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(54) Title: REACTOR COOLANT PUMP FLYWHEEL

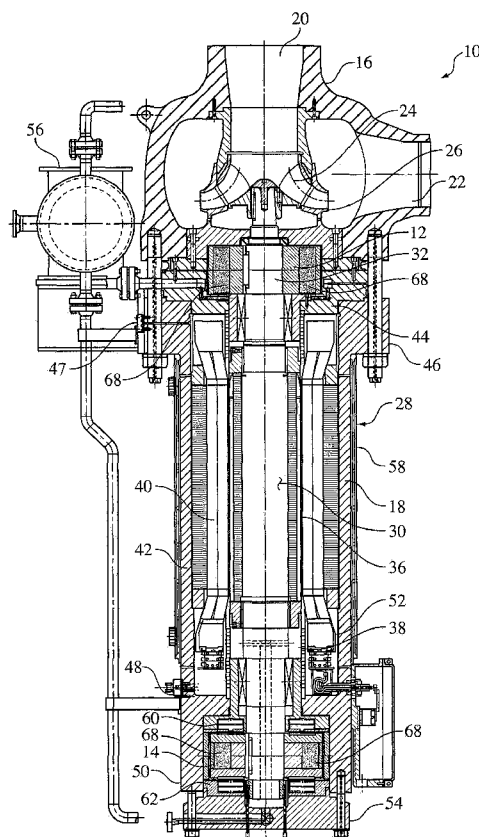


FIG. 1

(57) Abstract: A flywheel for a pump, and in particular a flywheel having a number of high density segments for use in a nuclear reactor coolant pump. The flywheel includes an inner member and an outer member. A number of high density segments are provided between the inner and outer members. The high density segments may be formed from a tungsten based alloy. A preselected gap is provided between each of the number of high density segments. The gap accommodates thermal expansion of each of the number of segments and resists the hoop stress effect/keystoning of the segments.



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REACTOR COOLANT PUMP FLYWHEEL

CROSS-REFERENCE TO RELATED APPLICATION

- [1] This application claims the benefit under 35 U.S.C. § 119(e) of the earlier filing date of U.S. Provisional Application Serial Number 61/057,446 filed on May 30, 2008, the contents of which are hereby incorporated by reference.

GOVERNMENT INTEREST

- [2] The United States Government has rights in this invention pursuant to Contract No. DE-FC07-07ID14779 between the U.S. Department of Energy and Westinghouse Electric Company.

FIELD OF INVENTION

- [3] The invention relates generally to a flywheel for use in a pump, and in particular to a high inertia flywheel using a number of high density segments for use in a nuclear reactor coolant pump.

BACKGROUND OF THE INVENTION

- [4] Flywheels are used in centrifugal pumps to mechanically store potential energy during operation of the pump, which energy may be utilized to maintain rotation of the pump in the event of loss of motive power. In nuclear reactors, this technology helps to maintain coolant circulation through the reactor core.
- [5] Exemplary flywheels for use in reactor coolant pumps are described in U.S. Patent Nos. 4,886,430 and 5,165,305,

the disclosures of which are incorporated by reference herein.

- [6] A need, however, exists for an improved reactor coolant pump flywheel.

SUMMARY OF THE INVENTION

- [7] In accordance with an embodiment of the invention, the invention provides a flywheel for a pump, and in particular a flywheel having a number of high density segments for use in a nuclear reactor coolant pump.

- [8] In accordance with an embodiment of the invention, the flywheel includes an inner member and an outer member. A number of high density segments are provided between the inner member and the outer member. The high density segments may be formed from a tungsten based alloy. A preselected gap is provided between each of the number of high density segments. The gap accommodates thermal expansion of each of the number of segments and resists any hoop stress effect or keystoneing of the segments. A number of upper pins and a number of lower pins are provided at an inner diameter of the segments in order to couple the number of segments to the inner member. An interference fit may be provided between the inner member, the segments and the outer member. A key, spline or interference fit is provided between the inner member and the rotatably operable shaft in order to couple the flywheel to the shaft. In combination with the pins and the coupling of the inner member to the rotatable operable shaft, the gap provides radial loading on the segments and gives the stability desired to resist motion which could show up as a balance change.

[9] In accordance with an embodiment of the invention, the flywheel includes an upper end cap member, a lower end cap member and a shell member capping the upper and lower surfaces of the high density segments and at least a portion of the outer member. The cap members ensure that the high density segments and at least a portion of the outer member do not get immersed in a solvent. The cap members prevent corrosion of the high density segments and contamination of the coolant by the tungsten material of the high density segments. In addition, the cap members provide positive encapsulation of at least a portion of the outer member for an axial seismic or shock event without resorting to friction.

[10] In accordance with an embodiment of the invention, a pair of flywheels is provided within the stator and casing of a nuclear reactor coolant pump, with one flywheel at each end of the pump in opposed relation to one another. The pump, according to one example of the invention, is for use in a pressurized water reactor nuclear power plant structured to generate at least 1000 MWe.

BRIEF DESCRIPTION OF THE DRAWINGS

[11] For the invention to be clearly understood and readily practiced, the invention will be described in conjunction with the following FIGS., wherein like reference characters designate the same or similar elements, which FIGS. are incorporated into and constitute a part of the specification, wherein:

[12] FIG. 1 is a side view, partially in cross-section, of a reactor coolant pump system having a number of flywheels incorporated therein;

- [13] FIG. 2 is a plan view of an upper flywheel;
- [14] FIG. 3 is a plan view of a lower flywheel;
- [15] FIG. 4 is a cross-sectional view of an upper flywheel disposed near the impeller end of the pump; and
- [16] FIG. 5 is a cross-sectional view of the lower flywheel.

DETAILED DESCRIPTION OF THE INVENTION

- [17] It is to be understood that the FIGS. and descriptions of the invention have been simplified to illustrate elements that are relevant for a clear understanding of the invention, while eliminating, for purposes of clarity, other elements that may be well known. Those of ordinary skill in the art will recognize that, such as, for example, all of the components of the reactor coolant pumps other than as shown in the FIGS. have not been described in detail herein for the purpose of simplifying the specification of the patent application.
- [18] For purposes of the description hereinafter, the terms "upper", "lower", "vertical", "horizontal", "axial", "top", "bottom", "aft", "behind", and derivatives thereof shall relate to the invention, as it is oriented in the drawing FIGS. However, it is to be understood that the invention may assume various alternative configurations except where expressly specified to the contrary. It is also to be understood that the specific elements illustrated in the FIGS. and described in the following specification are simply exemplary embodiments of the invention. Therefore, specific dimensions, orientations and other physical characteristics related to the embodiments disclosed herein are not to be considered limiting.

- [19] As used herein, the term "pin" means any suitable fastening, connecting or tightening mechanism such as dowel pins, fasteners, rivets, other connecting elements and the like. As used herein, the statement that two or more parts are "coupled" together means that the parts are joined together either directly or joined together indirectly through one or more intermediate parts.
- [20] The detailed description will be provided hereinbelow with reference to the attached drawings. In the drawings, like reference characters designate corresponding parts throughout the views.
- [21] Referring to FIG. 1, there is illustrated a reactor coolant pump generally designated by reference numeral 10 having a first or upper flywheel 12 and a second or lower flywheel 14 incorporated into a casing 16 and stator assembly 18 thereof. Pump 10 operates to circulate coolant fluid such as water. Pump casing 16 defines a suction nozzle 20 and a discharge nozzle 22. An impeller 24 is provided for centrifugally pumping the coolant fluid such that fluid is drawn through the suction nozzle 20, through an eye of the impeller 24, discharged through a diffuser 26 and out through the discharge nozzle 22.
- [22] Pump 10 further includes a motor 28 having a rotor assembly 30 mounted on a rotatably operable shaft 32 and the corresponding stator assembly 18. Rotor assembly 30 includes rotor can 36. Stator assembly 18 includes stator can 38, stator coils 40, stator shell 42, stator closure ring 44, stator main flange 46, stator vents 47, 48 a stator lower flange 50, stator end turns 52 and stator cap 54. Pump 10 also includes an external heat

exchanger 56 and stator cooling jacket 58 for removing heat generated within the pump 10.

- [23] Upper flywheel 12 is disposed proximate to the impeller 24 end of the pump 10 coupled to shaft 32 within the pump casing 16. Lower flywheel 14 is disposed on the other end of shaft 32 in opposed relation to the upper flywheel 12 coupled to the shaft 32 within the pump stator assembly 18. Disposed on an upper side and a lower side of lower flywheel 14 are an upper thrust bearing 60 and a lower thrust bearing 62.
- [24] Flywheels 12 and 14 are constructed in a similar manner. Lower flywheel 14, however, has a different profile as can be seen by comparing FIGS. 4 and 5. The description provided for the upper flywheel 12 is equally applicable to the lower flywheel 14 and the details of the lower flywheel 14 have been omitted for the purpose of simplifying the specification of the patent application since the lower flywheel 14 is similar in construction to the upper flywheel 12.
- [25] Flywheel 12 includes an inner member 64 and outer member 66 wherein the inner member 64 may be an inner tubular cylindrical member and the outer member 66 may be an outer tubular cylindrical member. A number of high density segments 68 are provided between the inner and outer members 64, 66. The high density segments 68 may be formed from a tungsten based alloy. Other high density materials, however, are suitable. A preselected gap 70 is provided between each of the number of high density segments 68. The gap 70 accommodates thermal expansion and Poisson's effect of each of the number of segments 68 and resists any hoop stress effect/keystoning of the segments 68. The gap 70 in an

embodiment is between about 0.010 to 0.050 inches (0.25 to 1.27 mm). An upper pin 72 and a lower pin 74 are provided at an inner diameter of the segments 68 at each gap 70 (see FIGS. 2-5). An interference or shrink fit may be provided between the inner member 64, segments 68 and the outer member 66. A key 76 may be provided between the inner member 64 and the high density segments 68. In combination with the upper and lower pins 72, 74, key 76 and the coupling to the shaft 32, the gap 70 provides for only radial loading on the segments 68 and gives the stability needed to resist any motion which could show up as a balance change.

- [26] As can be seen in FIGS. 4 and 5, the flywheel includes an upper cap member 78, a lower cap member 80, and an outer shell member 82 that cap the high density segments 68 and at least a portion of the outer member 66. Shell member 82 wraps around the outer member 66 and is attached to upper cap member 78 and lower cap member 80 by welding. The outer diameters of upper cap member 78 and lower cap member 80 have lips 84, 86, respectively, which curl around the ends of the outer member 66. The purpose of the lips is to provide support for the shell member 82 should differential thermal expansion occur between the upper and lower cap members 78, 80 and the outer member 66. This allows for the difference in displacement to be gradual along the length of the lips 84, 86 so that the outer member 66 is not forced to span the discontinuity directly. The upper and lower cap members 78, 80 are welded to inner member 64 with welds 88 at their inner diameters. In the illustrated embodiment, the flywheel also includes a leak test plug 90 for performing a leak test to make sure the welds 88 are leak tight.

- [27] Nothing in the above description is meant to limit the invention to any specific materials, geometry, or orientation of elements. Many parts/orientation substitutions are contemplated within the scope of the invention and will be apparent to those skilled in the art. The embodiments described herein were presented by way of example only and should not be used to limit the scope of the invention.
- [28] Although the invention has been described in terms of particular embodiments in an application, one of ordinary skill in the art, in light of the teachings herein, can generate additional embodiments and modifications without departing from the spirit of, or exceeding the scope of, the claimed invention. Accordingly, it is understood that the drawings and the descriptions herein are proffered only to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

CLAIMS

WHAT IS CLAIMED IS:

1. A flywheel for a pump, the flywheel comprising:
an inner member;
an outer member; and
a number of high density segments provided between the inner member and the outer member,
wherein the inner member is structured to be coupled to a rotatably operable shaft of the pump,
wherein a preselected gap is provided between each of the number of high density segments, and
wherein the gap is structured to accommodate thermal expansion of each of the number of segments.
2. The flywheel of claim 1 wherein the gap is structured to resist any hoop stress.
3. The flywheel of claim 1 wherein the gap is structured to provide radial loading of the number of segments.
4. The flywheel of claim 1 wherein the inner member is an inner tubular cylindrical member and the outer member is an outer tubular cylindrical member.
5. The flywheel of claim 1 further comprising an upper end cap member, a lower end cap member, and an outer shell member for containing the high density segments between the inner member and the outer member.
6. The flywheel of claim 1 wherein the inner member is keyed to the number of high density segments.

7. The flywheel of claim 1 wherein the high density segments comprise a tungsten based alloy.
8. The flywheel of claim 1 wherein the inner member is in an interference fit with at least one of the number of the high density segments and the outer member is in an interference fit with at least one of the number of high density segments.
9. The flywheel of claim 1 wherein the inner member is in a splined engagement with the rotatable operable shaft of the pump.
10. The flywheel of claim 1 wherein the inner member is optional and,
wherein the high density segments are structured to be coupled to the rotatably operable shaft of the pump.
11. A pump comprising:
a shaft;
an impeller mounted on the shaft;
a motor engaged with the shaft for turning the impeller; and
a first flywheel mounted on the shaft, the first flywheel comprising:
an inner member;
an outer member; and
a number of high density segments provided between the inner member and the outer member,
wherein the inner member is structured to be coupled to a rotatably operable shaft of the pump,
wherein a preselected gap is provided between each of the number of high density segments, and

wherein the gap is structured to accommodate thermal expansion of each of the number of segments.

12. The pump of claim 11 wherein the gap is structured to resist any hoop stress.

13. The pump of claim 11 wherein the gap is structured to provide radial loading of the number of segments.

14. The pump of claim 11 wherein the inner member is an inner tubular cylindrical member and the outer member is an outer tubular cylindrical member.

15. The pump of claim 11 further comprising an upper end cap member, a lower end cap member, and an outer shell member for containing the high density segments between the inner member and the outer member.

16. The pump of claim 11 wherein the inner member is keyed to the number of high density segments.

17. The pump of claim 11 wherein the high density segments comprise a tungsten based alloy.

18. The pump of claim 11 wherein the inner member is in an interference fit with at least one of the number of the high density segments and the outer member is in an interference fit with at least one of the number of high density segments.

19. The pump of claim 11 wherein the inner member is in a splined engagement with the rotatable operable shaft of the pump.

20. The pump of claim 11 wherein the inner member is optional and,

wherein the high density segments are structured to be coupled to the rotatably operable shaft of the pump.

21. The pump of claim 11, further comprising:

a second flywheel, wherein the second flywheel comprises:

an inner member;

an outer member; and

a number of high density segments provided between the inner member and the outer member,

wherein the inner member is structured to be coupled to a rotatably operable shaft of the pump,

wherein a preselected gap is provided between each of the number of high density segments, and

wherein the gap is structured to accommodate thermal expansion of each of the number of segments; and

wherein the second flywheel is in opposed relation to the first flywheel; and

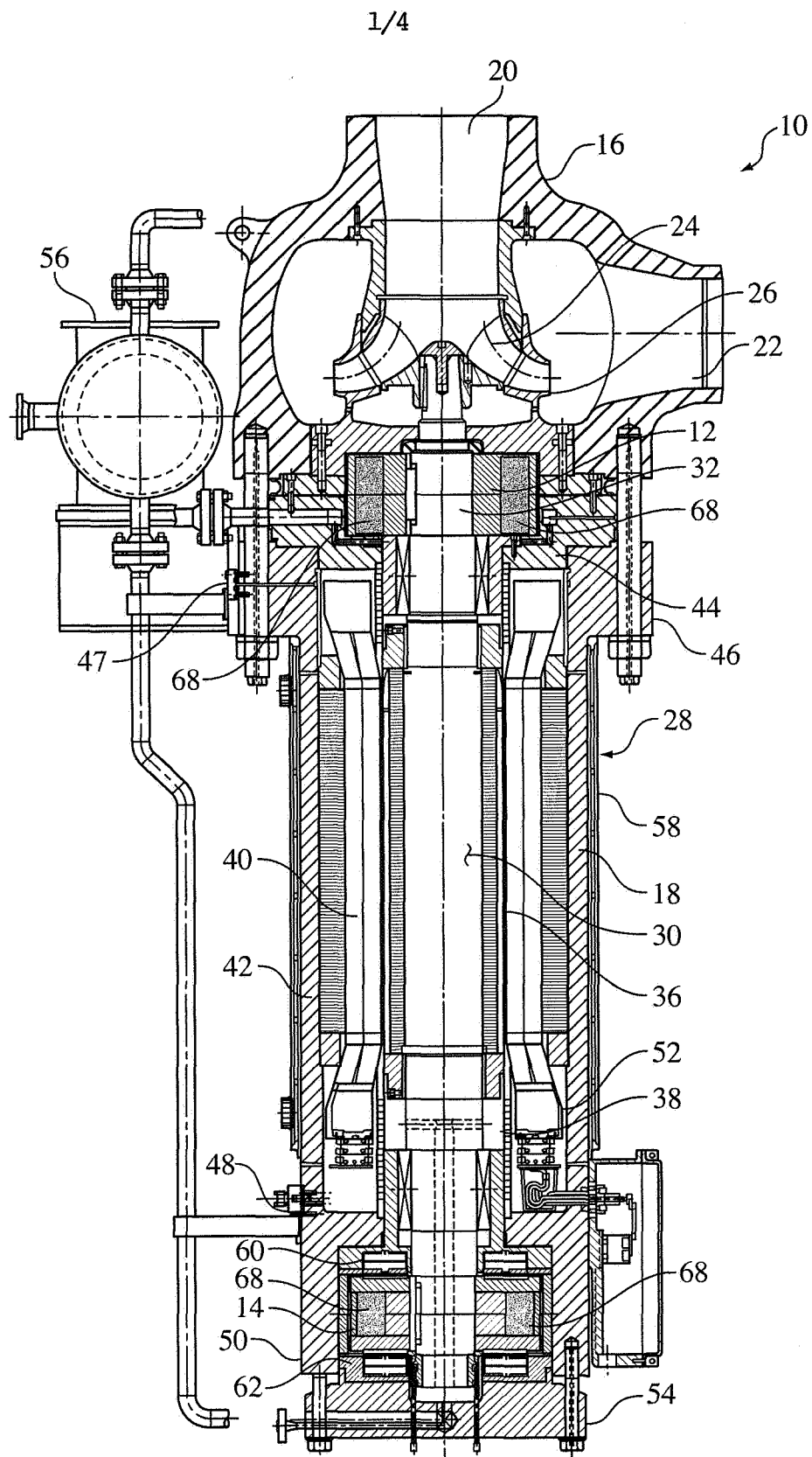
22. The pump of claim 21, further comprising:

a pump casing, wherein the first and second flywheels are located within the pump casing and are structured to allow coolant to circulate in order to reduce the risk of destroying the first and second flywheels.

23. The pump of claim 11 in combination with a nuclear power plant.

24. The combination of claim 23 wherein the nuclear power plant is structured to generate at least 1000 MWe.

25. The combination of claim 23 wherein the nuclear power plant has a pressurized water reactor.



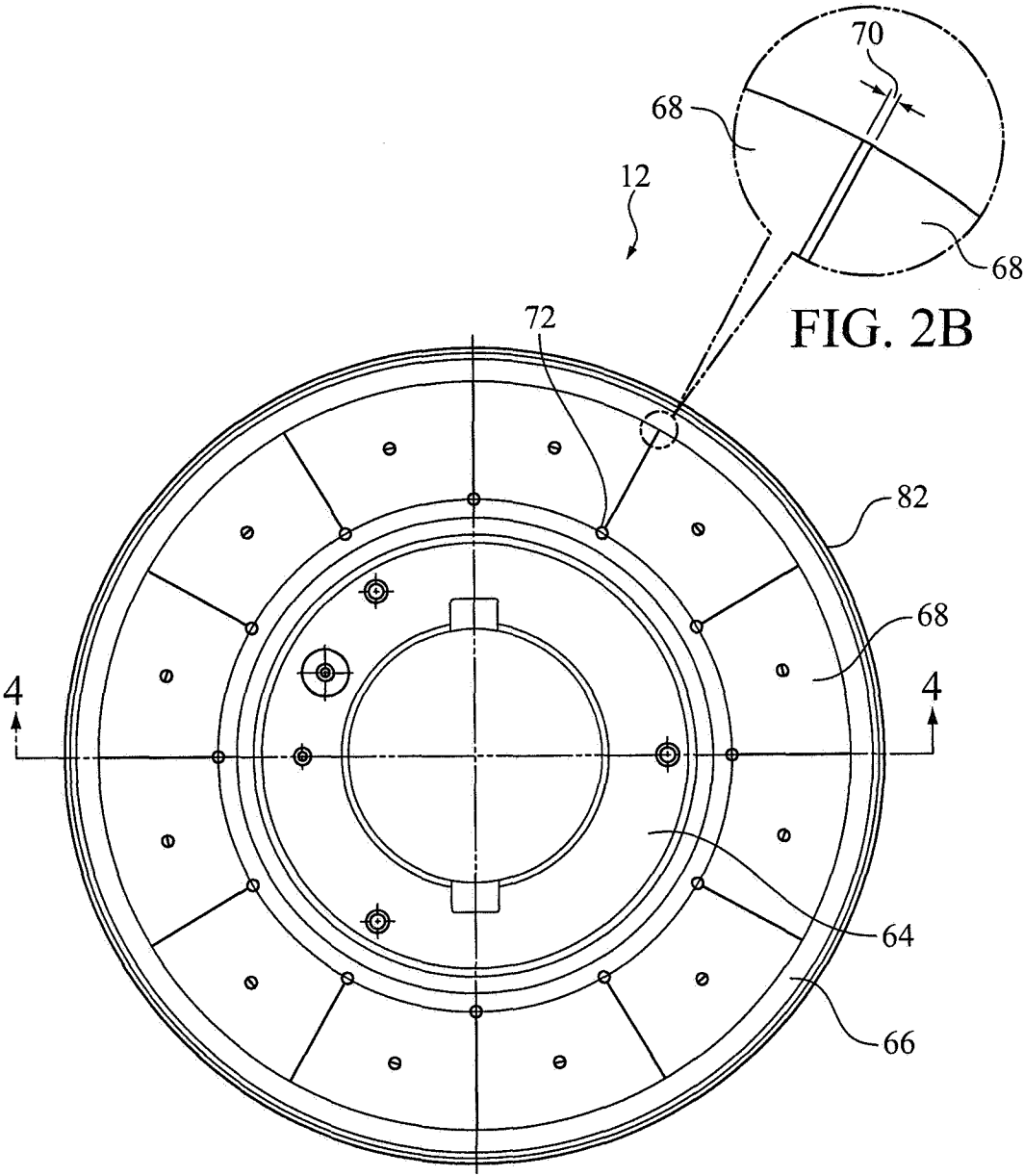


FIG. 2A

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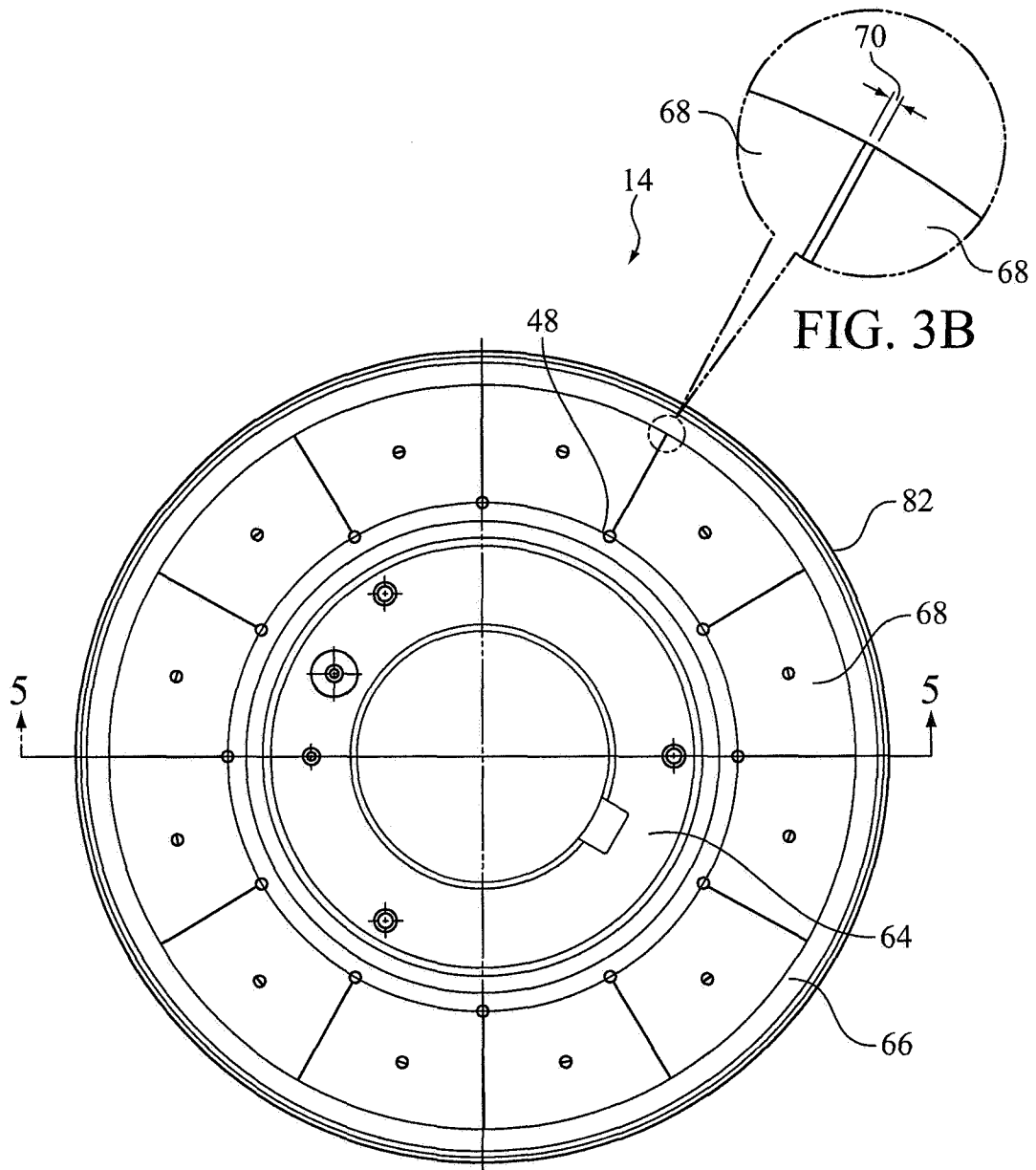


FIG. 3A

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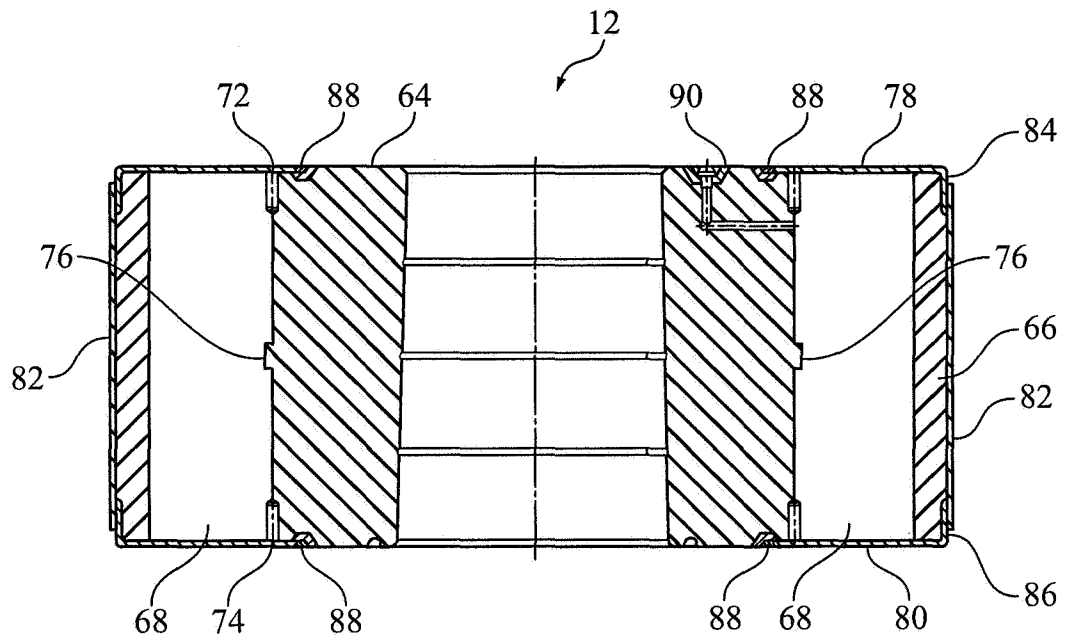


FIG. 4

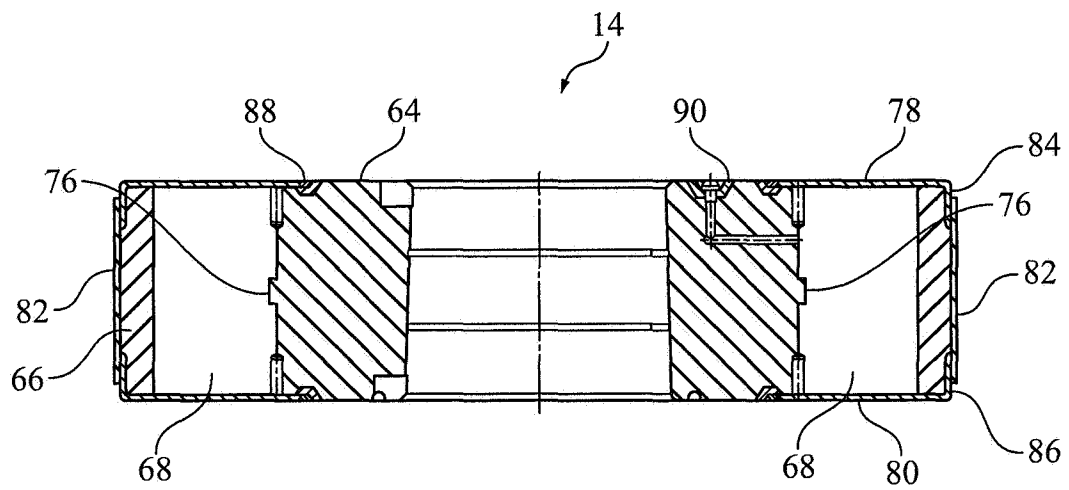


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2009/044878

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - 74/572.1 (2009.01)

USPC - F04B 39/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - 74/572.1, 573.1; 417/423.1, 423.7, 423.8 (2009.01)

USPC - F04B 39/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

MicroPatent, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,886,430 A (VERONESI et al) 12 December 1989 (12.12.1989) entire document	1-20, 23, 25
Y		21-22, 24
Y	US 4,754,606 A (NAM) 05 July 1988 (05.07.1988) entire document	21-22
Y	US 4,052,260 A (FORSTER et al) 04 October 1977 (04.10.1977) entire document	24

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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