(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 March 2015 (19.03.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/039008 A1

(51) **International Patent Classification**:
F04D 13/06 (2006.01) ***F04D 13/08*** (2006.01)

(21) **International Application Number**:
PCT/US2014/055595

(22) **International Filing Date**:
15 September 2014 (15.09.2014)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
61/877,998 15 September 2013 (15.09.2013) US

(71) **Applicant** *(for CA only)*: **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).

(71) **Applicant** *(for FR only)*: **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, F-75007 Paris (FR).

(71) **Applicant** *(for GB, JP, NL only)*: **SCHLUMBERGER HOLDINGS LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Islands, British, 1110 (VG).

(71) **Applicant** *(for all designated States except AE, AO, BH, CA, CN, FR, GB, GH, IN, JP, LY, MA, MZ, NA, NG, NL, PH, SD, SY, US, VN)*: **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).

(71) **Applicant** *(for AE, AO, BF, BH, BJ, CF, CG, CI, CM, CN, GA, GH, GN, GQ, GW, IN, KM, LY, MA, ML, MR, MZ, NA, NE, NG, PH, SD, SN, SY, TD, TG, VN only)*: **PRAD RESEARCH AND DEVELOPMENT LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Island, British, 1110 (VG).

(71) **Applicant** *(for US only)*: **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).

(72) **Inventors**: **LAM, Hao**; 710 River Delta Lane, Richmond, Texas 77469 (US). **WATSON, Arthur I.**; 6502 Knoll Park Drive, Sugar Land, Texas 77479 (US). **ORBAN, Jacques**; 488 west 1428 South, Orem, Utah 84058 (US). **ESLINGER, David Milton**; 15718 N 102nd E Avenue, Collinsville, Oklahoma 74021 (US). **DE CAMARGO NETTO, Lauro**; 05 Briarwood Ave. G103, Midland, Texas 79707 (US).

(74) **Agents**: **STONEBROOK, Michael** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,

[Continued on next page]

(54) **Title**: ELECTRIC SUBMERSIBLE PUMP WITH REDUCED VIBRATION

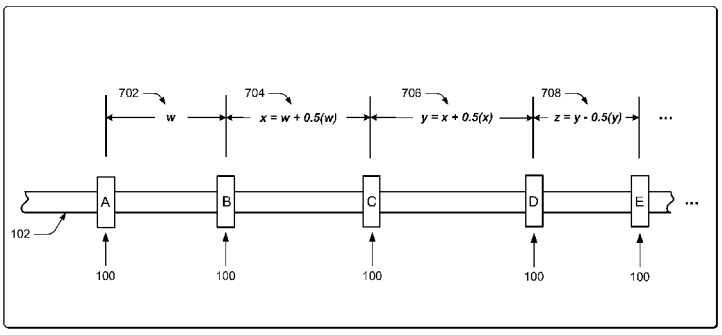


FIG. 7

(57) **Abstract**: An electric submersible pump (ESP) with reduced vibration is provided. In an implementation, an ESP section has radial bearings placed at shaft locations of reduced vibration to reduce wear. The locations of reduced vibration are selected to avoid areas of high vibration and vibrational waves that reinforce each other due to structure resonance and natural excitation frequencies. In an implementation, a radial bearing is positioned at a node of reduced vibration of a standing vibrational wave. In an implementation, a succession of multiple radial bearings are spaced at different intervals from each other to avoid conventional even spacing of the bearings that causes standing waves, resonance waves, and vibrational waves at natural excitation frequencies. In an implementation, a span between adjacent radial bearings is selected to spare other adjacent bearings at different spans the effects of vibrations that may extend over a range of excitation frequencies in the ESP section.

WO 2015/039008 A1

SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ELECTRIC SUBMERSIBLE PUMP WITH REDUCED VIBRATION

RELATED APPLICATIONS

[0001] This patent application claims the benefit of priority to U.S. Provisional Patent Application No. 61/877,998 to Lam et al., filed September 15, 2013, and incorporated by reference herein in its entirety.

BACKGROUND

[0002] Electric submersible pumps may have multiple pump stages, motors, and protector sections stacked in a single ESP string. Each segment in the string may have radial bearings in that section that support a rotating shaft for that segment. The shafts of the various segments in the string are coupled together mechanically, end-to-end, axially. Conventional ESP pumps intended for use in abrasive applications, for example, may have several ARZ (abrasion-resistant zirconia) radial bearings spaced at roughly equal intervals along the longitudinal axis in the stack of stages. For example, the interval may be approximately ten inches. Such ARZ radial bearings may consist of a ceramic sleeve keyed to the rotating pump shaft and a ceramic bushing located in a bearing carrier. These spaced radial bearings are important in maintaining shaft radial location and minimizing pump vibration in abrasive applications where an initial close-fitting radial bearing pair between mating impeller and diffuser hubs becomes significantly worn and provides minimal shaft support.

[0003] As shown in Fig. 1, conventional radial bearings 100 for the shaft 102 of a given single ESP section are evenly spaced, at roughly equal intervals "x", although the equal intervals may be unique for each section. For example, ESP protectors have radial bearings located at approximately equal intervals determined by length of the protector module. Similarly, ESP motors have radial bearings located at approximately equal intervals as determined by length of the rotor sections. Thus, each pump, protector, and motor section has evenly spaced bearings 100 to provide accurate location and alignment of each high-speed shaft 102 for the associated section, and to hold the shaft 102 for that section true, in spite of shaft vibration. However, radial wear of these bearings 100 and subsequent loss of accurate radial location of the shaft 102 is directly related to radial reaction loads on each bearing 100. A significant portion of the radial reaction loads is caused by vibration.

SUMMARY

[0004] An apparatus includes at least one electric submersible pump (ESP) section, and at least a shaft for rotation in the ESP section. In an implementation, the ESP section has locations of increased vibration and locations of decreased vibration along the shaft due to at least one natural frequency of vibration of the ESP section and shaft. A bearing for radial support of the shaft is positioned at a location of reduced vibration along the shaft. In an implementation, an ESP section has at least one shaft section capable of rotation, at least four successive radial bearings along the at least

one shaft section, and a first bearing span between two adjacent radial bearings of the at least four successive radial bearings with a length at least 5% different then at least a second bearing span between two other adjacent radial bearings of the at least four successive radial bearings. An example method includes detecting a location of reduced vibration along a shaft of an electric submersible pump (ESP) component, and positioning a radial bearing to support the shaft at the location of reduced vibration. This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein.

[0006] Fig. 1 is a diagram of conventional ESP stages that have radial bearings located at regular intervals, causing vibrational resonance and standing waves that increase wear on the radial bearings.

[0007] Fig. 2 is a diagram of an ESP component with radial bearings for a shaft located at nodes of decreased vibrational energy.

[0008] Fig. 3 is a diagram of spans between adjacent bearings selected so that over a range of excitation frequencies, only two adjacent bearings undergo increased vibration to spare other bearings from increased vibrational wear.

[0009] Fig. 4 is a diagram of example bearing spans on a shaft of an ESP pump for reducing vibrational wear of the radial bearings and the shaft, in which a middle span varies from adjacent spans.

[0010] Fig. 5 is a diagram of example bearing spans on a shaft of an ESP protector for reducing vibrational wear of the radial bearings and the shaft, in which a first bearing span varies from a second bearing span by at least five percent.

[0011] Fig. 6 is a diagram of example bearing spans on a shaft of an ESP motor for reducing vibrational wear of the radial bearings and the shaft, in which a first bearing span varies from a second bearing span by at least five percent.

[0012] Fig. 7 is a diagram of example successive bearing spans on a shaft for reducing vibrational wear of the radial bearings and the shaft, in which successive bearing spans vary from each other by at least five percent.

[0013] Fig. 8 is a flow diagram of an example method of constructing an ESP component with a radial bearing placed for low wear.

[0014] Fig. 9 is a flow diagram of an example method of spacing bearings in an ESP component for low wear.

DETAILED DESCRIPTION

[0015] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

Example Systems

[0016] Example systems described herein reduce vibrations of the shaft 102 and vibrations and subsequent wear of radial bearings 100 in electric submersible pumps (ESPs). An example system may reduce vibration of the shaft 102 and wear of radial bearings 100 by placing the radial bearings 100 at shaft locations of low vibrational energy. The example system may also space adjacent or nearby radial bearings 100 in each of the pump, protector, and motor sections of an ESP at different intervals, irregular intervals, or at intervals specifically calculated to reduce or defeat the wave and vibration phenomena that increase wear on the radial bearings 100 and shaft 102.

[0017] The spans between bearings 100 may be varied so that one bearing 100 can spare other bearings from vibrational wear. The example spacing for the bearings 100 can reduce the effect of destructive resonance of

vibrating components, and minimize the effects of vibrational waves reinforcing each other at the location of a bearing 100.

[0018] Fig. 2 shows an example ESP shaft 102 with radial bearings 100 located at nodes 202 of minimum vibration when the host ESP component (pump, protector, or motor) undergoes a standing vibrational wave, or undergoes vibration from a range of excitation frequencies. The location of bearings 100 also avoids antinodes 204 of the vibrational waves, where vibrational amplitude is at a maximum. This anti-vibration bearing spacing 206 can be used with submersible pumps and associated components, including those driven by electric power (ESP), driven by a shaft from the surface, or driven by fluid power. Thus, an example ESP section has bearings 100 located near the nodes 202, where the amplitude is minimized, rather than at or near the antinodes 204.

[0019] In an implementation, an example system reduces ESP shaft vibrations and subsequent wear of radial bearings 100 by spacing neighboring or adjacent radial bearings 100 in each of the pump, protector, and motor at specifically selected or varying (e.g., irregular) intervals along the rotating shaft 102. The undesirable vibrations can be excited by shaft rotation itself, by gas slugging, and by a host of other causes: such as vibration of slightly worn bearings 100 resonating with the geometry of the section structure, interaction of high-speed moving parts (e.g., the bearings 100) with abrasive particulates in the fluid being pumped, by slight shaft misalignment, which is common, and by movement of fluid through the hardware, especially when

high-speed pump components interact with fluids containing dissolved and undissolved gases, and oil and water phases of different densities. The example system aims to place bearings 100 in locations along the shaft 102 that avoid areas of increased vibration in the section and that avoid vibration wave antinodes 204, where vibration is maximum or reinforced.

[0020] When the natural frequency of excitation of a bearing span, including the shaft 102, coincides with the frequency of excitation of the ESP section, the structure resonates during operation, producing much higher amplitudes of vibration than non-resonant vibration of the structure. In an implementation, an example system has a distance between bearings 100 that forms a span of the shaft 102 and resulting support structure with a natural frequency of excitation that does not coincide with the overall resonant excitation frequency of the ESP section structure.

[0021] As shown in Fig 3, it is not always practical to avoid resonance because the ESP, or ESP section, may be operated over a wide range of excitation frequencies 302 dictated by the application, one of which may coincide with the natural frequency of a span "a" 304 between bearings 306 & 308. In this case, resonance of the overall machine is minimized by varying the bearing spacings "a," "b," and "c" along the shaft(s) 102 significantly enough to avoid more than one nearby span being excited at any given excitation frequency. Also, any span may be chosen to cancel out natural frequencies of nearby spans.

Example ESP Configurations

Example Pump

[0022] Fig. 4 shows an example shaft 102 and bearing 100 configuration in an example ESP pump section. In an implementation, radial bearings 100, such as ARZ ceramic bearings, are spaced along the shaft 102 at a nominal standard spacing, at approximately ten inch intervals, for example, but which on the example shaft 102 is varied from the standard spacing to reduce or avoid vibration. Using four successive ARZ radial bearings A, B, C, D, an example anti-vibration spacing 402 between middle bearings B and C may be at least 0.50 inch different (approximately 5% different) than the nominal ten inch spacing 404 between bearings A and B and between C and D.

Example Protector

[0023] Fig. 5 shows an example shaft 102 and bearing 100 configuration in an example ESP protector section. Conventional radial bearings 100 for a protector module within an ESP protector section are spaced along the shaft 102 at a fixed interval determined by the length of the ESP protector section. In an implementation, using two adjacent protector modules in an ESP stack, with successive bearing spans AB and BC at a nominal standard length, such as ten inches, an example anti-vibration spacing 502 for span BC may be at least 0.5 inch different (e.g., 5%) than the nominal spacing 504 of span AB. For more bearing spans, the length of each successive bearing span for

adjacent protector modules is at least 5% different from the length of each neighboring bearing span.

Example Motor

[0024] Fig. 6 shows an example shaft 102 and bearing 100 configuration for example ESP motor sections. Conventional radial bearings 100 for a motor section in an ESP stack are spaced along the shaft 102 at a fixed interval determined by the length of each rotor section. In an implementation, using two adjacent motor sections in an ESP stack, with successive bearing spans AB and BC at a nominal standard length, such as ten inches, an example anti-vibration spacing 602 for span BC may be at least 0.5 inch different (e.g., 5%) than the nominal ten inch spacing 604 of span AB. The length of each successive bearing span for adjacent motor sections is at least 5% different from the length of each neighboring bearing span.

[0025] Fig. 7 shows multiple bearing spans w, x, y, z for multiple motor sections, multiple protector sections, or multiple pump sections in series, in an ESP stack. Beginning with a nominal bearing span of "w" 702, the length of each succeeding bearing span for adjacent sections is at least 5% different from the length of each neighboring bearing span. Thus, adjacent bearing span "x" 704 can be w + 0.5(w), bearing span "y" 706 can be x + 0.5(x), bearing span "z" 708 can be y – 0.5(y), and so forth. A succeeding bearing span can be 5% longer or 5% shorter than its neighboring bearing spans.

Example Methods

[0026] Fig. 8 shows an example method of constructing an ESP component with anti-vibration bearings to reduce wear. In the flow diagram, operations are shown in individual blocks.

[0027] At block 802, a shaft location of reduced vibration in the ESP component is detected or calculated.

[0028] At block 804, a radial bearing is positioned to support the shaft at the shaft location of reduced vibration.

[0029] Fig. 9 shows another example method of constructing an ESP component with anti-vibration bearings to reduce wear. In the flow diagram, operations are shown in individual blocks.

[0030] At block 902, a first span between two radial bearings along a shaft of the ESP component is determined.

[0031] At block 904, an adjacent span between radial bearings along the shaft is varied by at least 5% from the first span to avoid areas of high vibration in the ESP component.

Conclusion

[0032] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are

intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

1. An apparatus, comprising:

at least one electric submersible pump (ESP) section;

at least a shaft for rotation in the at least one ESP section;

locations of increased vibration and locations of reduced vibration along the shaft due to at least one natural frequency of vibration of the at least one ESP section and shaft; and

a bearing for radial support of the shaft, positioned at one of the locations of reduced vibration along the shaft.

2. The apparatus of claim 1, further comprising a bearing support in the ESP section disposed along the shaft to position the bearing at the location of reduced vibration along the shaft.

3. The apparatus of claim 1, wherein the bearing is positioned at a vibrational node of a standing wave, the vibrational node having reduced vibration.

4. The apparatus of claim 1, wherein the bearing is positioned along the shaft to avoid a vibrational antinode of a standing wave, the vibrational antinode having increased vibration.

5. The apparatus of claim 1, further comprising multiple bearings, wherein the multiple bearings are spaced at different intervals from each other along the shaft to reduce vibrational wear on the multiple bearings.

6. The apparatus of claim 5, wherein neighboring or adjacent bearings are spaced at intervals calculated to reduce or defeat wave and vibration phenomena that increase wear on the bearings and shaft.

7. The apparatus of claim 5, wherein the bearings are located to reduce an effect of a destructive resonance or to reduce an effect of vibrational waves reinforcing each other.

8. The apparatus of claim 5, wherein a span between two bearings of the multiple bearings is selected to possess a natural vibrational frequency that does not coincide with a natural frequency, an excitation frequency, or a resonance of the at least one ESP section.

9. The apparatus of claim 5, wherein a first span between two bearings of the multiple bearings has a length that cancels out natural vibrational frequencies of one or more nearby spans between bearings of the multiple bearings.

10. The apparatus of claim 5, wherein when the ESP is operated over a wide range of excitation frequencies, a span between two bearings of the multiple bearings along the shaft has a length that prevents a nearby span between bearings of the multiple bearings from being excited at an excitation frequency in the range of excitation frequencies.

11. The apparatus of claim 10, wherein spacings between the multiple bearings along the shaft are arranged to minimize or reduce the number of bearings at or near an antinode of increased vibrational energy over the range of excitation frequencies.

12. The apparatus of claim 5, wherein at least two adjacent bearings of the multiple bearings have a distance between each other that varies from a distance between another two adjacent bearings of the multiple bearings by approximately one-twentieth or five percent of the distance between the other two adjacent bearings.

13. The apparatus of claim 5, wherein each distance between adjacent bearings of the multiple bearings is unique.

14. The apparatus of claim 5, wherein each distance between two adjacent bearings of the multiple bearings varies by at least one-twentieth or 5 percent of the distance between two bearings on either adjacent side of the two adjacent bearings.

15. An electric submersible pump (ESP) section, comprising:

at least one shaft section capable of rotation;

at least four successive radial bearings along the at least one shaft section; and

a first bearing span between two adjacent radial bearings of the at least four successive radial bearings having a length at least 5% different then at least a second bearing span between two other adjacent radial bearings of the at least four successive radial bearings.

16. The ESP section of claim 15, wherein the first bearing span prevents the second bearing span from vibrating at a resonance frequency of the ESP section; and

wherein the first bearing span prevents the second bearing span from vibrating at a natural excitation frequency of the at least one shaft section.

17. The ESP section of claim 15, wherein the ESP section is selected from the group consisting of a pump, a motor, and a protector.

18. The ESP of claim 15, wherein a second radial bearing and a third radial bearing of the at least four successive radial bearings are spaced with at least a 5% difference in distance between each other than a spacing between either the first and second bearings or the third and fourth bearings.

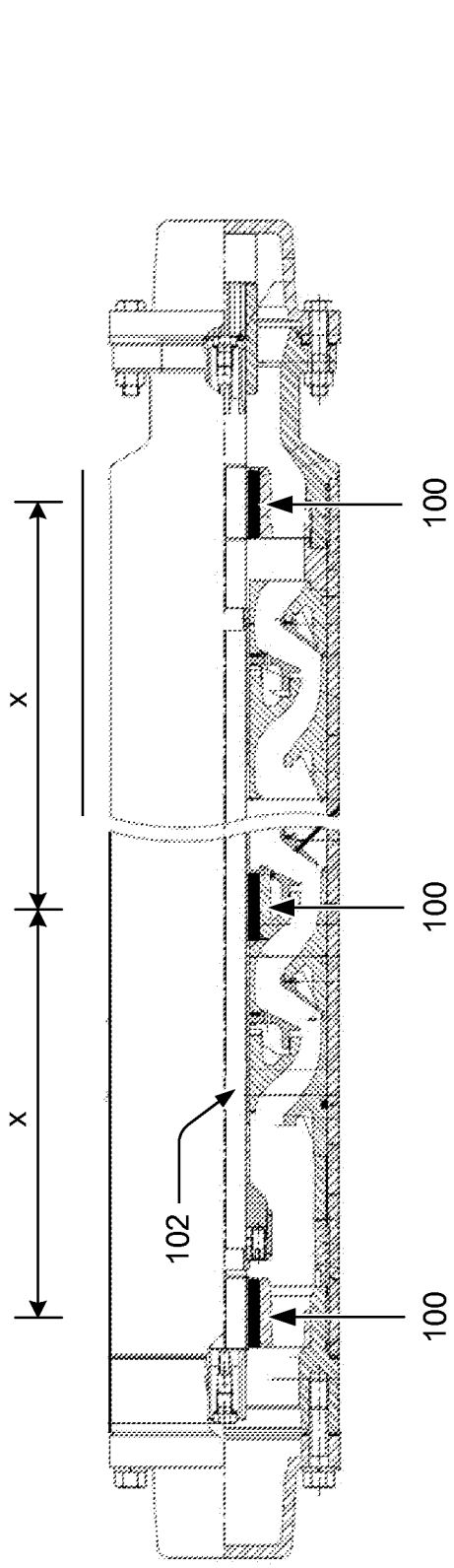
19. A method, comprising:

detecting a location of reduced vibration along a shaft of an electric submersible pump (ESP) component; and

positioning a radial bearing to support the shaft at the location of reduced vibration.

20. The method of claim 19, further comprising determining a first span between radial bearings along the shaft; and

varying an adjacent span between radial bearings along the shaft by at least 5% from the first span.



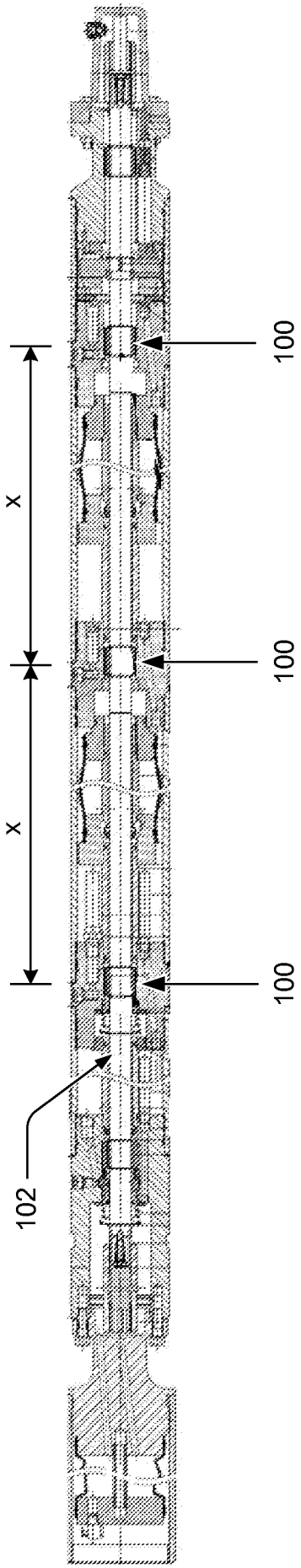


FIG. 1
(PRIOR ART)

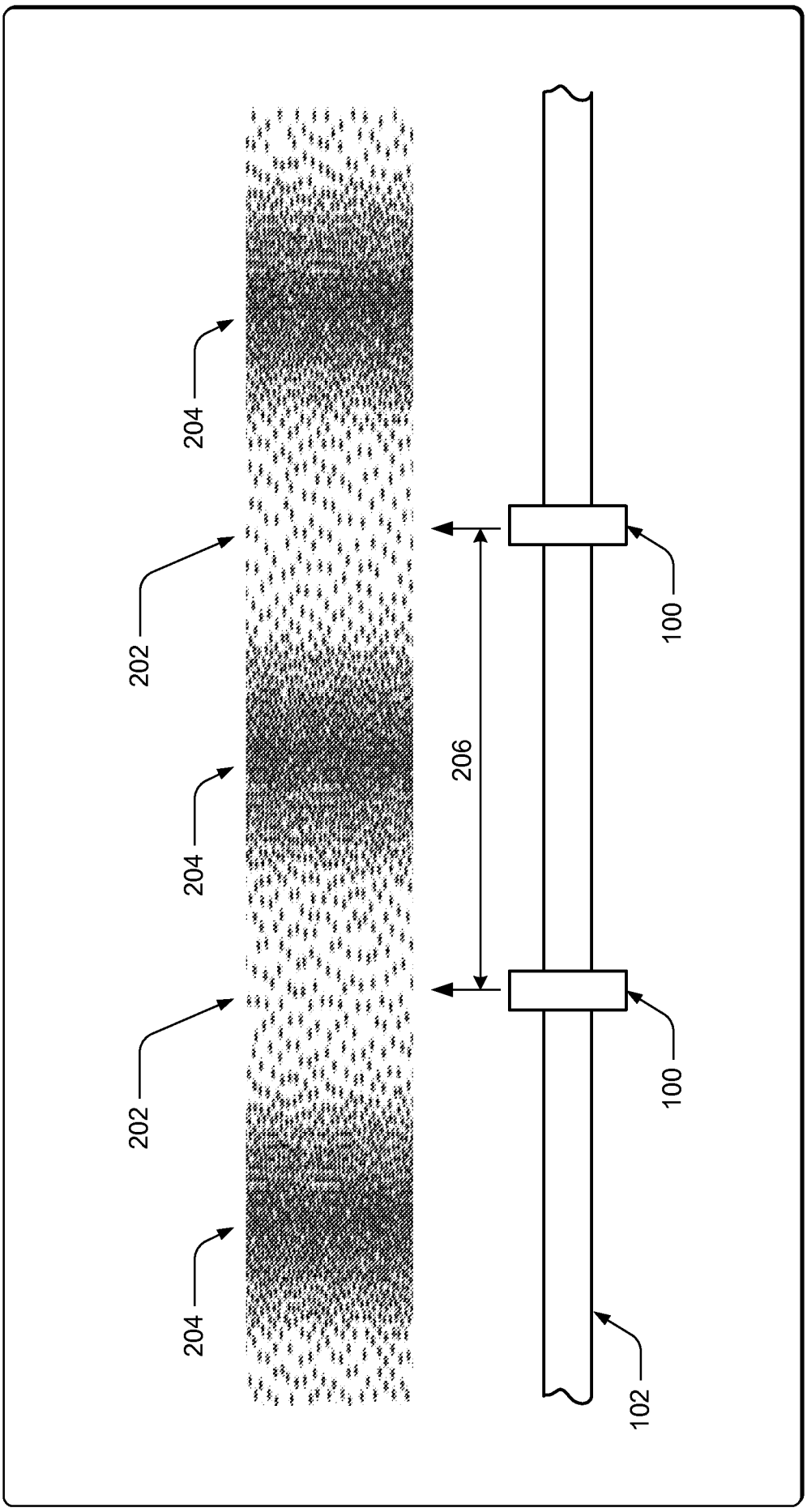


FIG. 2

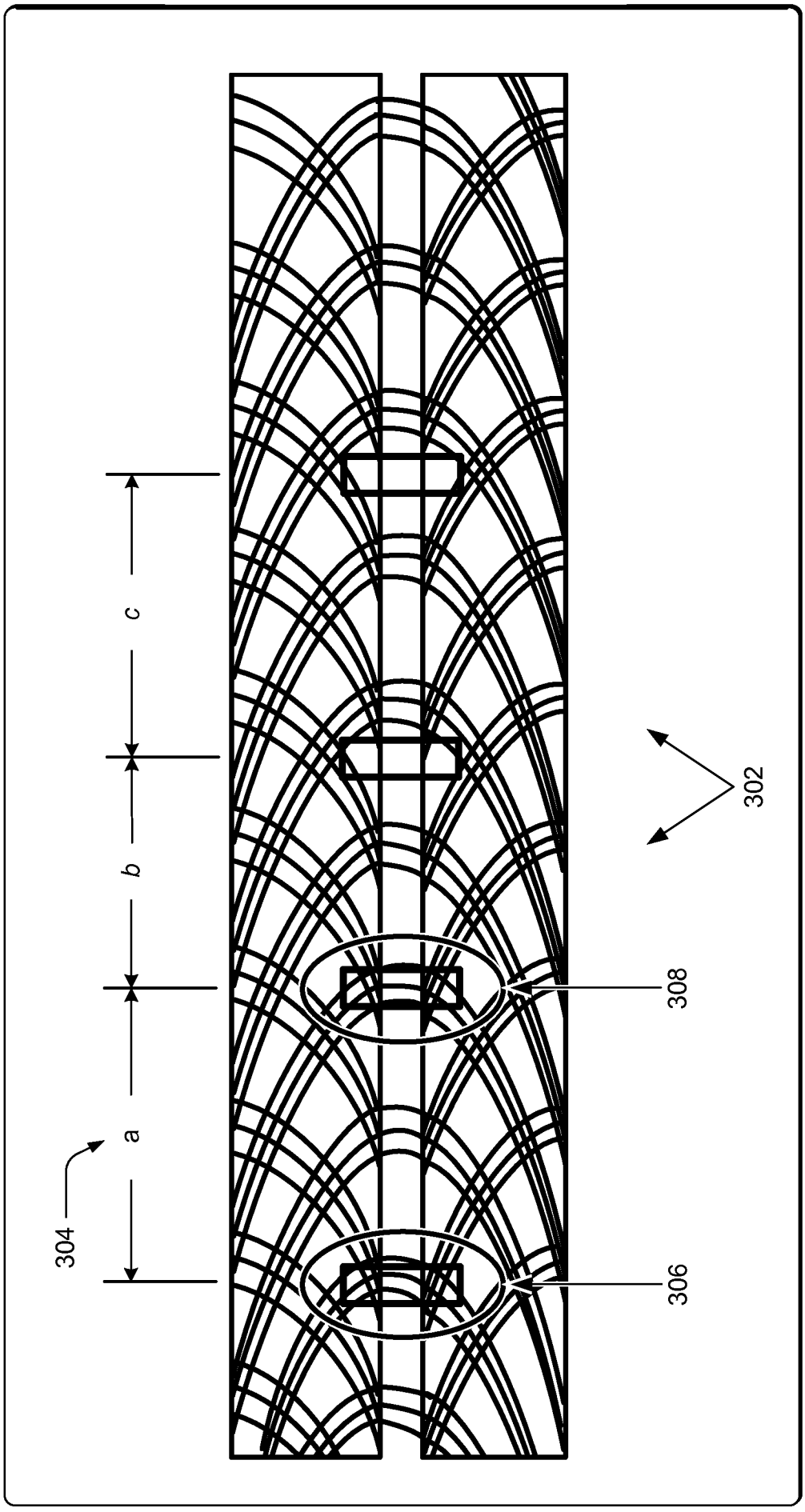


FIG. 3

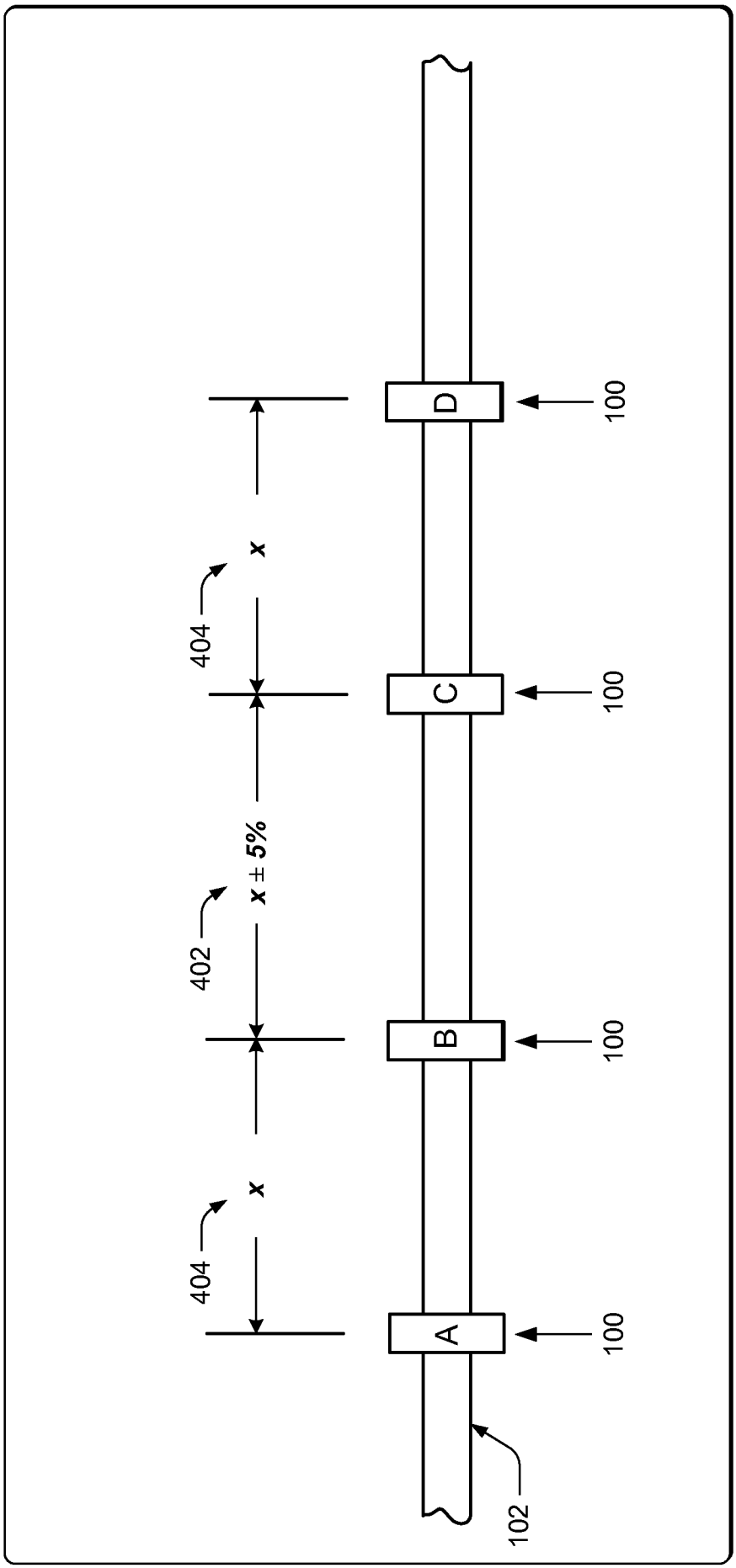


FIG. 4

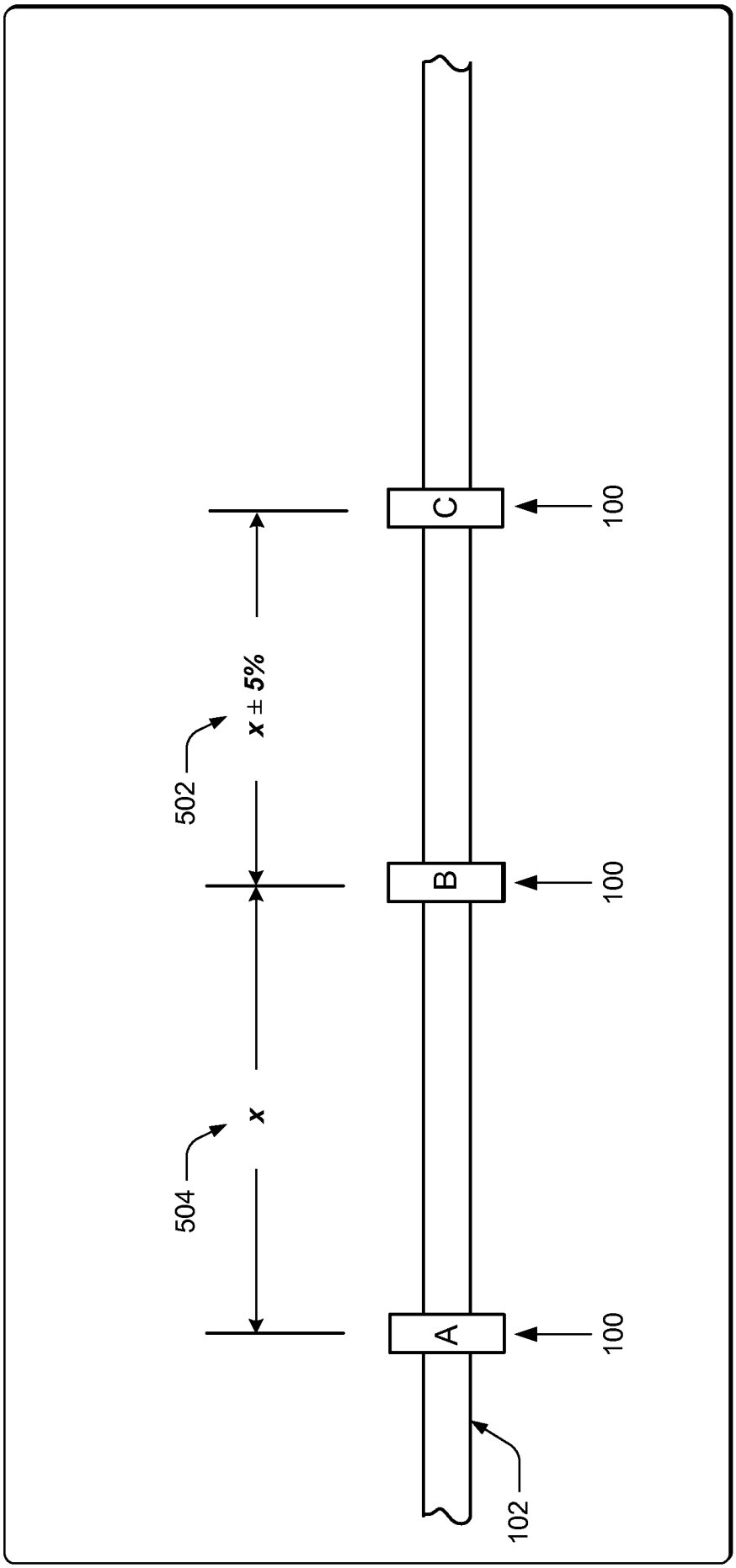


FIG. 5

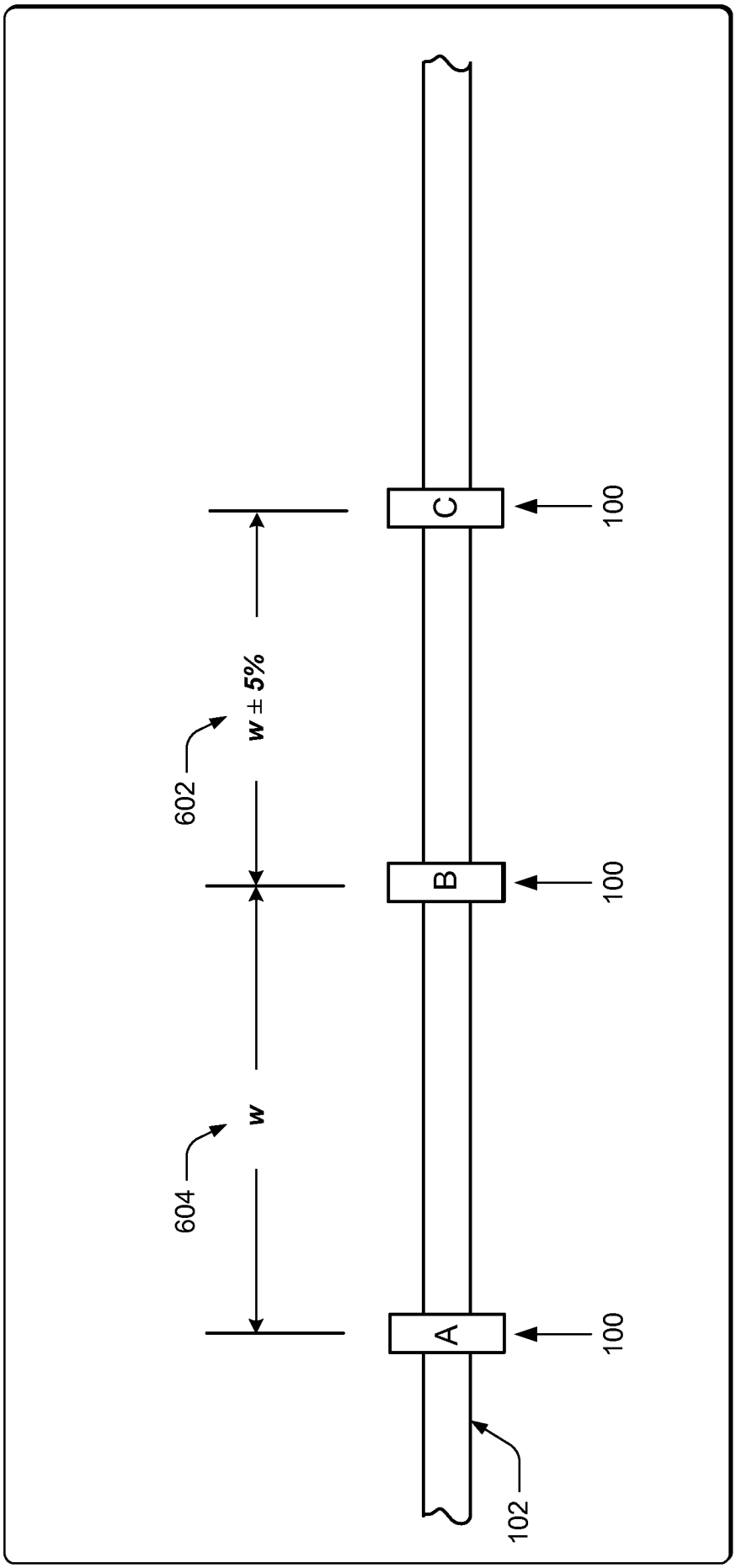


FIG. 6

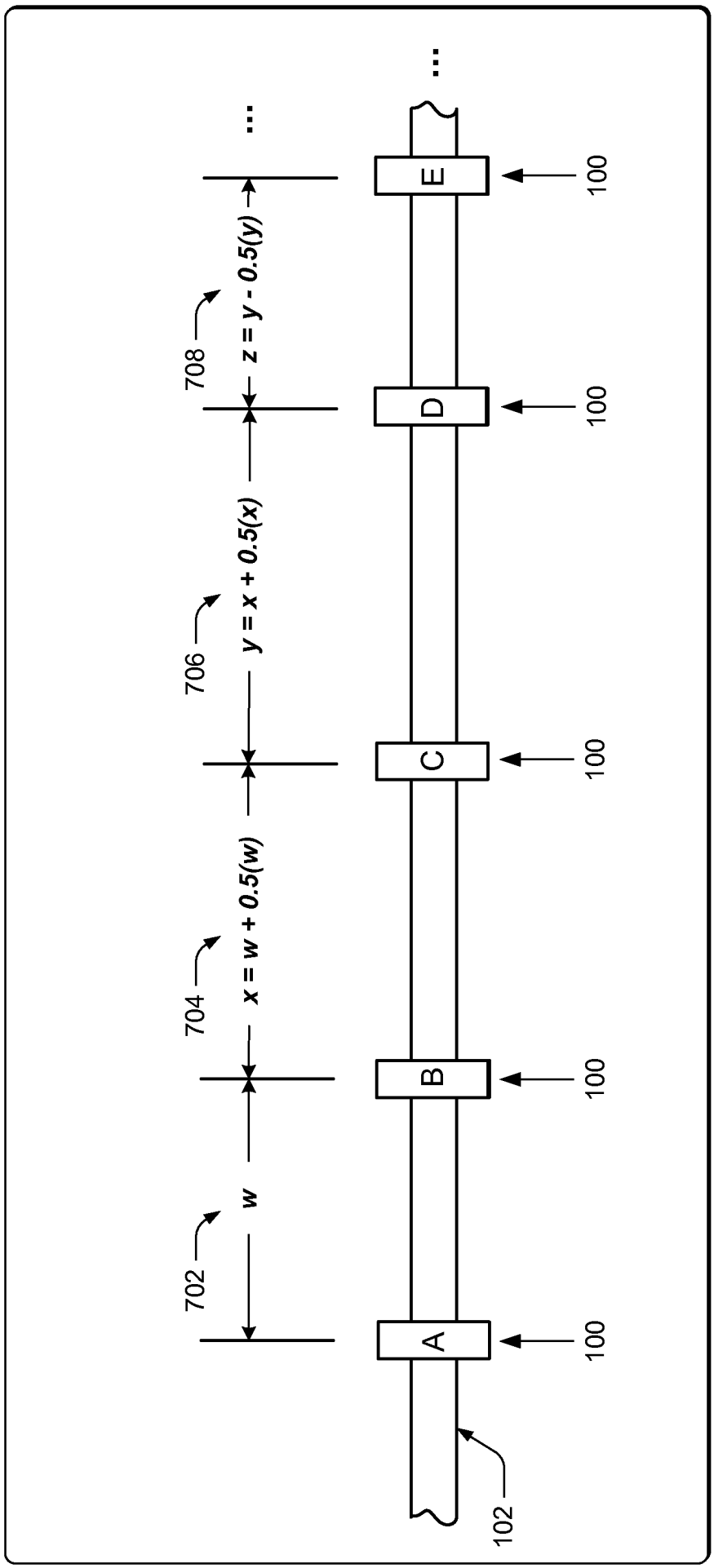


FIG. 7

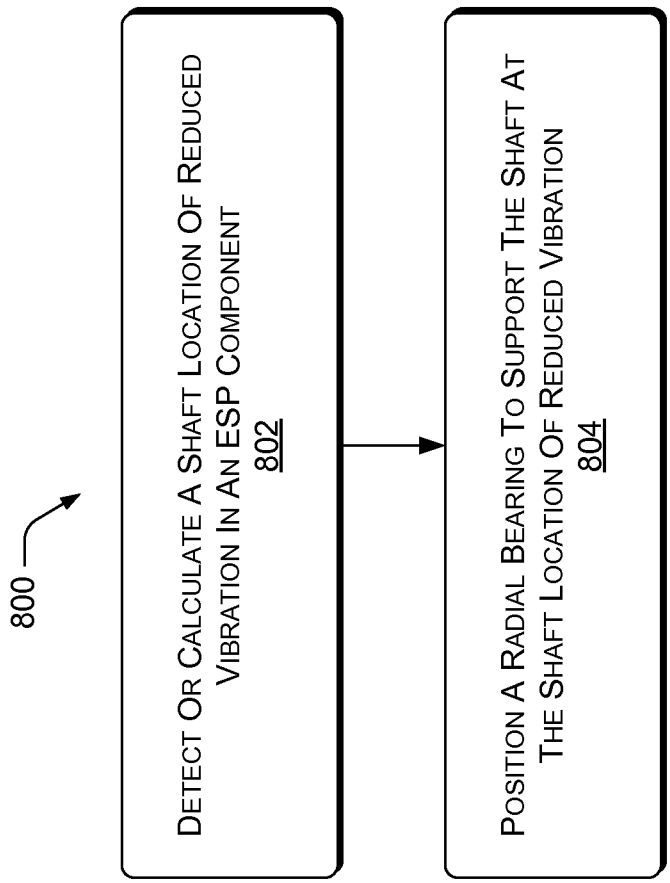

800
DETECT OR CALCULATE A SHAFT LOCATION OF REDUCED VIBRATION IN AN ESP COMPONENT
802
POSITION A RADIAL BEARING TO SUPPORT THE SHAFT AT THE SHAFT LOCATION OF REDUCED VIBRATION
804

FIG. 8

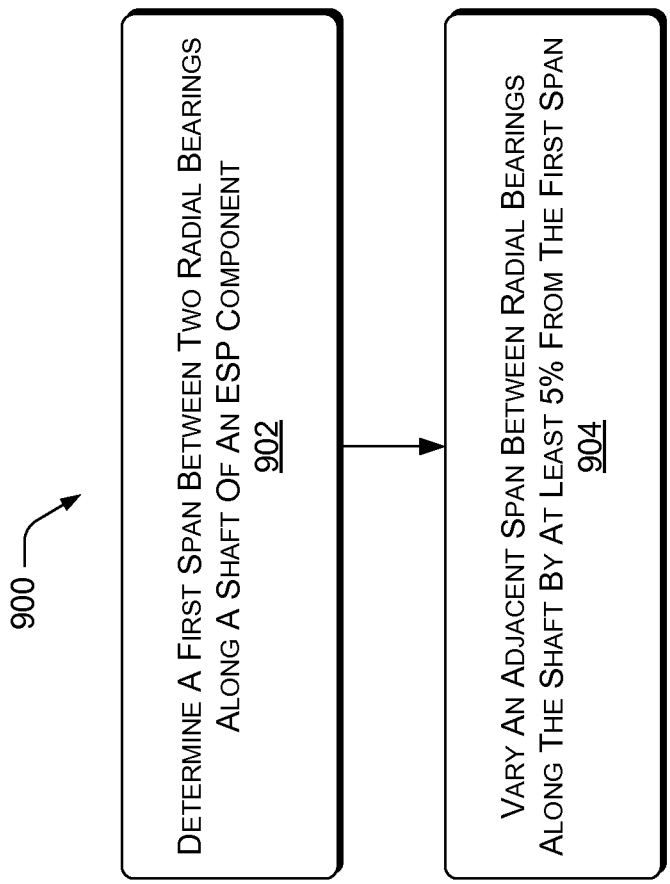

900
DETERMINE A FIRST SPAN BETWEEN TWO RADIAL BEARINGS ALONG A SHAFT OF AN ESP COMPONENT
902
VARY AN ADJACENT SPAN BETWEEN RADIAL BEARINGS ALONG THE SHAFT BY AT LEAST 5% FROM THE FIRST SPAN
904

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/055595

A. CLASSIFICATION OF SUBJECT MATTER

F04D 13/06(2006.01)i, F04D 13/08(2006.01)i

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)
F04D 13/06; F04B 49/06; F04D 29/66; F04D 19/04; F04D 13/08; F04B 35/04; H02K 7/08; F04D 29/42; F16C 32/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: pump, bearing, vibration, position

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0058797 A1 (CARLOS PRIETO et al.) 07 March 2013 See abstract; paragraphs [0007]-[0011],[0026]-[0029]; claims 1-20; Fig 1-8.	1-20
A	EP 1574719 A2 (THE BOC GROUP, INC.) 14 September 2005 See abstract; claims 1,7,14; Fig 4.	1-20
A	US 8162596 B1 (KAMIO KEIJUN) 24 April 2012 See abstract; claims 1-5	1-20
A	JP 2004-286045 A (BOC EDWARDS KK) 14 October 2004 See abstract; claims 1-5	1-20
A	US 04350911 A (WILSON; BROWN L. et al.) 21 September 1982 See abstract; column 1, line 60 - column 2, line 63; claims 1-7, 17	1-20

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

☒ See patent family annex.

* 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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 December 2014 (08.12.2014)	**08 December 2014 (08.12.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
HONG, Geun Jo
Telephone No. +82-42-481-8560

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/055595

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0058797 A1	07/03/2013	US 8851864 B2	07/10/2014
EP 1574719 A2	14/09/2005	EP 1574719 A3	22/03/2006
		IL166712D0	15/01/2006
		JP 2005-233189A	02/09/2005
		US 2005-0186099 A1	25/08/2005
US 8162596 B1	24/04/2012	None	
JP 2004-286045 A	14/10/2004	DE602004026954 D1	17/06/2010
		EP 1460293 A2	22/09/2004
		EP 1460293 A3	09/03/2005
		EP 1460293 B1	05/05/2010
		KR 10-1050336 B1	19/07/2011
		KR20040082953A	30/09/2004
		US 2005-0179333 A1	18/08/2005
		US 6949853 B2	27/09/2005
US 04350911 A	21/09/1982	US 04409504 A	11/10/1983