(12) STANDARD PATENT (11) Application No. AU 2012355357 B2
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Internal baffle for suppressing slosh in a core-in-shell heat exchanger

(51) International Patent Classification(s)
F28F 9/22 (2006.01)

(21) Application No: **2012355357** (22) Date of Filing: **2012.12.18**

(87) WIPO No: **WO13/096323**

(30) Priority Data

(31) Number	(32) Date	(33) Country
13/718,240	**2012.12.18**	**US**
61/578,133	**2011.12.20**	**US**

(43) Publication Date: **2013.06.27**
(44) Accepted Journal Date: **2016.12.22**

(71) Applicant(s)
ConocoPhillips Company

(72) Inventor(s)
Davies, Paul R.;James, Will T.;Gravois, Shaun P.;Oshinowo, Olanrewaju M.

(74) Agent / Attorney
Phillips Ormonde Fitzpatrick, L 16 333 Collins St, Melbourne, VIC, 3000

(56) Related Art
US 5651270 A
US 6164247 A
US 3326280 A

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 June 2013 (27.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/096323 A1

(51) International Patent Classification: ***F28F 9/22*** (2006.01)

(21) International Application Number: PCT/US2012/070374

(22) International Filing Date: 18 December 2012 (18.12.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/578,133 20 December 2011 (20.12.2011) US
13/718,240 18 December 2012 (18.12.2012) US

(71) Applicant: **CONOCOPHILLIPS COMPANY** [US/US]; IP Services Group - Attn: Docketing, 600 N. Dairy Ashford Bldg. ML-1065, Houston, Texas 77079 (US).

(72) Inventors: **DAVIES, Paul R.**; 4315 Colony West, Richmond, Texas 77406 (US). **JAMES, Will T.**; 11007 Brighton Gardens Drive, Richmond, Texas 77406 (US). **GRAVOIS, Shaun P.**; 21522 Santa Clara Drive, Katy, Texas 77450 (US). **OSHINOWO, Olanrewaju M.**; 6434 Haywards Crossing S. Cir., Katy, Texas 77494 (US).

(74) Agent: **PIO, Michael Sungjoon**; Conocophillips Company, IP Services Group - Attn: Docketing, 600 N. Dairy Ashford, Houston, TX 77079 (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, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, 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, 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, ML, MR, NE, SN, TD, TG).

Published:

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

(54) Title: INTERNAL BAFFLE FOR SUPPRESSING SLOSH IN A CORE-IN-SHELL HEAT EXCHANGER

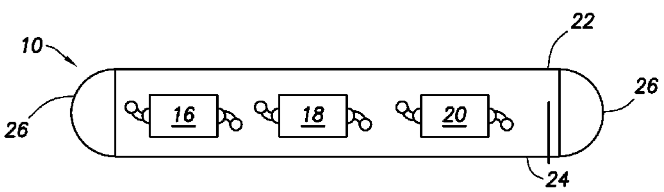

FIG. 1

(57) Abstract: Apparatuses and methods for suppressing slosh in a core-in-shell type heat exchanger are provided. One embodiments provides a heat exchanger including: (a) an internal volume defined within a shell; (b) a plurality of spaced apart cores disposed within the internal volume of the shell, and (c) slosh suppressing baffles disposed within the internal volume to separate the plurality of spaced apart cores, wherein each core is partially submerged in a liquid shell-side fluid, wherein the slosh suppressing baffles allow limited distribution of the liquid shell-side fluid between each core, wherein the slosh suppressing baffles can withstand cryogenic temperatures, wherein the slosh suppressing baffles can withstand and divert the flow of the liquid shell-side fluid between each core.

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INTERNAL BAFFLE FOR SUPPRESSING SLOSH IN A CORE-IN-SHELL HEAT EXCHANGER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority benefit under 35 U.S.C. Section 119(e) to U.S. Provisional Patent Serial No. 61/578,133 filed on December 20, 2011, the entire disclosure of which is incorporated herein by reference and is related to "Method and Apparatus for Reducing the Impact of Motion in a Core-in-Shell Heat Exchanger" filed on December 18, 2012.

FIELD OF THE INVENTION

[0002] This invention relates to a baffle for suppressing slosh in a core-in-shell type heat exchanger.

BACKGROUND OF THE INVENTION

[0002a] A reference herein to a patent document or other matter which is given as prior art is not to be taken as an admission that that document or matter was known or that the information it contains was part of the common general knowledge as at the priority date of any of the claims.

[0003] Natural gas in its native form must be concentrated before it can be transported economically. The use of natural gas has increased significantly in the recent past due to its environmentally-friendly, clean burning characteristics. Burning natural gas produces less carbon dioxide than any other fossil fuel, which is important since carbon dioxide emissions have been recognized as a significant factor in causing the greenhouse effect. Liquefied natural gas (LNG) is likely to be used more and more in densely-populated urban areas with the increased concern over environmental issues.

[0004] Abundant natural gas reserves are located all over the world. Many of these gas reserves are located offshore in places that are inaccessible by land and are considered to be stranded gas reserves based on application of existing technology. Existing technical reserves of gas are being replenished faster than oil reserves, making the use of LNG more important to meeting the demands of future energy consumption. In liquid form, LNG occupies 600 times less space than natural gas in its gaseous phase. Since many areas of the world cannot be reached by pipelines due to technical, economic, or political limits, locating the LNG processing plant offshore and utilizing a nautical vessels to directly transport the LNG offshore from the processing plant to the transportation vessel can reduce initial capital expenditure and release otherwise uneconomical offshore gas reserves.

[0005] Floating liquefaction plants provide an off-shore alternative to on-shore liquefaction plants and alternative to costly subsea pipeline for stranded offshore reserves. A floating liquefaction plant can be moored off the coast, or close to or at a gas field. It also represents a moveable asset, which can be relocated to a new site when the gas field is nearing the end of its production life, or when required by economic, environmental or political conditions.

[0006] One problem encountered in floating liquefaction vessels is the sloshing of vaporizing fluid inside heat exchangers. Sloshing in a heat exchanger may result in the production of forces that can affect stability and control of the heat exchanger. If the vaporizing fluid is allowed to slosh freely inside the shell of the heat exchanger, the moving fluid can have an adverse effect on the thermal function of the heat exchanger core. Furthermore, the cyclical nature of motion may result in cyclical behavior in heat transfer efficiency, and hence, process conditions in the LNG liquefaction plant may be impacted. These instabilities may result in poorer overall plant performance and may lead to narrower operating envelopes and limits to the available production capacity.

[0007] Therefore, a need exists for a slosh suppressing baffle to reduce the impact of motion within a core-in-shell type heat exchanger.

SUMMARY OF THE INVENTION

[0008] In an embodiment, a heat exchanger includes: (a) an internal volume defined within a shell; (b) a plurality of spaced apart cores disposed within the internal volume of the shell, and (c) slosh suppressing baffles disposed within the internal volume to separate the plurality of spaced apart cores, wherein each core is partially submerged in a liquid shell-side fluid, wherein the slosh suppressing baffles allow limited distribution of the liquid shell-side fluid between each core, wherein the slosh suppressing baffles can withstand cryogenic temperatures, wherein the slosh suppressing baffles can withstand and divert the flow of the liquid shell-side fluid between each core.

[0009] In another embodiment, a method for reducing the impact of motion in a heat exchanger, wherein the heat exchanger includes an internal volume defined within a shell, wherein the internal volume within the shell includes a plurality of spaced apart cores, said method includes: (a) installing slosh suppressing baffles within the internal volume within the shell, wherein the slosh suppressing baffles separate the plurality of cores in the internal volume; (b) partially submerging each core in a liquid shell-side fluid, wherein the slosh suppressing baffles allow limited distribution of the liquid shell-side fluid between each core; (c) introducing a core-side fluid into each core; (d) cooling the core-side fluid thereby producing a cooled stream in each core; and (e)withdrawing the cooled stream from each core.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention, together with further advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

[0011] FIG. 1 is a schematic of a core-in-shell type heat exchanger.

[0012] FIG. 2 is a schematic of a core-in-shell type heat exchanger, according to one embodiment of the invention.

[0013] FIG. 3 is a schematic of a core-in-shell type heat exchanger, according to one embodiment of the invention.

[0014] FIG. 4 is a schematic of a core-in-shell type heat exchanger, according to one embodiment of the invention.

[0015] FIG. 5 is a schematic of a core-in-shell type heat exchanger, according to one embodiment of the invention.

[0016] FIG. 6 is a schematic of a core-in-shell type heat exchanger, according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Reference will now be made in detail to embodiments of the present invention, one or more examples of which are illustrated in the accompanying drawings. Each example is provided by way of explanation, not as a limitation. It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used in another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modifications and variations that come within the scope of the appended claims and their equivalents.

[0018] Referring to FIG. 1, a heat exchanger 10 is illustrated generally comprising a shell 12 and a plurality of spaced apart cores, i.e., a first core 16, a second core 18, and a third core 20. The plurality of spaced apart cores within the heat exchanger includes at least two cores. The shell 12 is substantially cylindrical with an internal volume 14 and is defined by an upper sidewall 22, a lower sidewall 24, and a pair of end caps 26. For illustrative purposes, the heat exchanger is horizontally disposed; however, the heat exchanger can be positioned in any commercially operable manner, such as vertically, for example.

[0019] The first core 16, the second core 18, the third core 20 are disposed within the internal volume 14 of the shell and are partially submerged in the liquid shell-side fluid. In an embodiment, the liquid shell-side fluid is a vaporizing fluid, i.e., a refrigerant. The liquid shell-side fluid and the core-side fluid flow in a counter-current or cross-current manner through each core.

[0020] The plurality of spaced apart cores each receives a separate core-side fluid, allowing for simultaneous indirect heat transfer between the liquid shell-side fluid and the separate core side-fluid.

[0021] One principle of design behind the core-in-shell heat exchanger is the cross exchange of core-side fluid against a liquid shell-side fluid. The liquid shell-side fluid resides in a pressure vessel where brazed aluminum compact exchanger cores are mounted and submerged into the liquid shell-side fluid which is at or near its boiling point. The liquid is drawn into the bottom face of the exchanger where it contacts the hotter surfaces within the core. The liquid shell-side fluid then transfers heat through the exchanger core channels. The majority of the heat transfer is from the latent heat of vaporization of the liquid shell-side fluid. The core-side fluid is cooled or condensed as it passes through the opposite side of the channels in the exchanger cores.

[0022] The thermal and hydraulic performance of the core-in-shell heat exchanger is dependent upon the liquid level in the exchanger. A driving force for circulation of the liquid shell-side fluid into the exchanger cores is the thermosiphon effect. The thermosiphon effect is a passive fluid transfer phenomenon resulting from natural convective thermal forces. As the vaporization of the fluid occurs, the fluid is heated and the fluid density decreases to become lighter. As it naturally flows upward in the channels, fresh liquid is drawn in. This results in a natural circulation of the liquid shell-side fluid into the core channels induced by the thermal gradient inside the core. Not all liquid in the channel is vaporized and a mixture of liquid and vapors are transported up through the exchanger core channels and expelled through the top of the core. Above the core, adequate space must be provided for the vapor and liquid to disengage so that only vapor leaves the overhead section of the shell side of the core. Liquid that separates in the upper section of the exchanger is then re-circulated to the bottom of the vessel where it is then vaporized in the core. The driving force for separation of the liquid and the gas in the upper section of the core-in-shell heat exchanger is gravity.

[0023] The thermosiphon circulation effect in the core is enhanced or impaired by the external hydraulic pressure (level differences) between the effective liquid level inside the core versus the liquid level outside the core. As the liquid level in the shell falls, the driving force for the transfer of the liquid into the exchanger core is decreased, and the effective heat transfer is reduced. When the liquid level fall below the core, the liquid shell-side fluid circulation stops due to the loss of the thermosiphon effect which results in the loss of heat transfer. If the heat exchanger is operated with a liquid level higher than the core (flooded) the heat transferred is impaired further as the vapor produced in the core has to overcome the additional head to escape from the core. The more severe of the conditions is having a liquid level below the exchanger cores as this reduces the heat transfer to near zero.

[0024] As previously discussed, sloshing of vaporizing fluid inside heat exchangers can effect the stability and control of the exchanger. Furthermore, the cyclical nature of motion will result in cyclical behavior in heat transfer efficiency, and hence, process conditions in the LNG liquefaction plant. These instabilities may result in poorer overall plant performance and will lead to narrower operating envelopes.

[0025] The slosh suppressing baffles of the present invention reduce the impact of motion on the core-in-shell heat exchanger. The slosh suppressing baffles are located within the internal volume of the shell to separate the plurality of spaced apart cores. Each slosh suppressing baffle allows for limited distribution of the liquid shell-side fluid between each core. The slosh suppressing baffles can withstand cryogenic temperatures. The slosh suppressing baffles can withstand and divert the flow of the liquid shell-side fluid between each core.

[0026] Referring to FIG. 2, the slosh suppressing baffle 28 is a solid plate to provide for reduced sloshing of the liquid shell-side fluid within the heat exchanger 10. The solid plate slosh suppressing baffle 28 includes an opening at the bottom of the baffle to allow for limited distribution of the liquid shell-side fluid between the cores. The height of the solid plate slosh suppressing baffle 28 depends on the extent of motion anticipated. In an embodiment, the height of the solid plate motion suppressing baffle is at or near the top of the core assembly. Placement and sizing of the baffle is critical due to the added motion in the bottom of the core and the resultant potential impact to the thermo-siphon effect. Critical to the sizing of the opening is to ensure that the thermo siphon effect is not impaired.

[0027] Referring to FIG. 3, the slosh suppressing baffle 30 is a perforated plate located at the midsection of the core to dampen the motion effect. In an embodiment, the perforated plate slosh suppressing baffle is a single plate. In another embodiment, the perforated plate slosh suppressing is a double plate with congruent holes. With double plates, the vaporizing liquid has to change direction and slow down further to pass through the second plate. A solid plate slosh suppressing baffle 28 is also depicted between each core. This embodiment more evenly distributes the liquid and has a lesser impact to the motion underneath the core and minimal impact on the thermo siphon.

[0028] Referring to FIG. 4, the slosh suppressing baffles, 32, 34, 36, 38, 40 and 42, are located at the edge of each core assembly. The slosh suppressing baffles can be solid plates, perforated plates, or combinations thereof. In an embodiment, the area between each core assembly is left open. In another embodiment, the area between each core assembly is filled with a packing material to dampen the flow movement.

[0029] Referring to FIG. 5, the slosh suppressing baffles are installed between the cores horizontally to ensure that the upward momentum is reduced. The slosh suppressing baffles can be solid plate, perforated plates, or combinations thereof.

[0030] Referring to FIG. 6, to reduce the wave motion over the top of the core, which will result in potentially excessive liquid entrainment due to lifting of the liquid up into the vapor disengaging space, angled or rounded slosh suppressing baffles are placed at or near the top of the core assemblies to re-direct the liquid away from the top of the core assemblies.

[0031] Any individual or combination of slosh suppressing baffles described can be utilized to effectively and efficiently reduce the effect of motion on the heat exchanger.

[0032] In addition to the installation of motion suppressing baffle plates, certain types of packing material suitable for cryogenic services, such as stainless steel structured or random packing material could also be added to the void spaces in the shell in order to suppress motion. It is unlikely that structured or random packing alone will provide sufficient pressure drop to slow the momentum of the moving fluid but can be used in conjunction with the baffle plates to provide motion dampening.

[0033] Very small wave motions can have a dramatic impact to the performance of the core-in-shell exchanger due to the normally large length of these exchangers. Narrow operating ranges result in sensitivity to motion. Through careful consideration of the placement of motion reducing baffles, the compact designs of the core-in-shell type heat exchangers can be made to work in motion environments and alternatives like shell-and-tube exchangers can be avoided thus saving considerable cost.

[0034] In closing, it should be noted that the discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication date after the priority date of this application. At the same time, each and every claim below is hereby incorporated into this detailed description or specification as a additional embodiments of the present invention.

[0035] Although the systems and processes described herein have been described in detail, it should be understood that various changes, substitutions, and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. Those skilled in the art may be able to study the preferred embodiments and identify other ways to practice the invention that are not exactly as described herein. It is the intent of the inventors that variations and equivalents of the invention are within the scope of the claims while the description, abstract and drawings are not to be used to limit the scope of the invention. The invention is specifically intended to be as broad as the claims below and their equivalents.

[0036] Throughout the description and claims of the specification, the word "comprise" and variations of the word, such as "comprising" and "comprises", is not intended to exclude other additives, components, integers or steps.

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The claims defining the invention are as follows:

1. A heat exchanger comprising:

   a. an internal volume defined within a shell;

   b. a plurality of spaced apart cores disposed within the internal volume of the shell, and

   c. slosh suppressing baffles disposed within the internal volume to separate the plurality of spaced apart cores, wherein each core is partially submerged in a liquid shell-side fluid, wherein the slosh suppressing baffles allow limited distribution of the liquid shell-side fluid between each core, wherein the slosh suppressing baffles can withstand cryogenic temperatures, wherein the slosh suppressing baffles can withstand and divert the flow of the liquid shell-side fluid between each core.

2. The heat exchanger according to claim 1, wherein the slosh suppressing baffles are installed at the core midsection.

3. The heat exchanger according to claim 1, wherein the slosh suppressing baffles are installed between each core and at the core midsection.

4. The heat exchanger according to any one of claims 1 to 3, wherein the slosh suppressing baffle is a solid plate, wherein the solid plate includes a passageway near the bottom of the internal volume within the shell.

5. The heat exchanger according to any one of claims 1 to 3, wherein the slosh suppressing baffle is a perforated plate.

6. The heat exchanger according to any one of claims 1 to 3, wherein the slosh suppressing baffle is a double perforated plate.

7. The heat exchanger according to claim 1, wherein the slosh suppressing baffles are located at the edge of each core.

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8. The heat exchanger according to claim 7, wherein the area between the slosh suppressing baffles is filled with packing material.

9. The heat exchanger according to any one of claims 1 to 6, wherein the area between the slosh suppressing baffles is filled with packing material.

10. The heat exchanger according to any one of claims 1 to 9, wherein the liquid shell-side fluid is a vaporizing fluid.

11. The heat exchanger according to claim 10, wherein the liquid shell-side fluid is a refrigerant.

12. A method for reducing the impact of motion in a heat exchanger as claimed in any one of claims 1 to 11, wherein the heat exchanger includes an internal volume defined within a shell, wherein the internal volume within the shell includes a plurality of spaced apart cores, said method comprising:

a. installing slosh suppressing baffles within the internal volume within the shell, wherein the slosh suppressing baffles separate the plurality of cores in the internal volume;
b. partially submerging each core in a liquid shell-side fluid, wherein the slosh suppressing baffles allow limited distribution of the liquid shell-side fluid between each core;
c. introducing a core-side fluid into each core;
d. cooling the core-side fluid thereby producing a cooled stream in each core; and
e. withdrawing the cooled stream from each core.

13. The method according to claim 12, wherein the slosh suppressing baffles can withstand cryogenic temperatures.

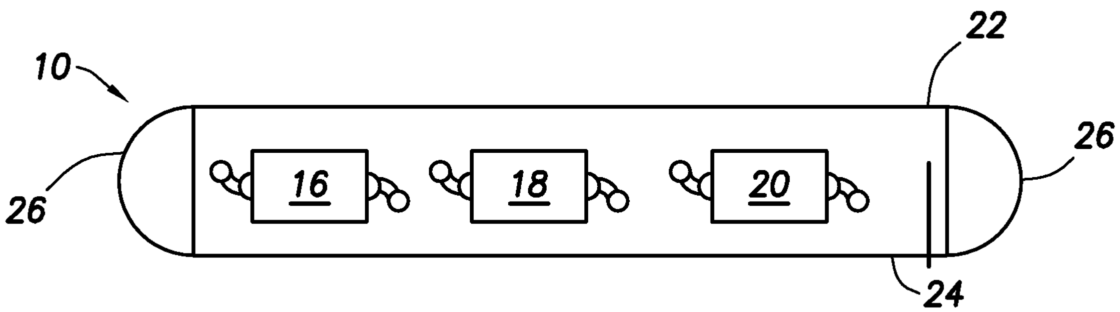

FIG.1

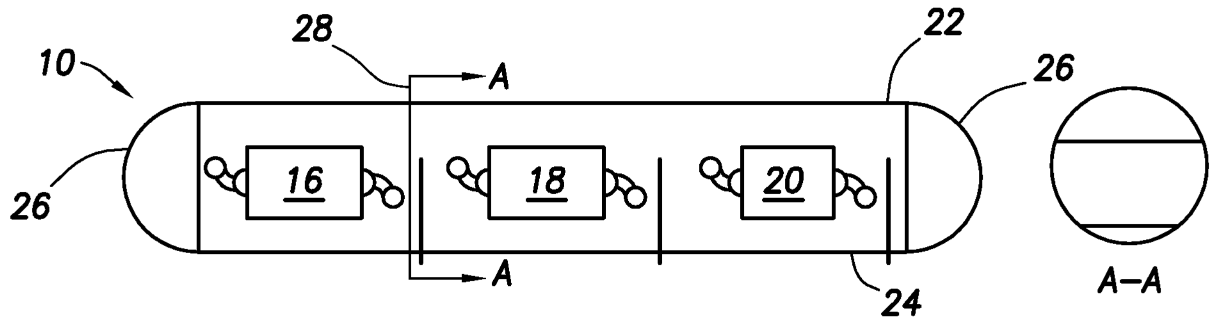

FIG.2

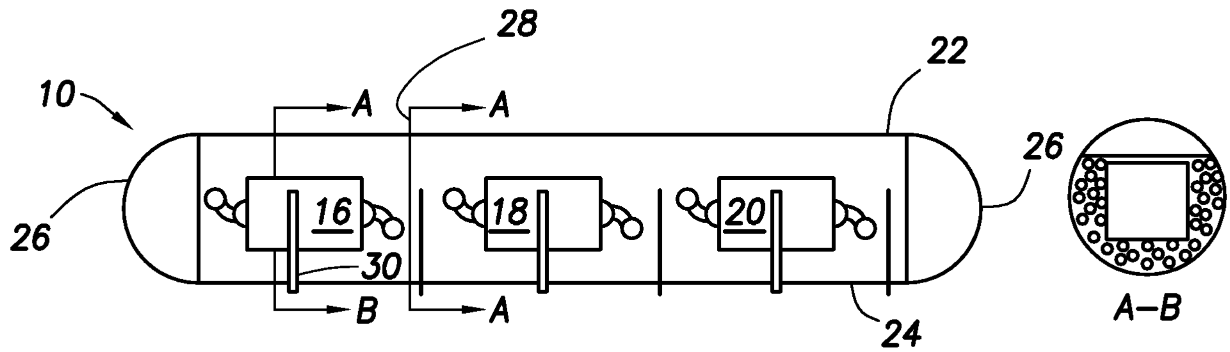

FIG.3

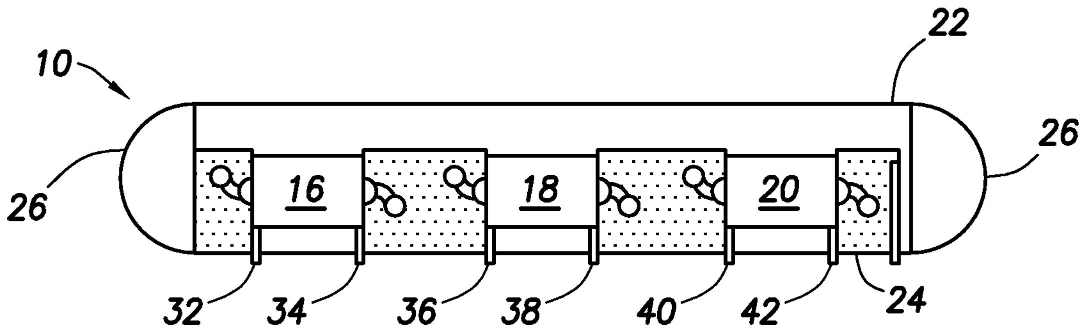

FIG.4

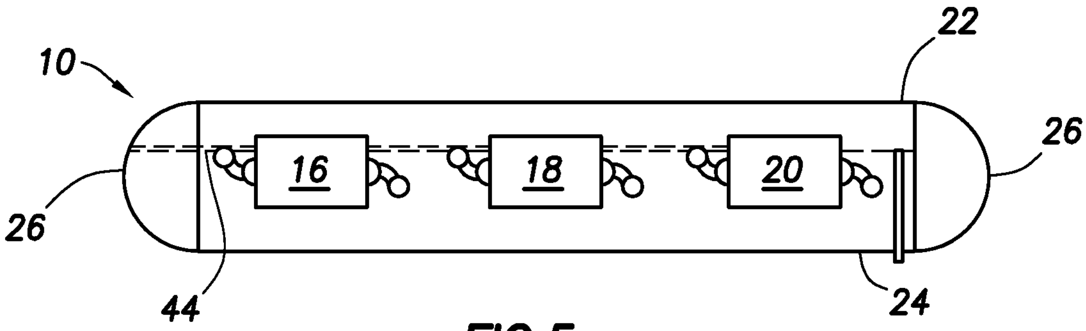

FIG.5

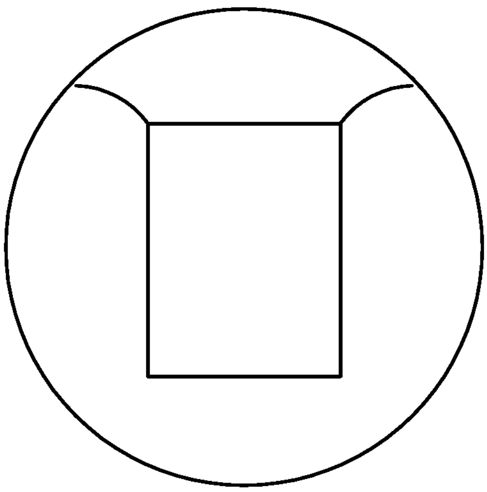

FIG.6