(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 372 085 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
05.10.2011 Bulletin 2011/40

(51) Int Cl.:
F01D 5/08 *(2006.01)*

(21) Application number: **10195081.4**

(22) Date of filing: **15.12.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **30.12.2009 US 649470**

(71) Applicant: **General Electric Company**
Schenectady, NY 12345 (US)

(72) Inventors:
- **Mani, Bhaskar**
  560066 Bangalore (IN)
- **Muralidharan, Vasanth**
  560066 Bangalore (IN)
- **Pandey, Vishwas K.**
  560066 Bangalore (IN)
- **Nath, Vemula Gopinath Upendra Prabhu**
  560066 Bangalore (IN)
- **Ali, Sulficker**
  560066 Bangalore (IN)

(74) Representative: **Gray, Thomas**
GE International Inc.
Global Patent Operation - Europe
15 John Adam Street
London WC2N 6LU (GB)

(54) Internal reaction steam turbine cooling arrangement

(57) A rotor 12 of a turbomachine 10 includes a rotor drum 13 located at a central axis 14 and a plurality of buckets 16 secured to the rotor drum. A first negative reaction stage includes axial entry dovetailed buckets 116. An axial passage 70 for cooling flow 72 is provided between the bucket dovetail 50 and the dovetail slot 32 in the rotor drum 13. Cool steam at taken between a first stage bucket 116 and a second stage nozzle 118 and passed through the axial passage 70 to a low pressure sink 140 at an upstream end of the rotor 12.

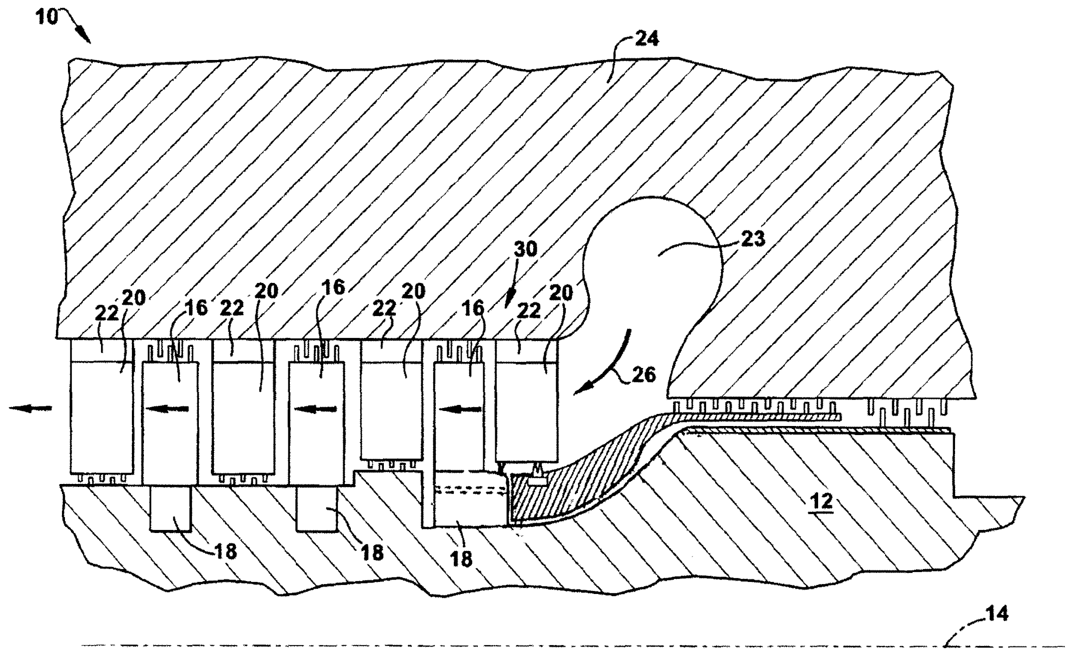

Fig. 1

EP 2 372 085 A2

Description

BACKGROUND OF THE INVENTION

[0001] The invention generally relates to turbomachine rotors. More specifically, the present disclosure relates to cooling of steam turbine rotors.

[0002] As steam turbine systems rely on higher steam temperatures to increase efficiency, steam turbines, especially those utilizing drum rotor construction, must be able to withstand the higher steam temperatures so as not to compromise the useful life of the rotor. Materials that are more temperature-resistant may be used in the rotor construction, but use of such materials often substantially increases the cost of rotor components. High pressure, lower temperature steam may be used as a coolant for the rotor, but use of this coolant from a source outside of the steam turbine can significantly increase cost of the rotor and degrade the rotor performance.

[0003] It would be desirable to provide a low cost means to maintain the drum rotor of a turbomachine so as not to degrade rotor performance without the need to utilize expensive temperature-resistant materials.

BRIEF DESCRIPTION OF THE INVENTION

[0004] According to a first aspect of the invention, a rotor of a turbomachine is provided. The rotor includes a rotor drum disposed at a central axis. A plurality of dovetailed buckets for a stage of the turbomachine are provided. The plurality of dovetailed buckets are secured to the rotor drum at mating surfaces within corresponding dovetailed slots cut in the rotor drum. At least one cooling passage is formed within the rotor drum for the stage of the turbomachine. A low pressure sink disposed at an upstream end of the rotor drum is receptive of a coolant flow through the cooling passage.

[0005] According to another aspect of the present invention a multi-stage steam turbine is provided. The steam turbine includes a stator disposed at a central axis and a rotor disposed radially inboard of the stator. The rotor includes a rotor drum and a plurality of dovetailed buckets for a stage of the steam turbine. The plurality of dovetailed buckets are secured to the rotor drum at mating surfaces within a corresponding dovetailed slots cut in the rotor. At least one cooling passage is formed within the rotor drum for the stage of the turbomachine. A low pressure sink disposed at an upstream end of the rotor is receptive of a coolant flow through the cooling passage.

[0006] According to a further aspect of the present invention, a method for installing axial entry dovetailed buckets into dovetail slots of a stage of a drum rotor is provided. The method includes inserting twist lock devices into an axial through-hole in a base of a dovetail slot of a stage of a drum rotor for each of the dovetailed buckets. A half-head of a front head of the twist lock device is oriented in an inward radial direction to allow entry of the dovetailed bucket into the dovetail slot. A spacer is temporarily installed in a space in the drum rotor between a stage and a succeeding stage. The dovetailed bucket is fully inserted into the dovetail slot of the stage of the rotor drum. The half-head of the front head of the twist-lock device is oriented in an outward radial direction to lock the bucket in place. The spacer is removed.

[0007] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] There follows a detailed description of embodiments of the invention by way of example only with reference to the accompanying drawings, in which:

FIG. 1 is a partial cross-sectional view of an embodiment of a steam turbine;

FIG. 2 illustrates a radial view of a sector of a first stage with axial female tree dovetail slots cut in the drum rotor;

FIG. 3 illustrates a twist lock device adapted for holding axial entry dovetailed buckets in axial dovetailed slots;

FIG. 4 illustrates the twist lock device in place within the female dovetail slot in preparation for axial insertion of bucket dovetail;

FIG. 5 illustrates an axial cutaway view of a stage sector of a turbine including buckets with male dovetails installed in female dovetail slots of a drum rotor;

FIG. 6 illustrates a wheel staking groove in the wheel (rotor) face;

FIG. 7 illustrates an expanded radial view of a cooling space between a male dovetail of the bucket and a slot in a drum rotor;

FIG. 8 illustrates an axial view of an embodiment of axial entry bucket with a cooling passage for cooling the rotor drum;

FIG. 9 illustrates an axial view of an embodiment of a reaction stage with a cooling passage for cooling the rotor drum; and

FIG. 10 illustrates a tangential entry bucket of a first reaction stage with a cooling passage in a root that utilizes higher downstream pressure steam from a bucket of a reaction stage to cool the drum-rotor.

DETAILED DESCRIPTION OF THE INVENTION

[0009] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

[0010] The present invention has many advantages including providing cooling for a reaction stage of a drum rotor in order to preserve life of the rotor and permit the rotor to be formed with standard rotor materials instead of expensive materials that are temperature resistant. The first stage of a rotor for a steam turbine is generally exposed to the highest temperatures and pressures. Therefore it is desirable to provide cooling in particular for the first stage section of the rotor drum. Due to negative root reaction in the first stage, the temperature out the outlet of the stage bucket will be cooler than the inlet to the stage bucket but the pressure at the outlet of the stage bucket will be higher than the pressure at the inlet. Hence steam at the outlet of the stage bucket at a higher pressure than the inlet to the stage bucket may be used to force the cooler steam downstream from the bucket through a path which cools the first stage of the drum rotor and which discharges to a low pressure sink. Hence, an arrangement is provided to extract a lower temperature steam downstream from a stage in a reaction turbine with drum-rotor construction by a cooling passage that is formed by arranging axial entry dovetails over the axial slots cut on the drum-rotor. The cooling passage is formed within the drum-rotor at the mating surfaces of the drum-rotor and the dovetail. This will allow the cooling flow to pass through the dovetails and later mix with the flow leaking to the packing side from the downstream side of the first nozzle. This mix flow will flow from the packing side and cool the drum-rotor.

[0011] The above-described arrangement may provide for performance gain by allowing more flow to pass over the first stage bucket than a standard design. The arrangement also allows cooling directed to the high temperature zones of a reaction/impulse rotor. Further with the advantageous cooling, there is no need for costly material at higher operating temperature. Additionally, no new significant major components need to be added to implement the cooling.

[0012] Shown in FIG. 1 is an embodiment of a turbomachine, such as a steam turbine with an inventive cooling mechanism for the rotor. The steam turbine 10 includes a rotor 12 rotatably disposed at an axis 14 of the steam turbine. A first stage of the turbine includes a nozzle buckets 16 are secured in a plurality of bucket slots 18 in a rotor drum 13 and are typically arranged in a number of rows, or stages, that extend around a circumference of the rotor 12 at axial locations along the rotor 12. A plurality of stationary nozzles 20 are secured in a plurality of nozzle slots 22 in a stator 24 of the steam turbine 10. For example, the nozzle slots 22 may be located in an inner carrier of the stator 24. The nozzles 20 are arranged in circumferential stages that are located between stages of buckets 16. The rotor 12 and the stator 24 defme a primary flowpath 26 therebetween. A fluid, for example, steam is directed from steam inlet 23 along the primary flowpath 26, which urges rotation of the rotor 12 about the axis 14.

[0013] FIG. 2 illustrates a radial view of a sector of a first stage 30 with axial female tree dovetail slots 32 cut in the rotor drum 13. At the base of the female tree dovetail slot 32 is a channel 34 cut to accept a twist lock device (not shown) that is used to axially lock in place the male tree dovetail 50 of the buckets 16.

[0014] The buckets may be assembled onto the wheel (rotor) in the axial direction. A stopping/locking mechanism is provided that will hold the bucket in place. FIG. 3 illustrates a side view of a twist lock device 40 adapted for holding axial entry dovetailed buckets in axial dovetailed slots. The twist lock device 40 includes a center pin 42 with heads 44 at each end of the center pin. The head 44 at a first end of the center pin 42 is formed as a half head 46 and includes a staking tab. The head 44 at the second end of the center pin 42 includes a full head 48. The channel 34 in the rotor is sized for the center pin. The length 43 of the center pin 42 is set to match the channel with the half head 46 outside the front face of the rotor and second head 48 of the pin outside the downstream face of the rotor stage.

[0015] Before the buckets are installed, the twist lock device 40 is positioned such that the half head 46 is oriented in the inward radial direction. The twist lock device 40 is then lowered into the channel 34 below the female dovetail slot 32 into the rotor drum. FIG. 4 illustrates the twist lock device 40 in place within the channel 34 of female dovetail slot 32 in preparation for axial insertion of a bucket male tree dovetail. If the twist lock device 40 is inserted into wheel (rotor) dovetail with the half head 46 in an outward radial orientation, the half head 46 will block sliding the axial entry male dovetail 50 of the bucket inside the wheel (rotor) slot.

[0016] The axial entry male dovetail 50 of the bucket is then slid into the wheel (rotor) slot in the axial direction. With the axial entry male dovetail bucket in place, the twist lock device 40 is rotated by 180 degrees such the half head 46 oriented outward radially and flat surface 45 is radially inward as shown in FIG. 5 The head 46 for the twist lock 20will be bent inside a wheel staking groove 47 in the wheel (rotor) face 49 as shown in FIG. 6. Insufficient space is available on the downstream side for staking so the twist lock device 40 has a full cylindrical head 48 on the downstream side. Staking of the twist lock device 40 prevents axial movement of the installed bucket. Other buckets may be installed in a similar manner.

[0017] In a further aspect of the invention, when the female tree dovetails are cut in the drum for the stage, an annular space downstream of the stage section is also cut into the rotor drum to allow a space for the cutting tool to be removed. A spacer ring forming at least a sector of the removed downstream annular space is installed to facilitate installation of the buckets. The thickness of the spacer ring is set to limit the insertion of the male dovetail for the bucket, thereby establishing proper axial orientation. After the buckets have been inserted the proper axial distance and locked in place, the spacer is removed.

[0018] FIG. 7 illustrates an expanded radial view of a cooling space 70 between the male dovetail 50 of the first stage bucket and a complimentary male projection of the rotor drum 13. The male dovetails include an expanded space 75 at an outer end that provides the axial channel for the flow of cooling steam. The channel discharges into a low-pressure channel downstream that will be described in greater detail below.

[0019] FIG. 8 illustrates a cutaway axial view of a cooling path 70 for a rotor drum 13 with axial entry dovetailed bucket 116 installed rotor drum 13. The annular space 60 downstream from the bucket includes the spacer 65 (shown prior to removal). The staked twist lock device 40 axially holds the male dovetail 50 (FIG. 6) of the bucket 116 in place within the rotor drum 13. FIG. 8 also illustrates the axial flow channel 70 for cooling steam 72. The cooling steam 72 is received from the annular space 60 downstream of the reaction stage where, for a reaction stage, the pressure is higher than the upstream side but the steam temperature is substantially cooler. The cooling steam 72 may pass through the axial space 70 between the male dovetail of the bucket and the female dovetail cut into the drum rotor.

[0020] FIG. 9 illustrates a reaction first reaction stage 110 with an axial entry dovetailed bucket 116. The bucket 116 with male dovetail 50 is disposed between an upstream first stage nozzle 114 and a downstream second stage nozzle 118. The dovetailed bucket 116 is installed axially in the dovetailed slots in the rotor drum 13. The nozzle 114, 118 may be supported by an outer casing (not shown). The nozzles 114, 118 may include various seals mounted on end shrouds 27 to prevent leakage past the nozzle blades 115, 119. The seals may include tooth seals, J-seals, and labyrinth seals. The axial channel 70 through the space between the male dovetail of the bucket and the slot of the drum rotor may direct the downstream cooling steam to the low-pressure channel leakoff discharge path 140. The labyrinth seal 132 on the first stage nozzle 114 prevents higher pressure from the nozzle block 23 in the downstream leakoff path. The higher pressure from the nozzle block 23 could prevent the cooling flow through the cooling path. Similarly, the tooth seal or the J-seal may limit leakage between the first stage nozzle 114 and the first stage bucket 116 from entering the leakoff path 140 and thereby limiting cooling flow 72.

[0021] In a further aspect of the present invention, first stage tangential entry buckets 150 with blade 151 in rotor drum 13 of rotor 12 is disposed between first stage nozzle 114 with blade 115 and second stage nozzle 118 with blade 119. The bucket 150 dovetail 153 may be provided with a cooling passage that utilizes higher pressure steam P2 165 downstream from the bucket 150 of a reaction stage 110 to cool the rotor drum 13 as illustrated in FIG. 10. An axial cooling passage 155 is provided between the bucket 150 and the next nozzle 118. The cooling passage 155 through root 180 of bucket 150 again discharges cooling steam to the low-pressure leakoff discharge path 140. Seals 131 and 132 limit leakage from steam inlet 23 and from space between first stage nozzle 114 and first stage bucket 150 from entering the leakoff path 140 and thereby limiting cooling flow.

[0022] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

[0023] For completeness, various aspects of the invention are now set out in the following numbered clauses:

1. A rotor of a turbomachine comprising:

    a rotor drum disposed at a central axis;

    a plurality of dovetailed buckets for a stage of the turbomachine, wherein the plurality of dovetailed buckets are secured to the rotor drum at mating surfaces within a corresponding plurality of dovetailed slots cut in the rotor drum;

    at least one cooling passage formed within the rotor drum for the stage of the turbomachine; and

    a low pressure sink disposed at an upstream end of the rotor drum receptive of a coolant flow through the cooling passage.

2. The rotor of clause 1, wherein the stage if a first stage, reaction stage for a rotor of a steam turbine.

3. The rotor of clause 2, wherein the coolant flow comprises steam routed into the cooling passage from a downstream portion of the steam turbine including a space immediately downstream from each of the plurality of dovetailed bucket in the stage.

4. The rotor of clause 3, wherein the plurality of dovetailed slots are cut in the rotor drum for axial entry of the plurality of dovetailed buckets.

5. The rotor of clause 4, wherein the at least one cooling passage formed within the rotor drum for the stage of the turbomachine comprises at least one space formed between a male dovetail of the dove-

tailed bucket and a complimentary male projection of the rotor drum.

6. The rotor of clause 3, wherein the plurality of dovetailed slots are cut in the rotor drum for tangential entry of the plurality of dovetailed buckets and the at least one cooling passage formed within the rotor drum for the stage of the turbomachine comprises a hole bored axially through a root of the bucket above the dovetail.

7. The rotor of clause 1, further comprising:

an axial through-hole of the rotor drum at a base of each dovetail slot of the plurality of dovetail slots; and
a twist-lock device installed in the axial through-hole of the rotor drum and adapted for the axially retaining the dovetailed bucket, the twist lock device including a center pin, a retaining head at each end of the center pin wherein a forward head includes a rotatable half-head, being rotatable to an inward radial position allowing entry of the dovetailed bucket into the dovetailed slot and being rotatable to an outward radial position retaining the dovetailed bucket in the dovetailed slot.

8. The rotor of clause 7, further comprising:

an annular spacer adapted to mount around the rotor drum between a first stage and a second stage for temporary use during insertion of dovetailed buckets into axial dovetail slots of the rotor drum, wherein an axial length of the annular spacer is sized for axial positioning of the plurality of dovetailed buckets.

9. The rotor of clause 1, comprising:

at least one rotor drum through hole extending from the cooling passage to the low pressure sink, wherein the low pressure sink comprises at least a root spill of the a first stage.

10. The rotor of clause 9, further comprising:

sealing means between an upstream root of the plurality of buckets and the root spill of the first stage, wherein the sealing means include J-seals.

11. A multi-stage steam turbine comprising:

a stator disposed at a central axis; and

a rotor disposed radially inboard of the stator including:

a rotor drum;

a plurality of dovetailed buckets for a stage of the steam turbine, wherein the plurality of dovetailed buckets are secured to the rotor drum at mating surfaces within a corresponding plurality of dovetailed slots cut in the rotor;

at least one cooling passage formed within the rotor drum for the stage of the turbomachine; and

a low pressure sink disposed at an upstream end of the rotor receptive of a coolant flow through the cooling passage.

12. The rotor of clause 11, wherein the stage of the steam turbine is a first stage reaction stage.

13. The steam turbine of clause 12, wherein the coolant flow comprises steam routed into the cooling passage from a downstream portion of the steam turbine including a space immediately downstream from each of the plurality of dovetailed bucket in the stage.

14. The rotor of clause 13, wherein the plurality of dovetailed slots are cut in the rotor drum for axial entry of the plurality of dovetailed buckets.

15. The rotor of clause 14, wherein the at least one cooling passage formed within the rotor drum for the stage of the turbomachine comprises at least one space formed between a dovetail of the dovetailed bucket and a complimentary male projection of the rotor drum.

16. The rotor of clause 12, wherein the plurality of dovetailed slots are cut in the rotor drum for tangential entry of the plurality of dovetailed buckets.

17. The rotor of clause 16, wherein the at least one cooling passage formed within the rotor drum for the stage of the turbomachine comprises a hole bored axially through a root of the bucket above the dovetail.

18. The rotor of clause 1, comprising at least one rotor drum through hole extending from the cooling passage to the low pressure sink.

19. The rotor of clause 1, further comprising:

an axial through-hole of the rotor drum at a base of each dovetail slot of the plurality of dovetail slots; and

a twist-lock device installed in the axial through-hole of the rotor drum and adapted for the axially retaining the dovetailed bucket, the twist lock device including a center pin, a retaining head at each end of the center pin wherein a forward head includes a rotatable half-head, being rotatable to an inward radial position allowing entry of the dovetailed bucket into the dovetailed slot and being rotatable to an outward radial position retaining the dovetailed bucket in the dovetailed slot.

20. A method for installing axial entry dovetailed buckets into dovetail slots of a stage of a drum rotor, the method comprising:

inserting a twist lock device into an axial through-hole in a base of a dovetail slot of a stage of a drum rotor for each of a plurality of dovetailed buckets;

orienting a half-head of a front head of the twist lock device in an inward radial direction;

inserting a spacer in a space in the drum rotor between a stage and a succeeding stage;

fully inserting the dovetailed bucket into the dovetail slot of the stage of the rotor drum;

orienting the half-head of the front head of the twist-lock device in an outward radial direction; and

removing the spacer.

Claims

1. A rotor 12 of a turbomachine 10 comprising:

a rotor drum 13 disposed at a central axis 14;
a plurality of dovetailed buckets 16 for a stage 30 of the turbomachine 10, wherein the plurality of dovetailed buckets are secured to the rotor drum 13 at mating surfaces within a corresponding plurality of dovetailed slots 32 cut in the rotor drum;
at least one cooling passage 70 formed within the rotor drum 13 for the stage 30 of the turbomachine 10; and
a low pressure sink 40 disposed at an upstream end of the rotor drum 13 receptive of a coolant flow 72 through the cooling passage 70.

2. The rotor 12 of claim 1, wherein the stage 30 is a first stage, negative reaction stage for a rotor drum 13 of a steam turbine 10.

3. The rotor 12 of claim 2, wherein the coolant flow 72 comprises steam routed into the cooling passage 70 from a downstream portion of the steam turbine 10 including a space 65 immediately downstream from each of the plurality of dovetailed bucket 16 in the stage 30.

4. The rotor 12 of claim 3, wherein the plurality of dovetailed slots 32 are cut in the rotor drum 13 for axial entry of the plurality of dovetailed buckets 16.

5. The rotor 12 of claim 4, wherein the at least one cooling passage 70 formed within the rotor drum 13 for the stage 30 of the turbomachine 10 comprises at least one space formed 75 between a male dovetail 50 of the dovetailed bucket 16 and a complimentary male projection 35 of the rotor drum 13.

6. The rotor 12 of claim 3, wherein the plurality of dovetailed slots 32 are cut in the rotor drum 13 for tangential entry of the plurality of dovetailed buckets 150 and the at least one cooling passage 155 formed within the rotor drum for the stage 110 of the turbomachine 10 comprises a hole bored axially through a root 180 of the dovetailed bucket above the dovetail.

7. The rotor 12 of any of the preceding claims, further comprising:

an axial through-hole 34 of the rotor drum 13 at a base of each dovetail slot 32 of the plurality of dovetail slots; and
a twist-lock device 40 installed in the axial through-hole 34 of the rotor drum 13 and
adapted for the axially retaining the dovetailed bucket 60, the twist lock device 40 including a center pin 42, a retaining head 44 at each end of the center pin wherein a forward head includes a rotatable half-head 46, being rotatable radially inward and
allowing entry of the dovetailed bucket 16 into the dovetailed slot 32 and being rotatable radially outward, retaining the dovetailed bucket in the dovetailed slot.

8. The rotor 12 of claim 7, further comprising:

an annular spacer 65 adapted to mount around the rotor drum 13 between a first stage bucket 116 and a second stage nozzle 118 for temporary use during insertion of dovetailed buckets 116 into the rotor drum 13, wherein the annular spacer is sized for axial positioning of the plurality of dovetailed buckets 116.

9. The rotor 12 of any of the preceding claims, comprising:

at least one rotor drum through hole 140 extending from the cooling passage 70 to a low pressure sink, wherein the low pressure sink comprises at least a root spill of the a first stage 110.

10. The rotor of claim 9, further comprising:

sealing means between an upstream root of the plurality of buckets and the root spill of the first stage, wherein the sealing means include J-seals.

11. A method for installing axial entry dovetailed buckets into dovetail slots of a stage of a drum rotor, the method comprising:

inserting a twist lock device into an axial through-hole in a base of a dovetail slot of a stage of a drum rotor for each of a plurality of dovetailed buckets;
orienting a half-head of a front head of the twist lock device in an inward radial direction;
inserting a spacer in a space in the drum rotor between a stage and a succeeding stage;
fully inserting the dovetailed bucket into the dovetail slot of the stage of the rotor drum;
orienting the half-head of the front head of the twist-lock device in an outward radial direction; and
removing the spacer.

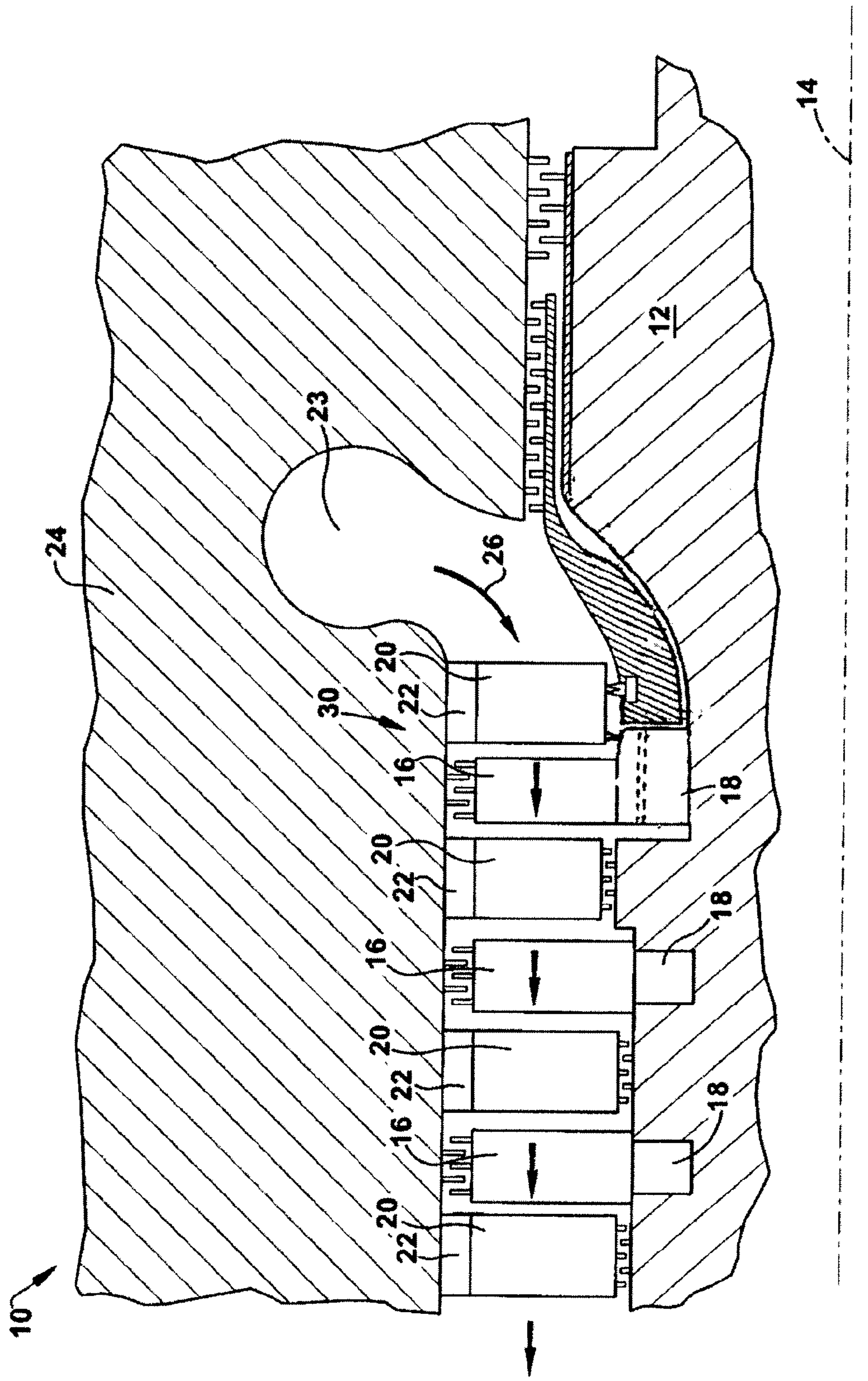

Fig. 1

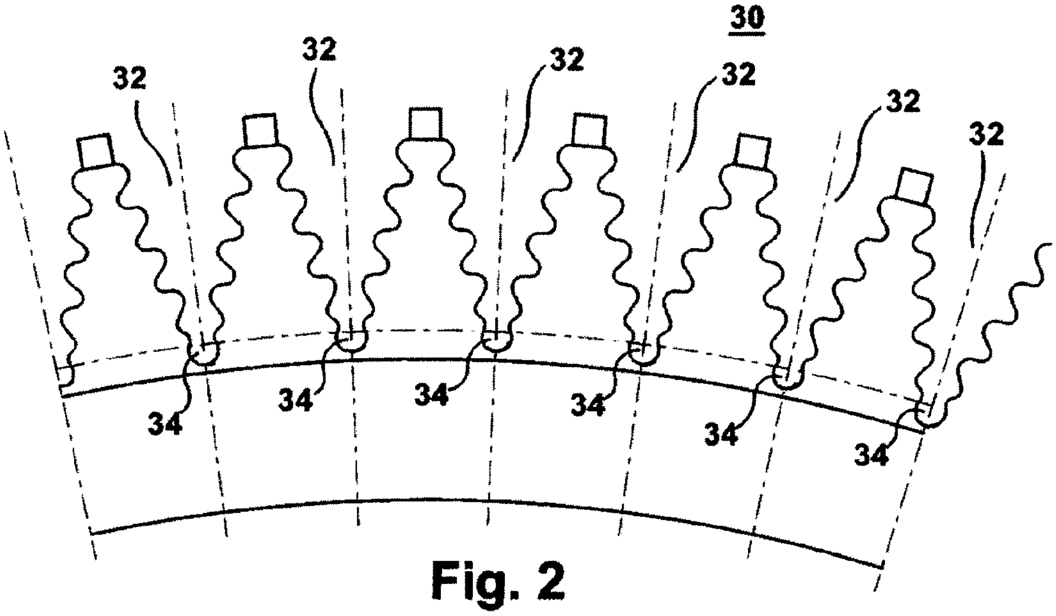

Fig. 2

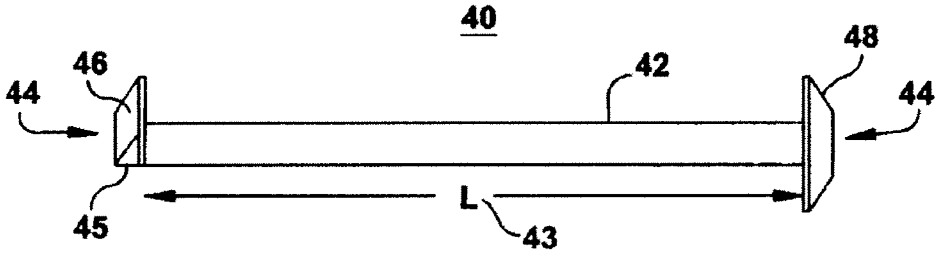

Fig. 3

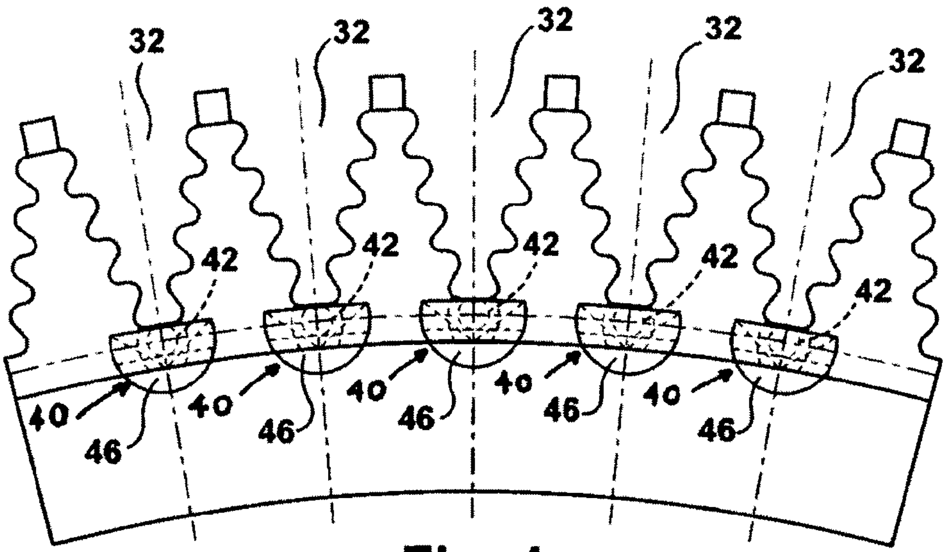
32
32
32
32
32
32
42
42
42
42
42
40
40
40
40
40
46
46
46
46
46

Fig. 4

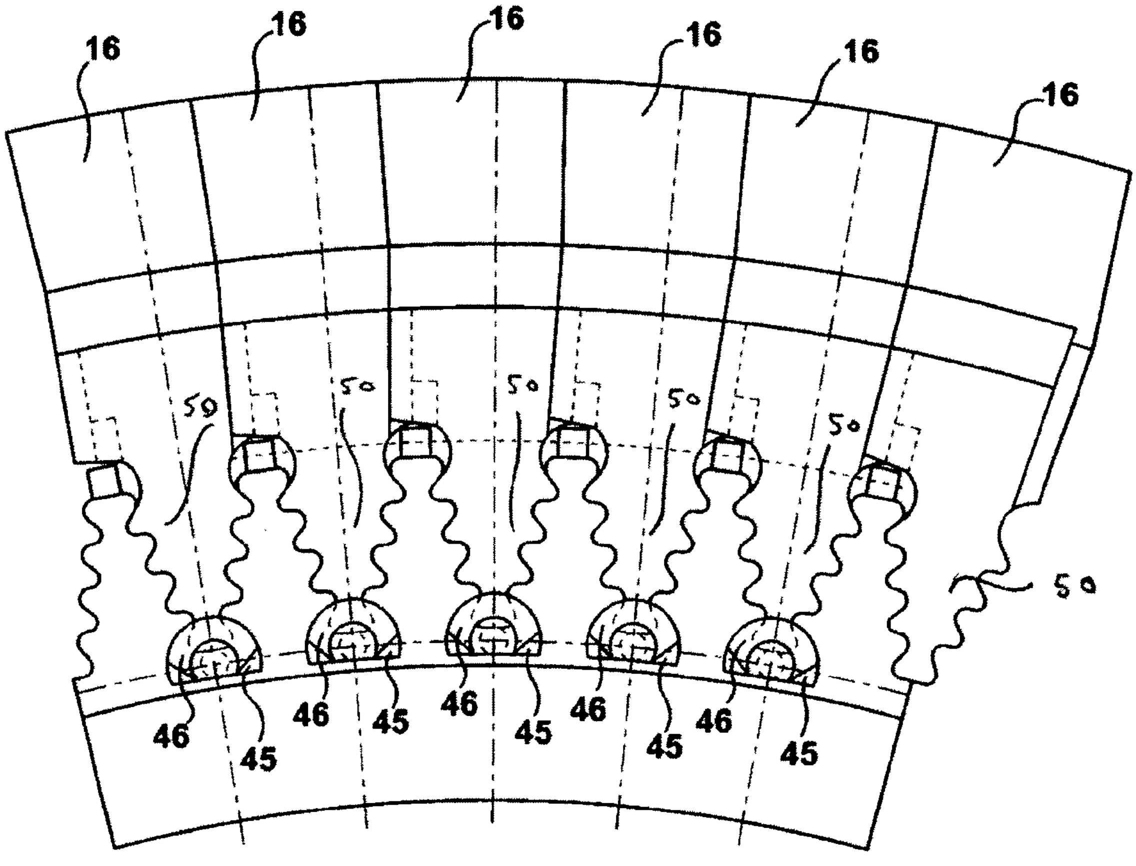
16
16
16
16
16
16
50
50
50
50
50
50
50
46
46
46
46
46
45
45
45
45
45

Fig. 5

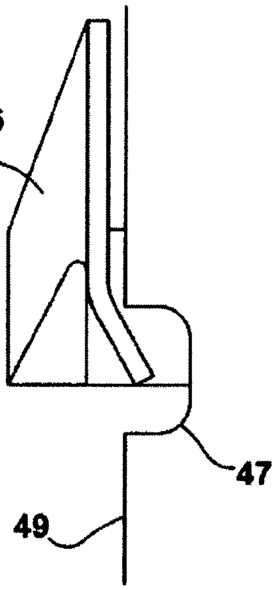

Fig. 6

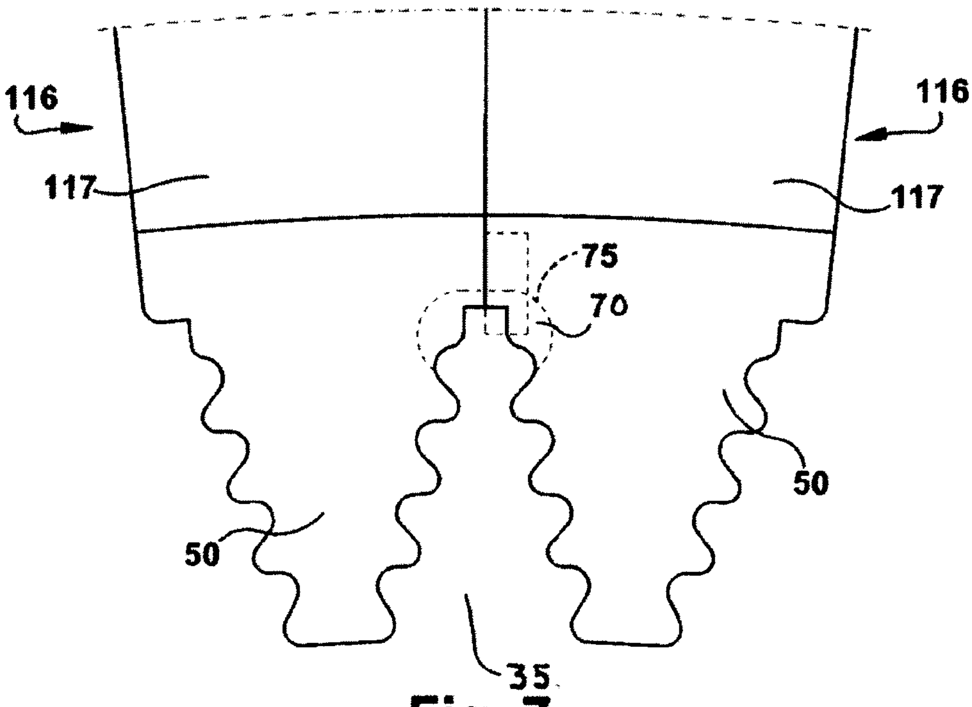

Fig. 7

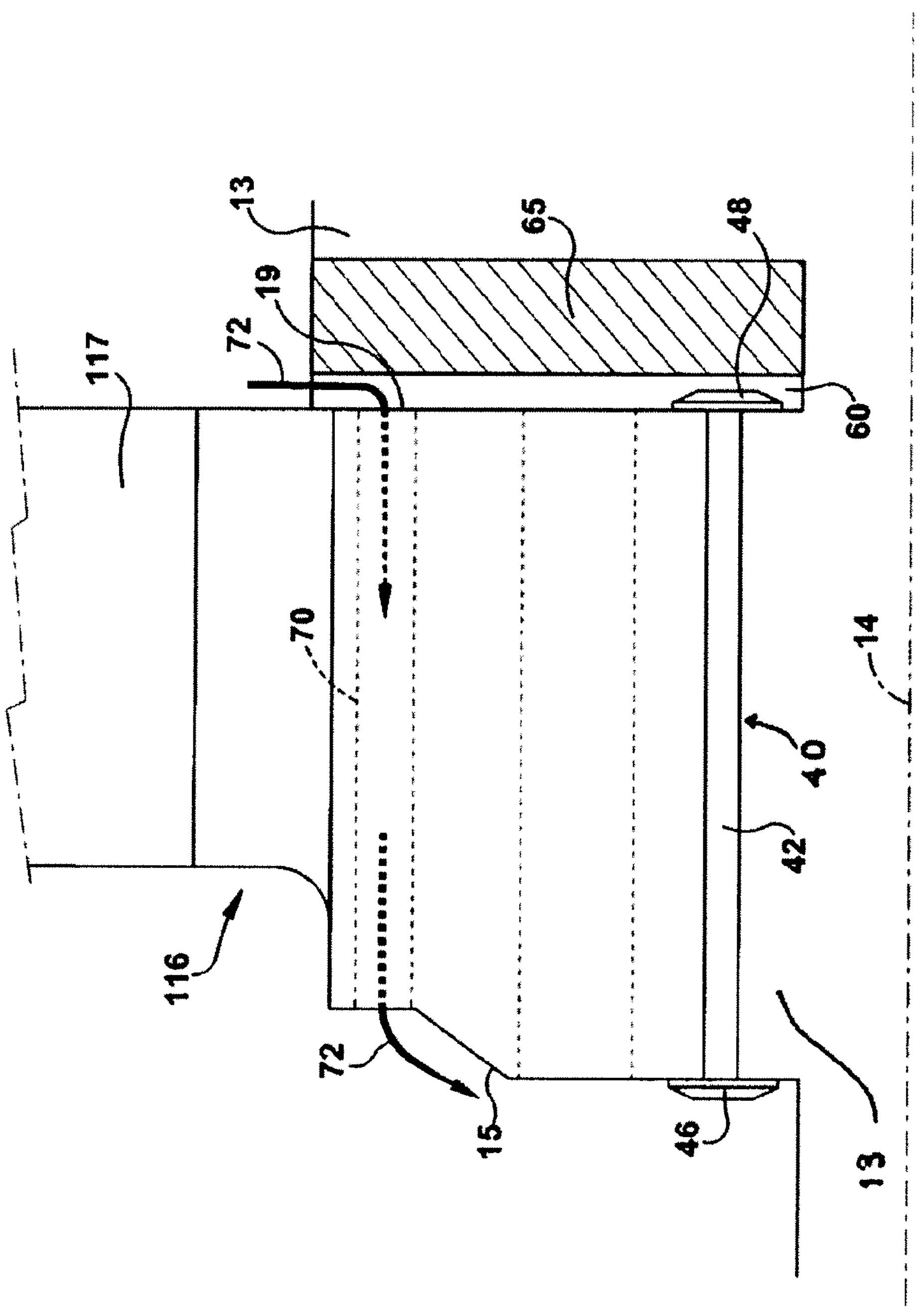

Fig. 8

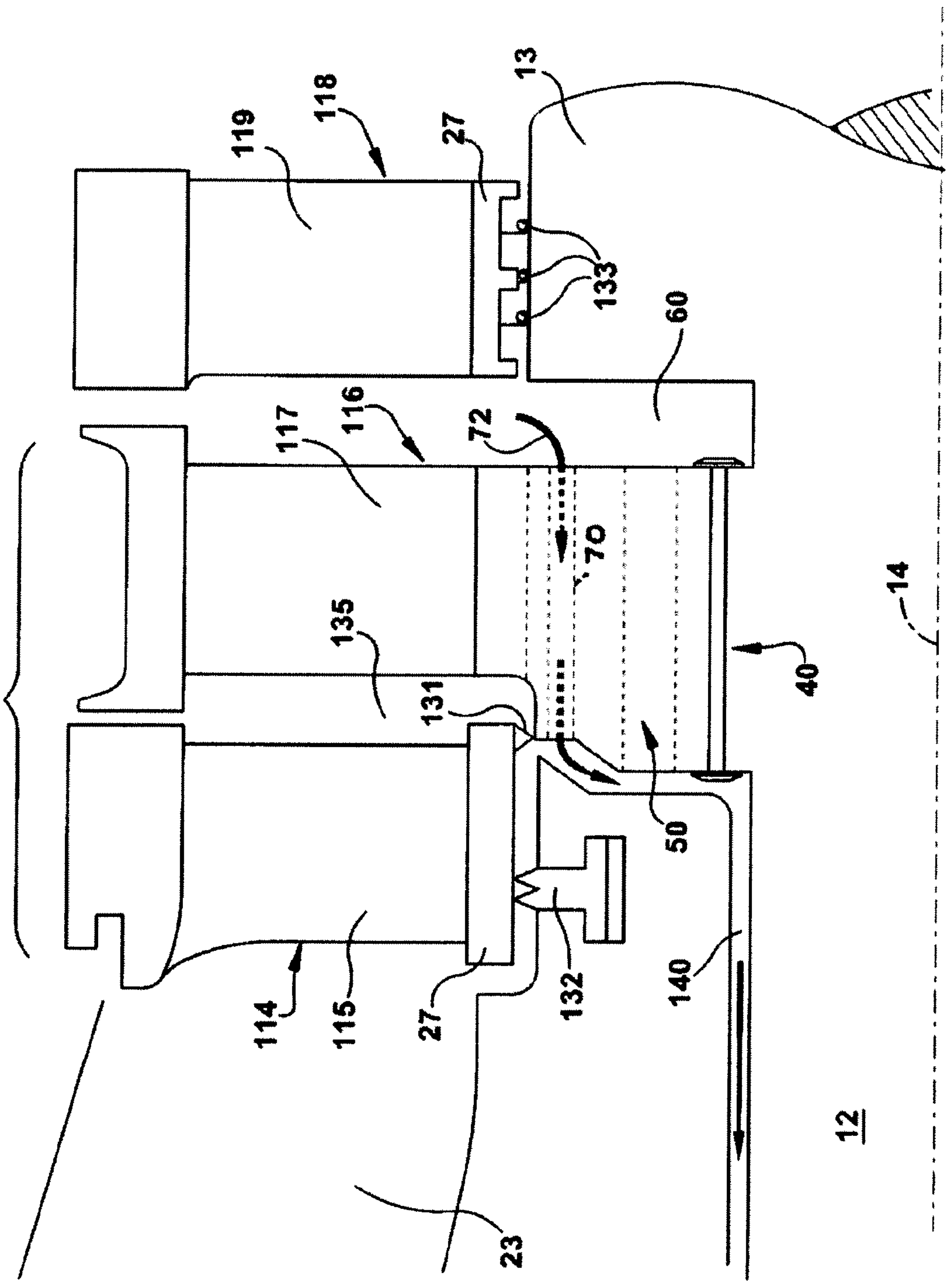
13
118
119
27
133
60
117
116
72
70
135
131
110
14
40
50
114
115
27
132
140
23
12

Fig. 9

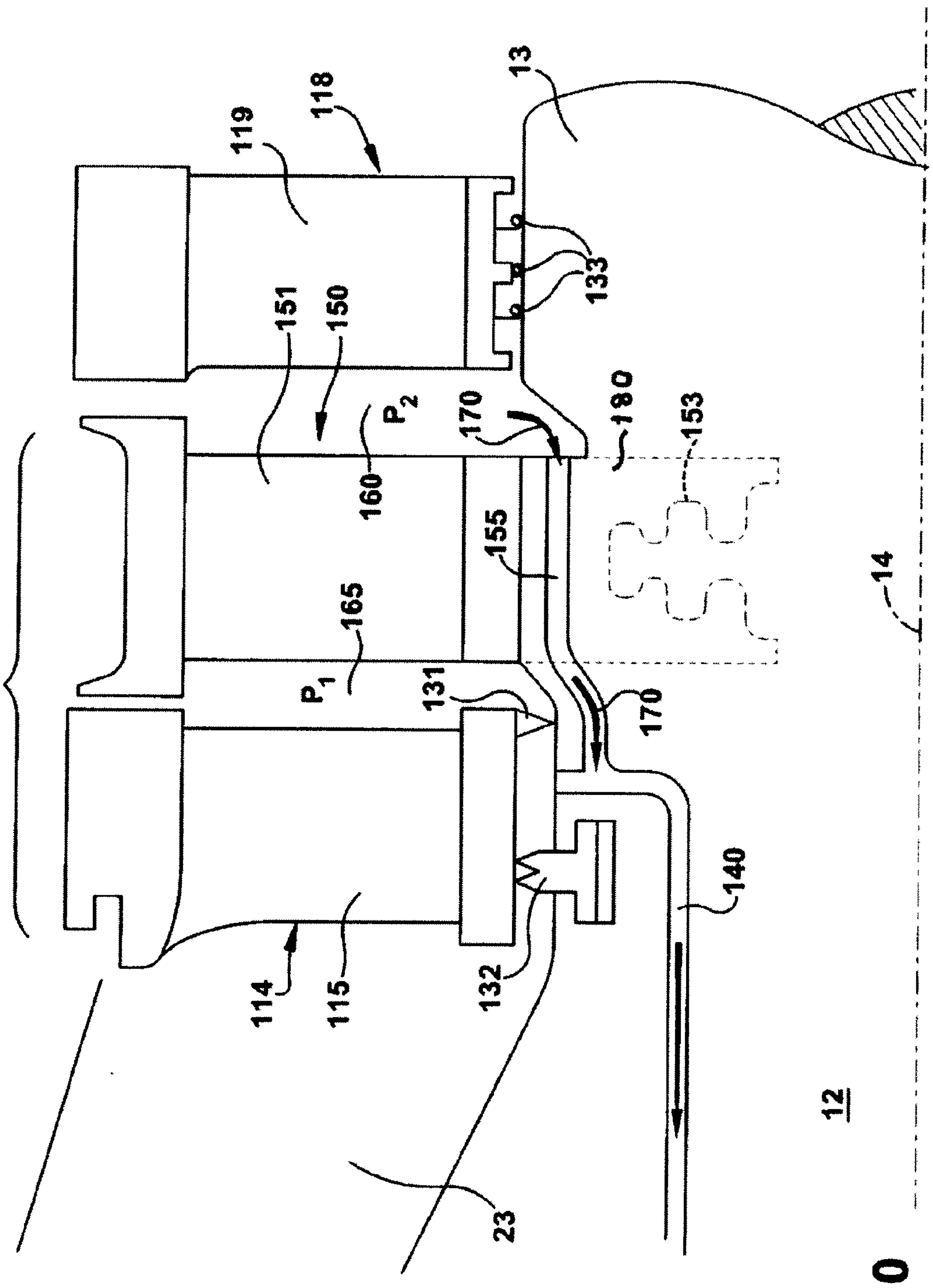
110
114
115
118
119
13
133
151
150
P2
170
180
153
160
155
14
165
P1
131
170
140
132
23
12

Fig. 10