



- (51) International Patent Classification:
C10J 3/30 (2006.01) C10J 3/50 (2006.01)
- (21) International Application Number:
PCT/US2013/045077
- (22) International Filing Date:
11 June 2013 (11.06.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13/563,401 31 July 2012 (31.07.2012) US
- (71) Applicant: PRATT & WHITNEY ROCKETDYNE, INC. [US/US]; 6633 Canoga Avenue, Canoga Park, California 91309 (US).
- (72) Inventors: SPROUSE, Kenneth M.; 6633 Canoga Avenue, Canoga Park, California 91309 (US). SONWANE, Chandrashekhar; 6633 Canoga Avenue, Canoga Park, California 91309 (US). SAUNDERS, Timothy; 6633

Canoga Avenue, Canoga Park, California 91309 (US). FITZSIMMONS, Mark Andrew; 6633 Canoga Avenue, Canoga Park, California 91309 (US).

(74) Agent: KOZIARZ, Matthew L.; Carlson, Gaskey & Olds, 400 W. Maple, Suite 350, Birmingham, Michigan 48009 (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, 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.

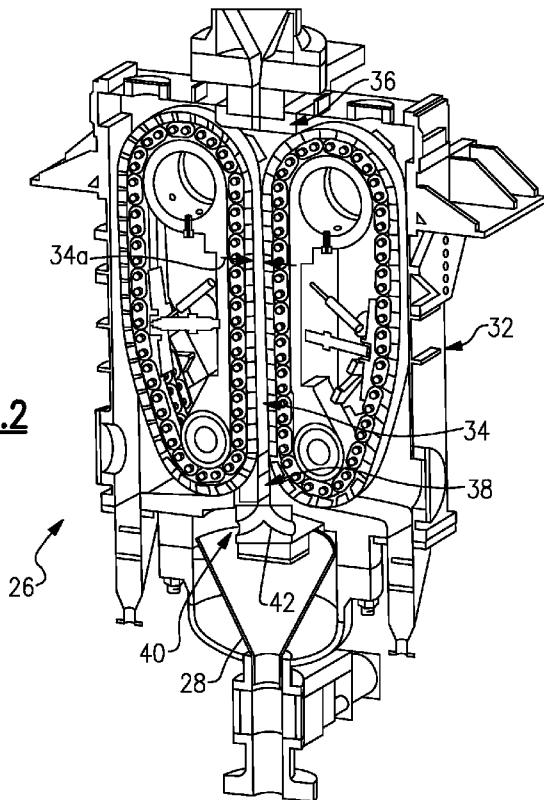
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,

[Continued on next page]

(54) Title: PUMP APPARATUS INCLUDING DECONSOLIDATOR

(57) Abstract: A pump apparatus includes a particulate pump that defines a passage that extends from an inlet to an outlet. A duct is in flow communication with the outlet. The duct includes a deconsolidator configured to fragment particle agglomerates received from the passage.

FIG. 2



WO 2014/021993 A1

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, **Published:**
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, — *with international search report (Art. 21(3))*
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).

PUMP APPARATUS INCLUDING DECONSOLIDATOR

RELATED APPLICATION

[0001] This application is a continuation-in-part of U.S. Application No. 12/758,846, filed on April 13, 2010.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with government support under contract number DE-FC26-04NT42237 awarded by United States Department of Energy. The government has certain rights in the invention.

BACKGROUND

[0003] Coal gasification involves the conversion of coal or other carbon-containing solids into synthesis gas. While both dry coal and water slurry are used in the gasification process, dry coal pumping may be more thermally efficient than water slurry technology.

[0004] In order to streamline the process and increase the mechanical efficiency of dry coal gasification, a particulate material extrusion pump is utilized to pump pulverized carbon-based fuel such as dry coal. The pulverized carbon-based fuel downstream of the particulate material extrusion pump requires breaker mills, ball end mills or other pulverization machines to deconsolidate the dry coal.

SUMMARY

[0005] A pump apparatus according to one non-limiting embodiment of the present disclosure includes a particulate pump defining a passage extending from an inlet to an outlet and a duct in flow communication with the outlet. The duct includes a deconsolidator configured to fragment particle agglomerates received from the passage.

[0006] In a further non-limiting embodiment of any of the examples herein, the deconsolidator is selected from the group consisting of a grinder, a vibrator, a mesh, a divider and combinations thereof.

[0007] In a further non-limiting embodiment of any of the examples herein, the duct is connected at the outlet of the passage.

[0008] In a further non-limiting embodiment of any of the examples herein, the duct includes a duct outlet and a movable door having open and closed positions with respect to the duct outlet.

[0009] In a further non-limiting embodiment of any of the examples herein, the deconsolidator is a divider splitting the duct into multiple passages.

[0010] In a further non-limiting embodiment of any of the examples herein, the multiple passages turn laterally with respect to the passage of the particulate pump.

[0011] In a further non-limiting embodiment of any of the examples herein, the multiple passages are laterally offset from each other.

[0012] In a further non-limiting embodiment of any of the examples herein, the deconsolidator includes a grinder.

[0013] In a further non-limiting embodiment of any of the examples herein, the deconsolidator includes a vibrator.

[0014] In a further non-limiting embodiment of any of the examples herein, the deconsolidator includes a mesh.

[0015] In a further non-limiting embodiment of any of the examples herein, the duct includes a hard-face coating.

[0016] A pump apparatus according to a non-limiting embodiment of the present disclosure includes a particulate pump defining a passage extending from an inlet and an outlet and a duct in flow communication with the outlet. The duct includes a duct outlet and a moveable door having open and closed positions with respect to the duct outlet.

[0017] In a further non-limiting embodiment of any of the examples herein, the movable door is biased toward the closed position.

[0018] In a further non-limiting embodiment of any of the examples herein, the movable door is movable in response to a pressure in the duct exceeding a threshold.

[0019] In a further non-limiting embodiment of any of the examples herein, the movable door is moveable by non-electronic actuation.

[0020] In a further non-limiting embodiment of any of the examples herein, the movable door seals against the duct outlet in the closed position.

[0021] A method of operating a pump apparatus according to a non-limiting embodiment of the present disclosure includes moving a particulate material through a particulate pump that defines a passage that extends from an inlet to an outlet and

fragmenting particle agglomerates of the particulate material with a deconsolidator in a duct that is in flow communication with the outlet of the passage.

[0022] A further non-limiting embodiment of any of the examples herein includes controlling discharge of the particulate material from the duct by actuating a movable door between open and closed positions with respect to a duct outlet of the duct.

[0023] In a further non-limiting embodiment of any of the examples herein, the actuating includes actuating the movable door in response to a pressure in the duct.

[0024] A further non-limiting embodiment of any of the examples herein includes maintaining the movable door in the closed position in response to the pressure in the duct being below a threshold, to limit a backflow of pressure into the duct.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

[0026] Figure 1 is an example carbonaceous gasifier system.

[0027] Figure 2 is an example pump apparatus including a deconsolidator.

[0028] Figure 3A is a portion of a duct and deconsolidator of a pump apparatus.

[0029] Figure 3B is a portion of a duct and deconsolidator of Figure 3A.

[0030] Figure 4 is a portion of a pump apparatus and deconsolidator in operation.

[0031] Figure 5 is another example duct and deconsolidator.

[0032] Figure 6 is another example duct and deconsolidator.

[0033] Figure 7 is another example duct and deconsolidator that includes a grinder.

[0034] Figure 8 is a perspective view of a dry coal extrusion pump;

[0035] Figure 9 is a sectional view of a deconsolidation device;

[0036] Figure 10 is a sectional view of a one non-limiting embodiment of a deconsolidation device;

[0037] Figure 11 is a sectional view of a another non-limiting embodiment of a deconsolidation device;

[0038] Figure 12 is a graphical representation of various deconsolidation device flow path area ratio and angle relationship;

[0039] Figure 13 is a perspective view of a deconsolidation device with one non-limiting embodiment of a flow control arrangement;

[0040] Figure 14 is a sectional view of a deconsolidation device with one non-limiting embodiment of a flow control arrangement;

[0041] Figure 15 is a sectional view of a deconsolidation device with another non-limiting embodiment of a flow control arrangement; and

[0042] Figure 16 is a sectional view of a deconsolidation device with another non-limiting embodiment of a flow control arrangement.

DETAILED DESCRIPTION

[0043] Figure 1 schematically illustrates selected portions of a carbonaceous gasifier system 20 configured for gasification of coal, petcoke or the like to produce synthesis gas (also known as “syngas”). In this example, the gasifier system 20 generally includes an entrained-flow gasifier 22, or reactor vessel. The gasifier 22 is connected with a low pressure hopper 24, a pump apparatus 26 and a high pressure tank 28 for providing carbonaceous particulate material to the gasifier 22.

[0044] The gasifier 22 includes an injector 30 to receive and inject the carbonaceous particulate material and an oxidant into the interior volume of the gasifier 22. As an example, the injector 30 is an impingement-style, jet injector. The carbonaceous particulate material combusts within the gasifier 22 to produce the syngas, which may then be provided downstream to one or more filters for further processing, as is known.

[0045] Although the pump apparatus 26 is discussed herein with regard to moving carbonaceous particulate material, the pump apparatus 26 may be used in other systems to transport other types of particulate material in various industries, such as petrochemical, electrical power, food and agricultural. That is, the pump apparatus 26 is not limited to use with coal, carbonaceous materials or gasification, and any industry that processes particulate material may benefit from the pump apparatus 26.

[0046] Figure 2 shows an example of the pump apparatus 26. The pump apparatus 26 generally includes a particulate pump 32 (particulate extrusion pump) that defines a passage 34 that extends between an inlet 36 and an outlet 38. A “particulate pump” as used herein refers to a pump that is configured to move particulate material from a low pressure

environment, such as the low pressure hopper 24, to a high pressure environment, such as the high pressure tank 28. The particulate pump 32 constricts lateral movement of the particulate material and thereby consolidates the particulate material into a plug of consolidated particulate material. The plug is densely packed to function as a seal that limits backflow of gas, although a limited amount of gas may leak through open interstices between the packed particles. The plug acts as a “dynamic seal” that is in continuous motion as the particulate material compacts and replenishes consolidated particulate material of the plug that is discharged.

[0047] In this example, the passage 34 includes a cross-sectional area, as represented by dimension 34a, which is substantially constant between the inlet 36 and the outlet 38 of the particulate pump 32. That is, the cross-sectional area does not vary by more than 10% along the length of the passage 34.

[0048] It is to be understood that the particulate pump 32 can alternatively be another type of particulate pump. As an example, the particulate pump 32 is a moving-wall pump, a piston pump, a screw pump, a centrifugal pump, a radial pump, an axial pump or other type of mechanical pump configured to move particulate material. One example moving-wall pump is disclosed in U.S. Patent No. 7,387,197, incorporated herein by reference. Further, in operation, the inlet 36 may be at a first pressure and the outlet 38 may be at a second pressure that is greater than the first fluid pressure such that the particulate pump 32 moves the particulate material from a low pressure area to a higher pressure area.

[0049] A duct 40 (shown schematically) is coupled at the outlet 38 of the particulate pump 32. The duct 40 includes deconsolidator 42 configured to fragment particle agglomerates received from the passage 34. The duct 40 and/or deconsolidator 42 may be part of the particulate pump 32 or a separate part from the particulate pump 32. On average, the particulate material discharged from the pump apparatus 26 should have a similar size to the size of the particulate material before entering the pump apparatus 26. However, the particulate material can agglomerate into larger lumps or blocks due to compression at the sidewalls of the passage 34 of the particulate pump 32. The agglomerates can cause blockages further downstream in the gasifier system 20, such as at the injector 30.

[0050] The degree of agglomeration can depend upon various coal parameters, such as porosity, Hardgrove Grindability Index (HGI), surface energy, flow rate and discharge pressure. The deconsolidator 42 serves to apply shear forces to the particulate material, which

fragments agglomerates that may form. Furthermore, the ability to fragment agglomerates permits the use of different feedstocks such as petcoke, coal from different mine sources, sub-bit coal or the like without the need to replace hardware on the pump apparatus 26 to account for different levels of agglomeration of different feedstocks.

[0051] Figures 3A and 3B show selected portions of the duct 40 and the deconsolidator 42. The deconsolidator 42 can include a divider (i.e., splitter), a grinder, a vibrator, a mesh or combinations thereof to fragment, or breakup, agglomerates. In the illustrated example, the deconsolidator 42 includes a divider 44. The divider 44 splits the duct 40 into multiple passages 46a/46b, which are laterally offset from each other in this example, to generate a shear force on the flowing particulate matter and thereby fragment agglomerates. Each of the passages 46a/46b receives particulate material from the passage 34 of the particulate pump 32 through an opening 48 on the top of the duct 40. In this example, each of the passages 46a/46b turns laterally with respect to the longitudinal length of the passage 34 of the particulate pump 32 and terminates at a duct outlet 50 (one shown). The lateral turning also facilitates the generation of the shear forces.

[0052] In this example, the duct 40 also includes a movable door 52 (Figure 3A) that is movable between open and closed positions with respect to the duct outlet 50. That is, each duct outlet 50 of each corresponding passage 46a/46b can include a movable door 52.

[0053] The movable door 52 is mounted on a door support structure 54 for linear movement, as represented at 56, between open and closed positions. The movable door 52 includes a plate 58 with guide bosses 60 extending therefrom. The guide bosses 60 are slideably supported on respective struts 62 of the support structure 54. The struts 62 house bias members 64 (shown schematically), such as springs, for biasing the movable door 52 toward the closed position shown in Figure 3A.

[0054] Referring to Figure 4, the moveable door 52 is movable along linear direction 56 between a closed position in which the movable door 52 seals the duct outlet 50 and an open position, shown in phantom at 52', in which the movable door 52 permits particulate material to discharge through the duct outlet 50.

[0055] In this example, the movable door 52 actuates by non-electronic actuation and in response to a pressure in the duct 40 exceeding a threshold. Thus, the moveable door 52 operates passively, without the need for external electronic control signals. For example, in operation of the pump apparatus 26, particulate material moves through the passage 34 and

into the duct 40. A build-up of particulate material in the duct 40 causes a pressure increase within the duct 40. Once the pressure exceeds the threshold pressure necessary to overcome the biasing force of the bias member 64, the movable door 52 slides on the struts 62 from the closed position to the open position at 52'.

[0056] Once open, the particulate material discharges through the duct outlet 50 and into the high pressure tank 28. Upon release of particulate material into the high pressure tank 28, the pressure within the duct 40 decreases and the bias member 64 moves the movable door 52 back into the closed position, sealing the duct outlet 50. A backflow of pressure can go through a plug of the particulate material that forms in the passage 34 of the particulate pump 32 and discharge as a stream of particulate material from the inlet 36 of the particulate pump 32. However, in the closed, sealed position, the moveable door 52 limits or prevents pressure backflow through the duct 40 and into the particulate pump 32, which facilitates isolation of the low pressure environment at the inlet 36 from the high pressure environment at the outlet 38 and improves operation of the particulate pump 32 by reducing the need to re-pressurize the low pressure environment due to undesired pressure losses.

[0057] Figure 5 illustrates selected portions of another example duct 140 that is somewhat similar to the duct 40 described above. In this disclosure, like elements are understood to incorporate the same features and benefits of the corresponding elements. In this example, the duct 140 includes an additional deconsolidator 142 that is a mesh 160 arranged over the duct outlet 50 of the duct 140. For example, the mesh 160 is a wire screen that is mounted over the duct outlet 50 and serves to fragment particle agglomerates that are not already fragmented by the deconsolidator 42. Alternatively, or in addition to the mesh 160, another mesh 160 can be provided over the opening 48.

[0058] Figure 6 illustrates another example duct 240 that is somewhat similar in geometry to the duct 40 as described above. That is, the duct 240 includes the deconsolidator 42, or divider, that splits into the passages 46a/46b. However, in this example, the duct 240 additionally includes a deconsolidator represented at 242. The deconsolidator 242 is a vibrator that moves the duct 240 laterally to further facilitate the fragmentation of particle agglomerates received from the passage 34 of the particulate pump 32. As an example, the deconsolidator 242 includes an actuator to vibrate the duct 240 at a desired frequency to fragment the particle agglomerates. The vibration can be linear or rotatory, for example.

[0059] Additionally, in this example, the duct 240 includes a hard-face coating 270 that lines the passages 46a/46b to protect against erosion, corrosion and the like. In one example, the hard-face coating 270 is an anodized coating on an aluminum substrate that forms the geometry of the duct 240. In other examples, the hard-face coating 270 can have a different composition, but is harder than the underlying substrate on which it is disposed. As can be appreciated, any of the hard-face coating 270 is also applicable to any of the other examples herein.

[0060] Figure 7 illustrates another example duct 340 that includes a deconsolidator 342. In this example, the deconsolidator 342 includes a grinder 380. The grinder 380 in this example includes moving or rotatable pieces 382 that exert shear forces on the particulate material received from the passage 34 of the particulate pump 32 to fragment particle agglomerates.

[0061] Moreover, the use of the movable door reduces backflow of high pressure coal or gases in the system, which may otherwise hinder the feed of the coal particulate material or cause shutdown of system. Additionally, the duct and deconsolidators disclosed herein can be retrofit onto an existing particulate pump in response to a change in feedstock, flow rate, etc. In some examples, the duct and deconsolidator requires minimal energy input, which reduce auxiliary loads on the particulate pump.

[0062] Figure 8 schematically illustrates a perspective view of a particulate material extrusion pump 1000 for transportation of a dry particulate material. Although particulate pump 1000 is discussed as a transport for pulverized carbon-based fuel such as coal, biomass, petroleum coke, waste or other feedstock, the particulate pump 1000 may alternatively transport any dry particulate material and may be used in various other industries, including, but not limited to: coal gasification, petrochemical, electrical power, food, and agricultural.

[0063] The particulate pump 1000 generally includes an inlet zone 1012, a compression work zone 1014 and an outlet zone 1016. The inlet zone 1012 generally includes a hopper 1018 and an inlet 1020. The compression work zone 1014 generally includes a passageway 1022 defined by a moving wall 1024 and drives system 1026 therefor. The outlet zone 1016 generally includes an outlet 1028 and a deconsolidation device 1030.

[0064] The deconsolidation device 1030 deconsolidates the coal which may be consolidated within the passageway 1022 by the moving wall 1024. That is, the pulverized carbon-based fuel may be tightly compacted from the passageway 1022. The pulverized

carbon-based fuel has a natural angle of repose. That is, a natural angle forms between the horizontal at the top of a pile of unconsolidated material, and the sides. The consolidated pulverized carbon-based fuel has been compressed into a state where the particulate adhere to each other forming a mass which may stand vertically unsupported at angles higher than the natural angle of repose. Partially deconsolidated material may have a natural angle of repose but still consist of a mixture of unconsolidated and consolidated material that may be further reduced by shearing the largest particle masses against each other or the surfaces of a device.

[0065] Referring to Figure 9, the deconsolidation device 1030 includes an inlet 1032 which defines a first cross-section which is generally equivalent to the cross-section formed by the passageway 1022 and an outlet 1034 which defines a second cross-section different than the first cross-section to break the compressed pulverized consolidated particulate into a fine powder consistency. After being passed through the device once, the carbon based material is no longer prevented from lying at a natural angle of repose. The flow path 1036 between the inlet 1032 and the outlet 1034 forces pulverized coal particles to move in relation to each other without re-compaction. A three dimensional shape change is provided by a flow path 1036 between the inlet 1032 and the outlet 1034 of the deconsolidation device 1030. The flow path 1036 provides the requisite particle breakage as the pulverized carbon-based fuel is forced to change direction and allowed to expand in volume.

[0066] Referring to Figure 10, one non-limiting embodiment of the flow path 1036A of the deconsolidation device 1030 provides a rectilinear inlet 1032A as the first cross-section which is generally equivalent to the cross-section formed by the passageway 1022, and an outlet 1034A which defines the second cross-section which includes radiused corners. The flow path 1036A also turns through an at least ninety (90) degree turning angle.

[0067] Referring to Figure 11, another non-limiting embodiment of the flow path 1036B of the coal deconsolidation device 1030 provides a rectilinear inlet 1032B as the first cross-section which is generally equivalent to the cross-section formed by the passageway 1022, and an outlet 1034B which defines the second cross-section which defines a round outlet. The flow path 1036A also turns through an at least ninety (90) degree turning angle.

[0068] Referring to Figure 12, various tradeoffs result from the relationship along the flow path 1036. It should be understood that various combinations of area ratios along the flow path 1036 may be utilized herewith. The transition from a rectilinear inlet to a round outlet results in an increase in area relatively slowly along the flow path 1036B-1, 1036B-2,

1036B-3, 1036B-4 while changing the shape relatively more quickly. A relatively simple angle is also effective yet total efficiency may be relatively less.

[0069] Referring to Figure 13, another non-limiting embodiment of the flow path 1036C of the coal deconsolidation device 1030 provides a rectilinear inlet 1032C as the first cross-section which is generally equivalent to the cross-section formed by the passageway 1022, and a first and second outlet 1034B1, 1034B2 which each define the second cross-section. It should be understood that the first and second outlet 1034B1, 1034B2 may be of various forms such as those discussed above. The flow path 1036C also turns through an at least ninety (90) degree turning angle.

[0070] Referring to Figure 14, the flow path 1036 may additionally be arranged to assure the flow path 1036 remains full as the pulverized carbon-based fuel moves through the coal deconsolidation device 1030. In one non-limiting embodiment, the flow path 1036 turns through a turning angle which may be greater than a ninety (90) degree turning angle through an extension 1038. The turning angle may turn through an at least one hundred thirty five (135) degree turning angle which essentially defines a J-shape.

[0071] Referring to Figure 15, another non-limiting embodiment includes a valve 1040 (illustrated schematically) to assure the flow path 1036 remains full as the pulverized carbon-based fuel moves through the coal deconsolidation device 1030. The valve 1040 may be a check-valve or other valve arrangement which requires a predetermined pressure for passage of the deconsolidated particulate material.

[0072] Referring to Figure 16, another non-limiting embodiment arranges the particulate pump 1000 such that the flow path 1036 is arranged in a direction with regard to gravity to assure the flow path 1036 remains full. That is, the coal deconsolidation device 1030 may be located above the particulate pump 1000 with respect to gravity such that the pulverized carbon-based fuel must move in opposition to gravity.

[0073] The coal deconsolidation device 1030 allows the particulate pump 1000 to operate without heretofore required breaker mills, ball end mills or other moving pulverization machines.

[0074] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the

portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0075] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

CLAIMS

What is claimed is:

1. A pump apparatus comprising:
a particulate pump defining a passage extending from an inlet to an outlet; and
a duct in flow communication with the outlet, the duct including a deconsolidator configured to fragment particle agglomerates received from the passage.
2. The pump apparatus as recited in claim 1, wherein the deconsolidator is selected from the group consisting of a grinder, a vibrator, a mesh, a divider and combinations thereof.
3. The pump apparatus as recited in claim 1, wherein the duct is connected at the outlet of the passage.
4. The pump apparatus as recited in claim 1, wherein the duct includes a duct outlet and a movable door having open and closed positions with respect to the duct outlet.
5. The pump apparatus as recited in claim 1, wherein the deconsolidator is a divider splitting the duct into multiple passages.
6. The pump apparatus as recited in claim 5, wherein the multiple passages turn laterally with respect to the passage of the particulate pump.
7. The pump apparatus as recited in claim 5, wherein the multiple passages are laterally offset from each other.
8. The pump apparatus as recited in claim 1, wherein the deconsolidator includes a grinder.
9. The pump apparatus as recited in claim 1, wherein the deconsolidator includes a vibrator.
10. The pump apparatus as recited in claim 1, wherein the deconsolidator includes a mesh.
11. The pump apparatus as recited in claim 1, wherein the duct includes a hard-face coating.

12. A pump apparatus comprising:
a particulate pump defining a passage extending from an inlet and an outlet; and
a duct in flow communication with the outlet, the duct including a duct outlet and a moveable door having open and closed positions with respect to the duct outlet.
13. The pump apparatus as recited in claim 12, wherein the movable door is biased toward the closed position.
14. The pump apparatus as recited in claim 12, wherein the movable door is movable in response to a pressure in the duct exceeding a threshold.
15. The pump apparatus as recited in claim 12, wherein the movable door is moveable by non-electronic actuation.
16. The pump apparatus as recited in claim 12, wherein the movable door seals against the duct outlet in the closed position.

17. A method of operating a pump apparatus, the method comprising:
moving a particulate material through a particulate pump that defines a passage that extends from an inlet to an outlet; and
fragmenting particle agglomerates of the particulate material with a deconsolidator in a duct that is in flow communication with the outlet of the passage.
18. The method as recited in claim 17, further comprising controlling discharge of the particulate material from the duct by actuating a movable door between open and closed positions with respect to a duct outlet of the duct.
19. The method as recited in claim 18, wherein the actuating includes actuating the movable door in response to a pressure in the duct.
20. The method as recited in claim 19, further comprising maintaining the movable door in the closed position in response to the pressure in the duct being below a threshold, to limit a backflow of pressure into the duct.

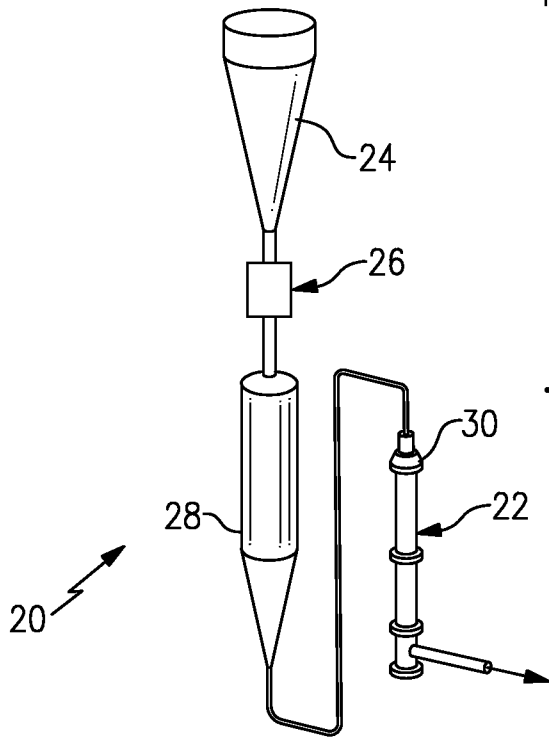
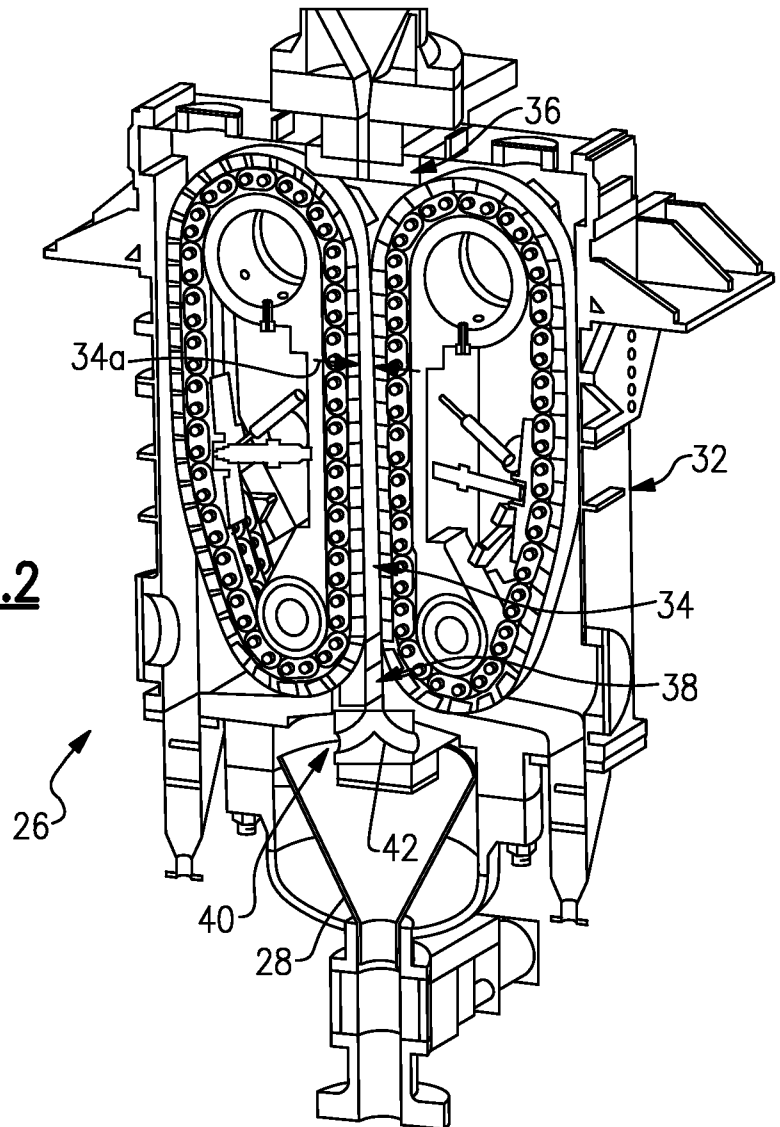


FIG. 2



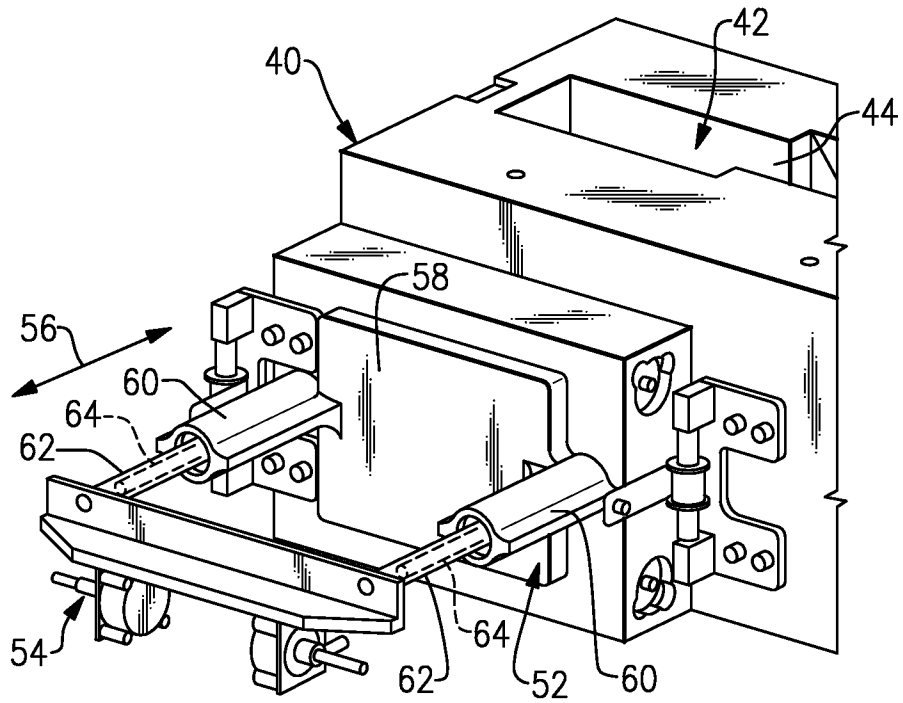


FIG.3A

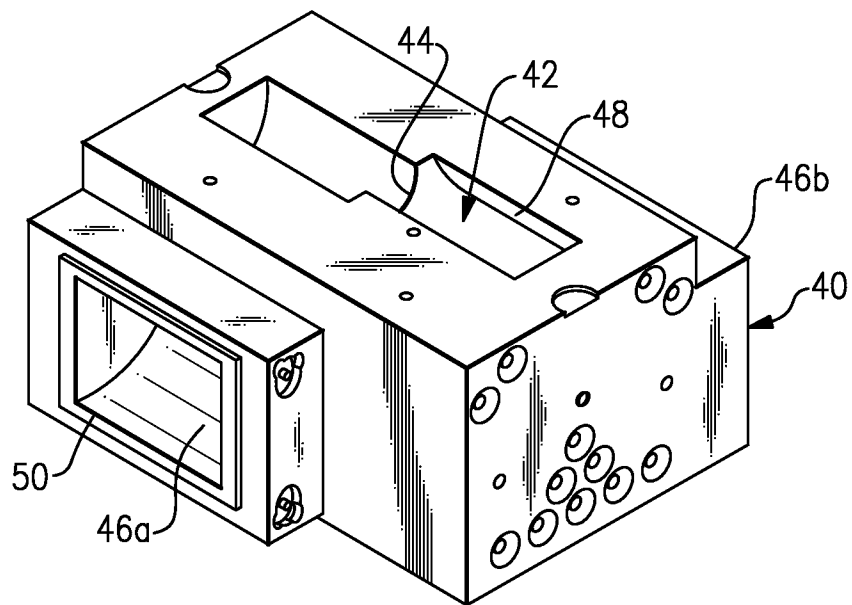


FIG.3B

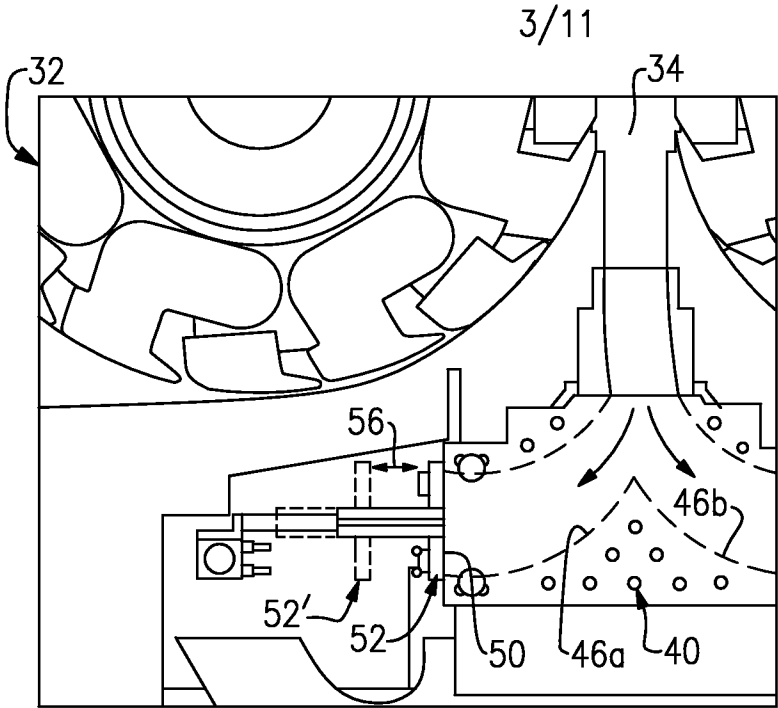


FIG. 4A

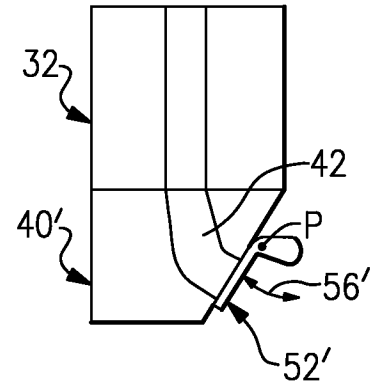


FIG. 4B

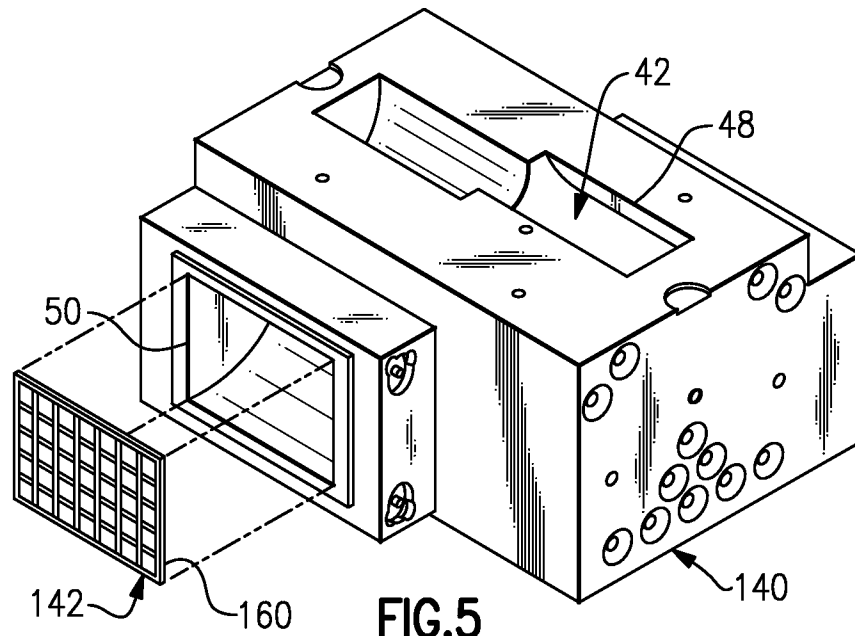


FIG. 5

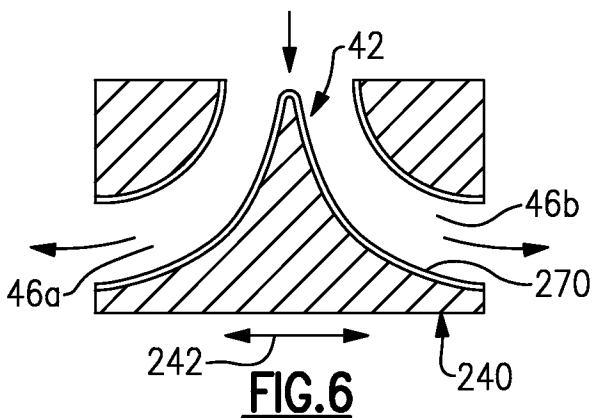


FIG. 6

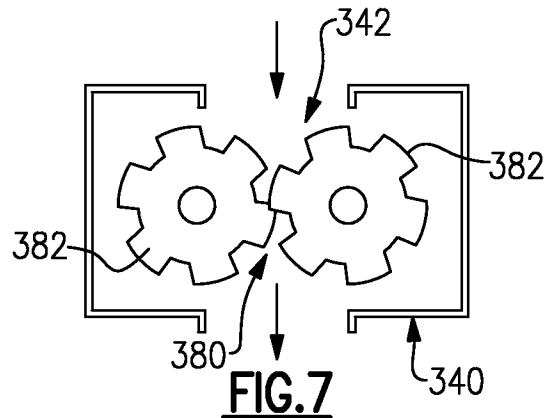


FIG. 7

4/11

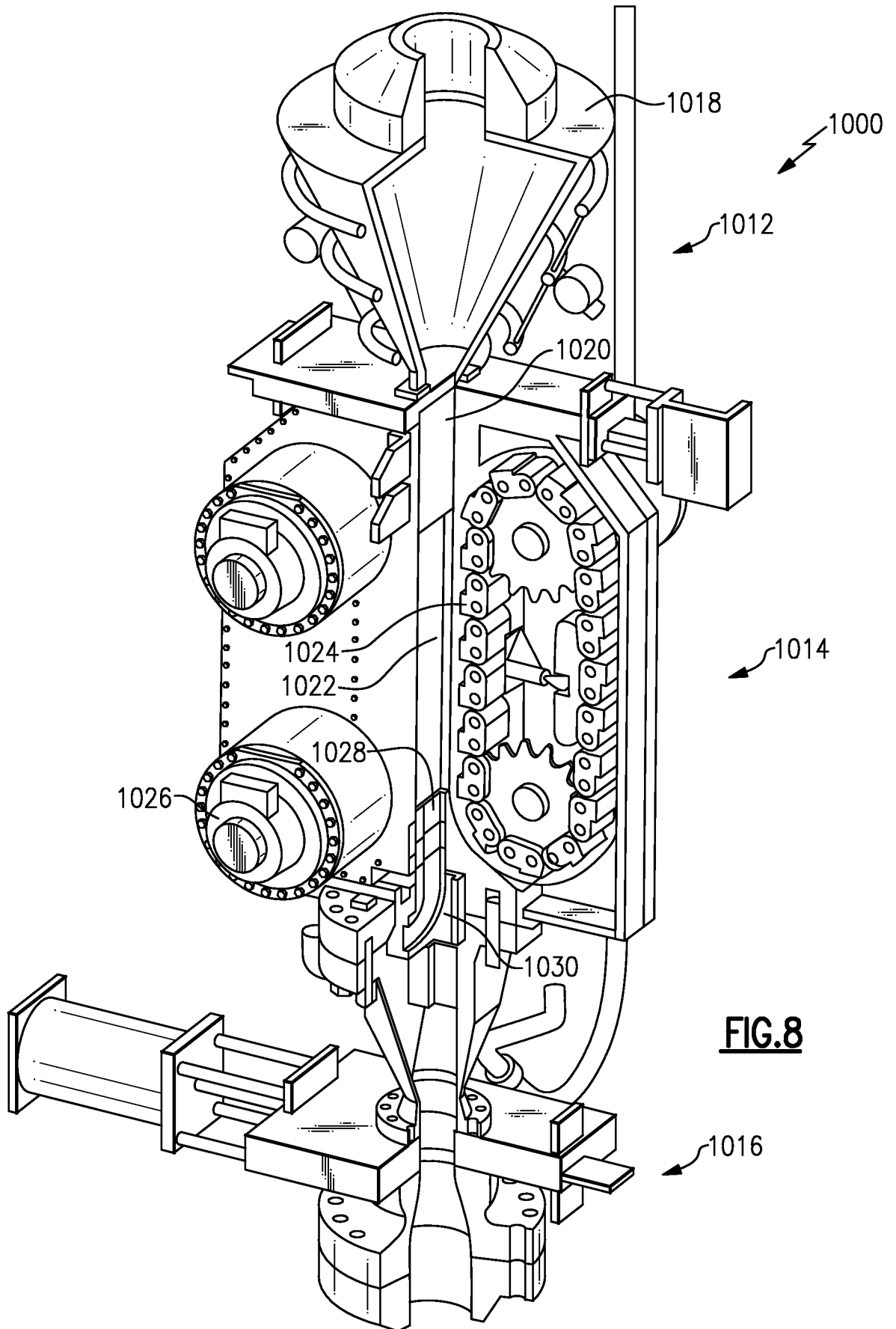


FIG. 8

5/11

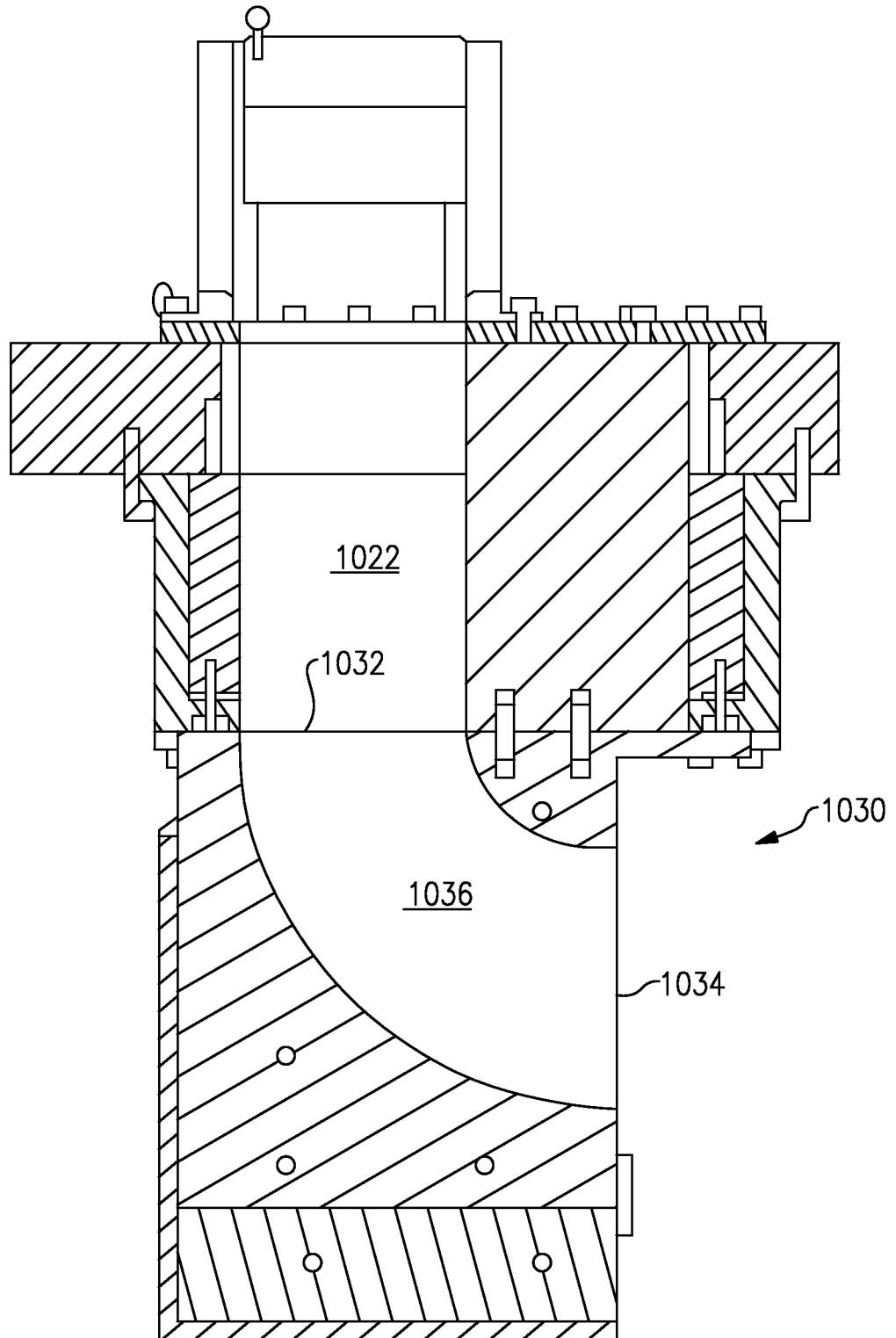


FIG.9

6/11

FIG.10

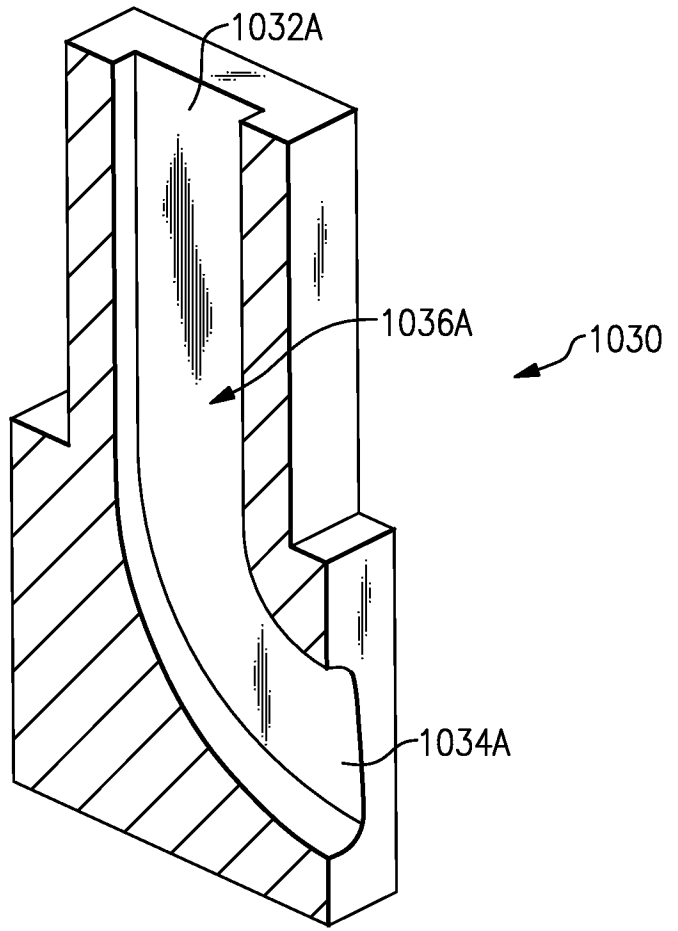
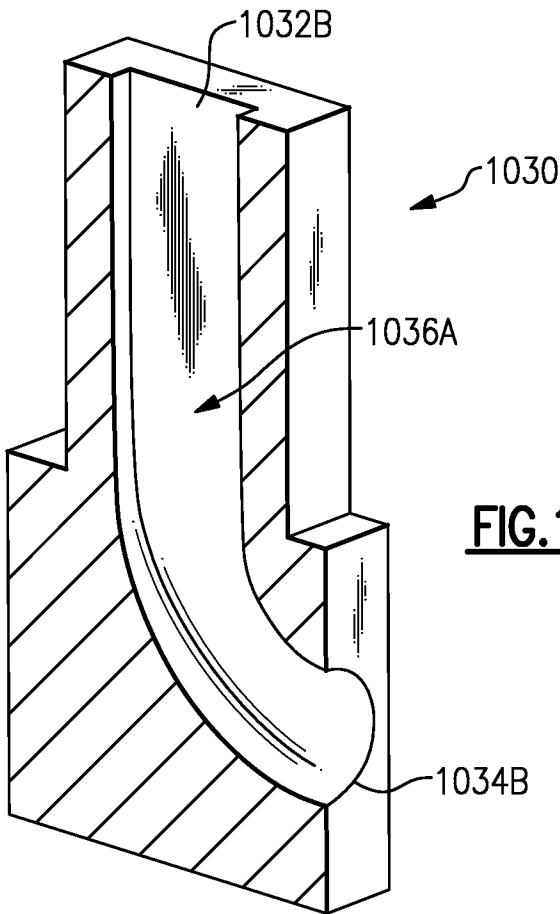


FIG.11



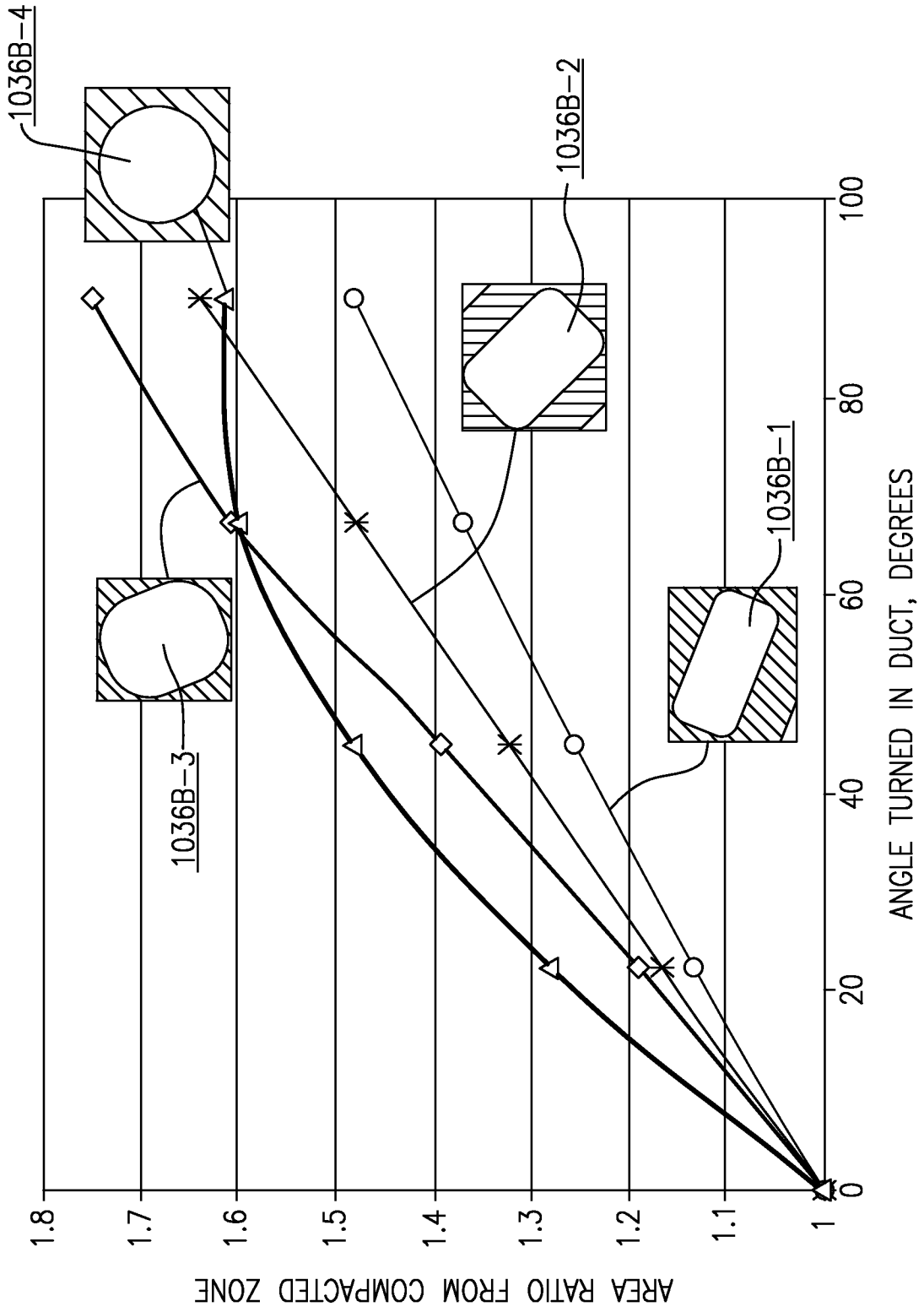


FIG.12

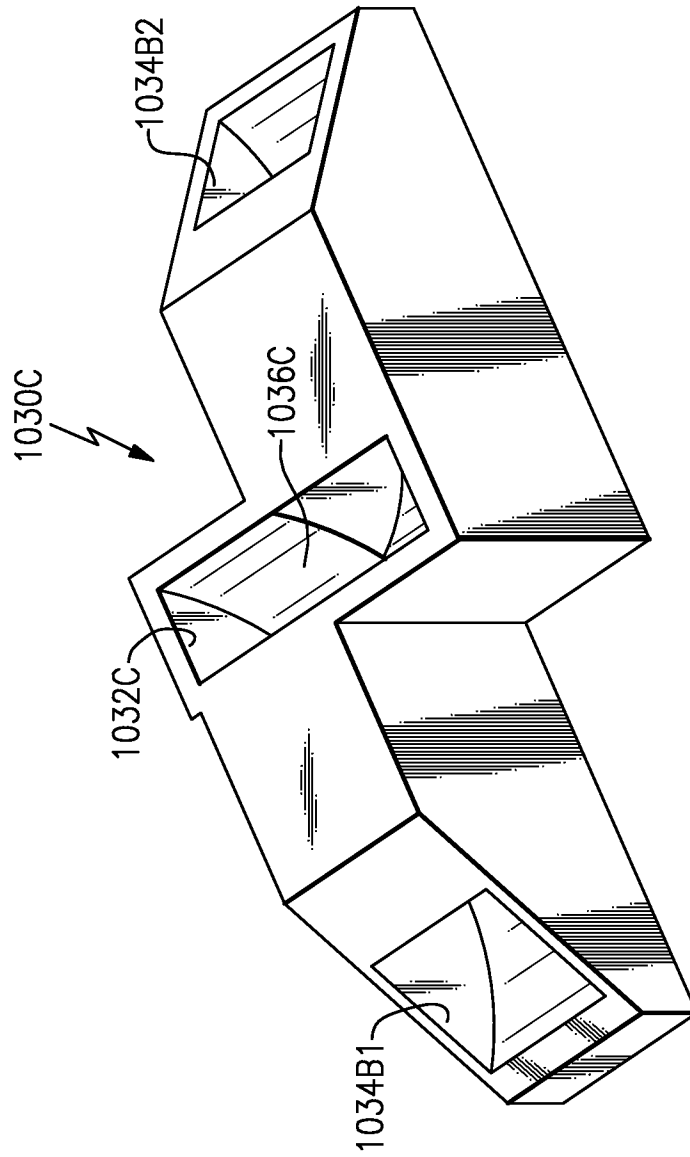


FIG.13

9/11

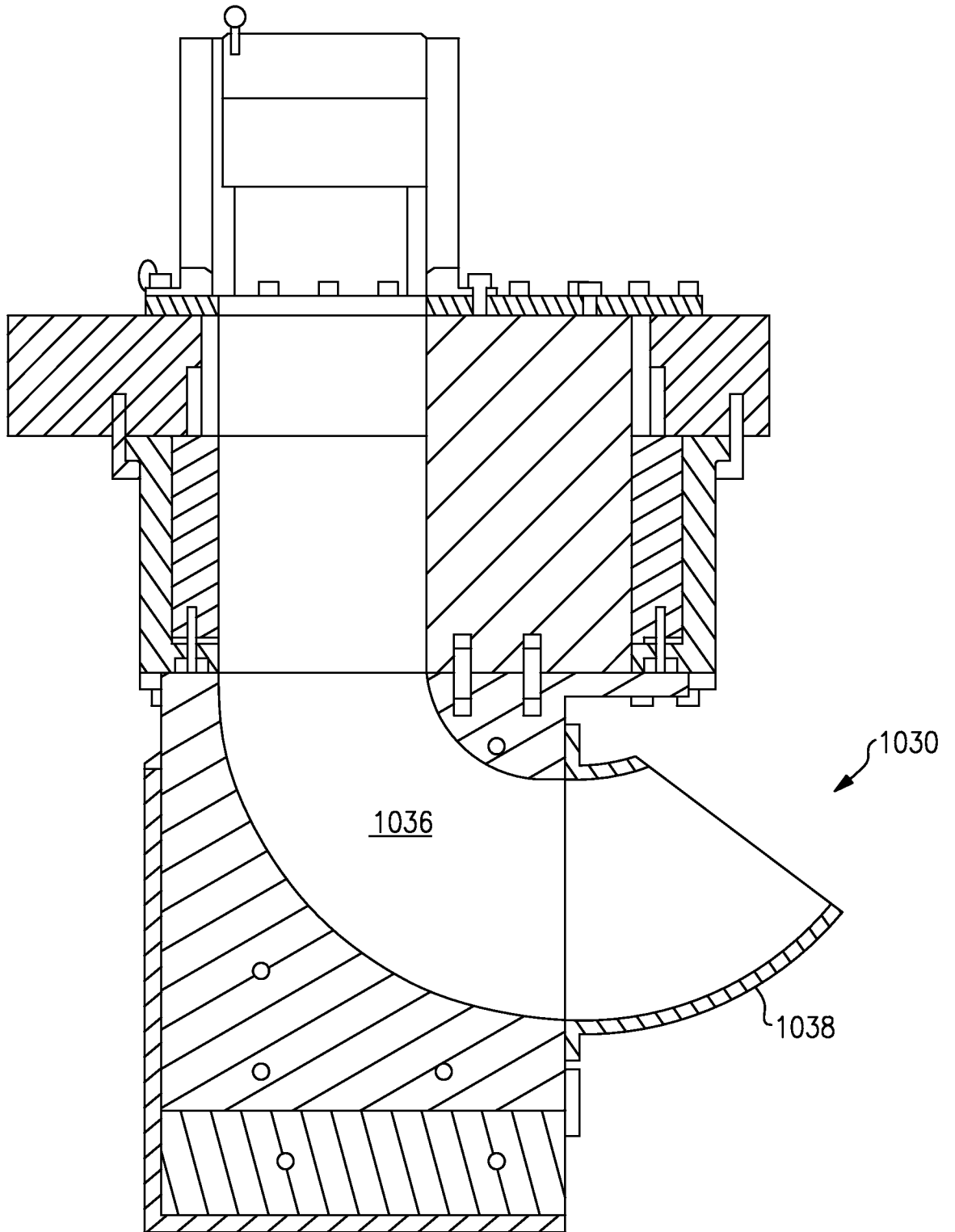


FIG. 14

10/11

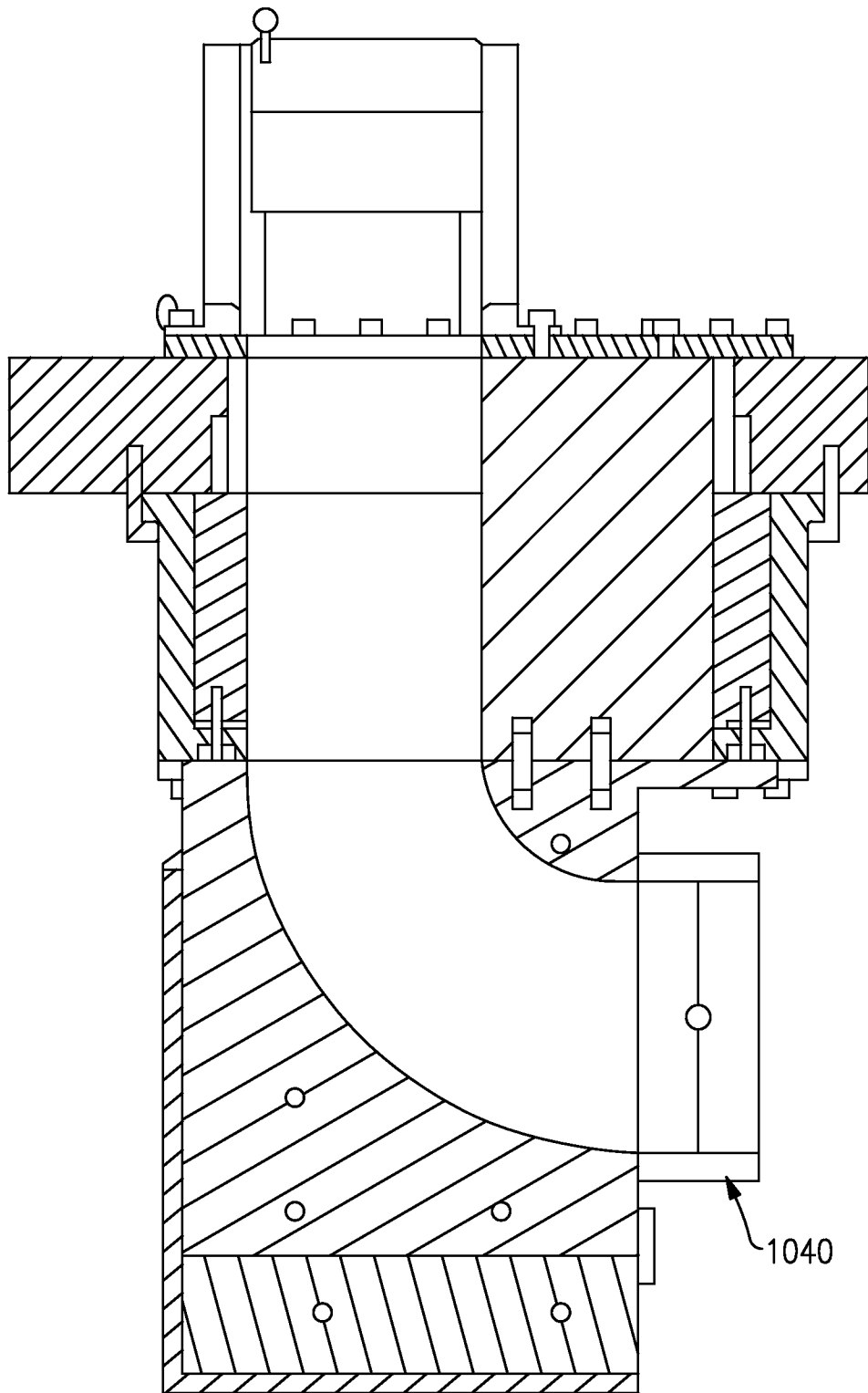


FIG. 15

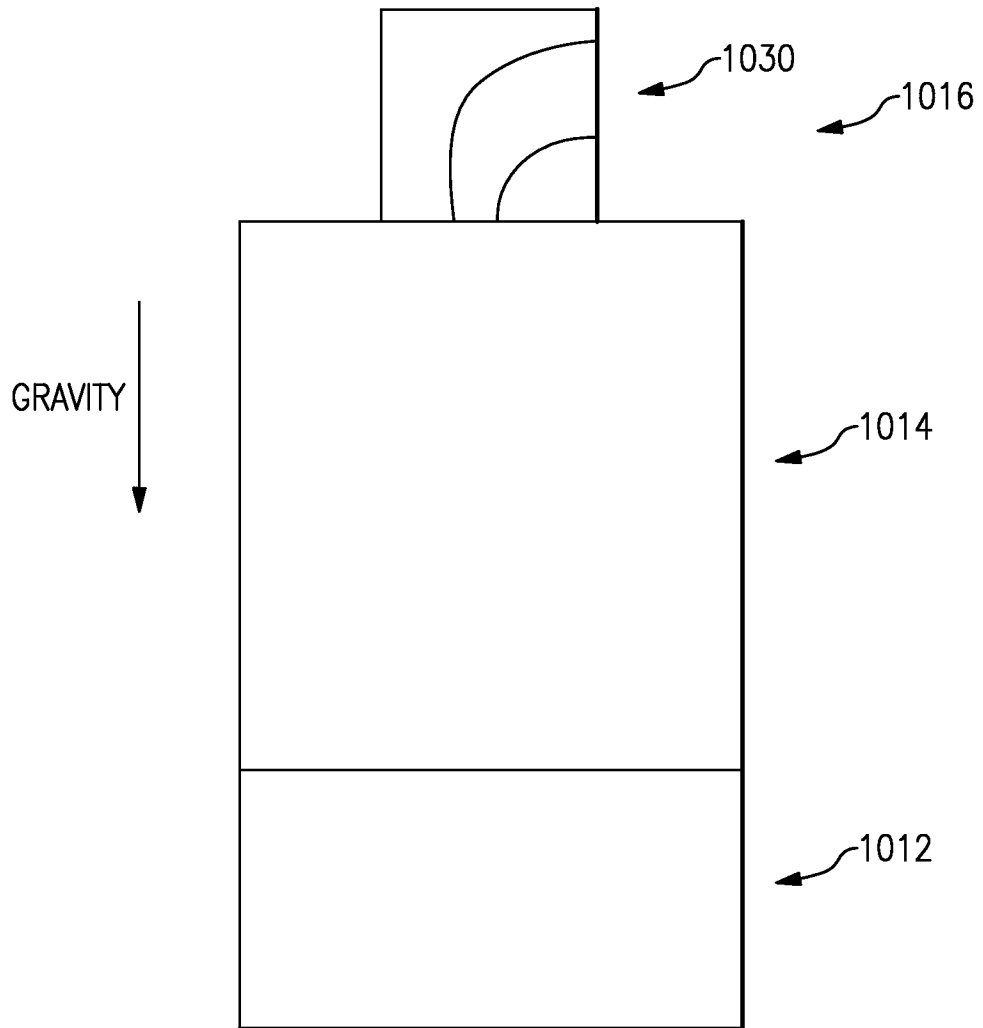


FIG.16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/045077**A. CLASSIFICATION OF SUBJECT MATTER****C10J 3/30(2006.01)i, C10J 3/50(2006.01)i**

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

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
C10J 3/30; B65G 15/00; B01J 1/00; B65G 53/04; F26B 3/08; B65G 31/00; B65G 37/00; C10J 3/50Documentation 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 modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: pump, particulate, passage, inlet, outlet, duct, deconsolidator, fragment, agglomerate, moveable door**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2011-0247916 A1 (FITZSIMMONS, MARK ANDREW) 13 October 2011 See abstract; paragraphs [0015], [0016]; claim 1; and figure 1.	1-3, 8-11, 17 4-7, 12-16, 18-20
Y A	US 5402876 A (HAY, ANDREW G.) 04 April 1995 See abstract; column 9, line 62 - column 10, line 22; claims 1, 23; and figure 6.	1-3, 8-11, 17
A	US 8006827 B2 (ALDRED, DEREK LESLIE et al.) 30 August 2011 See abstract; column 6, lines 40 - 47; column 15, line 18 - column 16, line 36; claim 1; and figures 1 (a), 10 (a).	1-20
A	US 4191500 A (OBERG, CARL L. et al.) 04 March 1980 See abstract; column 4, lines 20 - 30; column 5, lines 45 - 50; column 6, lines 12 - 19; and figure 1.	1-20
A	US 5325603 A (EASTHAM, DONALD H. et al.) 05 July 1994 See column 3, line 56 - column 4, line 6; column 4, line 55 - column 5, line 26; column 7, line 59 - column 8, line 6; and claim 1.	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 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

24 September 2013 (24.09.2013)

Date of mailing of the international search report

24 September 2013 (24.09.2013)

Name and mailing address of the ISA/KR


 Korean Intellectual Property Office
 189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City,
 302-701, Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

LEE Dong Wook

Telephone No. +82-42-481-8163



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/045077

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0247916 A1	13/10/2011	CN 102219110 A	19/10/2011
		EP 2378231 A1	19/10/2011
		JP 05192562 B2	08/05/2013
		JP 2011-219274 A	04/11/2011
		KR 10-2011-0114445 A	19/10/2011
US 05402876 A	04/04/1995	CA 2164622 A1	22/12/1994
		CA 2164622 C	12/10/2004
		CA 2170272 C	05/04/2005
		CN 1051291 C	12/04/2000
		CN 1064922 C	25/04/2001
		CN 1125427 A	26/06/1996
		CN 1125427 C	26/06/1996
		CN 1129929 A	28/08/1996
		CN 1129929 C	28/08/1996
		EP 0701528 A1	06/09/2000
		EP 0701528 B1	05/12/2001
		EP 0725752 A1	13/10/1999
		EP 0725752 A4	15/04/1998
		EP 0725752 B1	31/01/2001
		JP 03548575 B2	28/07/2004
		JP 03659645 B2	15/06/2005
		JP 08511499 A	03/12/1996
		JP 09502152 A	04/03/1997
		KR 10-0324139 B1	22/06/2002
		KR 10-1996-0704789 A	09/10/1996
		US 05355993 A	18/10/1994
		US 05381886 A	17/01/1995
		US 05402876 A	04/04/1995
US 05485909 A	23/01/1996		
WO 94-29202 A1	22/12/1994		
WO 95-06610 A1	09/03/1995		
US 8006827 B2	30/08/2011	US 2010-0021247 A1	28/01/2010
		WO 2009-009189 A2	15/01/2009
		WO 2009-009189 A3	12/03/2009
US 04191500 A	04/03/1980	JP 54027186 A	01/03/1979
		JP 63006449 B	09/02/1988
US 05325603 A	05/07/1994	US 05175943 A	05/01/1993
		US 05325603 A	05/07/1994