described below.

The end wall **142** is formed with inlet and outlet apertures **164, 165,** the first connecting with the longitudinal passages **149** and the second with the passages **150,** flow between aperture **164** and passages **149** being separated from that between passages **150** and aperture **165** by a wall (not shown) extending inwards from the end wall **142** and serving also to rigidify the construction.

In operation the blower formed by impeller **157** and stator blades **163** induces a flow of air through inlet aperture **164,** passages **159,** impeller **157,** passages **150** and outlet aperture **165.** The air flows over the ends of the winding **147** and the outer surface of the stator **146** and cools them: it also keeps the casing cool. The windings **147** project into the stream through the impeller

157 so as to be directly cooled thereby. The impeller 157 (which is conveniently constructed as a unit) is made of a metal which acts as a good conductor of heat, e.g., copper or brass, and is in heat-transmitting relation with the rotor 151 through end disc 158 which is made of a good heat conductor so that heat generated therein is conducted to the rotor blades 161 and thence dissipated into the air stream. The impeller is conveniently formed as a unit. The stator blades 163; which are also good heat conductors, conduct heat away from the stator 146, and this heat is also dissipated into the air stream.

If desired, the windings 147 may be brought out to form loops as in the motor of FIGURES 1 and 2.

FIGURES 10 to 12 show two forms of external-rotor motor having cooling arrangements at either end: for economy of illustration the axial section of FIGURE 10 shows one form of cooling arrangement at one end, the transverse section of which appears in FIGURE 11, and another form of such arrangement at the other end, the transverse section of which appears in FIGURE 12: in practice however a given motor will in general be cooled by similar arrangements at both ends.

Referring to FIGURES 10 and 11, the motor comprises a base plate 300 mounting upstanding end plates 301, 302 between which is secured a horizontal shaft 303 carrying a laminated stator 304 having windings 305. Adjacent the end plate 301 the shaft 303 carries a fixed disc 306 with a bushing 307 for leads (not shown) to the stator 304. At its periphery the disc 306 mounts a large ball bearing 308 supporting one end member 309 of a rotor designated generally 310. The other end member 311 of the rotor 310 is mounted on the shaft 303 by a small ball bearing 312 adjacent end plate 302. The rotor 310 includes a central laminated generally cylindrical part 313 and two series of longitudinally extending blades 314, 315 arranged in a ring about the axis, one at either end of the part 313, which blades mount that part between the end members 309, 311. The blades 314, 315 are of heat conducting metal secured to metal rings 314*a*, 315*a* fixed at opposite ends of the rotor laminations, so that heat can be conducted readily from the laminations to the blades. The blades 314, 315 are concave facing in the direction of intended rotation shown by the arrow 316 and have their outer edges leading their inner edges. A drive pulley 311*a* is secured to the end plate 311.

Turning to the left hand end of FIGURE 10, and FIGURE 11, the base plate mounts a guide body 317 of rounded generally triangular formation extending the length of the blades 314 and having one concave surface 318 defining with the envelope of the blades 314 a gap 319 which tapers in the direction of rotor rotation as shown by the arrow 316. On rotation of the rotor 310 the blades 314 and guide body combine to set up a vortex having a core V and to cause flow through the blades as indicated by the arrows F, MF.

Turning now to the right hand end of FIGURE 10 and FIGURE 12, the shaft 303 carries a fixed guide body 320 of airfoil cross-section extending over the length of the blades 315; the body 320 is recessed at 321 to accommodate the ends of the windings 305. On rotation of the rotor blades 315 in the direction of the arrow 316 a flow is set up as shown by the arrows.

In both cooling arrangements of FIGURES 10 to 12 heat generated in the rotor part 313 is conducted into the blades 314 or 315 and dissipated in the air stream, while this air stream cools the ends of the stator 304 and windings 305 thereon.

FIGURE 13 shows a blower comprising a rotor designated generally 400 mounted by means not shown for rotation about its axis in the direction of the arrow 400*a*. The rotor 400 has a series of blades 401 arranged in a ring about the axis and extending parallel to it. The blades 401 are similar, and similarly oriented, and have inner and outer edges 402, 403 on inner and outer coaxial cylindrical envelopes 404, 405. The blades 401 are concave facing in the direction of rotation shown by arrow 400*a* and have their outer edges 403 leading their inner edges 402: preferably, but not essentially, the blades have an airfoil profile with the inner edges 402 the thicker. The ends of the rotor 400 are closed, and its interior is wholly uobstructed.

A guide body 406 extends the length of the rotor 400 with constant cross section, and presents thereto a concave surface 407 defining a gap 408 tapering in the direction of rotation. The guide body 406 subtends only a small arc—say 20°—at the rotor axis. A guide wall 409 may also be present opposite the guide body 406, and is shown dotted. The guide body 406 and guide wall 409 (if present) are spaced from the rotor 400 by at least half the radial depth of the blades 401 at the lines of nearest approach: at such lines they define an entry arc of just over 180°, while on the exit side they define an outlet duct, which may take the form of a diffusor.

In operation of the FIGURE 13 blower a vortex of Rankine type is set up, the core region of which is eccentric to the rotor axis and indicated by the flow lines shown chain dotted at V; the whole throughput flows twice through the rotor blades 401 in a direction always perpendicular to the rotor axis as indicated in general direction only by the chain dotted flow lines F, MF.

FIGURE 14 shows the distribution of velocity in the vortex. The chain dotted line 441 represents a diameter of the rotor taken through the axis 442 of the vortex core V. Velocity of fluid at points on the line 441 by reason of the vortex is indicated by the horizontal lines 443*a*, 443*b*, etc. the length of each line 443*a*, 443*b*, etc., being a measure of the velocity at the point 443*a'*, 443*b'*, etc. respectively. The envelope of these lines is shown by the curve 444, which has two portions, one 444*a* approximately a rectangular hyperbola and the other, 444*b* a straight line. The curve 444*a* relates to the field region of the vortex and the curve 444*b* to the core region.

The core V of the vortex is a whirling mass of air with no translational movement as a whole, and velocity diminishes going from the periphery of the core to its axis 442. Static pressure along the line 441 is shown by the curve 445: it will be seen that the vortex core V is a region of low pressure. The location of the core region can be discovered by investigation of pressure distribution within the rotor.

It will be understood that the curves in FIGURE 11 are those of an ideal or "mathematical" Rankine vortex and actual flow conditions will only approximate to those curves. Although for convenience the vortex core V has been shown circular and has been regarded as possessing an axis, the core will usually not be truly circular.

The velocity profile of the air at the second entrance thereof to the rotor blades will be that of the vortex. In the ideal case of FIG. 14 this profile will be that of the Rankine vortex there shown by curves 444*a*, 444*b*; in an actual case the profile will still have the general character of a Rankine vortex. Thus there will be in the region of the periphery of the core V a flow of high velocity indicated at MF in FIGURE 13 by the heavier chain dots while the flow tubes remote from the periphery of the core will have a very much smaller velocity. On account of the vortex there is at the exit from the rotor 1 a velocity profile such as shown (somewhat exaggerated) in FIGURE 16*a* where the line PQ represents the exit arc and the ordinates represent velocity. The curve exhibits a pronounced maximum at R which is much higher than the average velocity represented by the dotted line (the average being obtained by dividing the total throughput per unit of time by the area represented by the exit arc).

It will be appreciated that much the greater amount of air flows in the flow tubes in the region of maximum velocity. It has been found that some 80% of the flow

is concentrated in the portion of the output represented by the line ST corresponding to the points A and E on the line PQ, which is less than 30% of the total exit arc. A much smaller arc is in fact all that needs to be considered. A normal velocity profile for a fluid flow in a defined passage is shown by way of contrast in FIGURE 16*b*; those skilled in the art will regard this as an approximately rectangular profile.

The maximum velocity R as shown in FIGURE 16*a* appertains to a maximum-velocity flow tube indicated in FIGURE 11 by the heavier chain dots and designated MF. With a given construction the physical location of the flow tube MF is fairly closely defined. Therefore in the restricted zone of the rotor blades **3** through which this flow tube MF passes, the relative velocity between blades and fluid is much higher than it would be in a flow machine which following the principles adhered to hitherto in the art, was designed for a rectangular velocity profile and uniform loading of the blades in the zones thereof where fluid passes.

The Reynolds number at a particular fluid flow condition is a dimensionless number representing the ratio of the product of flow velocity and a character linear dimension of the part under observation to the kinematic viscosity of the fluid. For a given bladed rotor the Reynolds number (Re) is herein defined as:

$$Re=d.c./\nu$$

d being the blade depth in the radial direction *c* the peripheral speed of the rotor and ν the kinematic viscosity, the latter being equal to the quotient of dynamic viscosity and density. A Reynolds number is considered herein to be low, if as above-defined, it is less than 5×10^4. It will be appreciated that the air passing a rotor forming part of apparatus according to the invention will be heated by the heat developed in operation of the apparatus: this increases the kinematic viscosity and reduces the Re number.

Very often the designer will be forced to operate the rotor under conditions of low Reynolds numbers despite the fact that it is well known that separation losses are much greater when flow takes place under those conditions.

As the velocity of the flow tube MF is several times greater than the average velocity (see FIGURE 16*a*), in the restricted blade zones through which the flow tube MF passes there will be much less separation loss than if that tube flowed at the average velocity of throughput; in the flow tube MF, that is, transfer of momentum to the air occurs under excellent conditions. The transfer of momentum in the flow tubes travelling below the average velocity will be poorer, but on balance there is a substantial gain because by far the greater proportion of throughput is associated with the flow tube MF.

It follows that the throughput is greater than with a comparable rotor and guide means as heretofore known operating under the same conditions.

FIGURE 15 shows the maximum velocity flow tube MF intersecting the envelope **404** at **460, 461**. It will be seen that ideally the maximum velocity flow tube MF undergoes a change of direction of about 180° in passing through the interior of the rotor, and that the major part of the throughput (represented by the flow tube MF) passes through the rotor blades where they have a component of velocity in a direction opposite to the main direction of flow within the rotor indicated in FIGURE 15 by the arrow A'.

Vector diagrams are shown in FIGURE 15 for the velocities at the points **460** and **461**. In the diagrams U' is the velocity of the inner edges of the blades at the points **460, 461** respectively, V'A' the absolute velocity of the air in the flow tube MF at the point **460, 461**, and V'R' the velocity of that air relative to the blade as found by completing the triangle. The rotor blade angles can be designed for shock-free flow of the maximum flow tube MF since, as shown above, it flows through narrowly defined zones of the rotor.

It is considered that the angles and curvature of the blades **401** determine the character of the vortex while the position of the vortex core is determined by means of the guide body **406**.

It is considered that in a given case the particular blade angles and blade curvature, depends on the following parameters among others: the diameter of the blades, the depth of the blade in radial direction, the density and viscosity of the fluid, the dispositions of the external guide body, the rotational speed of the rotor, as well as on the ratio between overall pressure and back pressure. These parameters must be adapted to correspond to the operating conditions ruling in a given case. In a given case the teaching given imposes the adoption of quite definite blade angles and curvature (blade curvature is in this connection to be understood to mean not only the curvature of a blade of uniform thickness, but also, the curvatures of the contours of profiled blades). Whether or not the angles and curvatures have been fixed at optimum values is to be judged by the criterion that the flow tubes close to the vortex core should be deflected by approximately 180°.

An important advantage of the rotor and guide means described is that when the throughput is throttled to zero the power consumption of the rotor is very small. Thus the throughput may be throttled to provide whatever cooling may be necessary without consuming more power than is absolutely essential.

It will be seen that the embodiments of FIGURES 10 and 11 operate on the principles enunciated in FIGURES 13 to 16*b*; the description of those embodiments should be read with the disclosures of FIGURES 13 to 16*b* in mind.

I claim:

1. An apparatus comprising a rotary heat-conducting part from which heat is to be dissipated in operation, heat dissipation means comprising a series of fluid impeller blades of high heat conducting material mounted for rotation with said rotary part, connecting means of high heat conducting material and substantially coextensive in area with the end of the rotor connecting the outer axial extremity of said rotary heat conducting part and said heat dissipation means, said blades being arranged in a ring about the rotational axis and extending generally longitudinally thereof and defining an interior space, and means to guide cooling fluid through the rotor in a radial direction from one radial side of the ring of blades through the path of the rotating blades to the interior space and thence curved in the direction of rotation to pass again through the path of the rotating blades to another radial side of the ring of blades, said cooling fluid twice flowing past the blades in opposite directions relative to a given blade in its passage from said one to said other side and heat being conducted from the rotary part of said blades and being dissipated therefrom to said cooling fluid as it passes over said blades.

2. An electric machine comprising a stator, a rotor mounted for rotation about an axis fixed with respect to the stator, a series of air impeller blades of conductive material rotating with the rotor and mounted on the outer axial extremity thereof in heat transmitting relation therewith and arranged in a ring about the axis to extend generally longitudinally thereof and define an interior space, means substantially closing the ends of the space, guide means cooperating with said blades on rotation of the rotor to induce a flow of cooling air generally transverse to the axis from one side of the ring of blades through the path of the rotating blades to the interior space and thence again through the path of the rotating blades to another side of the ring of blades said cooling air twice flowing past the blades, in opposite directions relative to a given blade, and heat being conducted from the rotor to said blades and being dissipated therefrom to said cooling air as it passes over the blades.

3. An electric machine as claimed in claim **2**, wherein

the impeller blades are mounted on a heat-conducting member substantially coextensive in area with the end of the rotor and secured in area heat-transmitting contact with one end lamination of the rotor.

4. An electric machine comprising a stator, a casing surrounding said stator and defining with portions of said stator inlet and outlet flow passages, a rotor mounted for rotation about an axis fixed with respect to the stator, a series of air impeller blades rotating with the rotor and arranged in a ring about the axis to extend generally longitudinally thereof and define an interior space, means substantially closing the ends of the space, guide means co-operating with said blades on rotation of the rotor to induce a flow of cooling air for the machine through an inlet flow passage to one radial side of the ring of blades through the path of the rotating blades to the interior space and thence again through the rotating blades to another radial side of said ring of blades and through an outlet flow passage whereby cooling air flows over a portion of said stator; said stator being external to said rotor and said machine and said guide means comprising stator blades of heat conductive material secured in heat transmitting relation between the stator and the casing with

said stator blades running generally longitudinally of said axis in radial alignment with the rotating blades so that in operation heat is conducted into the stator blades and dissipated into the cooling air.

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