Nov. 8, 1949

G. K. W. BOESTAD ET AL

2,487,514

TURBINE ROTOR COOLING

Filed Dec. 1, 1943

4 Sheets-Sheet 1

Fig.1

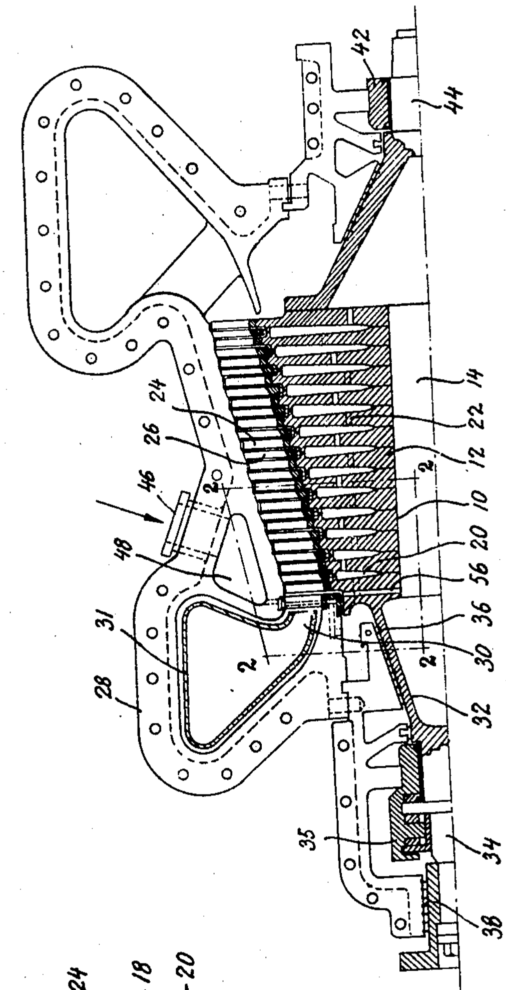
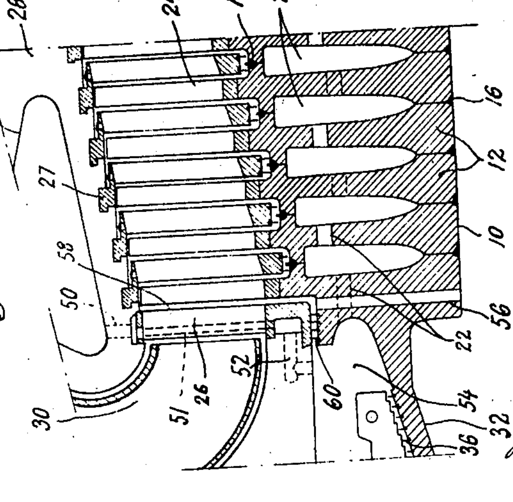


Fig. 2



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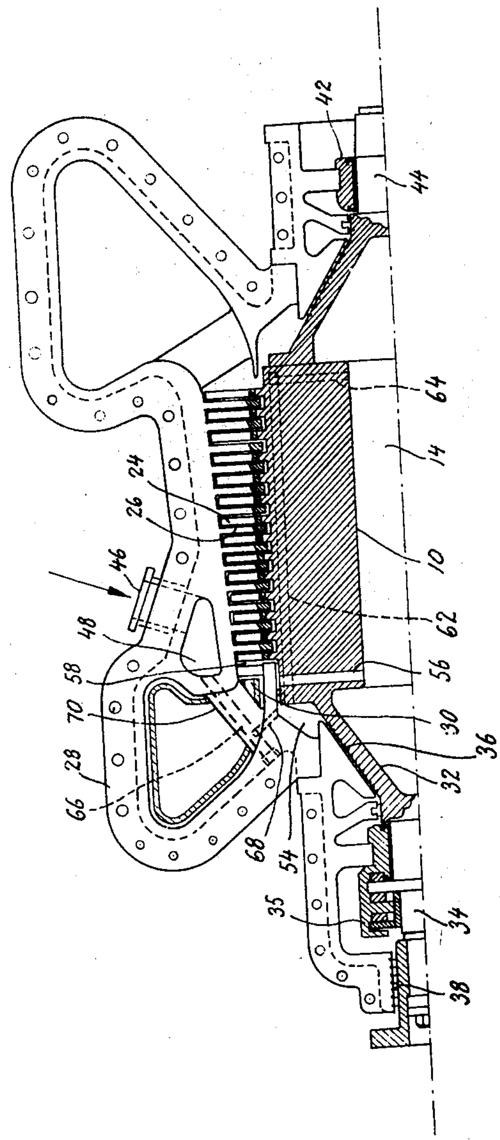

Fig. 3

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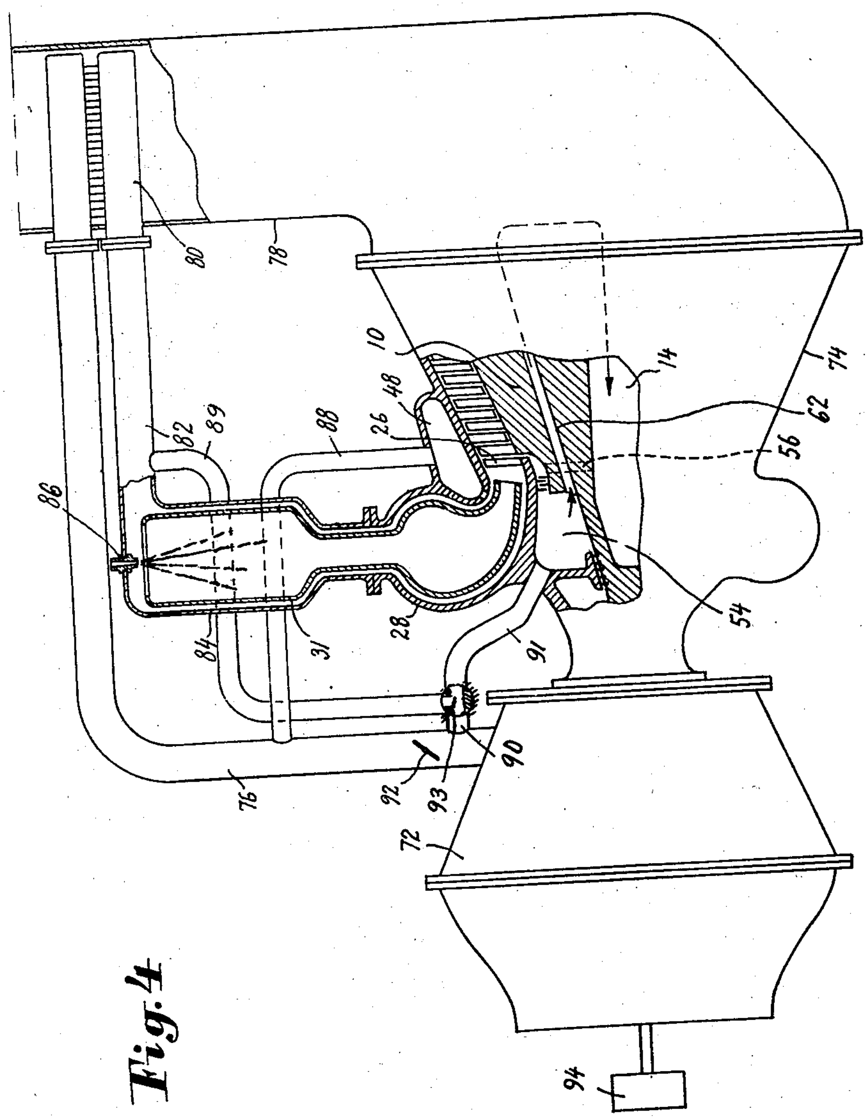

Fig. 4

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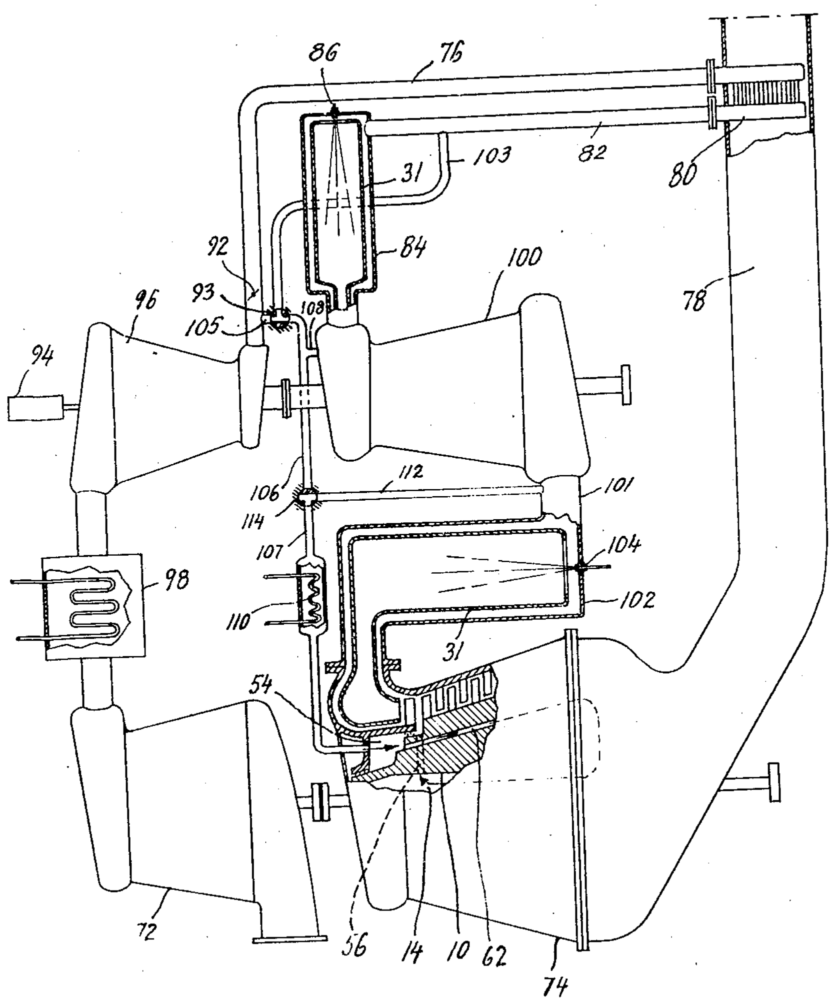
Fig. 5



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Patented Nov. 8, 1949

2,487,514

UNITED STATES PATENT OFFICE

2,487,514

TURBINE ROTOR COOLING

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Application December 1, 1943, Serial No. 512,474
In Sweden January 16, 1943

6 Claims. (Cl. 60—41)

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This application is a continuation-in-part and as to common subject matter disclosed constitutes a division of our copending application Serial No. 509,800 filed November 10, 1943, (now Patent No. 2,462,600).

In turbines operating with high temperature motive fluid such for example as in gas turbines, it is desirable to cool the turbine blades particularly the rotating blades, but it is difficult and requires much energy to directly cool the rotating blades effectively, since their total surface area is large and the coefficients of heat transfer between the gaseous motive fluid and the blade surfaces are very high.

It is therefore a general object of the present invention to provide improved rotor cooling means, more particularly for turbines of the multi-stage type, which will have a high cooling effect and which will require only a small consumption of energy. This is accomplished substantially by the fact that the interior of the rotor communicates through channels with the passage containing the blades, preferably with the space behind the first guide blade, so that the gaseous or vaporous cooling medium after having passed the rotor escapes to said passage. According to a further feature of the invention, the cooling agent has, immediately before entering the rotor, a pressure which is somewhat higher than the pressure of the driving medium in that portion of the passage wherein said channels open. In the application of the invention in gas turbine plants, the interior of the rotor communicates with a compressor or some other part of the gas turbine plant through conduits adapted to take off a portion of the working medium and to introduce the same into the rotor.

For example, if 3% of the air quantity delivered by the compressor is used for the cooling of the rotor and such air is introduced behind the first guide blade in a turbine comprising ten rotational blade rims, the loss in work for the gas turbine plant will only be about 0.3%. A reduction of the temperature by 100° C., permitting an increase of the temperature of the driving or working medium by a corresponding amount, results in an increase of the quantity of heat utilized in the turbine of the magnitude of 10%. By the fact that the cooling medium is subjected to pres-

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sure, the coefficient of heat transfer between the same and the surfaces of the rotor will be high.

If the rotor is composed of disks carrying the various rotational blade rims, which are provided with mutual radial spaces, and which are connected with each other radially inside and outside these spaces, the latter may communicate with one another through openings in the disks, said openings being located alternately on different radii. The air will thus have imparted thereto, simultaneously with the axial movement, a rotary movement relatively to the rotor disks, which further increases the coefficient of heat transfer between the cooling air and the walls of the rotor disks. It is important, moreover, that the outer portions of the rotor be cooled as effectively as possible, and that the path of heat conduction between the root of the blade and the cooled rotor surface be short. By such construction the blade root and the portion of the blade adjacent to the root and subjected to the highest stresses will also be effectively cooled.

If there are no radial spaces as stated above in the rotor, which is the case, for instance, where the rotor has an integral blade-carrying part, the cooling channels are arranged outside the average diameter of the rotor and preferably near the peripheral portion of the rotor, to ensure effective cooling of the blade attachments, besides which the whole rotor is kept at a low temperature inside the channels.

Further objects and advantages of the invention will be apparent from the following description considered in connection with the accompanying drawings which form a part of this specification, and of which:

Fig. 1 is a horizontal view, partly in section, of a gas turbine constructed in accordance with the invention.

Fig. 2 shows the portion of the turbine framed by the lines 2—2—2—2 in Fig. 1, on an enlarged scale.

Fig. 3 shows a gas turbine according to another embodiment and in the same projection as in Fig. 1.

Figs. 4 and 5 show two embodiments of gas turbine plants, partly in section, said plants being provided with a cooling device in accordance with the invention.

In the various figures, corresponding parts have been designated by the same reference numerals.

In Fig. 1, 10 designates the rotor generally which is composed of a number of turbine disks 12, the inner diameter of which is spaced apart from the axis of rotation, so that an inner axial passage 14 is produced. The disks 12 are preferably connected with each other through welding both at the inner and at the outer peripheral portions thereof, as indicated at 16, 18 (Fig. 2). The spaces 20 provided between the turbine disks and extending nearly out to the blade attachments will thus become sealed against the surrounding. The turbine disks 12 are provided with axial channels 22 which are disposed alternately on different radii and connect the various spaces 20 with each other.

The disks 12 of the rotor carry blades 24 which are arranged, together with guide blades 26 secured in the turbine housing 8, in a passage 30 having the gaseous working medium flowing therethrough. The outermost turbine disk 12 on the left hand side in Fig. 1 (the high pressure side of the turbine) may, over a preferably conical portion 32, be made integral with a shaft 34 cooperating in known manner with radial and axial thrust bearings 35 secured in the turbine housing. Arranged between the portion 32 and the shaft 34 are packing members 36, 38 on both sides of the bearing 35. The outermost disk 12 on the opposite side of the rotor is connected to a shaft 44 mounted in bearing 42. A small portion of the working medium of the gas turbine plant, such as the air which is compressed by a compressor contained in the gas turbine plant, may be conveyed through a socket 46 to an annular chamber 48 in the housing 28 and thence through channels 50 as well as through channels 51 in the first guide blade rim 26 at the high pressure end of the turbine to channels 52 opening into a chamber 54 at the left hand of the disk 12 in the drawings. From the chamber 54, the cooling air flows through the channels 22 to the spaces 20 in the rotor, a relative rotary movement being set up between the cooling air and the walls of the turbine disk, so that high coefficients of heat transfer are obtained. The cooling air then enters the channel 14, which is closed on both sides, and continues through a radial channel 56 in the first turbine disk 12 at the high pressure end of the rotor, whereupon the cooling air is introduced into the space 58 behind the first guide blade 26 and is carried along with the current of driving medium flowing through the passage 30. The space 58 is separated from the chamber 54 by means of packings 60.

The cooling air is taken off at such a point on or behind the compressor that when entering the interior of the rotor it will have a pressure somewhat higher than the pressure in the space 58.

The rotor 10 may be made from steel of the martensitic or some equivalent type. On the other hand, the blades 24 are made from austenitic or some equivalent steel having a high heat resistivity. The latter steel at the same time has a coefficient of heat expansion about 50% greater and a less heat conductivity than martensitic steels. Hereby, the rotor proper as well as the turbine housing may be constructed from a cheaper steel having a good heat conductivity and a small coefficient of expansion, which involves that the disadvantages of different expansions of the rotor and the housing at changes in temperature are reduced to a great extent. The blades occupy a comparatively small portion of the radial extension of the turbine, by reason of which a greater heat expansion on the part of the blades is of little import. The turbine housing 28 is preferably made from a material having a coefficient of heat expansion of the same magnitude as that of the rotor material. Furthermore, the housing 28 may be protected against the hot working medium by means of rings 27 from austenitic or some equivalent steel, in which the guide blades 26 are secured. Provided in the inlet passage of the turbine is a partition or jacket 31 having a cooling agent flowing thereabout on the outside.

The embodiment according to Fig. 3 differs from the preceding one substantially only in that the rotor 10 is made with an integral blade-carrying part. This part is provided with channels 62 for the cooling air extending axially therethrough, said channels being located outside the average radius of the rotor as near to the points of attachment of the blades 24 as possible. The channels 62 are no through-passages at the right hand end of the rotor 10 in the drawing, but communicate through radial channels 64 with the central channel 14. The cooling air is conveyed from the space 48 to the chamber 54 through passages 66, 68 in reinforcing members 70 located in front of the first guide blade and in the housing 28.

The gas turbine plant illustrated in Fig. 4 comprises a compressor 72 which is driven by the gas turbine 74, the blade-carrying rotor 10 of which may form an integral part as in the embodiment according to Fig. 3. The air compressed in the compressor flows through a conduit 76 to a heat exchanger 80 arranged in the outlet conduit 78 from the turbine, and further through a conduit 82 to a combustion chamber 84 into which the fuel is introduced through a nozzle 86. Disposed in the combustion chamber 84 is a partition or cooling jacket 31 in which the hot working medium flows. The space around the cooling jacket 31 is traversed by comparatively cold air adapted to cool the wall of the combustion chamber and the turbine housing, said air then entering the blade system together with the hot working medium. Through a pipe 88, cooling air is being supplied to the annular chamber 54 in the turbine housing. From this chamber, the cooling air may then be introduced into the space between the jackets 31 and 84, or may be conveyed to the blade system. Through a conduit 89, 91 extending from the conduit 82, cooling air is conveyed to the chamber 54 and thence through the channels 62, 14, 56 to the rear side of the first guide blade rim 26 in the turbine. A conduit 90 extending from the conduit 76 may be connected with the conduits 89, 91, a three-way valve 93 being inserted therebetween so that the cooling air may be taken from either the conduit 82 alone or from said conduit and the conduit 76. The air coming from the conduit 82 is warmer than that from the conduit 76, and by this arrangement the setting up of stresses in the rotor material by too great differences of temperature in its various parts is avoided. In this guide blade rim, the drop of heat may be so great, without any detrimental effect, that a sufficient drop of pressure is obtained to keep a sufficient quantity of air in circulation through the cooling passages of the rotor in normal operation.

It is advantageous to form the turbine in such manner that the rotor may be heated up more slowly than the housing. When the turbine is cut off, the opposite will then be the case, in that the rotor will cool down more slowly, whereby the plays between the turbine blades and the housing are reduced and the sealing edges between the latter may be worn to greater plays in normal operation of the turbine. To obviate disadvantages of this kind, there is provided a valve 92 in the conduit 76 behind the outtake for the conduit 90, viewed in the direction of flow of the air. The valve 92 is closed more or less, while the fuel supply through the nozzle 86 is cut off at the same time. All air from the compressor 96 now flows through conduits 90, 91 to the interior of the rotor. To this end the valve 93 may be operated automatically to open the passage between the said conduits when the valve 92 is closed. Through the kinetic energy of the rotating masses, the rotor is kept running for a while, and the rotation may be maintained for a longer time with the aid of the starting motor 94, if required. In this way, an efficient cooling of the rotor may be had also when the rotation is slow.

In the embodiment according to Fig. 5, 72 designates a low pressure compressor and 96 a high pressure compressor, the conduit between them having an air cooler 98 arranged therein. 74 denotes the low pressure turbine driving the compressor, and 100 designates the high pressure turbine driving the compressor 96. The air compressed in the compressor 96 to its final pressure flows through the conduit 76, the heat exchanger 80 and the combustion chamber 84 to the gas turbine 100 and from the latter to a combustion chamber 102, into which the fuel is introduced through a nozzle 104 to reheat the working medium, before the same enters the turbine 74. The turbine 74 also drives a generator (not shown), for example. In both turbines, the rotor is provided with a system of cooling passages according to the invention.

Extending from the conduit 82 and preferably also from the conduit 76 are conduits 103 and 105, respectively, which by the three-way valve 93 are connected to a conduit 106. Cooling air is supplied through said conduits and a branch conduit 108 to the rotor of the high pressure turbine 100. The conduit 106 communicates with a conduit 112 extending from the outlet 101 of the high pressure turbine to the cooling system of the low pressure turbine, as well as with a conduit 107 opening into the chamber 54 of the low pressure turbine. The conduit 107 may have a cooler 110 connected into the same. Provided between the conduits 106, 107 and 112 is a three-way valve 114 adapted to cut off the conduit 106 in normal operation, when cooling medium passes through the conduits 112, 107 and through the cooler 110 to the low pressure turbine. When the gas turbine plant is put out of operation, the valve 114 is shifted simultaneously with the closing of the valve 92, so that cooling air will now pass through the conduits 106 and 107 to the low pressure turbine. The valve 93 then also takes a position to allow a flow of air through the conduits 105 and 106. By this means, powerful cooling of both rotors will be obtained.

If desired, small holes or gaps may be provided in the outerbond of the disks 12 in the embodiment according to Figs. 1 and 2, said holes or gaps opening into the passage 30 for the driving medium, to which passage a portion of the cooling air will thus escape directly.

Gas turbine system structure herein disclosed forms the claimed subject mattter of our divisional application, Serial No. 78,262 filed February 25, 1949, the claimed subject matter in the present application being restricted to turbine structure per se, and while several embodiments of the latter have been shown, it is to be understood that they are illustrative only and that the scope of the invention includes all forms of structure falling within the purview of the appended claims.

What we claim is:

1. In an elastic fluid turbine, rotor and stationary structures carrying rotating and stationary blades respectively and providing between them a channel having a blade system therein for expansion of motive fluid, the interior of said rotor being provided with passages for conducting a fluid cooling medium therethrough to cool the blade carrying structure of the rotor, inlet means for introducing a cooling medium under pressure to said passages and outlet means for discharging the cooling medium from said passages to said channel, said outlet means communicating with a zone in said channel on the discharge side of at least the first row of blades in said blade system, and sealing means between said rotor and stationary structures located to close communication between the inlet side of said first row of blades and the place of communication of said outlet means with said channel.

2. A structure as set forth in claim 1 in which said cooling passages are arranged so that the cooling medium flows from said inlet means generally lengthwise of the rotor adjacent to the periphery of the blade carrying portion of the rotor structure.

3. A structure as set forth in claim 1 in which said cooling passages are arranged so that the cooling fluid flows from the inlet thereto generally lengthwise of the rotor adjacent to the outer periphery of the blade carrying portion of the rotor structure and thereafter flows generally lengthwise of the rotor through the central portion thereof.

4. A structure as set forth in claim 1 having said inlet means at the high pressure end of the rotor, said cooling passages comprising passages in the radially outer part of the blade carrying structure of the rotor communicating with said inlet means for flow of the cooling medium generally lengthwise of the rotor in the outer part thereof and a centrally located passage communicating with the passages in said radially outer part for return flow of cooling medium from the outlet toward the inlet end of the rotor, and said outlet means comprising passages for discharging the cooling medium from said central passage to the motive fluid channel adjacent to the inlet end of the rotor.

5. A structure as set forth in claim 1 having a hollow integral rotor structure, said cooling passages comprising a plurality of passages extending lengthwise through said structure and communicating at the high pressure end of the rotor with said inlet means and a central cooling passage communicating adjacent to the outlet end of the rotor with said lengthwise extending passages and said outlet means comprising passages providing communication between said central passage and the channel for motive fluid.

6. A structure as set forth in claim 1 in which the blade carrying portion of the rotor comprises a plurality of discs connnected together adjacent to their outer peripheries and also at places

spaced inwardly thereof, whereby to provide a series of annular spaces between the discs, and openings in said discs for connecting said spaces to provide therewith the cooling passages aforesaid, said openings being so located relative to each other in adjacent discs as to prevent straight axial flow through the rotor of the cooling medium and said spaces being connected for direct flow thereto of the cooling medium from said inlet means.

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