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(19) **United States**(12) **Patent Application Publication**  
**Kriehn**(10) **Pub. No.: US 2005/0069446 A1**(43) **Pub. Date: Mar. 31, 2005**(54) **COOLED SCREW VACUUM PUMP****Publication Classification**(76) **Inventor: Hartmut Kriehn, Koln (DE)**(51) **Int. Cl.<sup>7</sup> ..... F01C 21/04; F04C 15/00**(52) **U.S. Cl. .... 418/83; 418/94; 418/201.1**

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**Fay Sharpe Fagan****Minnich & McKee****Seventh Floor****1100 Superior Avenue****Cleveland, OH 44114-2518 (US)**(57) **ABSTRACT**(21) **Appl. No.: 10/169,329**(22) **PCT Filed: Dec. 7, 2000**(86) **PCT No.: PCT/EP00/12318**(30) **Foreign Application Priority Data**

Dec. 27, 1999 (DE)..... 19963171.9

The invention relates to a screw vacuum pump, comprising two shafts (7, 8), each bearing a rotor (3, 4) containing a hollow chamber (31). Said chamber (31) contains a second hollow chamber (32) which embodies a component of a coolant circuit. The shafts (7, 8) have open bores (41) on the delivery side, through which the coolant is supplied and evacuated to or from the additional hollow chambers (32). In order to improve the effectivity of the cooling of the rotors, guide components (44) are located in the open bores (41) of the shafts (7, 8). Said guide components separately guide the inflowing and outflowing coolant.

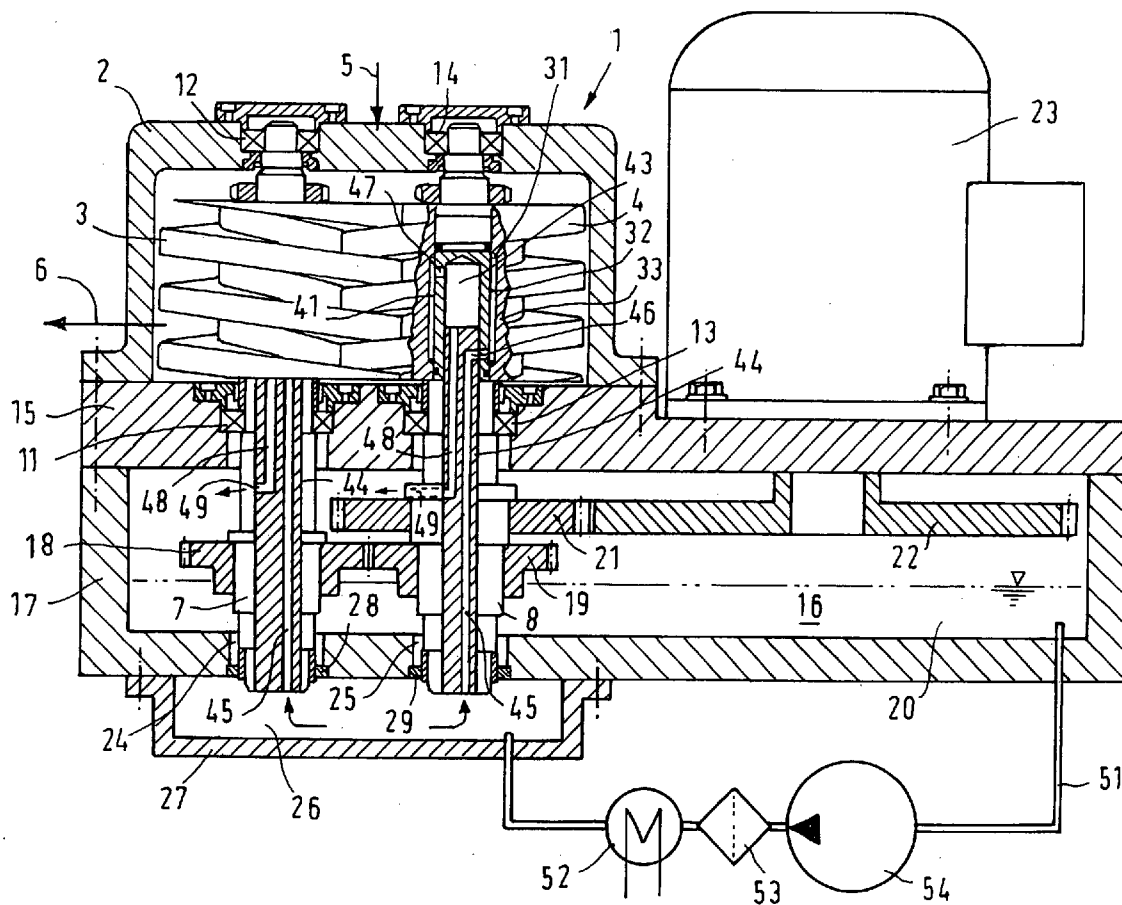
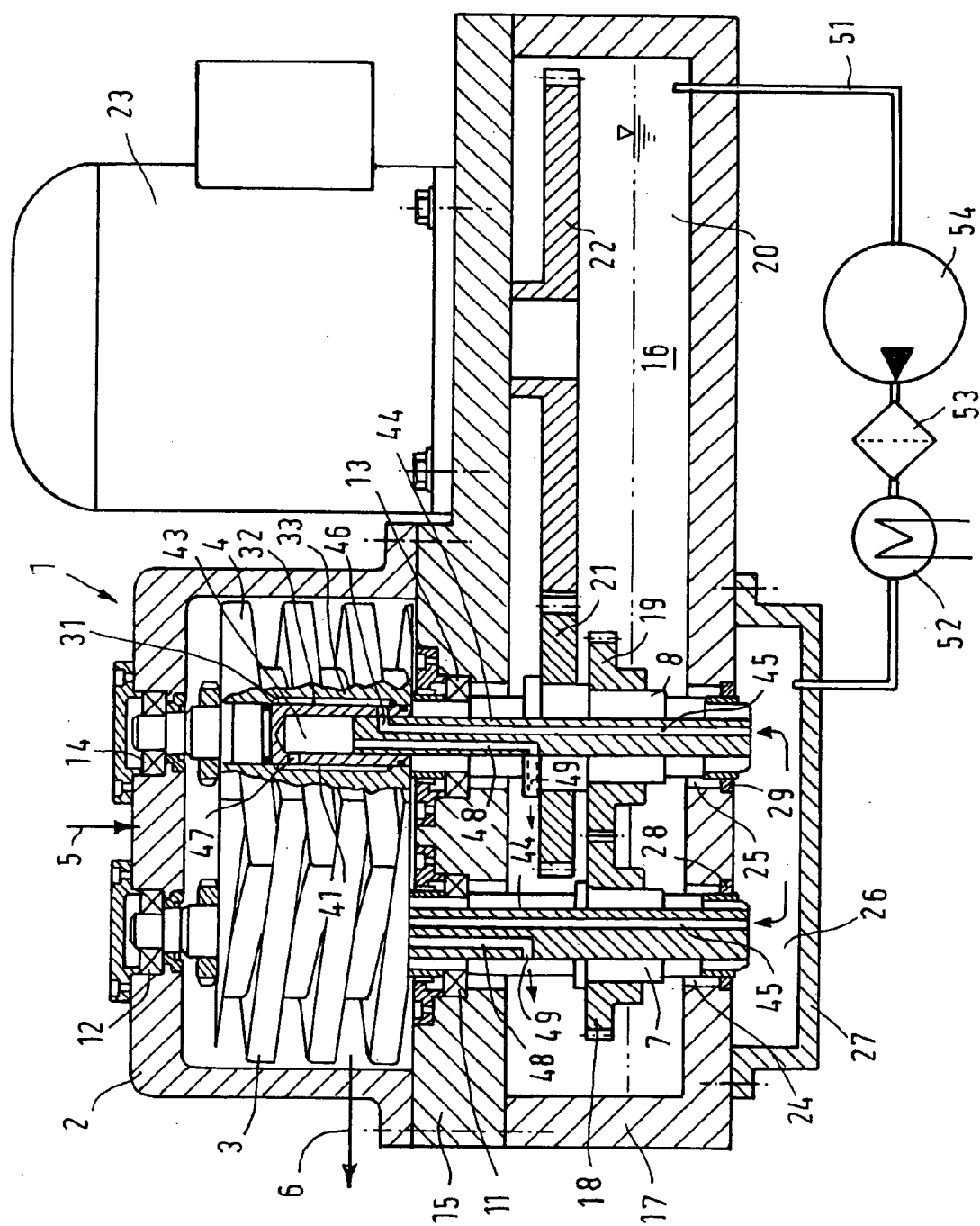


FIG. 1



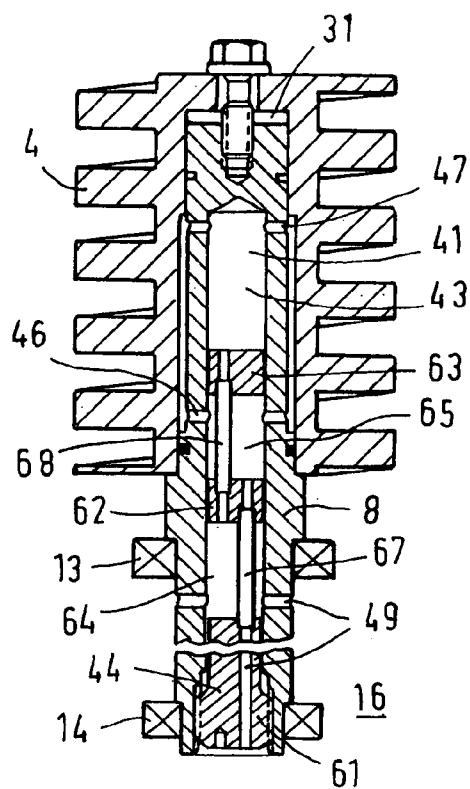


FIG. 2

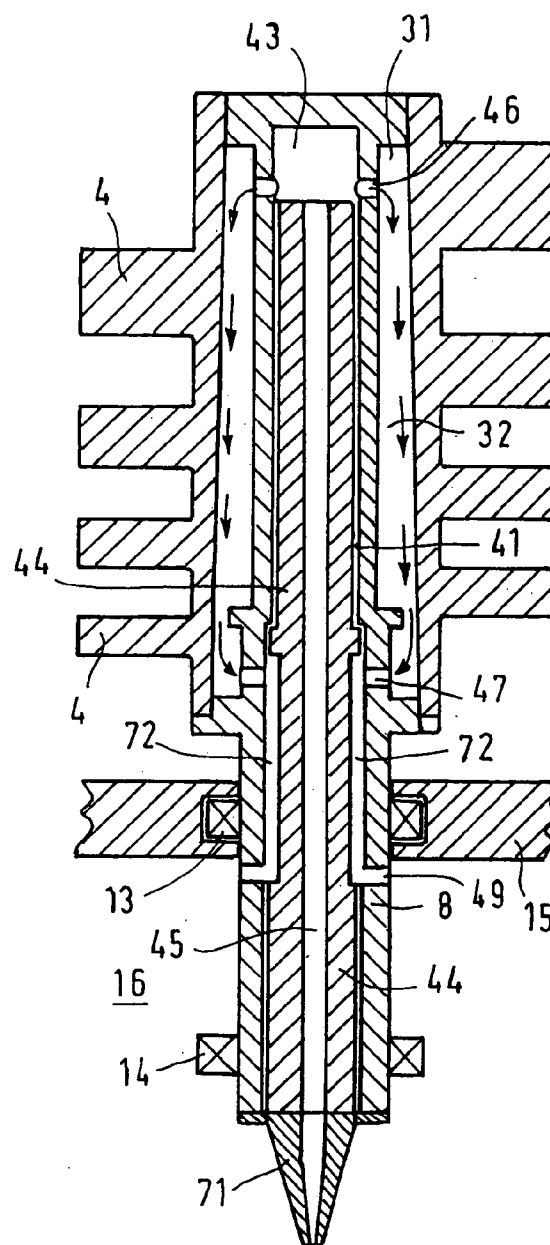
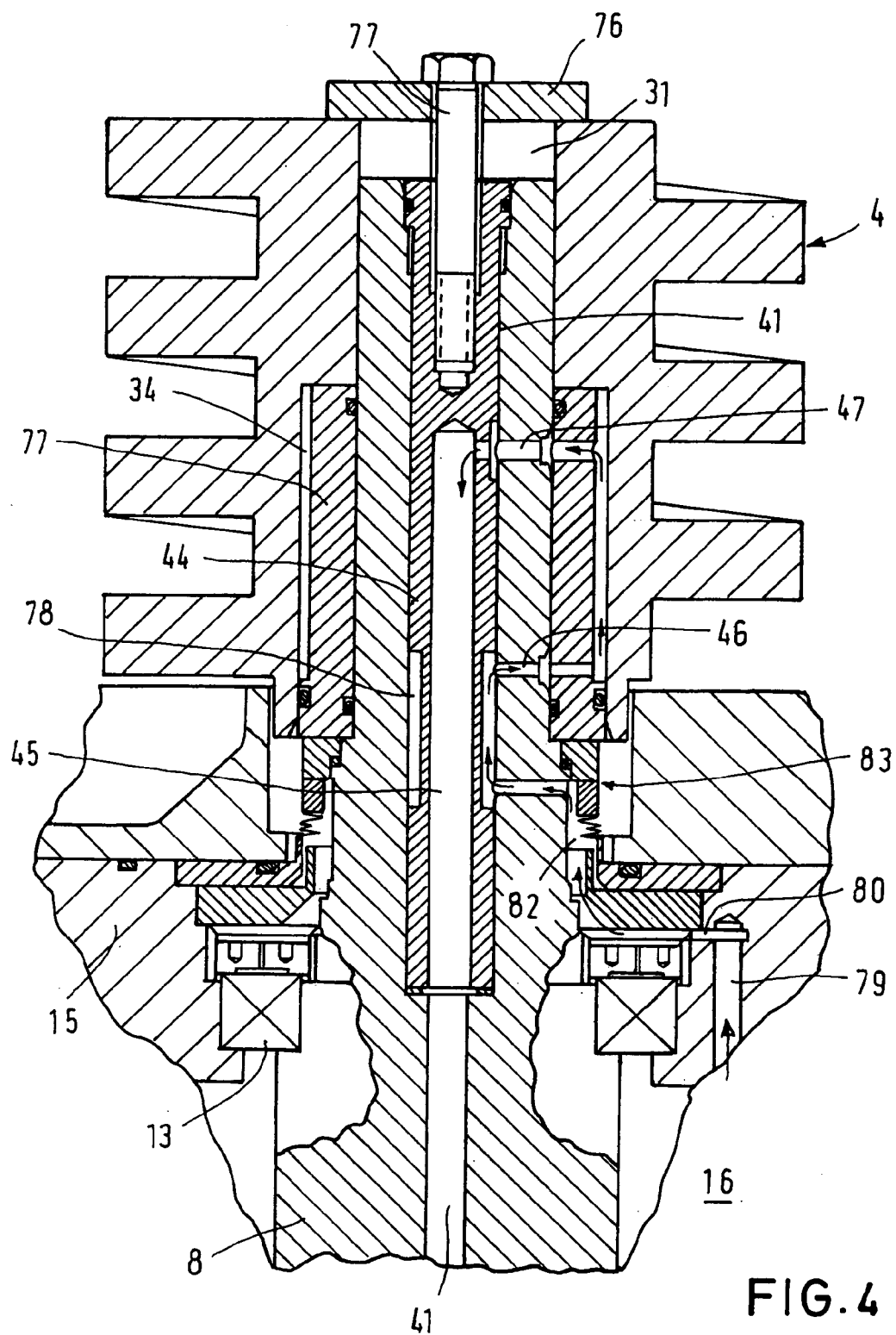


FIG. 3



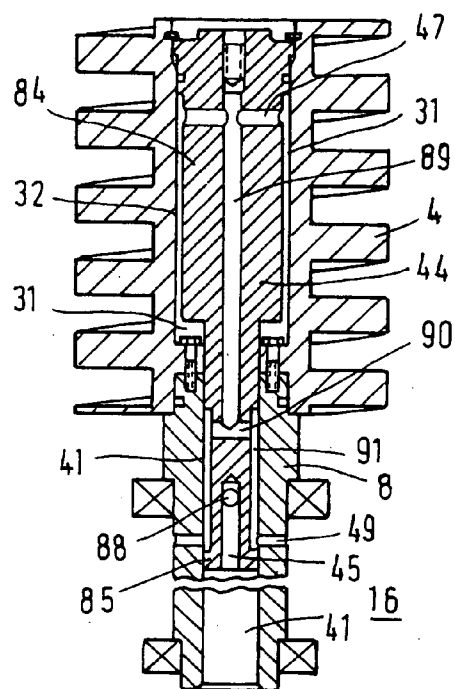


FIG. 5a

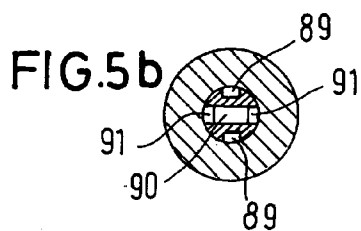


FIG. 5b

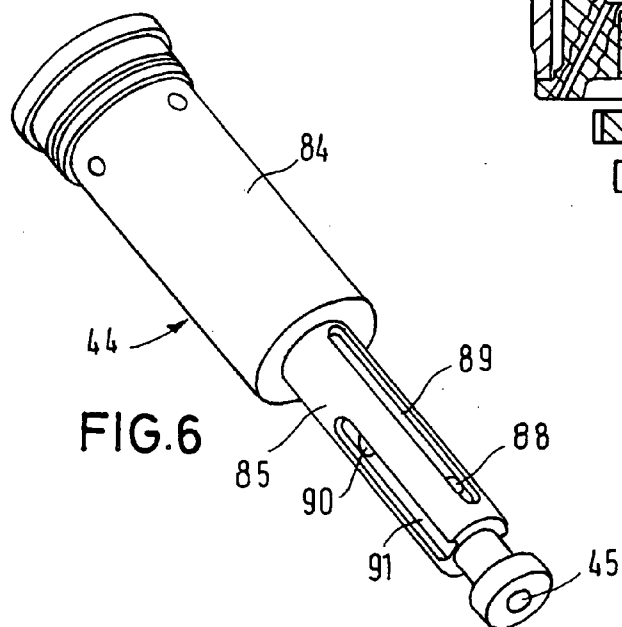


FIG. 6

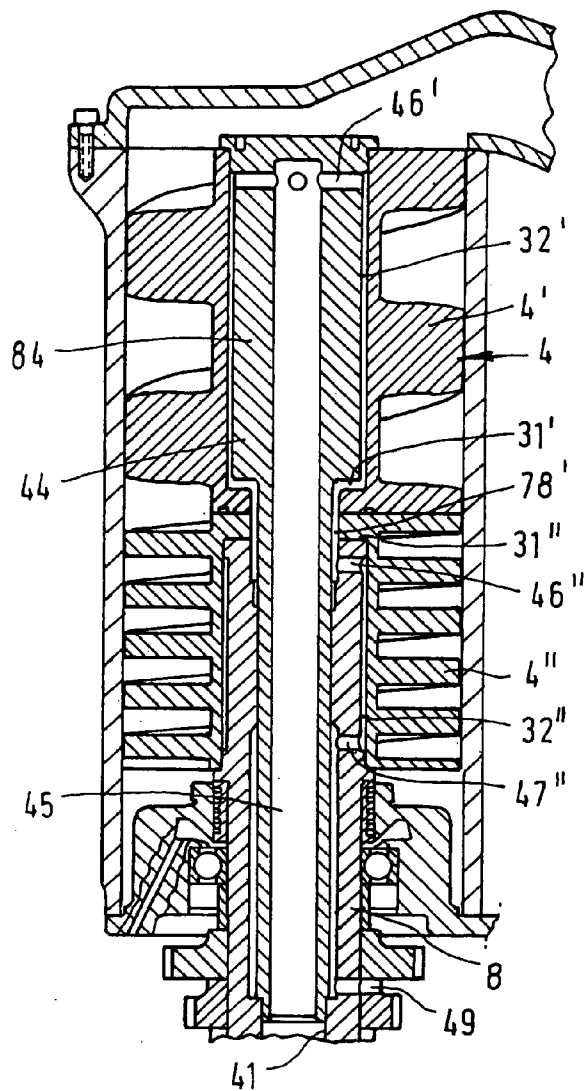


FIG. 7

### COOLED SCREW VACUUM PUMP

[0001] The present invention relates to a screw vacuum pump, comprising two shafts, each bearing a rotor containing a hollow chamber. Said chamber contains a second hollow chamber which embodies a component of a coolant circuit. The shafts have open bores on the delivery side, through which the coolant is supplied and evacuated to or from the additional hollow chambers.

[0002] A screw vacuum pump having these features is known from DE-A-198 20 523 (drawing FIG. 4). The coolant is injected into the bores in the shafts, said bores being open on the delivery side. On the suction side, the shafts are equipped with radial bores, through which the coolant enters into the hollow chambers in the rotor. The outside walls of these hollow chambers are designed to be conical, widening in the direction of the delivery side. Thus the coolant film forming on the outside walls flows in the direction of the delivery side. Via radial bores in the shaft on the delivery side the hot coolant returns through the respective central bore in the shaft and flows through these bores back to the respective opening. Of disadvantage in the instance of the known solution is, that the cold coolant is supplied and the hot coolant is evacuated in each case through a common bore in the shafts. Mixing of the coolant flows is unavoidable whereby the effectivity of the cooling arrangement is already impaired. Moreover, it is not possible to operate the cooling facility for the rotors in a "counterflow". The coolant first arrives at the cooler side of the rotors (on the suction side) and thereafter it flows to the delivery side where the amount of heat of compression which needs to be dissipated is greatest. Finally, the solution according to the state-of-the-art requires that the corresponding rotor chambers be designed to be conical, which can only be implemented with a manufacturing-wise relatively high complexity.

[0003] It is the task of the present invention to not only improve the supply of coolant into the rotor chambers in the instance of a screw vacuum pump of the kind mentioned above, but also improve the effectivity of the cooling arrangement.

[0004] This task is solved through the characterising features of the patent claims.

[0005] By employing guide components inserted in the central shaft bores, initially a reliable and effective separation between the inflowing cold coolant and the outflowing hot coolant can be attained, in particular when the guide components are manufactured of a material which does not conduct heat very well. The central shaft bore for accommodating the guide component may have a relatively large diameter. Such a bore can be manufactured in the shaft material in a significantly easier manner compared to individual deep bore holes for the supply and evacuation channels. Moreover, guide components will allow cooling of the rotors in a "counterflow", since even trouble-free crossing of the supplied and evacuated coolant flows can be arranged. Cooling the rotors in a counterflow offers the additional advantage of a more even temperature distribution, so that the slots between rotor and casing can be maintained small and uniform. Finally, the guide components allow cooling of the rotors in such a manner that all lines, slots, chambers or alike which are located within the rotor chambers and through which the coolant flows, are filled at all times

completely with the flowing coolant. The effectivity of the cooling arrangement is thus considerably improved.

[0006] Further advantages and details of the present invention shall be explained with reference to the design examples depicted schematically in drawing FIGS. 1 to 7. Depicted is/are in

[0007] drawing FIG. 1 a sectional view through a screw vacuum pump according to the present invention,

[0008] drawing FIGS. 2 and 3 sectional views through one each of two cantilevered rotors of a screw vacuum pump, depicting further solutions for the design of the guide component,

[0009] drawing FIG. 4 a sectional view through a rotor with means of displacing the cooling slot to the outside,

[0010] drawing FIGS. 5 and 6 a solution in which the guide component limits the cooling slot, and

[0011] drawing FIG. 7 a solution with a rotor consisting of two sections.

[0012] The screw vacuum pump 1 depicted in drawing FIG. 1 comprises pump chamber casing 2 with the rotors 3 and 4. Inlet 5 and outlet 6 of the pump 1 are schematically marked by arrows. The rotors 3 and 4 are affixed on to the shafts 7 and 8 respectively, said shafts being each supported by two bearings 11, 12 and 13, 14 respectively. One bearing pair 11, 13 is located in a bearing plate 15 which separates the pump chamber being free of lubricant from a gear chamber 16. The second bearing pair 12, 14 is located within pump chamber casing 2. Located in casing 17 of the gear chamber 16 are the synchronising toothed wheels 18, 19 affixed to the shafts 7 and 8, as well as a pair of toothed wheels 21, 22 serving the purpose of driving the pump 1, where one toothed wheel is coupled to the shaft of the drive motor 23 arranged vertically besides the pump 1. Moreover, the gear chamber has the function of an oil sump 20.

[0013] The ends of the shafts 7, 8 on the side of the gear chamber penetrate through bores 24, 25 in the bottom of the gear chamber casing 17 and end in an oil containing chamber 26 being formed by casing 17 and a thereto affixed trough 27. In the design example depicted, in which the pair of rotors 3, 4 is supported by bearings on both sides, the oil sump 16 is separated from the oil containing chamber 26 by seals 28, 29. In the instance of a cantilevered bearing for the pair of rotors 3, 4 the second pair of bearings 12, 14 is located in the area of the bores 24, 25.

[0014] From drawing FIG. 1 it is apparent that the rotors 3 and 4 each have a hollow chamber 31 in which the shaft 8 extends and in which a further chamber 32 is present through which coolant flows. Since only rotor 4 is depicted by way of a partial section, the present invention is explained only with reference to this rotor 4.

[0015] In the solution according to drawing FIG. 1, the chamber 32 through which the coolant flows is designed by way of a section of an annular gap and is located directly between shaft 8 (resp. 7) and rotor 4 (resp. 3). To this end the cylindrical inner wall of the rotor containing the hollow chamber 31 is equipped in its middle area with a section 33 turned off on a lathe, the depth of which corresponds to the

thickness of the cooling slot 32. On the suction side and the delivery side, the shaft 8 rests flush against the inner wall of the hollow chamber 31.

[0016] The cooling slot 32 is supplied with the coolant through the shaft 8. It is equipped with a central bore 41 extending from the bottom end of the shaft 8 to the end of the cooling slot 32 on the delivery side. It forms a chamber 43 in which a guide component 44 for the coolant is located. The guide component 44 extends from the bottom end of the shaft 8 up to and over the end of the cooling slot 32 on the delivery side. The coolant is supplied via the longitudinal bore 45 in the guide component 44, said bore being linked via truly aligned cross bores 46 through the component 44 and the shaft 8 to the end of the cooling slot 32 on the delivery side.

[0017] At the level of the cooling slot 32 on the suction side, the shaft 8 is equipped with one or several cross bores 47 which open out into the chamber 43 formed by the pocket hole 41 and the face side of the guide component 44. Said chamber is linked via the longitudinal bore 48 and the truly aligned cross bores 49 (in the guide component 44 and in the shaft 8) to the gear chamber 16.

[0018] The coolant is supplied from the oil containing chamber 26 through bores 45 and 46 into the cooling slot 32. The coolant flows through the cooling slot 32 from the delivery side to the suction side of the rotor 4. Since most of the heat which needs to be dissipated is generated on the delivery side of the rotor 4, the rotor 4 is cooled in a counterflow. The coolant is evacuated initially through the second bore 47 in the chamber 43 in the shaft 8 as well as through the bores 48, 49. The bore 48 extends from the suction side of the cooling slot 32 up to the level of the gear chamber 16. The cross bore 48 provides the link between bore 43 and the gear chamber 16.

[0019] Reliable cooling of the rotors 3, 4 is attained when the coolant is capable of flowing through the relatively narrow cooling slots 32 quickly and undisturbed (free of cavitation and contamination). For this reason it is expedient to ensure, besides cooling and filtering of the coolant, a sufficient pumping force. In the design example in accordance with drawing FIG. 1, therefore, the gear chamber 16, resp. the oil sump 20 is linked to the chamber 26 through a line 51 in which there is located besides a cooler 52 and a filter 53, an oil pump 54 which may be designed by way of a gear pump, for example. The oil pump 54 ensures that the coolant enters at the necessary pressure and free of cavitation from chamber 26 into the bore 41.

[0020] Moreover, there exists the possibility of arranging oil pumps (centrifugal pumps, gear pumps) in the area of the bottom ends of the shafts 7, 8. However, these need to be so designed that they are capable of meeting the requirements as to the desired pumping properties.

[0021] Depicted in drawing FIG. 2 is a solution in which the guide component 44 comprises three sections 61, 62, 63 which divide the hollow chamber in the shaft 8 in to three partial chambers 64, 65, 43 which are each located at the level of the cross bores 49, 46 and 47. Through suitable bores in the sections 61 to 63 as well as line sections 67 and 68 linking said bores, separate supply and evacuation of the coolant may be implemented.

[0022] In the embodiment in accordance with drawing FIG. 3, the coolant is supplied through the bore 45, which

in contrast to the embodiments in accordance with drawing FIGS. 1 and 2 centrally penetrates the guide component 44. The oil pumped by a centrifugal pump 71 into the bore 45 enters into the hollow space 43 formed by the pocket hole 41 as well as the guide component 44, and through the cross bore 46 into the chamber 32 through which the coolant flows. In contrast to the embodiments in accordance with drawing FIGS. 1 and 2, the chamber 32 through which the coolant flows has the shape of an annular chamber of a relatively large volume being formed by the shaft 8 and the inner wall of the hollow chamber 31. Since this inner wall is designed to be conical in such a manner that the rotor's hollow chamber 31 widens conically in the direction of the delivery side of the rotors 3, 4, the coolant injected from the bores 46 into the chamber 32 is conveyed in the direction of the rotor's delivery side. Bubble- or cavitation-free operation of the coolant circuit is not required. The coolant can be so metered that it will flow along the inner wall of the rotor's hollow chamber 31 by way of a thin film, for example.

[0023] The evacuation bores 47 are linked to lateral side channels 72 (or a section turned off on a lathe) in guide component 44 whereby said evacuation bores extend at the level of the bearing plate 15 up to the gear chamber 16 where they are linked to the cross bores 49.

[0024] The embodiment in accordance with drawing 4 differs from the embodiments detailed above in that a bore is provided fully penetrating the shaft 8 and the rotor 4. For the formation of the hollow chamber 31, a cover 76 is provided on the suction side, this cover being linked via a bolt 77 with the guide component 44. The guide component 44 is firmly inserted from the suction side. Together with bolt 77 and the cover 76 it serves the purposes of axially affixing the rotor 4. On the delivery side, bore 41 has a smaller diameter.

[0025] The shaft 8 is equipped with an outer sleeve 77 which together with the inner wall of the hollow chamber 31 in the rotor 4 forms the cooling slot 32<sup>1)</sup>. This slot extends substantially only at the level of the delivery side of the rotor 4. Radially displacing the cooling slot 32 towards the outside improves the cooling effect. The coolant is only supplied through relatively short sections of longitudinal grooves 78 (or a section turned off on a lathe, annular channel) in the guide component 44 up to the cross bores 46 which penetrate the shaft 8 and the sleeve 77. Before it enters into the longitudinal grooves 78, it flows through bores 79, 80 in the bearing plate 15 as well as the chamber 82 on the bearing side of an axial face seal 83 where it ensures the formation of the necessary barrier pressure. The coolant is returned through the cross bores 47 as well as the central bore 45 in the guide component 44, resp. the bore 41 in the shaft 8.

<sup>1)</sup>Translator's note: In the figure "34" is stated "32" would be more in line with the remaining text and the other drawing figures.

[0026] In the solution in accordance with drawing FIGS. 5a and 5b<sup>2)</sup>, the shaft 8 does not extend into the rotor's hollow chamber 31. Said shaft is linked to the rotor 4 at the level of the delivery side. The guide component 44 in the rotor's hollow space 31 has a section 84 with an increased diameter which together with the inner wall of the hollow chamber 31 in rotor 4 forms the cooling slot 32. A second section 85 having, compared to the section 84 a smaller diameter, penetrates the bore 41 in the shaft 8.

[0027] For thermal reasons of permitting on the one hand the supply of the coolant from the open side of the bore 41

through a central bore 45 in the guide component 44 and on the other hand to permit cooling of the rotor 4 in a counterflow, it is required that the guide component 44 provides a crossing for the coolant flows. This is implemented through cross bores and outer groove sections in the guide component 44 which are designed as detailed in the following (cf. drawing FIGS. 5a, 5b and 6):

[0028] Coolant supplied<sup>3)</sup> centrally through the pocket hole 45 enters through a cross bore 88 into two groove sections 89 facing each other and then the coolant enters into the hollow chamber 31 (delivery side). Thereafter the coolant flows through the cooling slot 32 and enters through cross bores 47 into a line section 89 located centrally in the guide component. Said line section extends to a second cross bore 90 placed on the suction side with respect to the first cross bore 88. The two cross bores 88 and 90 are arranged approximately perpendicular to each other. The cross bore 90

<sup>2)</sup>Translator's note: The German text states "... nach den FIG. 5a erstreckt ..." here whereas "... nach den FIG. 5a und 5b erstreckt ..." would make for a correct sentence. Therefore the latter has been assumed for the translation.

[0029] opens out into groove sections 91 facing each other, which are offset by about 90 degrees with respect to groove sections 89. Thus it is possible<sup>4)</sup> to guide the returning coolant through these groove sections 91 to the cross bores 49 in the area of the gear chamber 16.

[0030] In the design example in accordance with drawing FIG. 7, the rotor 4 comprises two sections 4' and 4" having differently designed threads as well as each with a hollow chamber 31' and 31" respectively. The shaft 8 extends into the hollow chamber 31' of the rotor section on the delivery side 4" and thus forms the cooling slot 32". The guide component 44 is similarly designed as in the embodiment in accordance with drawing FIGS. 5, 6. It has a section 84 with an increased diameter which is located in hollow chamber 31' of the rotor section 4' and which forms together with the inside wall of this rotor section 4' the cooling slot 32'. A further section 85 of the guide component 44 having a smaller diameter penetrates the central bore 41 in shaft 8. The guide component 44 is equipped with a central bore 45 extending to the suction side of the rotor 4.

[0031] For simplicity and better overview, a solution is presented in which the coolant is supplied through the central bore 45 and where the coolant flows through lateral bores 46' in section 84 on the suction side into the cooling slot 32'. Through a section 78' turned off on a lathe (or also through longitudinal grooves) as well as cross bores 46" the end of the cooling slot 32" on the delivery side is linked to the end of the

<sup>3)</sup>Translator's note: The German text states "... zugeführtes Kühlmittel wird über eine Querbohrung ..." here whereas "... zugeführtes Kühlmittel gelangt über eine Querbohrung ..." would make for a complete sentence. Therefore the latter has been assumed for the translation.

<sup>4)</sup>Translator's note: The German text states "... möglich dass das ..." here whereas "... möglich das ..." would make for a complete sentence. Therefore the latter has been assumed for the translation.

[0032] cooling slot 32" on the suction side so that the coolant passes sequentially through the two cooling slots 32', 32". Through a further section 78" turned off on a lathe, the evacuation opening 47" on the delivery side of the cooling slot 32" is linked to the evacuation opening 49 at the level of the gear chamber 16. Also in the instance of this

solution there exists the possibility of also employing the guide component 44 as a tie rod, specifically for affixing the rotor section 4'.

[0033] Of course there also exists the possibility in the instance of the embodiment in accordance with drawing FIG. 75) of designing the supply and evacuation lines for the coolant in such a manner that the cooling slots 32', 32" are supplied separately and/or in a counterflow.

[0034] The solutions in accordance with drawing FIGS. 5 to 7 are of particular advantage when the rotors 3, 4 are cantilevered, since then there exists the possibility of

<sup>5)</sup>Translator's note: The German text states "FIG. 9" whereas "FIG. 7" would be appropriate. Therefore the latter has been assumed for the translation.

[0035] manufacturing the guide component 44<sup>6)</sup> of light materials like plastic, for example. Thus the mass of the rotors far from the bearing can be kept small. The usage of plastic or similar materials also offers the general advantage that there are located between the inflowing and the outflowing coolant materials which do not conduct heat very well.

<sup>6)</sup>Translator's note: The German text states "62" here whereas "44" would be more in line with the remaining text and the other drawing figures. Therefore "44" has been assumed for the translation.

#### 1. A screw vacuum pump, comprising:

two shafts, each bearing a rotor containing a first hollow chamber;

said first chambers each containing a second hollow chamber which defines a coolant channel;

the shafts have open bores on a delivery side, through which inflowing coolant is supplied to and outflowing coolant is evacuated from the second hollow chambers;

guide components located in the open bores of the shafts, said guide components separately guiding the inflowing and outflowing coolant.

2. The pump according to claim 1, wherein the open bores include:

lateral sections of longitudinal grooves or outer sections turned off on a lathe in the guide components.

3. The pump according to claim 1, wherein the guide components include:

axial and radial line sections arranged to allow for separate crossing guidance of the inflowing coolant and the outflowing coolant.

4. The pump according to claim 3, further including:

a first longitudinal groove or a pair of longitudinal grooves for supplying the inflowing coolant; and

a second longitudinal groove or pair of longitudinal grooves offset by 90 degrees for evacuating the outflowing coolant.

5. The pump according to claim 4, further including:

cross bores which cross the inflowing and outflowing coolant flows.

6. The pump according to claim 1, further including:

radial bores linking the open bores to the second hollow chamber.

7. The pump according to claim 1, wherein the guide components comprise:

three sections which divide the open bore in each shaft into three partial chambers which are each located at a level of a radial cross bore, longitudinal bores in the three sections and line sections linking said longitudinal bores, separate inflowing and outflowing coolant.

**8.** The pump according to claim 1, further including:

lines for evacuating the coolant out into a gear chamber.

**9.** The pump according to claim 1, wherein

an end of each shaft on the suction side is linked to an end of the rotor on the delivery sides and

the guide component extend up to and into the first hollow chambers.

**10.** The pump according to claim 9, wherein the guide components are made of a light plastic material.

**11.** The pump according to claim 1, wherein the first hollow chambers fully penetrates the rotors and the guide components function as tie rods for affixing the rotors to the shafts.

**12.** The pump according to claim 1, wherein an inside wall of each first hollow chamber limits the second hollow chamber and widens conically in a direction of the delivery side.

**13.** The pump according to claim 1, wherein each second hollow chamber is a relatively narrow cylindrical section of an annular ring through which the coolant flows, the section of the annular ring extending between one of the shaft and the guide component and a corresponding inner wall of the first hollow chamber and between a suction side and the delivery side of the rotor.

**14.** The pump according to claim 13, wherein:

the shaft is connected on the delivery side with the rotor and

the guide component extends into the first hollow chamber in the rotor and

the guide component and the inner wall of the rotor form the annular ring.

**15.** The pump according to claim 13, wherein the annular ring is located directly between the shaft and the inner wall of the first hollow chamber.

**16.** The pump according to claim 13, wherein the shaft is equipped with a sleeve, the outside of which limits the annular ring.

**17.** The pump according to claim 1, wherein the rotor has delivery side and suction side sections and delivery side and suction side hollow chambers are defined through which the coolant flows, said delivery side and suction side chambers being supplied through channels in the guide component.

**18.** The pump according to claim 17, wherein:

the shaft penetrates the rotor at the delivery side section;

the suction side section is connected to an end of the shaft on the delivery side;

the guide component extends up to and into the suction side hollow chamber of the suction side rotor section and limits the suction side hollow chamber.

**19.** The pump according to claim 1, wherein a direction of the flowing coolant is so selected that the flow passes through the second hollow chamber from the delivery side in the direction of a suction side.

**20.** The pump according to claim 1, further including:

coolant pumps located in an area of the shaft ends on the delivery side.

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