

## (51) International Patent Classification:

*F16K 1/34* (2006.01)      *F16K 1/38* (2006.01)  
*A61K 51/00* (2006.01)      *F16K 15/14* (2006.01)  
*A61M 39/26* (2006.01)      *F16K 15/16* (2006.01)  
*B65D 47/20* (2006.01)

## (21) International Application Number:

PCT/US2016/029242

## (22) International Filing Date:

25 April 2016 (25.04.2016)

## (25) Filing Language:

English

## (26) Publication Language:

English

## (30) Priority Data:

62/151,497      23 April 2015 (23.04.2015)      US

## (71) Applicant: HALKEY-ROBERTS CORPORATION

[US/US]; 2700 Halkey-Roberts Place North, St. Petersburg, FL 33716 (US).

## (72) Inventors: STANTON, Katherine, J.; 10475 Gandy

Blvd., St. Petersburg, FL 33702 (US). BELLO, Stephen, P.; 1466 Bugle Lane, Clearwater, FL 33764 (US).

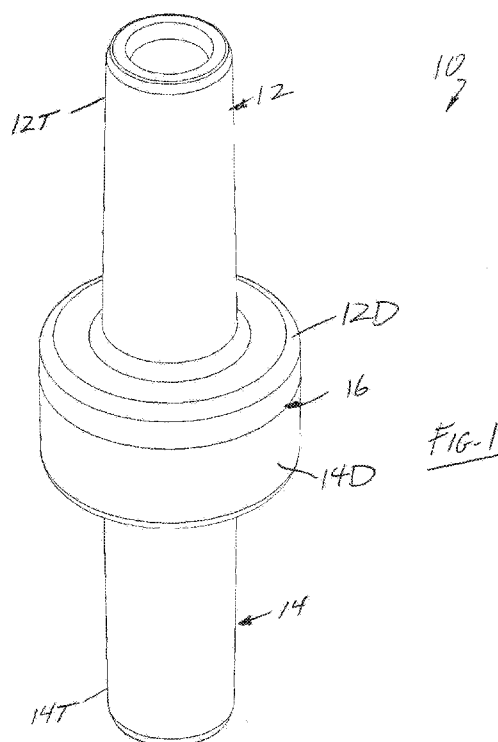
(74) Agents: STEIN, Stefan, V. et al.; GrayRobinson, P.A., 401 E. Jackson Street, Suite 2600, Tampa, FL 33602 (US).

(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, 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).

[Continued on next page]

## (54) Title: HIGH PRESSURE DOME CHECK VALVE



(57) Abstract: A check valve including an elastomeric valve element having a dome-shaped configuration that seals in its at-rest position occluding fluid flow in both directions. The dome-shaped elastomeric valve element is constructed in such a way to be deflectable, such as being activated by the external device such as a male luer whereupon the valve is cracked open to become a two-way valve allowing flow in both directions. The valve element may also be cracked open by sufficient fluid pressure in its inlet. The valve element is self-aligning. The dome-shaped of the valve element includes cut-outs for additional fluid flow, thereby streamlining flow while reducing the potential for air entrapment. The underside of the dome-shaped valve element also includes a thickened concave undersurface and thickened support legs to significantly increase the resistance to high backpressures, while also minimizing potential air entrapment.



---

**Published:**

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

## HIGH PRESSURE DOME CHECK VALVE

### [001] CROSS-REFERENCE TO RELATED INVENTIONS

[002] This application claims the benefit of provisional application number 62/151,497, filed April 23, 2015, the disclosure of which is hereby incorporated by reference herein.

### [003] BACKGROUND OF THE INVENTION

#### [004] Field of the Invention

[005] This invention relates to check valves, and relates more specifically to a check valve for medical usage.

#### [006] Description of the Background Art

[007] Presently, there are many types of check valves which are designed to control the one-way flow of a fluid therethrough. One common type of check valve comprises a valve element, such as a ball or spring biased valve stem, reciprocatingly positioned within a valve body providing a fluid passageway. The flow of fluid in one direction through the valve body is permitted upon displacement of the stem as it flows around the valve stem to exit the valve body. In the opposite direction, however, the fluid pressure along with the spring forces the valve stem against a valve seat, thereby inhibiting, or checking the flow of fluid therethrough. In this manner, this type of check valve effectively provides that fluid can flow only in one direction through the check valve. An example of this type of valve is found in United States Patent No. 5,349,984, the disclosure of which is hereby incorporated by reference herein.

**[0008]** Check valves employing an elastomeric stem without the use of a spring are described in U.S. Patent No. 3,831,629, the disclosure of which is hereby incorporated by reference herein. Other check valves employing umbrella or disk-like elastomeric elements are described in the following U.S. Patents: 5,992,462; 4,499,916 and 4,369,812, the disclosures of which are hereby incorporated by reference herein. Some check valves employ elastically deformable diaphragm-like elements as described in U.S. Patent 6,390,120, the disclosure of which is hereby incorporated by reference herein. Another check valve employing conical or hollow elastomeric elements where fluid flow is arranged to pass through the element itself is described in U.S. Patents 5,573,516 and 5,746,414, the disclosures of which are hereby incorporated by reference herein. Some of the designs described above allow for bi-directional fluid flow if accessed by the appropriate connector such as a luer fitting commonly used in the medical fluid delivery field.

**[0009]** More contemporary check valves are reflected in U.S. Patents 7,296,782 and 7,641,174 entitled "Dome Check Valve", the disclosures of which are hereby incorporated by reference herein. The present invention represents an improvement over such dome check valves to increase the operation of the valve at high pressures.

**[0010]** Therefore, it is an object of this invention to provide an improvement which overcomes the aforementioned inadequacies of the prior art devices and provides an improvement which is a significant contribution to the advancement of the check valve art.

**[0011]** Another object of this invention is to provide a valve that seals itself to restrict fluid flow at very high back pressure on the order of about 1200 psi.

**[0012]** Another object of this invention is to provide a valve that includes a valve element made from a dome-like shaped elastomeric material which seals in its at-rest position occluding fluid flow in both directions.

**[0013]** Another object of this invention is to provide a valve including a dome-shaped elastomeric valve element that is constructed in such a way to be deflectable, such as being activated by the external device such as a male luer whereupon the valve is cracked open to become a two-way valve allowing flow in both directions.

**[0014]** Another object of this invention is to provide a valve having a valve element that is self-aligning.

**[0015]** Another object of this invention is to provide a valve having a valve element is self-supporting and when assembled in the valve, exerts a predetermined pressure against the valve seat thus sealing the valve, the valve element deflecting at the center after pressure rises over the cracking pressure or by being accessed by a syringe or other device, thus opening the bi-directional flow path.

**[0016]** Another object of this invention is to provide a valve having a dome-shaped valve element wherein the dome includes cut-outs for additional fluid flow, thereby streamlining flow while reducing the potential for air entrapment.

**[0017]** Another object of this invention is to provide a valve having a dome-shaped valve element having a thickened concave undersurface and thickened support

legs to significantly increase the resistance to high backpressures, while also minimizing potential air entrapment that might otherwise occur underneath the prior art dome check valves noted above.

**[0018]** The foregoing has outlined some of the pertinent objects of the invention. These objects should be construed to be merely illustrative of some of the more prominent features and applications of the intended invention. Many other beneficial results can be attained by applying the disclosed invention in a different manner or modifying the invention within the scope of the disclosure. Accordingly, other objects and a fuller understanding of the invention may be had by referring to the summary of the invention and the detailed description of the preferred embodiment in addition to the scope of the invention defined by the claims taken in conjunction with the accompanying drawings.

**[0019]** SUMMARY OF THE INVENTION

**[0020]** For the purpose of summarizing the invention, this invention comprises a valve that seals itself to restrict fluid flow at very high back pressure on the order of about 1200 psi. The valve includes a valve element made from a dome-like shaped elastomeric material which seals in its at-rest position occluding fluid flow in both directions. The dome-shaped elastomeric valve element is constructed in such a way to be deflectable, such as being activated by the external device such as a male luer whereupon the valve is cracked open to become a two-way valve allowing flow in both directions. The valve element may also be cracked open by sufficient fluid pressure in its inlet. The valve element is self-aligning. The valve element is designed in such a way that various opening pressures are achievable by a simple modification of a mold tool, for example by changing a core pin.

**[0021]** The valve element of the valve is self-supporting and when assembled in the valve, exerts a predetermined pressure against the valve seat thus sealing the valve. The element deflects at the center after pressure rises over the predetermined cracking pressure or by being accessed by a syringe or other device, thus opening the bi-directional flow path.

**[0022]** Unlike the prior art dome check valves noted above, the dome of the valve element includes cut-outs for additional fluid flow, thereby streamlining flow while reducing the potential for air entrapment. The underside of the dome-shaped valve element also includes a thickened concave undersurface and thickened support legs to

significantly increase the resistance to high backpressures, while also minimizing potential air entrapment that might otherwise occur underneath the prior art dome check valves noted above.

**[0023]** The valve housing is manufactured in a modular fashion, allowing the assembly of the same valve element into various housings having different connecting arrangements, such as ML, MLL, tubing fitment or barbed connector. The components are producible reliably by high cavitation molds and are suitable for high speed assembly process, thereby resulting in a highly economical valve. None of the valve components require registration radially during assembly.

**[0024]** The foregoing has outlined rather broadly the more pertinent and important features of the present invention in order that the detailed description of the invention that follows may be better understood so that the present contribution to the art can be more fully appreciated. Additional features of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.



**[0025]**                      BRIEF DESCRIPTION OF THE DRAWINGS

**[0026]**                      For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

**[0027]**                      Fig. 1 is an enlarged isometric view of the valve of the invention having tubular inlet and outlet arrangements;

**[0028]**                      Fig. 2 is a top exploded view of Fig. 1 showing the inlet housing, the valve element and the outlet housing;

**[0029]**                      Fig. 3 is a bottom exploded view of Fig. 1 showing the inlet housing, the valve element and the outlet housing;

**[0030]**                      Figs. 4 is an enlarged top perspective view of the valve element;

**[0031]**                      Fig. 5 is an enlarged bottom perspective view of the valve element;

**[0032]**                      Fig. 6 is a cross-sectional view of Fig. 4 along lines 6-6;

**[0033]**                      Fig. 7 is a cross-sectional view of Fig. 4 along lines 7-7; and

**[0034]**                      Fig. 8 is a longitudinal cross-sectional view of Fig. 1.

**[0035]**                      Similar reference characters refer to similar parts throughout the several views of the drawings.

**[0036]**      DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0037]**      As best shown in Fig. 1, the valve 10 of the invention comprises inlet housing 12 and an outlet housing 14 fastened, preferably permanently, together at joint 16 such as by welding or bonding. The inlet and outlet housing 12 & 14 include tube fittings 12T and 14T respectively; however, it shall be appreciated that the housing 12 & 14 may include other types of fittings such as a luer lock fitting without departing from the spirit and scope of this invention. For example, one or both of the inlet and outlet housings 12 & 14 may be provided with barbed hose fittings, luer fittings or locking luer fitting (see the various embodiments in the Dome Check Valves of U.S. Patents 7,296,782 and 7,641,174 cited above). Both the inlet and outlet housing 12 & 14 further include a generally dome-shaped larger diameter configuration 12D and 14D respectively, that are appropriately configured to mate together to then be fastened at joint 16.

**[0038]**      As shown in Figs. 2 and 3, an elastomeric dome-shaped valve element 18 is entrained between the dome-shaped larger diameter configurations 12D & 14D of the inlet and outlet housing 12 & 14.

**[0039]**      As better shown in Figs. 4-7, the valve element 18 comprises a generally dome-shaped configuration 20 with a central integral stem 22, preferably frustoconical, positioned concentrically therewith that extends into the inlet housing 12. The central integral stem 22 comprises a star-shaped configuration with a plurality of equally-spaced radial projections 24 (e.g., 3 are shown respectively positioned at 120 degrees) to allow

fluid flow therearound in the event the stem 22 is engaged by the tip of a luer fitting such as a syringe or other device that might otherwise form a seal therewith if the stem 22 was configured circular cylindrically. Other configurations of the stem 22 may be employed without departing from the spirit and scope of this invention to preclude sealing with the tip of the access device, such as for example the slots and notches shown in the Dome Check Valves of U.S. Patents 7,296,782 and 7,641,174 cited above.

**[0040]** Unlike the Dome Check Valves of U.S. Patents 7,296,782 and 7,641,174 cited above, in the present invention the dome-shaped valve element 18 includes a plurality of equally-spaced cut-outs 26 (six are shown). The cut-outs 26 allow fluid flow therethrough thereby increasing the amount of fluid flow that may flow through the valve 10 when the valve element 18 is cracked open. The cut-outs 26 also streamline the fluid flow while minimizing the potential for air entrapment under the dome-shaped valve element 18. The generally dome-shaped configuration of the valve element 18 further comprises an integral annular skirt 30 extending about its periphery.

**[0041]** It is noted that the plurality of cut-outs 26 define a plurality of equally-spaced legs 28 (six are shown) extending generally radially outward then downwardly to merge into the annular skirt 30. The width of the legs 28 is defined by the width of the cut-outs 26, preferably to thereby define legs 28 having sufficient strength to achieve the desired cracking pressure (i.e., the heavier the legs 28 the stiffer they will be to increase the amount of cracking pressure necessary to crack the valve element 18).

**[0042]** As best shown in Fig. 6 as compared to Fig. 7, each of the legs 28

comprise an outer side wall 32 sloping outwardly from the inlet at a first angle and an inner side wall 34 sloping outwardly from the inlet at a second angle greater than the first angle, thereby achieving a substantially thick configuration. In comparison, the integral annular skirt 30 comprises a substantially thin configuration that serves to stabilize the legs 28 and keep them in their generally radial configuration relative to one another. The bottommost annular edge of the skirt 30 includes an inwardly extending rim 30R of increased thickness to provide additional stability.

**[0043]** Figs. 6 and 7 further illustrate the configuration of the underside of the dome-shaped valve element 18 as including a generally concave portion 36 extending circularly annularly about the underside to define an outwardly extending point 38 in the form of an upside-down three dimensional hyperbolic curve (i.e., similar to the curve of a single pole fabric tent). The concave portion 36 precludes the entrapment of air underneath the valve element 18 that might otherwise occur with the prior art dome check valves noted above. As shown in Fig. 7, the peripheral edges 36E of the concave portion 36 are rounded to blend into the cut-outs 26 and in doing so, as shown in Fig 6, define undercuts 40 between the peripheral edges 36E and the legs 28 while further streamlining the fluid flow through the cut-outs 26. The undercuts 40 function as a living hinge to facilitate the dome-shaped valve element 18 moving inwardly during cracking in a precise, controlled manner while further streamlining the fluid flow around the otherwise sharp corners between the legs 28 and the peripheral edges 36E.

**[0044]** Referring to Fig. 8 in combination with Figs. 2 and 3, the inside of the

dome-shaped larger diameter configuration 12D of the inlet housing 12 comprises an annular valve seat 42 which forms a seal with the upper surface of the dome-shaped configuration 20 of the valve element 18 when the valve element 18 is in its at rest position within the housings 12 & 14. The inside of the dome-shaped larger-diameter configuration 14D of the outlet housing 14 comprises an annular seat 44 on which the inwardly extending rim 30R of the annular skirt 30 is seated when the valve element 18 is in its at rest position within the housings 12 & 14. The inside of the dome-shaped larger-diameter configuration 14D of the outlet housing 14 comprises a plurality of castellations 46 (four are shown) having an inside diameter that is appreciably less than the outside diameter of the hyperbolic curve defined by the concave portion 36 to limit the inward travel of the valve element 18 as it is cracked open. It is noted that the number of legs 28 versus the castellations 46 are preferably different.

**[0045]** In operation, at rest bidirectional fluid flow through the valve 10 is blocked by virtue of the seal formed between the annular valve seat 42 and the upper surface of the dome-shaped configuration 20 of the valve element 18 under the resilient force of the legs 28 and skirt 30. The valve 10 may be opened or "cracked" either by fluid pressure in its inlet housing 12 or by a physical object such as the tip of a syringe that exerts a force on the central integral stem 22 of the valve element 18 against the resilient force of the legs 28 and skirt 30. Once the valve element 18 is cracked opened, fluid flow from the inlet housing 12 flows around the stem 22 radially across the outer surface of the dome-shaped configuration 20 of the valve element 18, through the cut-

outs 26 past the legs 28 and the castellations 46 and then out via outlet housing 14.

Importantly, a substantial flow of fluid is allowed to pass through the valve 10 once the valve element 18 is cracked. Once the cracking pressure is removed, either by the lack of sufficient pressure of the incoming fluid in inlet housing 12 or by removal of the object that cracked the valve 10, the inherent resiliency of the legs 28 and skirt 30 urges the dome-shaped configuration 20 of the valve element 18 back into sealing engagement with the annular valve seat 42 of the inlet housing 12. Preferably, the sealing force caused therebetween is sufficient to assure an adequate seal even when there is no fluid pressure in the outlet housing 14. Moreover, the dome-shaped configuration 20 of the valve element 18 is capable of remaining sealed even when significant back fluid pressure exits in the outlet housing 14. Further, the limited travel of the dome-shaped configuration 20 coupled with its dome-shaped configuration 20, assures that the valve element 18 does not deform (i.e., is not blown out) even when very high pressures exist in the inlet housing 12.

**[0046]** The present disclosure includes that contained in the appended claims, as well as that of the foregoing description. Although this invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and scope of the invention.

**[0047]** Now that the invention has been described,

[0048] WHAT IS CLAIMED IS:

1. A check valve, comprising in combination:  
a housing having an inlet with a dome-shaped interior configuration and an outlet;  
an elastomeric dome-shaped valve element positioned entrained between said inlet and said outlet to seal against said inlet, said valve element having a plurality of cut-outs that allow fluid flow therethrough thereby increasing the amount of fluid flow that may flow through the valve when said valve element is cracked open.
2. The check valve as set forth in Claim 1, wherein said valve element further comprises an integral annular skirt extending about its periphery.
3. The check valve as set forth in Claim 2, wherein said plurality of cut-outs define a plurality of equally-spaced legs extending generally radially outward then downwardly to merge into said annular skirt.
4. The check valve as set forth in Claim 3, wherein a width of said legs is defined by a width of said cut-outs to define said legs whose strength achieves a cracking pressure.
5. The check valve as set forth in Claim 4, wherein said legs each comprise an outer side wall sloping outwardly from said inlet at a first angle and an inner side wall sloping outwardly from said inlet at a second angle greater than said first angle.
6. The check valve as set forth in Claim 5, wherein said integral annular skirt comprises a substantially thin configuration that stabilizes said legs and maintains them in a generally radial configuration relative to one another.
7. The check valve as set forth in Claim 6, wherein a bottommost annular



edge of said skirt includes an inwardly extending rim of increased thickness to provide additional stability.

8. The check valve as set forth in Claim 4, wherein an underside of said valve element includes a generally concave portion extending circularly annularly about said underside to define an outwardly extending point having a form of an upside-down three dimensional hyperbolic curve that precludes entrapment of air underneath said valve element.

9. The check valve as set forth in Claim 8, wherein peripheral edges of said concave portion blend into said cut-outs to define undercuts between said peripheral edges and said legs to function as a living hinge to facilitate said valve element moving inwardly during cracking.

10. The check valve as set forth in Claim 8, wherein said valve element further comprises a central stem.

11. The check valve as set forth in Claim 10, wherein said central stem is frustoconical and extends into said inlet.

12. The check valve as set forth in Claim 10, wherein said central stem comprises a star-shaped configuration with a plurality of equally-spaced radial projections to allow fluid flow therearound.

13. The check valve as set forth in Claim 1, wherein said cut-outs are equally-spaced.

14. The check valve as set forth in Claim 10, wherein said outlet comprises a

dome-shaped interior configuration.

15. The check valve as set forth in Claim 14, wherein said dome-shaped interior configuration of said inlet comprises an annular valve seat which forms a seal with an upper surface of said valve element when said valve element is in its at rest position within the housing.

16. The check valve as set forth in Claim 15, wherein said dome-shaped interior configuration of said outlet comprises an annular seat on which said inwardly extending rim of said annular skirt is seated when said valve element is in its at rest position.

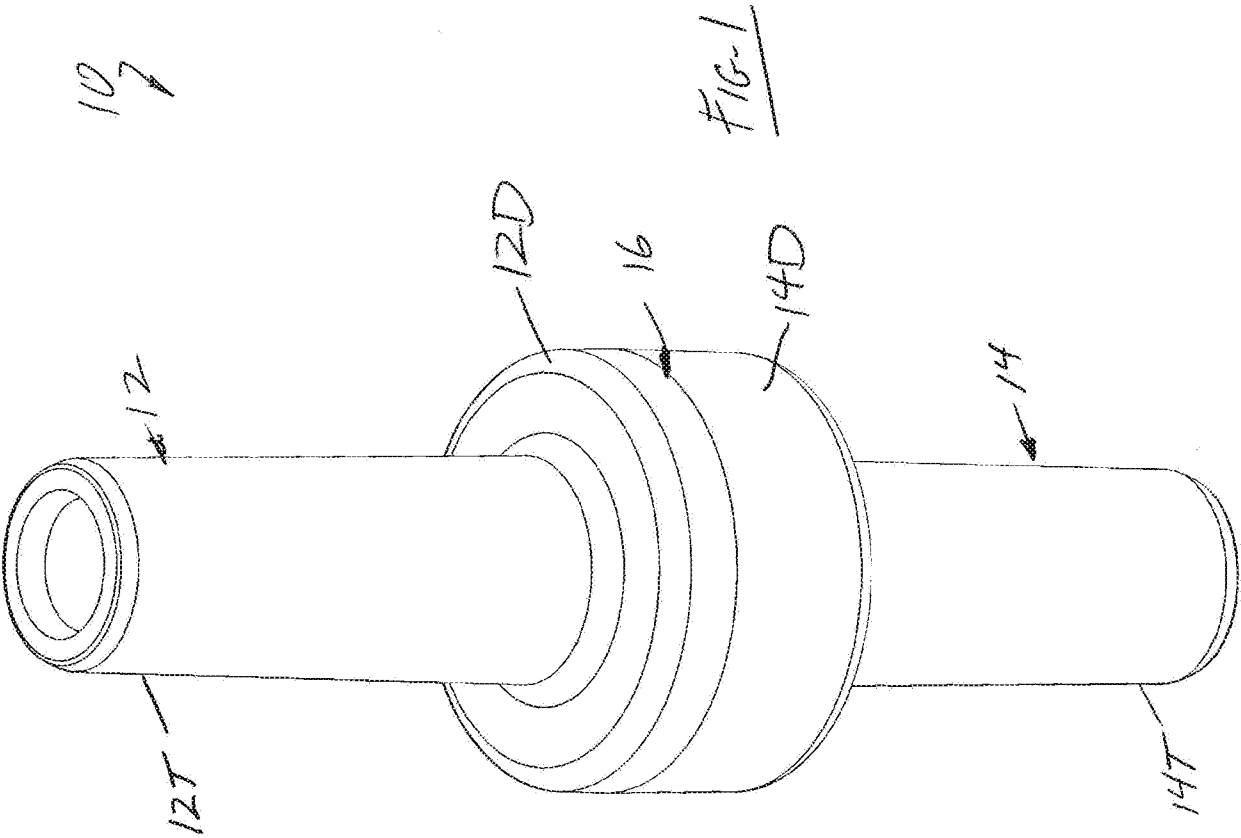
17. The check valve as set forth in Claim 16, wherein said dome-shaped interior configuration of said outlet comprises a plurality of castellations having an inside diameter that is appreciably less than an outside diameter of said hyperbolic curve defined by said concave portion to limit inward travel of said valve element as it is cracked open.

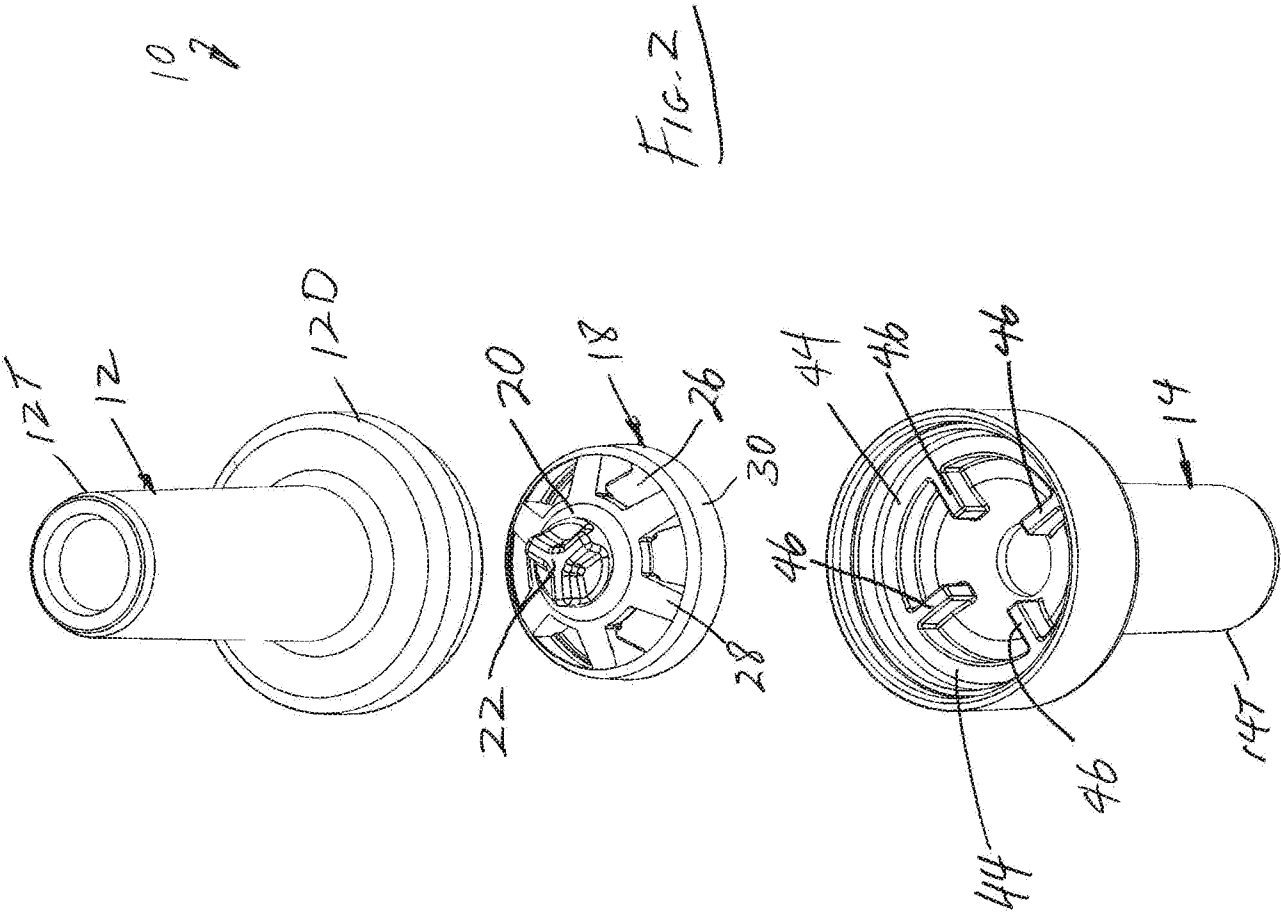
18. The check valve as set forth in Claim 17, wherein a number of said legs is different than a number of said castellations.

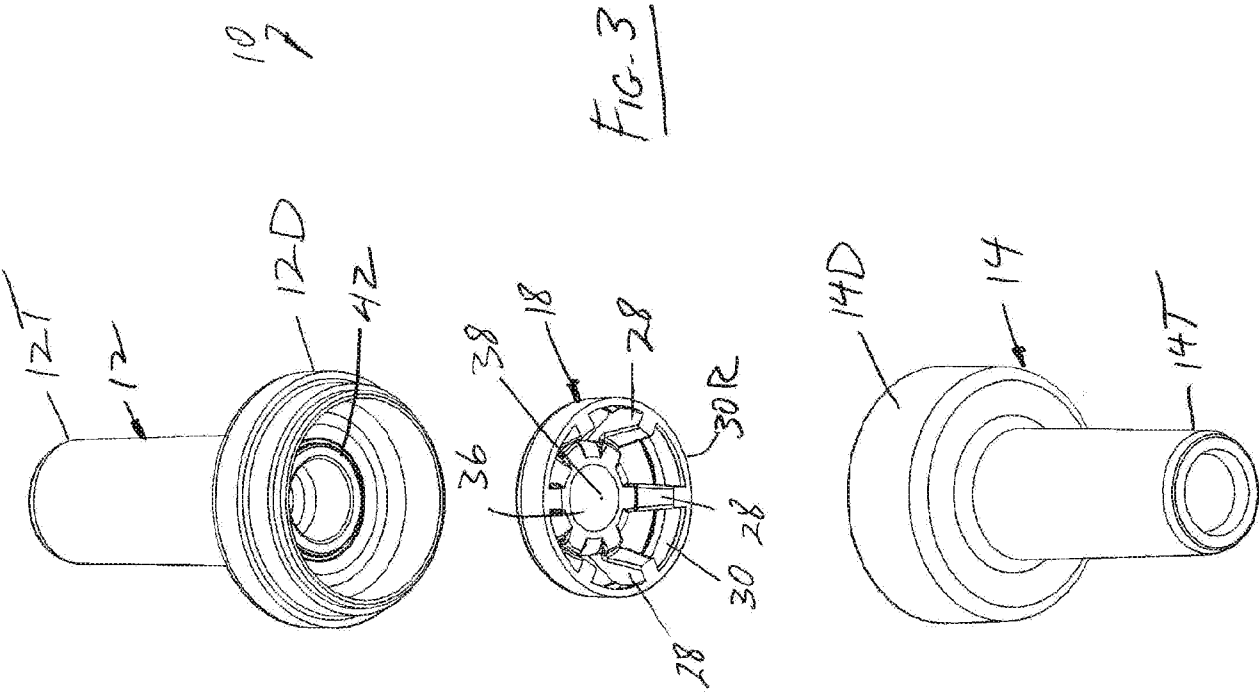
19. The check valve as set forth in Claim 18, wherein, at rest bidirectional fluid flow through the valve is blocked by virtue of the seal formed between said annular valve seat and said upper surface of said valve element under the resilient force of said legs and said skirt.

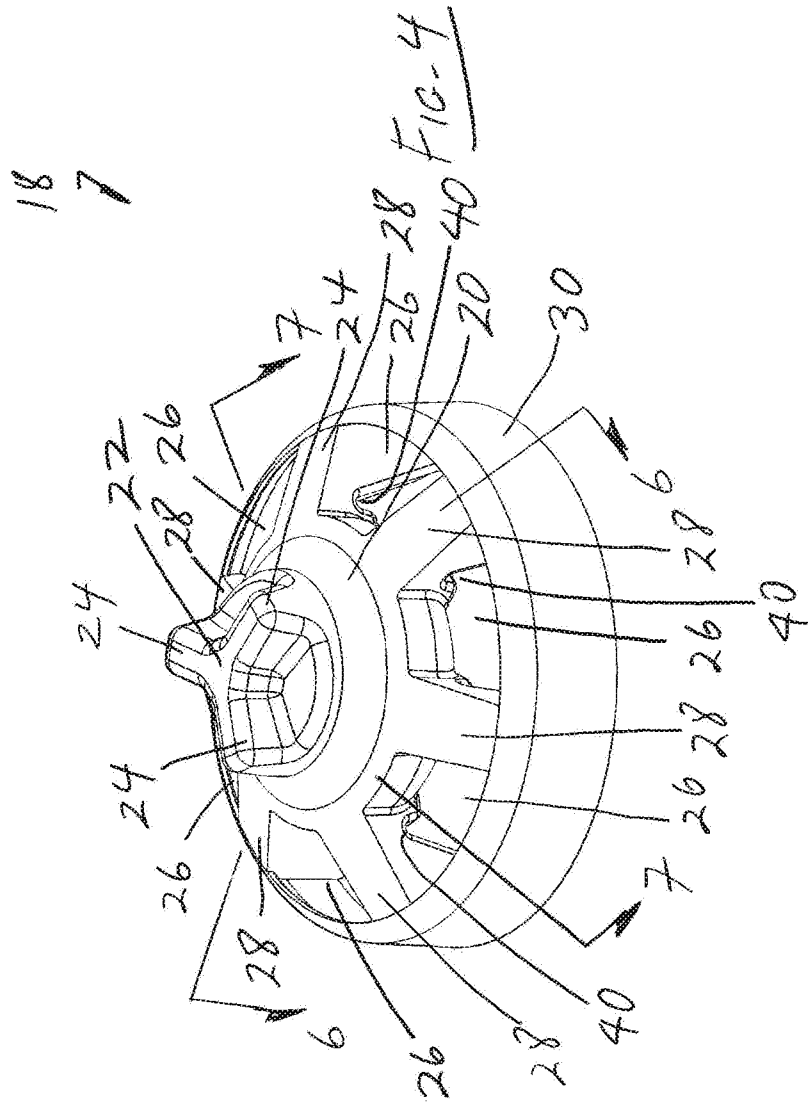
20. The check valve as set forth in Claim 19, wherein the valve may be

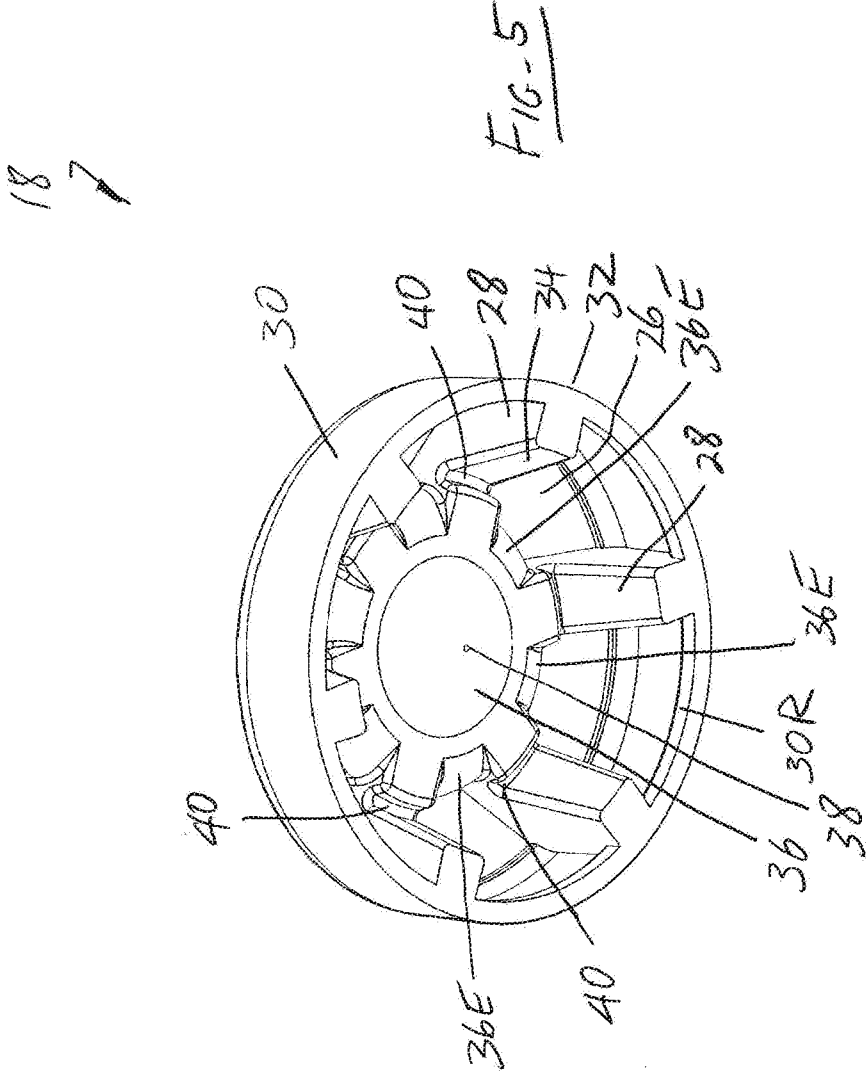
cracked open by a physical object inserted into said inlet that exerts a force on said central stem against the resilient force of said legs and said skirt, whereupon fluid flow from said inlet flows around said central stem radially across said outer surface of said valve element, through said cut-outs past said legs and said castellations and then exit via said outlet.



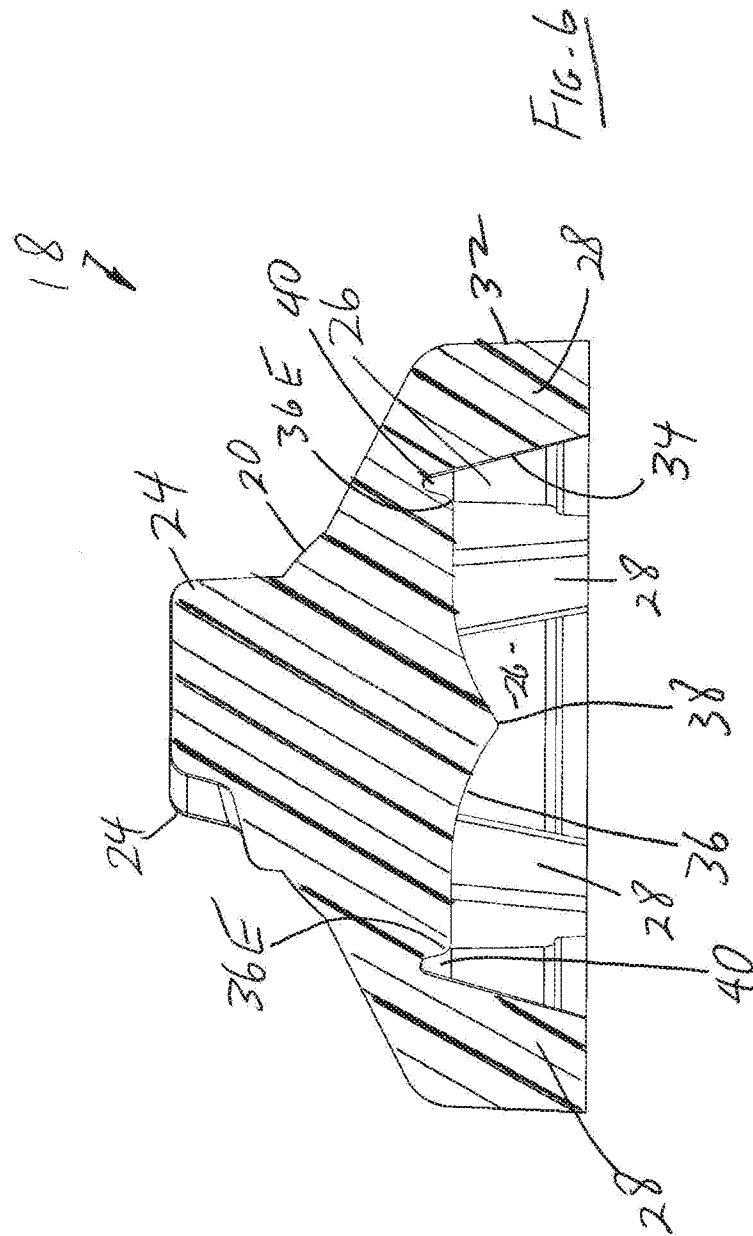


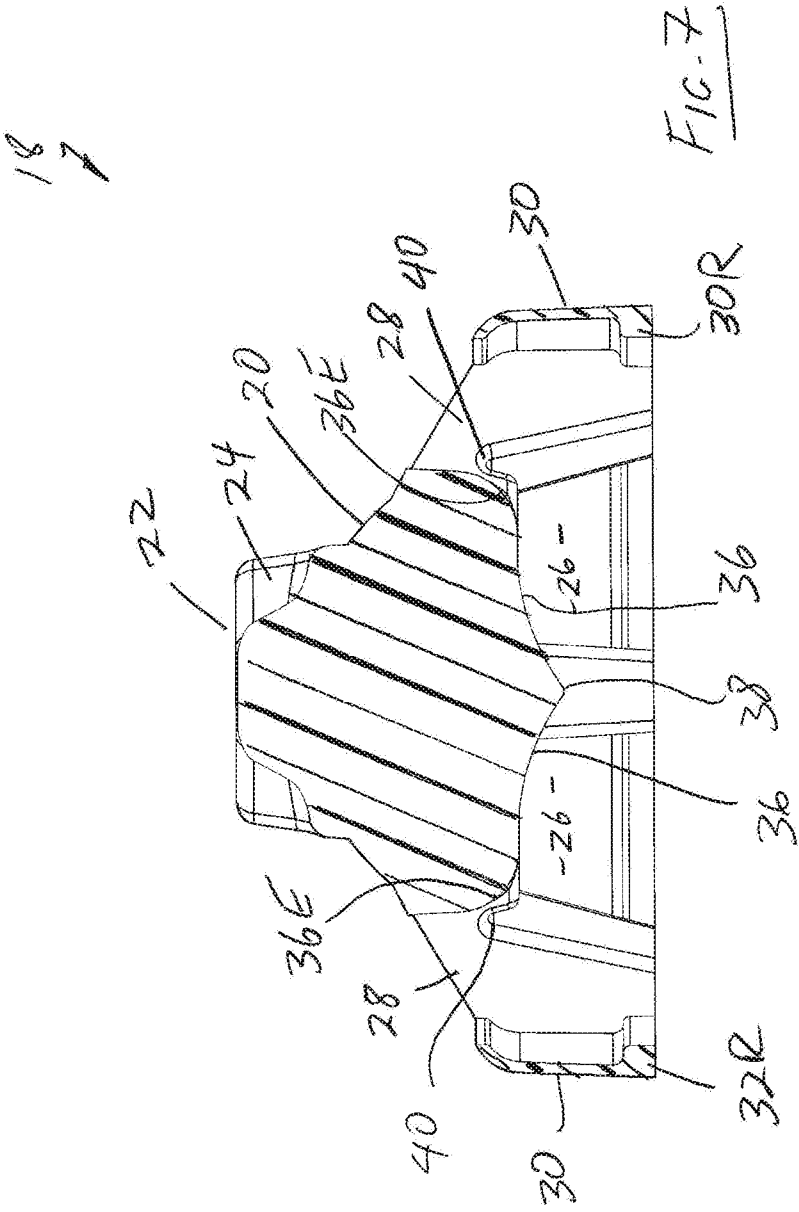


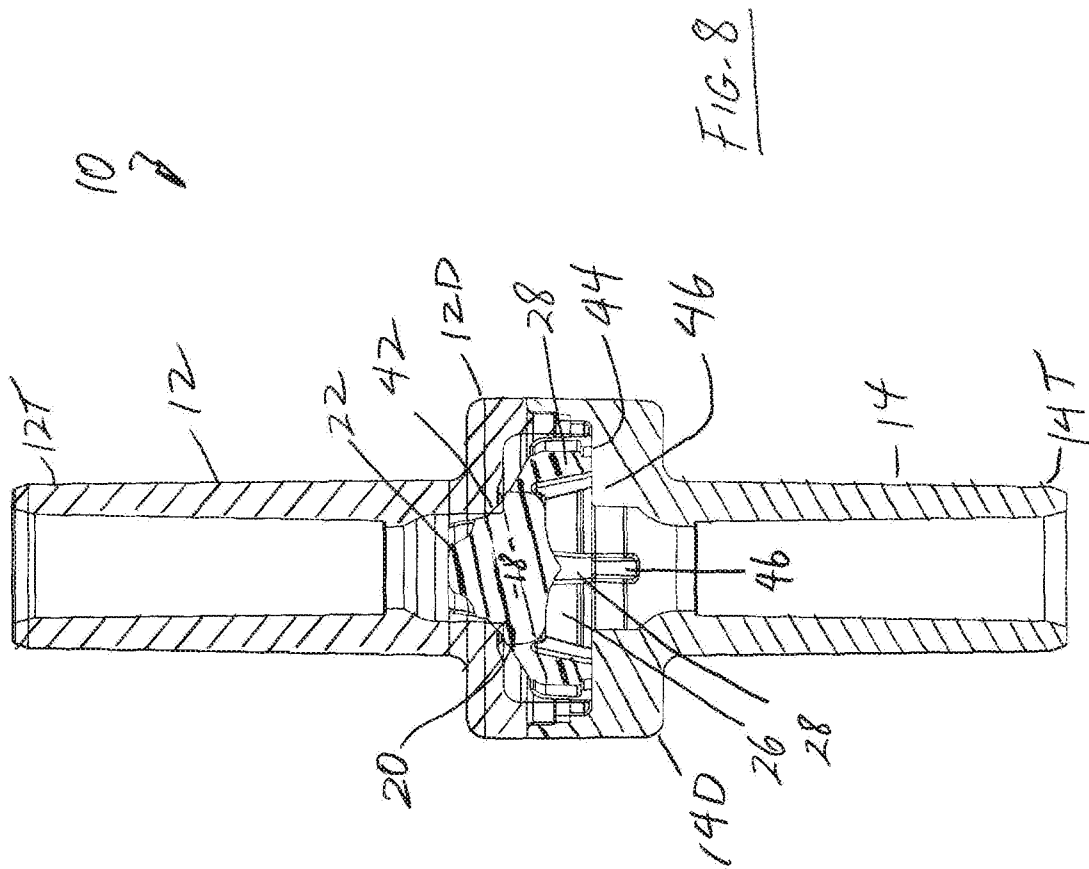












## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/029242

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F16K 1/34; A61K 51/00; A61M 39/26; B65D 47/20; F16K 1/38; F16K 15/14; F16K 15/16 (2016.01)

CPC - F16K 1/34; A61M 39/26; B65D 47/20; B65D 47/2018; F16K 1/38; F16K 15/14 (2016.05)

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 - A61K 51/00; A61M 39/26; B65D 47/20; F16K 1/34; F16K 1/38; F16K 15/14; F16K 15/16; F16K 51/00; F16L 29/00

CPC - A61M 39/26; B65D 47/20; B65D 47/2018; F16K 1/34; F16K 1/38; F16K 15/14; F16K 15/141; F16K 15/16; Y10T 137/7895

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

USPC - 137/859; 251/149.6; 251/149.7; 604/249; 604/256

IPC(8) cont. - F16L 37/28 (keyword delimited)

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

PatBase, Google Scholar, Google

Search terms used: Check valve, one way valve, valve element, windows, cut outs, flow passages, living hinge, legs, annular skirt, elastomeric, castellations, prevent trapped gas, preclude entrapped gas

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7,296,782 B2 (ENERSON et al) 20 November 2007 (20.11.2007) entire document	1-4, 13
Y	US 2013/0160891 A1 (BERRY PLASTICS CORPORATION) 27 June 2013 (27.06.2013) entire document	1-4, 13
A	US 7,291,133 B1 (KINDLER et al) 06 November 2007 (06.11.2007) entire document	1-20
A	US 4,749,003 A (LEASON) 07 June 1988 (07.06.1988) entire document	1-20
A	US 5,573,516 A (TYNER) 12 November 1996 (12.11.1996) entire document	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

"&amp;" document member of the same patent family

Date of the actual completion of the international search

28 June 2016

Date of mailing of the international search report

27 JUL 2016

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, VA 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774