



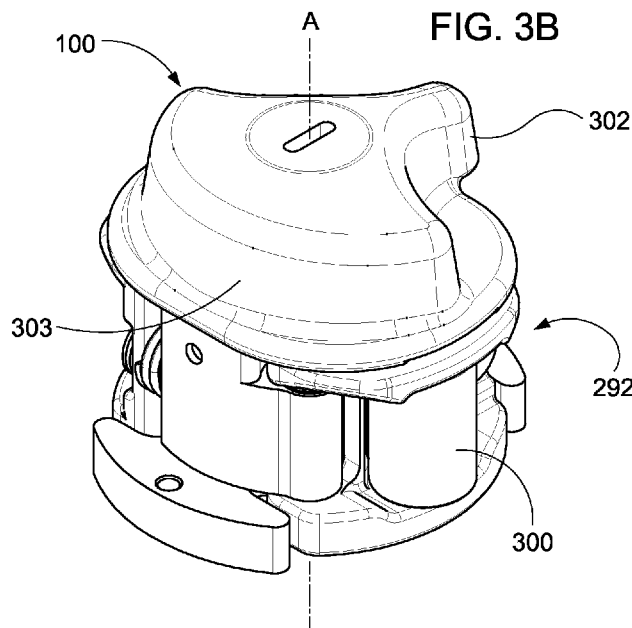
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- (71) Applicant: FENWAL, INC. [US/US]; 3 Corporate Dr.,
Lake Zurich, IL 60047 (US).
- (72) Inventor: WEST, Richard, L.; 3716 N. Lake Shore Drive,
Lake Villa, IL 60046 (US).
- (74) Agent: YOON, Hanna; Fenwal, Inc., 3 Corporate Dr.,
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(54) Title: AUTO LOADING AND UNLOADING PERISTALTIC PUMP APPARATUS



(57) Abstract: A peristaltic pumping apparatus for use in blood processing procedures, comprising: a pump rotor rotatable about a rotational axis and a pump raceway circumferentially spaced about the axis; a pump cap disposed atop the pump rotor, the pump cap having a finger configured to engage a tubing loop of a length of tubing at a time of loading the tubing and guide the tubing loop within the raceway along the length of the tubing loop; and wherein the pump cap further comprises a tensioning wall disposed laterally opposite the finger, the tensioning wall configured to engage a length of the tubing loop at a time of unloading the tubing and provide tension to the tubing length as the tubing loop exits the raceway.



TITLE

AUTO LOADING AND UNLOADING
PERISTALTIC PUMP APPARATUS

Cross-Reference to Related Applications

[0001] This application claims the benefit of U.S. Non-Provisional Patent App. No. 14/554,289 filed November 26, 2014, which is expressly incorporated herein by reference in its entirety.

Field of the Disclosure

[0002] The present disclosure is directed to systems and methods for pumping fluid within flexible tubing. More particularly, the present disclosure is directed to systems and methods for peristaltic pumping of fluids used in connection with medical devices.

Background

[0003] Roller or peristaltic pumps have many uses in the medical field. For example, roller pumps may be used in medical devices, such as automated apheresis and blood processing devices, to push fluid (e.g., blood or blood components) through flexible tubing. The operation of a roller pump is to pump fluid by positive displacement using revolving rollers that occlude the flexible tubing. Generally, roller pumps may be simply structured, generate a consistent flow, and use disposable tubing through which a fluid medium is transferred.

[0004] Roller pumps generally comprise a pump drive and a pump head. The pump drive causes rotation of the pump head to pump a fluid medium. The pump head often comprises a pump stator and a pump rotor. The pump stator may be a chamber or housing having an inner circumferential surface (or "raceway") against which one or

more tubes are compressed by the pump rotor. The pump rotor, which may be rotatable relative to the stator and raceway, may be arranged in the pump stator in such a manner that the pump rotor engages tubing loops positioned in the pump stator with one or more rollers. Upon rotation of the pump rotor by a rotating shaft that is otherwise part of the pump drive, the roller(s) may compress the tubing loop against the inner circumferential surface of the pump stator as it is rolled along the tubing. The fluid medium contained in the tubing may then be transported in a direction of the pump rotor rotation.

Summary

[0005] There are several aspects of the present subject matter which may be embodied separately or together in the devices and systems described and claimed below. These aspects may be employed alone or in combination with other aspects of the subject matter described herein, and the description of these aspects together is not intended to preclude the use of these aspects separately or the claiming of such aspects separately or in different combinations as set forth in the claims appended hereto.

[0006] According to an exemplary embodiment, the present disclosure is directed to a peristaltic pumping apparatus for use in blood processing procedures, comprising a pump rotor rotatable about a rotational axis and a pump raceway circumferentially spaced about the axis; a pump cap disposed atop the pump rotor, the pump cap having a finger configured to engage a tubing loop of a length of tubing at a time of loading the tubing and guide the tubing loop within the raceway along the length of the tubing loop; and wherein the pump cap further comprises a tensioning wall disposed laterally

opposite the finger, the tensioning wall configured to engage a length of the tubing loop at a time of unloading the tubing and provide tension to the tubing length as the tubing loop exits the raceway.

[0007] According to an exemplary embodiment, the present disclosure is directed to a method for loading and unloading a pump tubing loop into and out of a pump raceway, the method comprising: placing in the vicinity of a pump raceway a flexible tubing loop of a length of tubing; engaging the tubing loop with a finger of a pump cap positioned atop a pump rotor and guiding the tubing loop within the raceway along a length of the tubing loop with the finger, wherein the pump rotor is rotatable about a rotational axis and the pump raceway is circumferentially spaced about the axis; and unloading from the pump raceway the flexible tubing loop, wherein a tensioning wall disposed laterally opposite the finger engages a length of the tubing loop and provides tension to the tubing length as the tubing loop exits the raceway.

[0008] According to an exemplary embodiment, the present disclosure is directed to a peristaltic pumping apparatus for use in a medical device, comprising a pump rotor rotatable about a rotational axis and a pump raceway circumferentially spaced about the axis. The apparatus also comprises a pump cap disposed atop the pump rotor, the pump cap having a finger configured to engage a tubing loop of a length of tubing at a time of loading the tubing and guide the tubing loop within the raceway along the length of the tubing loop. The pump cap further comprises a tensioning wall disposed laterally opposite the finger, the tensioning wall configured to engage a length of the tubing loop at a time of unloading the tubing and provide tension to the tubing length as the tubing loop exits the raceway. The finger extends radially outward from the rotational axis of

the pump rotor beyond a circumference of the pump rotor and the tensioning wall has a contour that generally follows the circumference of the pump rotor.

Brief Description of the Drawings

[0009] Features, aspects, and advantages of the present embodiments will become apparent from the following description, appended claims, and the accompanying exemplary embodiments shown in the drawings, which are briefly described below.

[00010] Fig. 1 is a perspective view of a fluid processing system incorporating a peristaltic pumping apparatus, according to an exemplary embodiment;

[00011] Fig. 2 is a diagrammatic view of a disposable fluid circuit and cassette that may be used in combination with the fluid processing system of Fig. 1, according to an exemplary embodiment;

[00012] Fig. 3 is a perspective view of a pump cap known in the art, according to an exemplary embodiment;

[00013] Fig. 3A is a perspective view of a pump apparatus, according to an exemplary embodiment;

[00014] Fig. 3B is a perspective view of a pump rotor assembly and pump cap, according to an exemplary embodiment;

[00015] Figs. 4A-4C are perspective views of a cassette and associated tubing loop at various points of loading, according to an exemplary embodiment; and

[00016] Figs. 5A-5C are perspective views of a cassette and associated tubing loop at various points of unloading, according to an exemplary embodiment.

Detailed Description

[00017] Some embodiments may minimize tangling, bunching, and/or folding of pump tubing loops during the loading or unloading of the tubing loops into and out of the raceway.

[00018] Some embodiments may enable automatic loading of pump tubing loops into the pump raceway prior to a medical procedure and automatically unload pump tubing loops out of the pump raceway upon completion of the procedure.

[00019] Some embodiments may minimize loading and unloading issues with both shorter and longer tubing loops.

[00020] Some embodiments may minimize loading and unloading issues with both faster and slower pump rotational speeds.

[00021] Some embodiments may minimize loading and unloading issues with both faster and slower speeds with which a cassette is loaded and unloaded.

[00022] Fig. 1 shows an exemplary fluid processing system 10 incorporating a peristaltic pumping apparatus 92 used in conjunction with a disposable fluid circuit 12 (Fig. 2). The fluid processing system 10 may have one or more features of an apheresis device, such as a system marketed as the AMICUS® separator by Fenwal, Inc. of Lake Zurich, Illinois, as described in greater detail in U.S. Patent No. 5,868,696, which is hereby incorporated herein by reference in its entirety, although any suitable apheresis device or blood processing system may be used. The system 10 can be used for processing various fluids, including, but not limited to whole blood, blood components, or other suspensions of biological cellular materials. While an improved pumping apparatus 92 will be described herein with reference to exemplary system 10 and disposable fluid circuit 12, it should be understood that these principles may be

employed with other fluid processing systems and disposable fluid circuits without departing from the scope of the present disclosure.

[00023] Fluid entering the disposable fluid circuit 12 may be pumped thereinto by one or more pumps 92 of the fluid processing system 10 acting upon one or more of the flexible tubing loops 50 extending from the cassettes 16, 16a, and 16b of the flow circuit 12. The tubing loop 50 may be in an erect and outwardly bowed position from cassette 16, 16a, and 16b. An exemplary cassette 16, exemplary pump mechanism, and associated cassette holders 94 are described in greater detail in U.S. Patent No. 5,480,294, which is hereby incorporated herein by reference in its entirety, although any suitable cassette, pump mechanism, and cassette holder may be used. The pump mechanism may optionally be equipped with a pump cap, such as pump cap 100a that is known in the art, depicted in Fig. 3. The contour of known pump cap 100a generally conforms to the circumference of the underlying rotor of the pump mechanism and may play a role in protecting the rotor and pump mechanism.

[00024] Turning to the cassette holders 94 in Fig. 1, each may receive and grip one of the cassettes 16, 16a, and 16b along the two opposed sides edges 130 in the desired operating position. The cassette holder 94 may include a pair of peristaltic pump apparatuses 92. When the cassette 16 is gripped by the cassette holder 94, tubing loops 50 extending from the cassette 16 as shown in Fig. 2 may make operative engagement with the pump apparatuses 92. The pump apparatuses 92 may be operated to cause fluid flow through the cassette 16. Although the embodiment in Fig. 1 depicts three cassette holders 94 configured to engage tubing loops 50 of the fluid circuit 12, any number of cassette holders 94 may be incorporated into the fluid

processing system 10. Although Fig. 1 also depicts peristaltic pump apparatuses 92 disposed on laterally opposing sides of cassette holders 94, the pump apparatuses 92 may be oriented in a variety of configurations depending on the orientation and number of the tubing loops 50 extending from cassettes 16, 16a, and 16b.

[00025] Turning to Figs. 3A and 3B, detailed views of the pump apparatus 92 are shown. The pump apparatus 92 may comprise a pump rotor assembly 292 rotatable about a rotational axis A. An outer wall 294 may extend at least partially around the back side of each rotor assembly 292. The space between the outer wall 294 and the rotor assembly 292 forms a pump raceway 296 circumferentially spaced about the axis A. When a cassette 16, 16a, and 16b is gripped by the side edges 130, the tubing loops 50 may extend into the pump raceway 296. Loading a cassette 16 and tubing loop 50 may be performed by the side edges 130 moving the tubing loop 50 and cassette 16 toward the pump rotor in a direction generally parallel to the rotational axis A of the pump rotor. Unloading a cassette 16 and tubing loop 50 may be performed by the side edges 130 moving the tubing loop 50 and cassette 16 away from the pump rotor in a direction generally parallel to the rotational axis A. Each rotor assembly 292 may include a set of diametrically spaced rollers 300, although the spacing of one or more rollers 300 may be varied. In use, as the pump rotor 292 rotates, the rollers 300 in succession may compress the associated tubing loop 50 against the outer wall 294 of the pump raceway 296. This peristaltic pumping action may urge fluid through the associated loop 50.

[00026] Each rotor assembly 292 may have a pump cap 100 capping the assembly 292. The pump cap 100 may comprise a tensioning finger 302, which may extend

radially outwards from the rotational axis A of the pump rotor assembly 292 and beyond the circumference of the rotor assembly 292. The tensioning finger 302 may be disposed above the height of the rotor assembly 292 and the raceway 296 and may facilitate the smooth loading of the tubing loop 50 into the raceway 296 by catching and guiding the tubing loop 50 in place into the raceway 296. The tensioning finger 302 may assure that the tubing loops 50 are properly oriented and aligned within their respective pump races 296 so that the desired peristaltic pumping action occurs.

[00027] The pump cap 100 of the rotor assembly 292 may also comprise a tensioning wall 303 disposed laterally opposite the tensioning finger 302 and also above the height of the rotor assembly 292 and the raceway 296. The contour of the tensioning wall 303 may generally follow the circumference of the rotor assembly 292. The tensioning wall 303 may facilitate the smooth unloading of the tubing loop 50 out of the raceway 296 by preventing slack in the tubing loop 50 during unloading and providing tension to the tubing loop 50 as it exits the raceway 296. Providing tension to the tubing loop 50 may minimize the tubing loop 50 from bending and folding over itself during the unload process.

[00028] Fig. 4A depicts a cassette 16 and associated tubing loop 50 just prior to being loaded into the raceway 296. The tubing loop 50 is disposed in the vicinity of the raceway 296 at the height of the pump cap 100 above the raceway 296 and generally above the rotor assembly 292. The pump rotor 292 may begin rotating about its rotational axis A prior to the tubing loop 50 having settled within the raceway 296.

[00029] Turning to Fig. 4B, as the side edges 130 of the cassette holders 94 load the cassette 16 into the cassette holders 94, the tubing loop 50 may begin loading into

the raceway 296 around the rotor assembly 292, starting with the portions of the tubing loop 50 closest to the cassette 16. The portion of the tubing loop 50 distal from the cassette 16 may still be unloaded and may straddle a portion of the pump cap 100.

[00030] Referring to Fig. 4C, the rotation of the pump rotor 292 about its rotational axis A allows the finger 302 to catch the tubing loop 50 such that a portion of the loop 50 proximal to the cassette 16 is caught underneath the finger 302. The finger 302 may guide the tubing loop 50 along its length into the raceway 296. The finger 302 may take one or more rotations of the pump rotor 292 to guide the tubing loop 50 completely into the raceway 296. It may take more rotations of the finger 302 to guide the tubing loop 50 completely into the raceway 296 in cases where the tubing loop 50 is shorter. Once the tubing loop 50 has been fully loaded into the raceway 296, the rollers 300 of the rotating pump rotor 292 may facilitate transport of fluid along the tubing loop 50.

[00031] Fig. 5A shows an embodiment in which the cassette 16 is loaded into the cassette holders 94 and has just commenced the unloading process. As the side edges 130 elevate the cassette 16 into an unloading position, portions of the tubing loop 50 most proximal to the cassette 16 may first exit the raceway 296. The pump rotor 292 and hence the pump cap 100 may continue to rotate during the unloading process.

[00032] Referring to Fig. 5B, as portions of the tubing loop 50 more distal to the cassette 16 continue to exit the raceway 296, the tensioning wall 303 may progressively make more contact with the tubing loop 50. The tensioning wall 303 may create tension along the length of tubing loop 50 so as to avoid slack and therefore minimize portions of the tubing 50 bending and folding over itself as well as to expedite the exit of all portions of the tubing loop 50 from the raceway 296. Fig. 5C shows a point at which the

entire tubing loop 50 has exited the raceway 296. The tensioning wall 303 may hold a length of the tubing loop 50 taut so that loop 50 does not fall back into the raceway 296. The tensioning wall 303 may therefore allow the fluid processing system 10 and pumping apparatus 92 to accommodate tubing loops of shorter and longer lengths.

[00033] The embodiments disclosed herein are for the purpose of providing a description of the present subject matter, and it is understood that the subject matter may be embodied in various other forms and combinations not shown in detail. Therefore, specific embodiments and features disclosed herein are not to be interpreted as limiting the subject matter as defined in the accompanying claims.

Claims:

1. A peristaltic pumping apparatus for use in blood processing procedures, comprising:

a pump rotor rotatable about a rotational axis and a pump raceway circumferentially spaced about the axis;

a pump cap disposed atop the pump rotor, the pump cap having a finger configured to engage a tubing loop of a length of tubing at a time of loading the tubing and guide the tubing loop within the raceway along the length of the tubing loop; and

wherein the pump cap further comprises a tensioning wall disposed laterally opposite the finger, the tensioning wall configured to engage a length of the tubing loop at a time of unloading the tubing and provide tension to the tubing length as the tubing loop exits the raceway.

2. The peristaltic pumping apparatus of claim 1, wherein the pump rotor includes a set of diametrically spaced rollers.

3. The peristaltic pumping apparatus of claim 1, wherein the finger extends radially outward from the rotational axis of the pump rotor beyond a circumference of the pump rotor.

4. The peristaltic pumping apparatus of claim 1, wherein the tensioning wall has a contour that generally follows a circumference of the rotor.

5. The peristaltic pumping apparatus of claim 1, wherein the raceway comprises a space between the pump rotor and an outer wall extending at least partially around a back side of the pump rotor.

6. The peristaltic pumping apparatus of claim 1, wherein the length of tubing is configured to be loaded into the pump raceway by moving the tubing loop toward the pump rotor in a direction generally parallel to the rotational axis of the pump rotor.
7. The peristaltic pumping apparatus of claim 1, wherein at least a portion of the finger and/or at least a portion of the tensioning wall is disposed above the rotor assembly and the raceway.
8. The peristaltic pumping apparatus of claim 1, wherein the tensioning wall progressively makes more contact with the tubing loop as the tubing loop exits from the raceway.
9. A method for loading and unloading a pump tubing loop into and out of a pump raceway, the method comprising:
 - placing in the vicinity of a pump raceway a flexible tubing loop of a length of tubing;
 - engaging the tubing loop with a finger of a pump cap positioned atop a pump rotor and guiding the tubing loop within the raceway along a length of the tubing loop with the finger, wherein the pump rotor is rotatable about a rotational axis and the pump raceway is circumferentially spaced about the axis; and
 - unloading from the pump raceway the flexible tubing loop, wherein a tensioning wall disposed laterally opposite the finger engages a length of the tubing loop and provides tension to the tubing length as the tubing loop exits the raceway.
10. The method of claim 9, wherein the pump rotor includes a set of diametrically spaced rollers.

11. The method of claim 9, wherein the finger extends radially outward from the rotational axis of the pump rotor beyond a circumference of the pump rotor.
12. The method of claim 9, wherein the tensioning wall has a contour that generally follows a circumference of the rotor.
13. The method of claim 9, wherein the tensioning wall is configured to prevent slack in the tubing loop during unloading and provide tension to the tubing loop as it exits the raceway.
14. The method of claim 9, wherein the raceway comprises a space between the pump rotor and an outer wall extending at least partially around a back side of the pump rotor.
15. The method of claim 9, wherein the length of tubing is configured to be loaded into the pump raceway by moving the tubing loop toward the pump rotor in a direction generally parallel to the rotational axis of the pump rotor.
16. The method of claim 9, wherein at least a portion of the finger and/or at least a portion of the tensioning wall is disposed above the rotor assembly and the raceway.
17. A peristaltic pumping apparatus for use in a medical device, comprising:
 - a pump rotor rotatable about a rotational axis and a pump raceway circumferentially spaced about the axis;
 - a pump cap disposed atop the pump rotor, the pump cap having a finger configured to engage a tubing loop of a length of tubing at a time of loading the tubing and guide the tubing loop within the raceway along the length of the tubing loop;
 - wherein the pump cap further comprises a tensioning wall disposed laterally opposite the finger, the tensioning wall configured to engage a length of the tubing loop

at a time of unloading the tubing and provide tension to the tubing length as the tubing loop exits the raceway; and

wherein the finger extends radially outward from the rotational axis of the pump rotor beyond a circumference of the pump rotor and the tensioning wall has a contour that generally follows the circumference of the pump rotor.

18. The peristaltic pumping apparatus of claim 17, wherein the raceway comprises a space between the pump rotor and an outer wall extending at least partially around a back side of the pump rotor.

19. The peristaltic pumping apparatus of claim 17, wherein at least a portion of the finger and/or at least a portion of the tensioning wall is disposed above the rotor assembly and the raceway.

20. The peristaltic pumping apparatus of claim 17, wherein the tensioning wall progressively makes more contact with the tubing loop as the tubing loop exits from the raceway.

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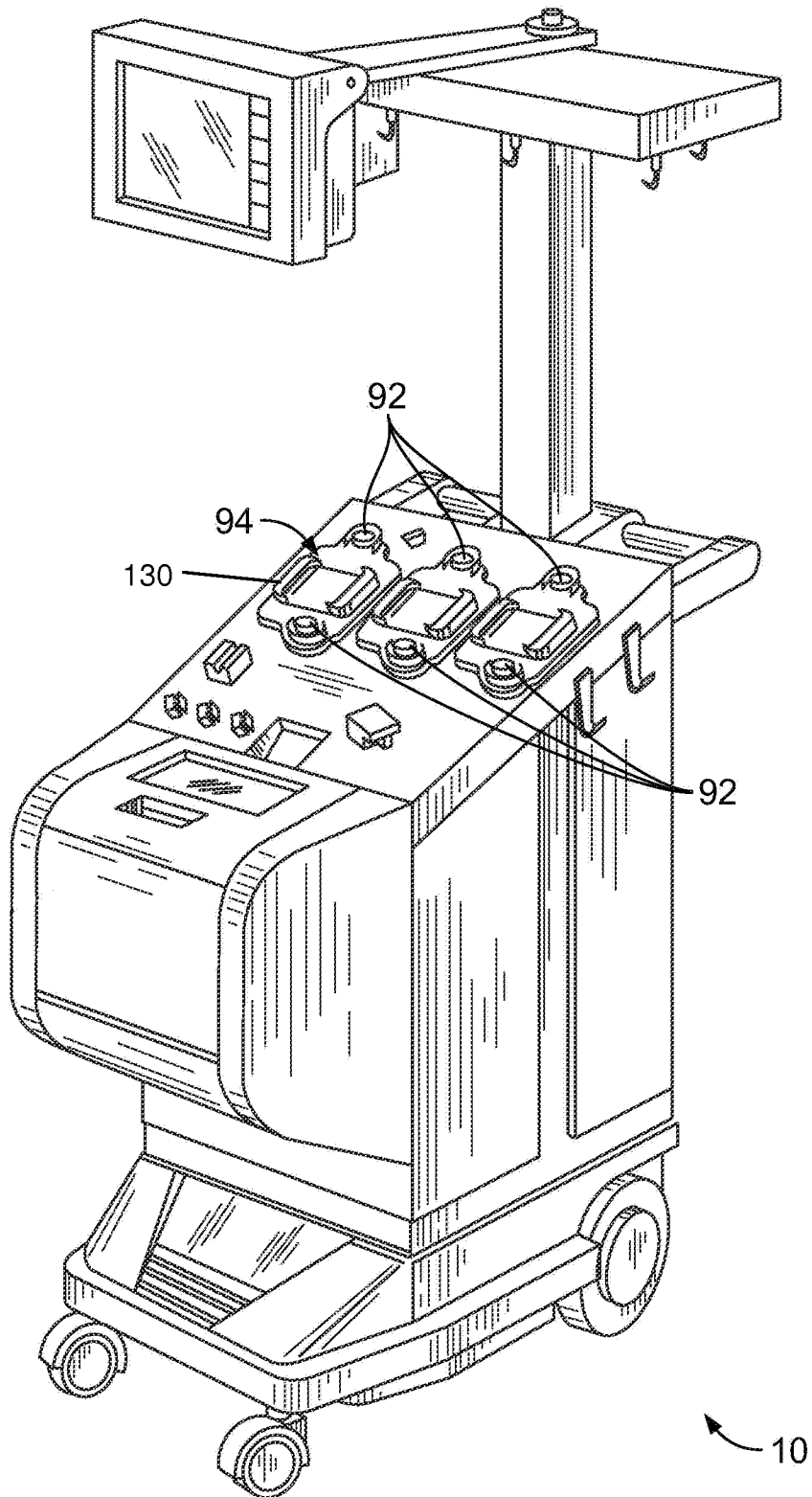


FIG. 1

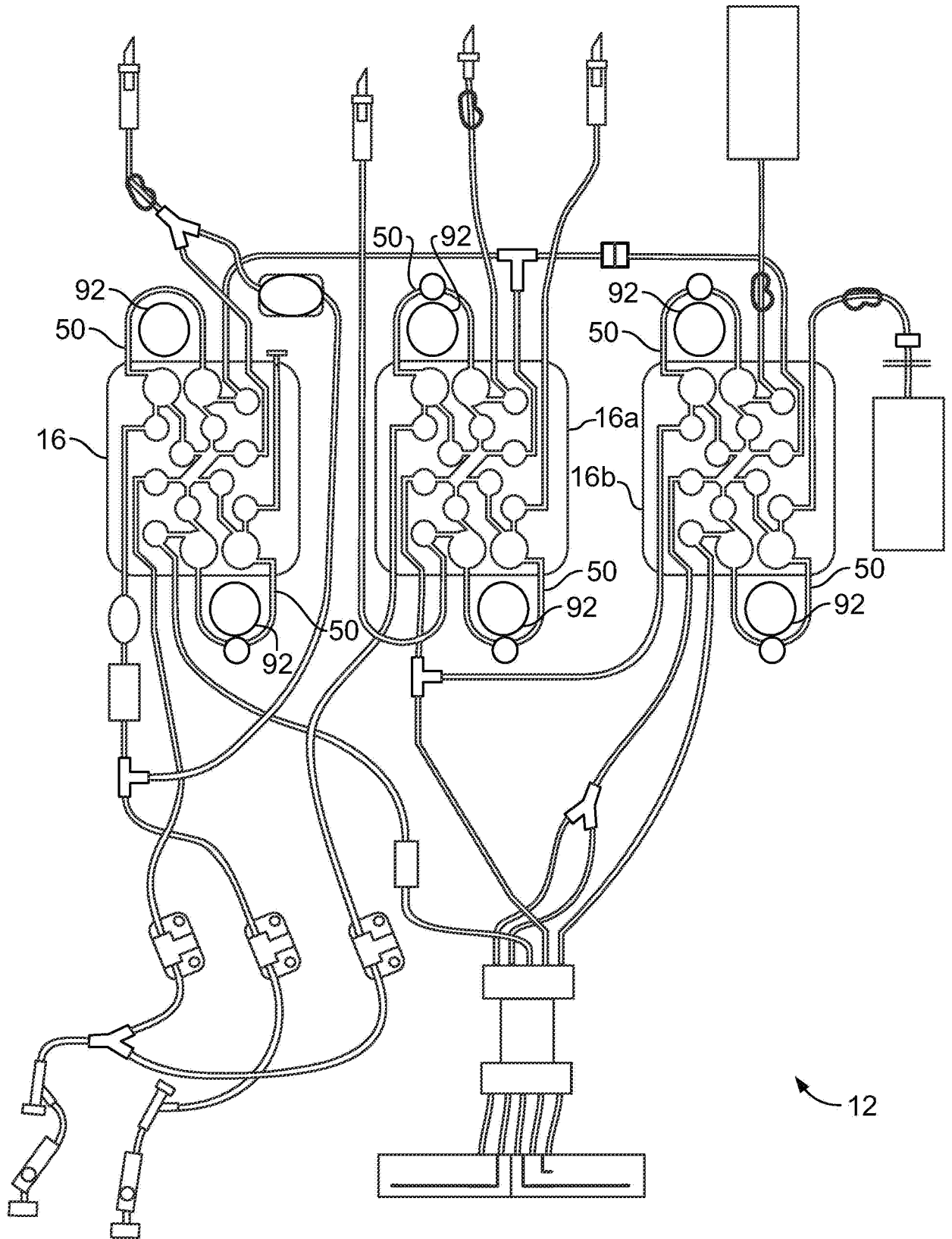


FIG. 2

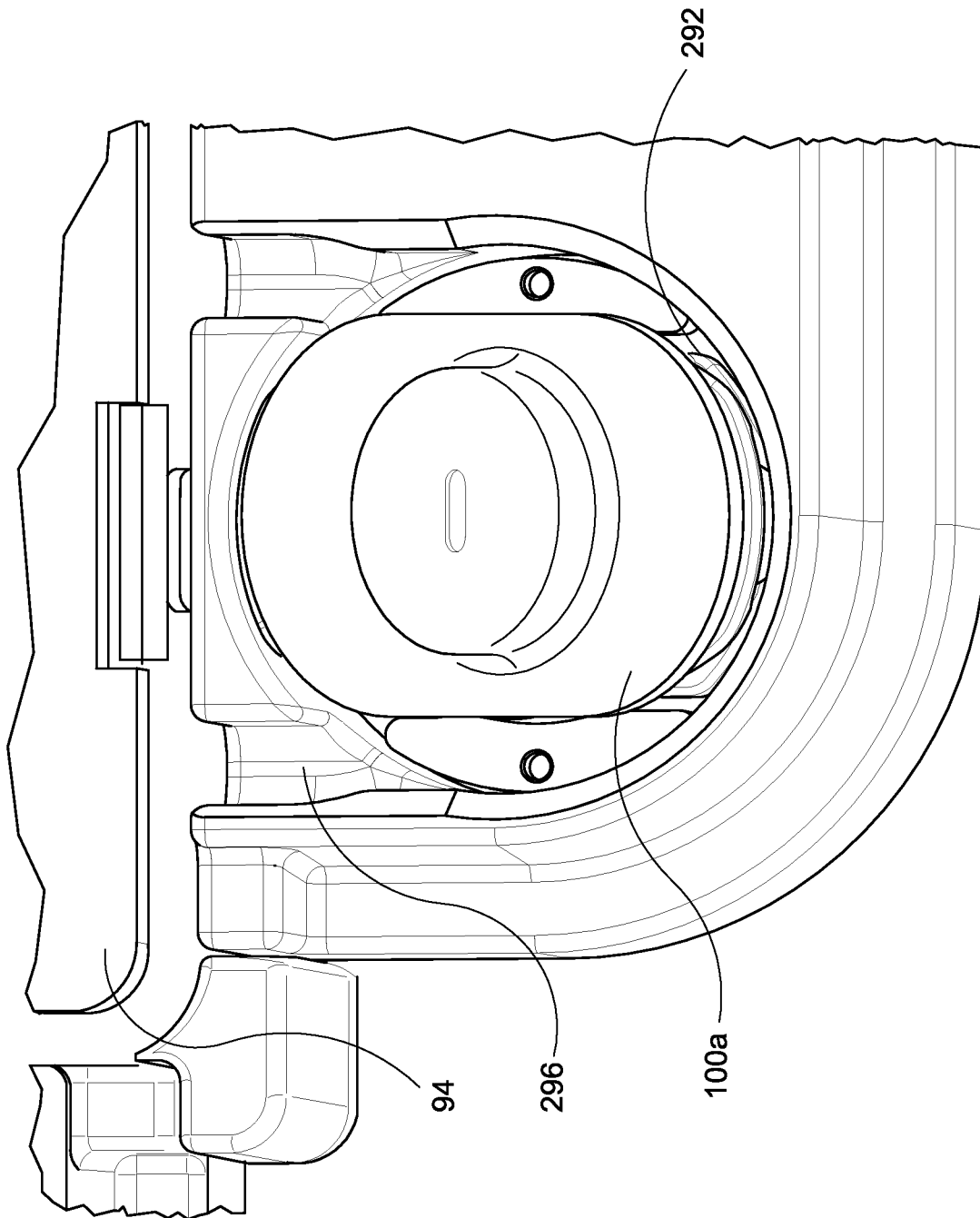


FIG. 3

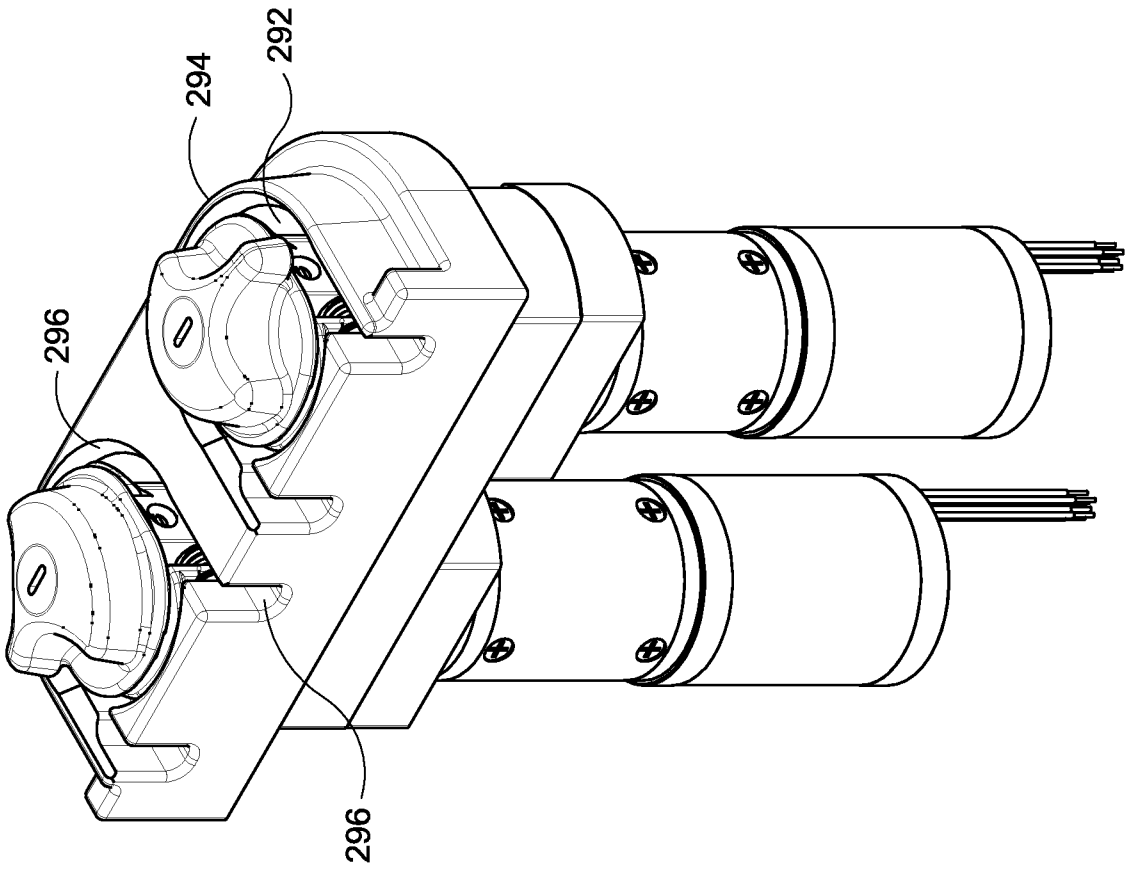


FIG. 3A

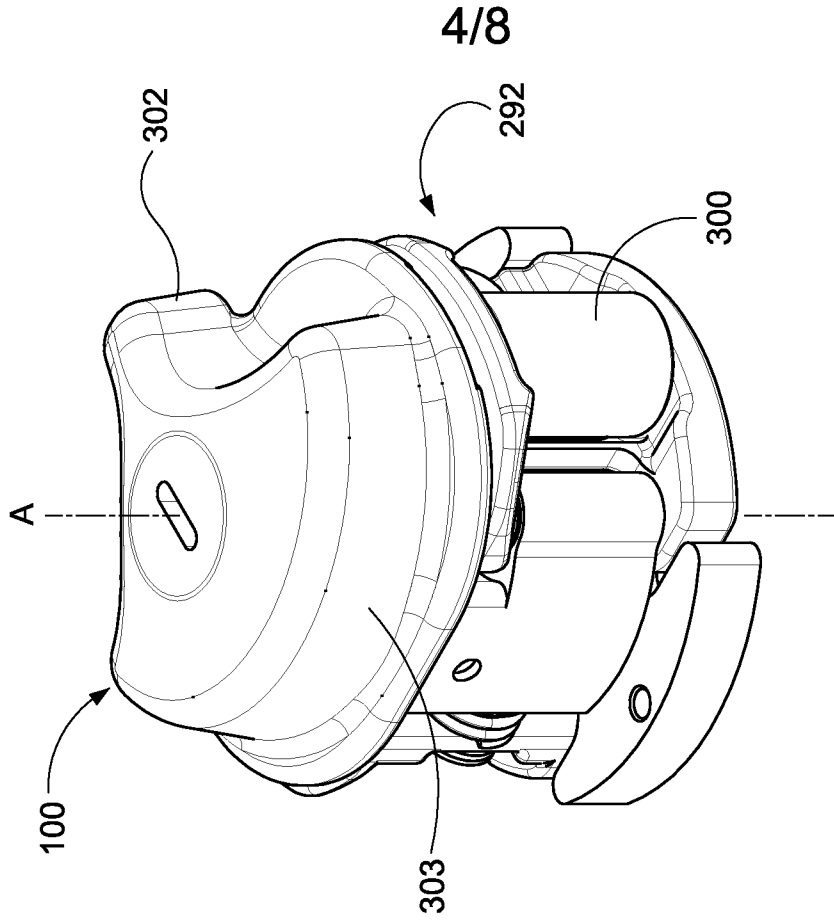


FIG. 3B

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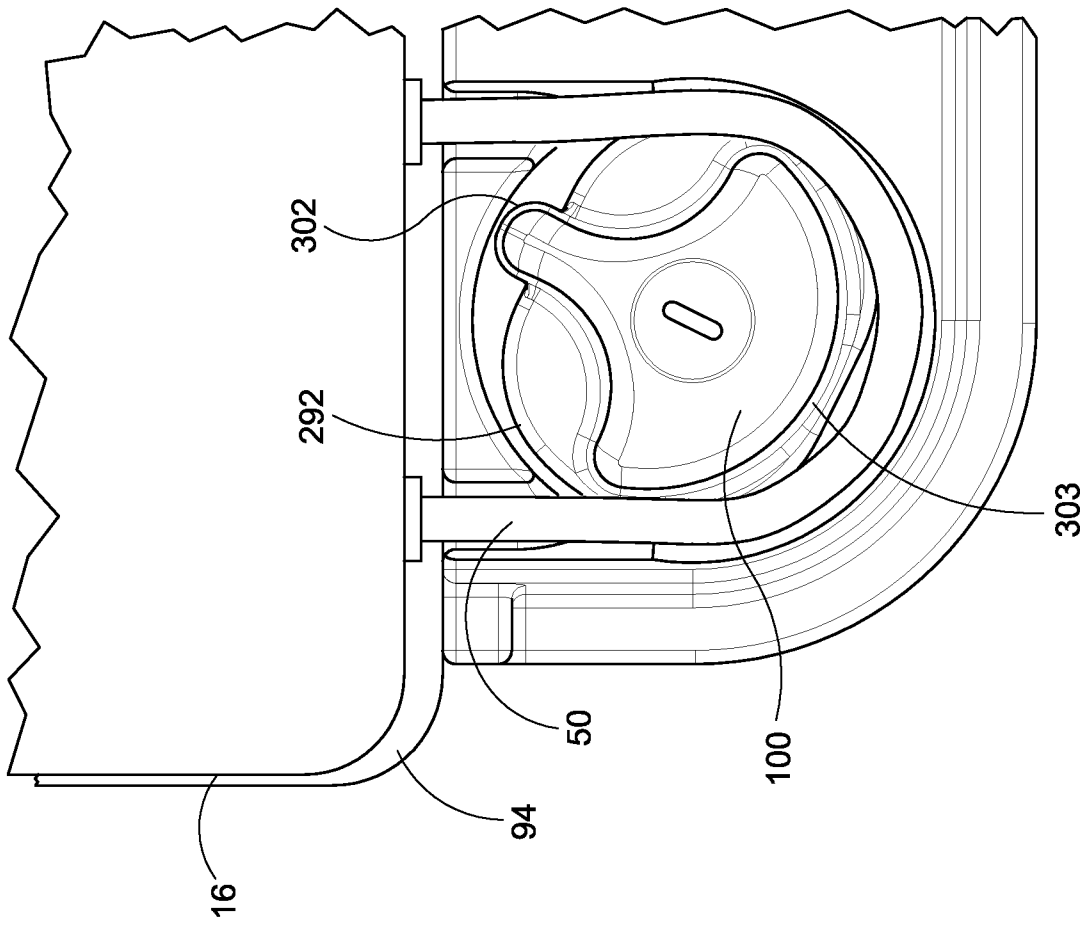


FIG. 4A

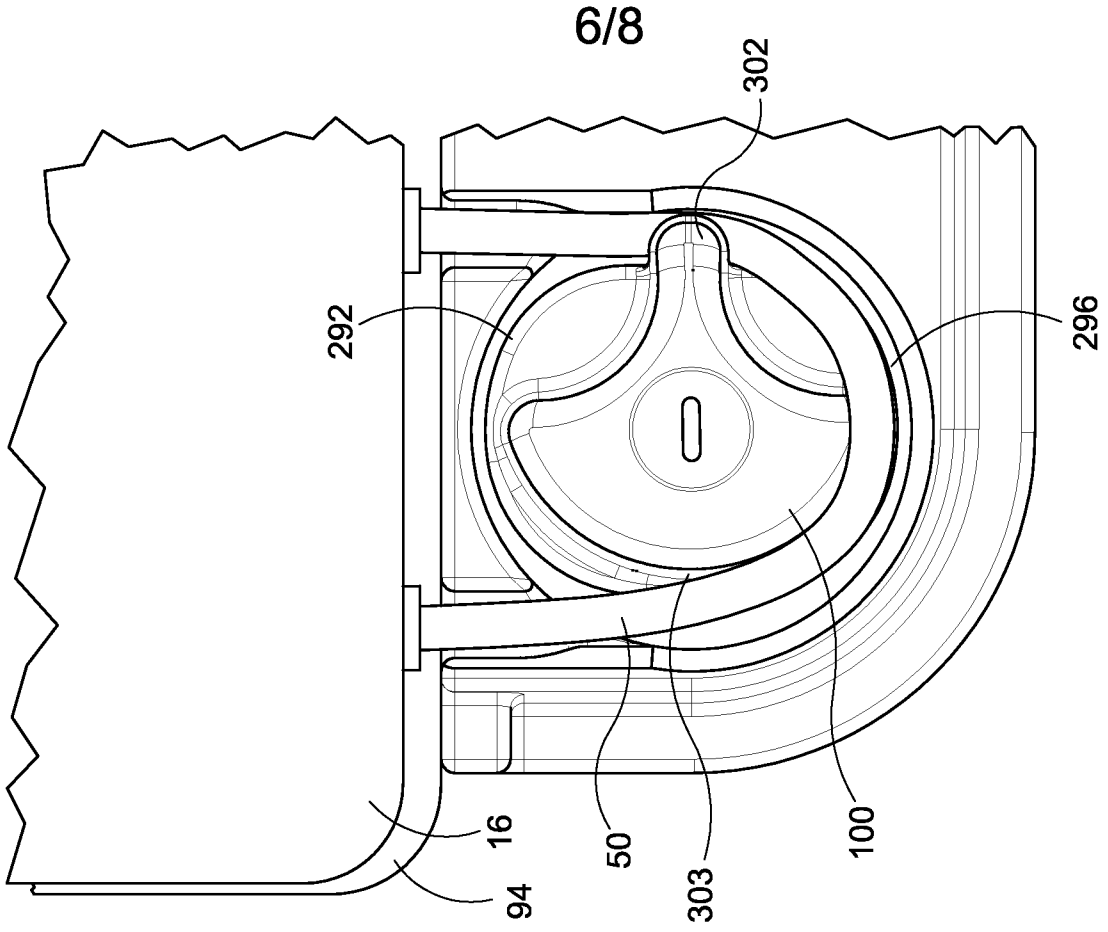


FIG. 4C

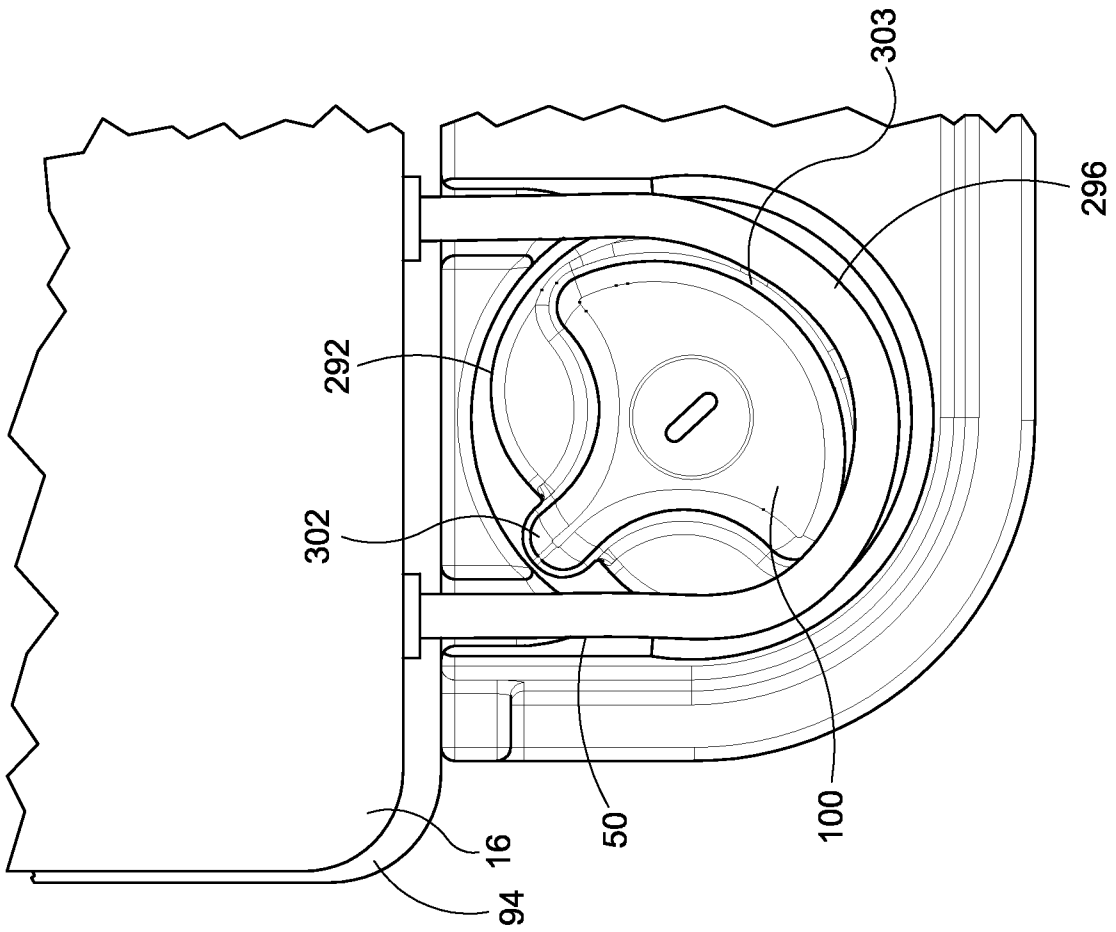


FIG. 4B

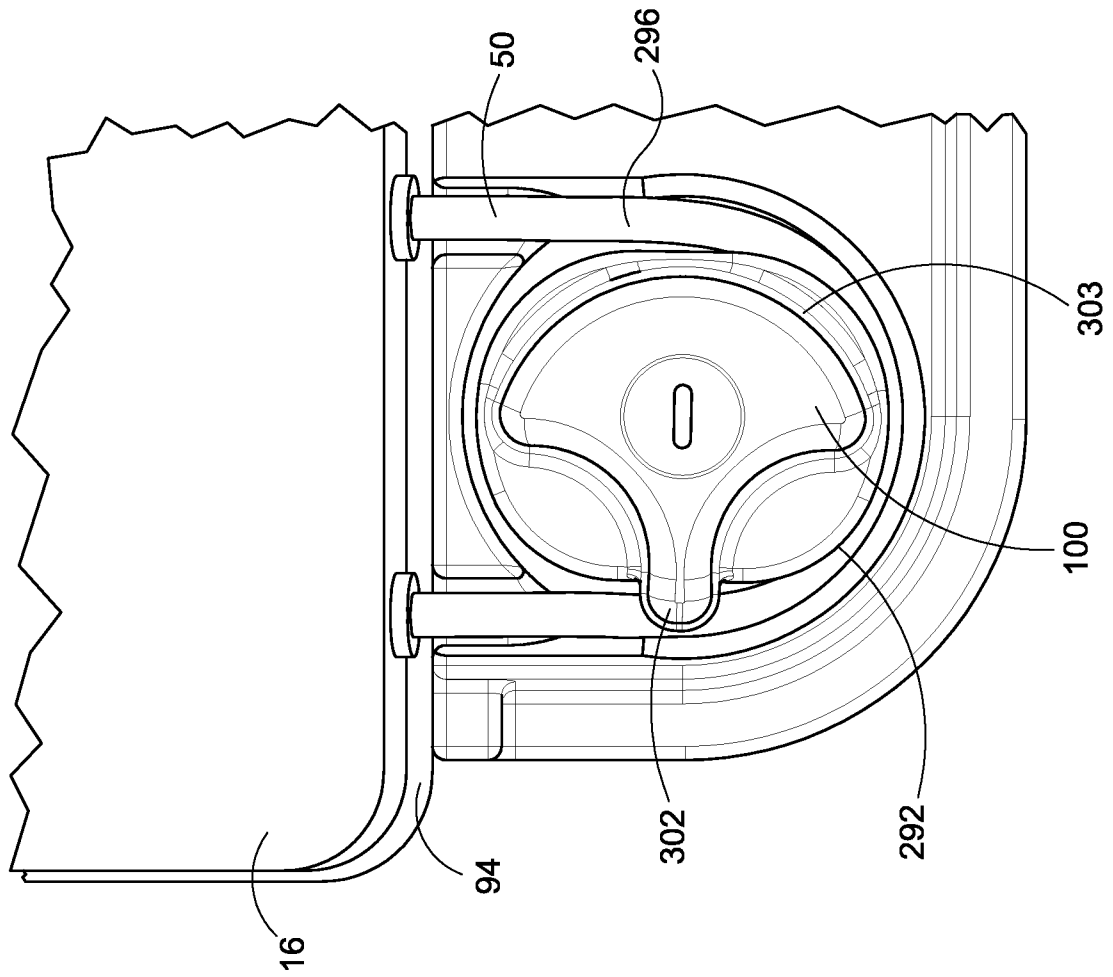


FIG. 5A

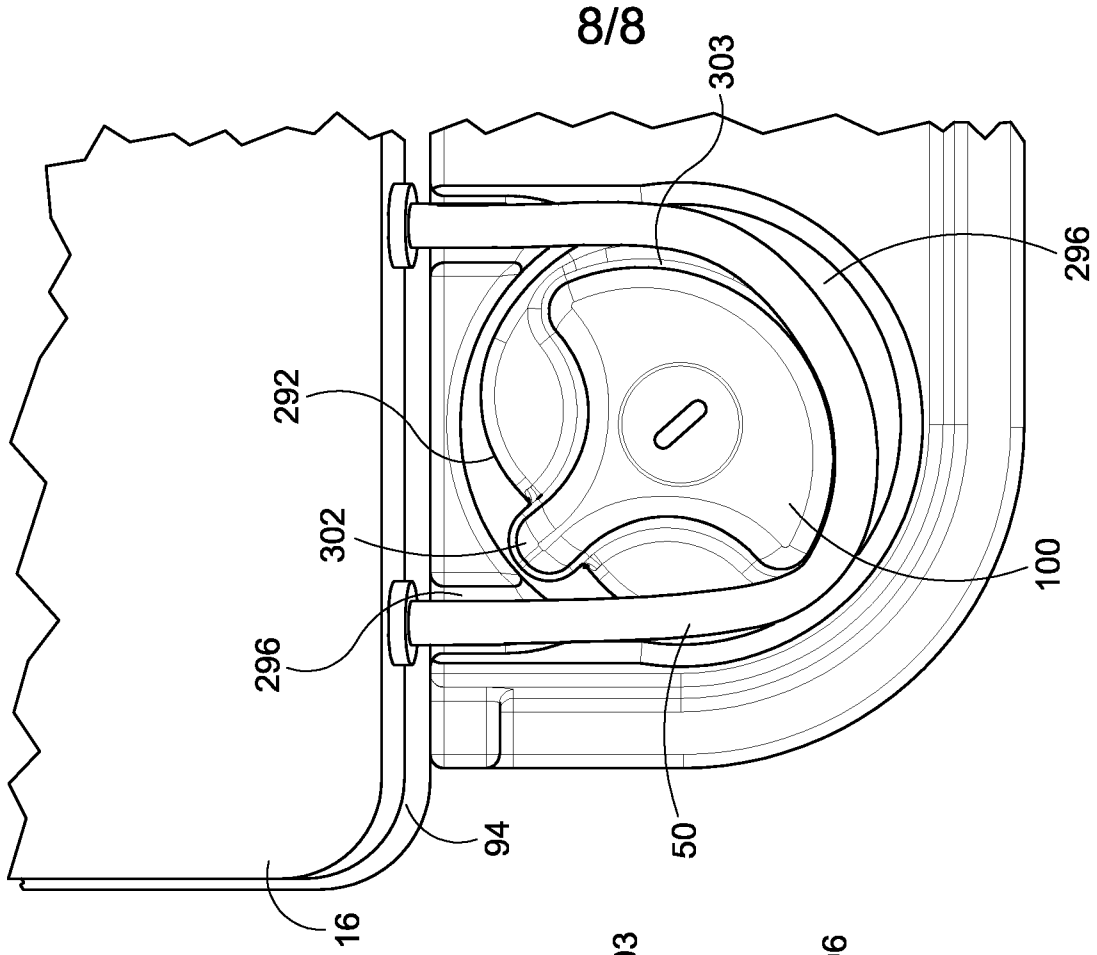


FIG. 5C

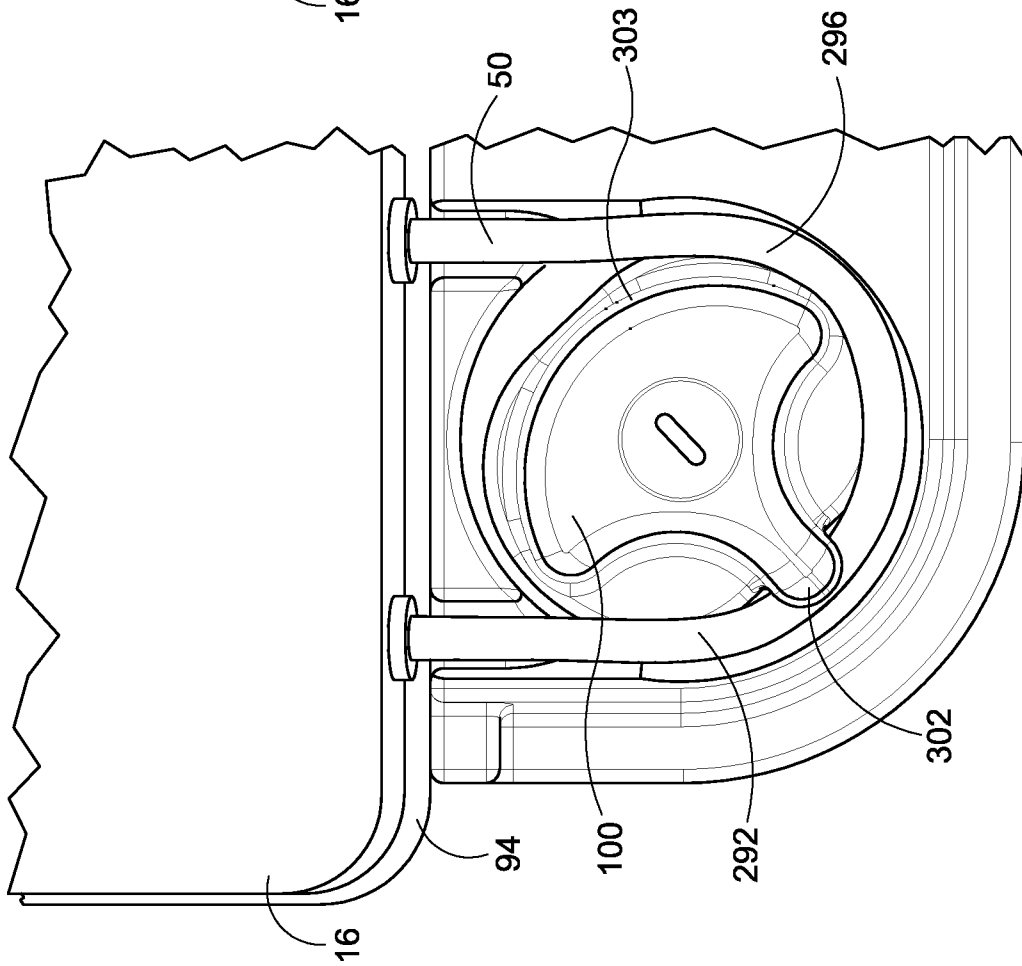


FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/062263

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M1/10
ADD.

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)
A61M

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)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95/17603 A1 (BAXTER INT [US]) 29 June 1995 (1995-06-29) abstract; figures page 49, line 22 - line 27 page 53, line 15 - line 27 -----	1-20
A	WO 2009/025686 A1 (KLEIN JEFFREY A [US]) 26 February 2009 (2009-02-26) abstract; figures -----	1
A	WO 2007/038364 A2 (MEDTRONIC INC [US]; LAWRENCE ROBERT JOHN [US]; CARPENTER WALTER LEE [U] 5 April 2007 (2007-04-05) abstract; figures -----	1

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	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 29 January 2016	Date of mailing of the international search report 08/02/2016
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Walvoort, Bert
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/062263

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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			US 2008213113 A1 04-09-2008
			WO 2007038364 A2 05-04-2007
