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(54) **FEEDER**

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(57) **ABSTRACT**

A feeder operable to convey a divided solids material comprises a conduit and an actuator. The conduit has a hollow body with a length, a first end, a second end opposite the first end and a displaceable body segment defined along at least a portion of the length. The displaceable body segment has at least a first fixable location positionable at a first fixed location. The actuator is positioned to apply force to the conduit and is controllable to cause selected flow of divided solids material in a feed direction extending generally from the first end to the second end. Methods are also disclosed.

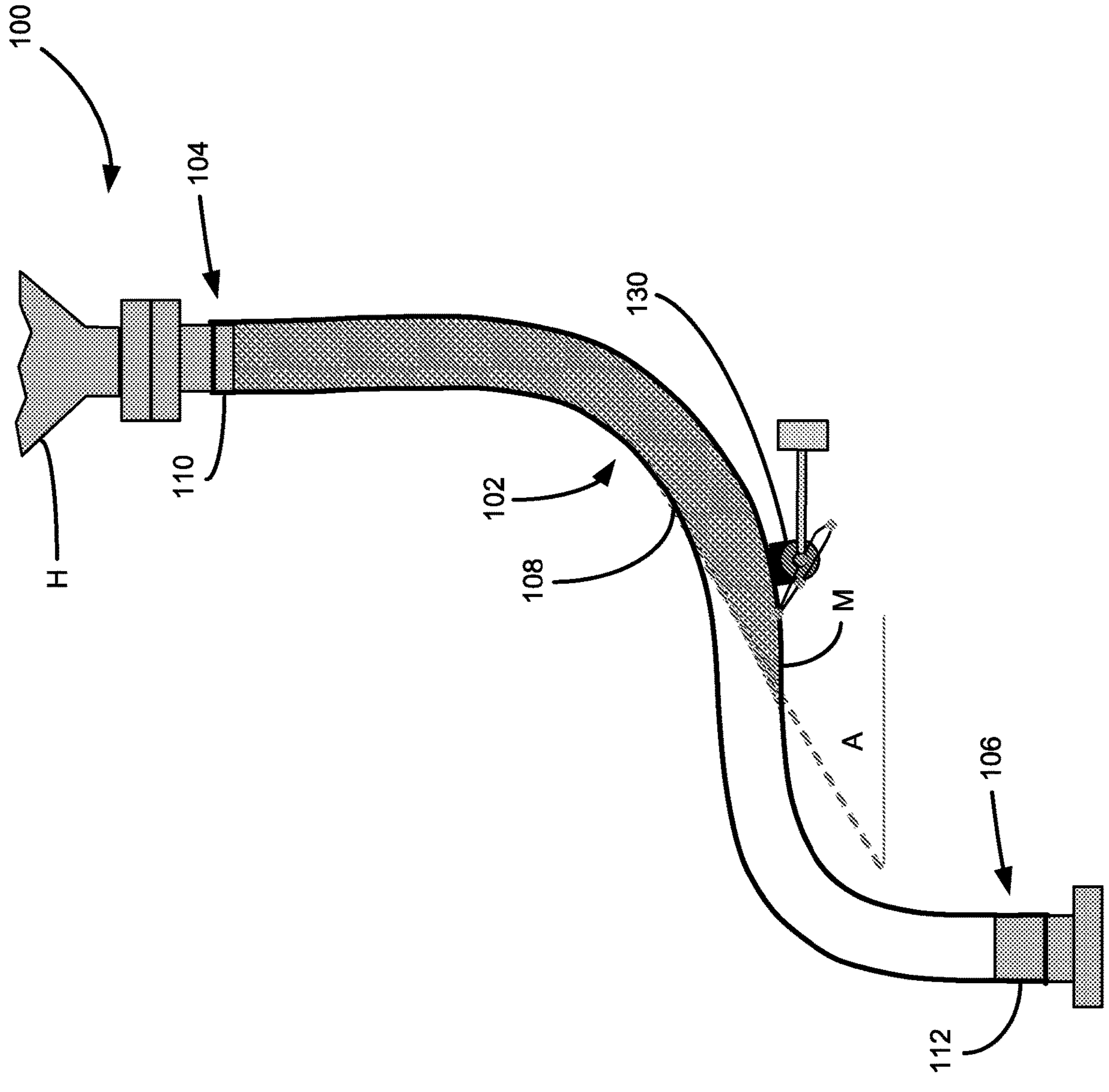


Fig. 1

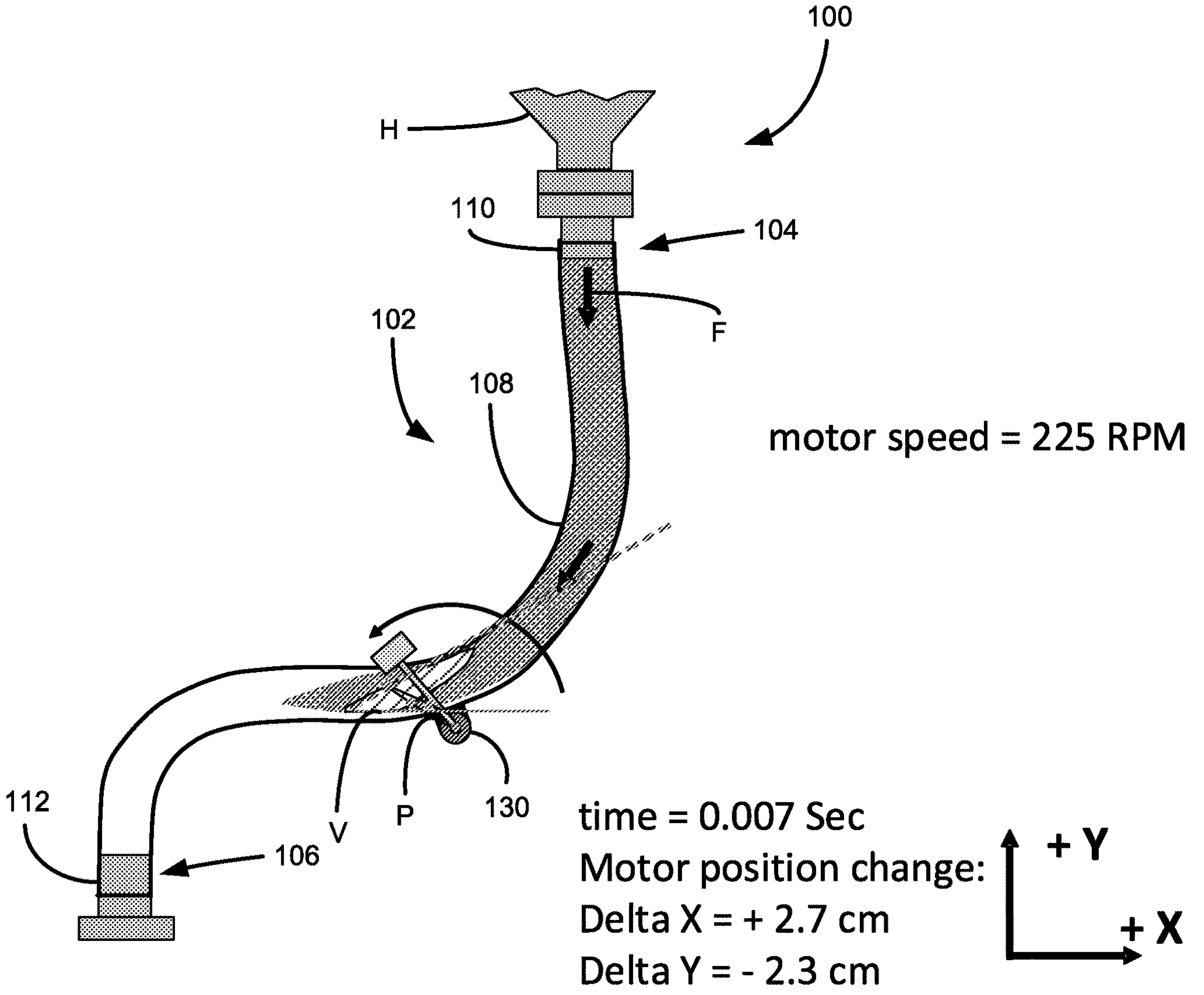

100
H
110
104
F
102
108
motor speed = 225 RPM
112
V
P
130
106
time = 0.007 Sec
Motor position change:
Delta X = + 2.7 cm
Delta Y = - 2.3 cm
+ Y
+ X

Fig. 2

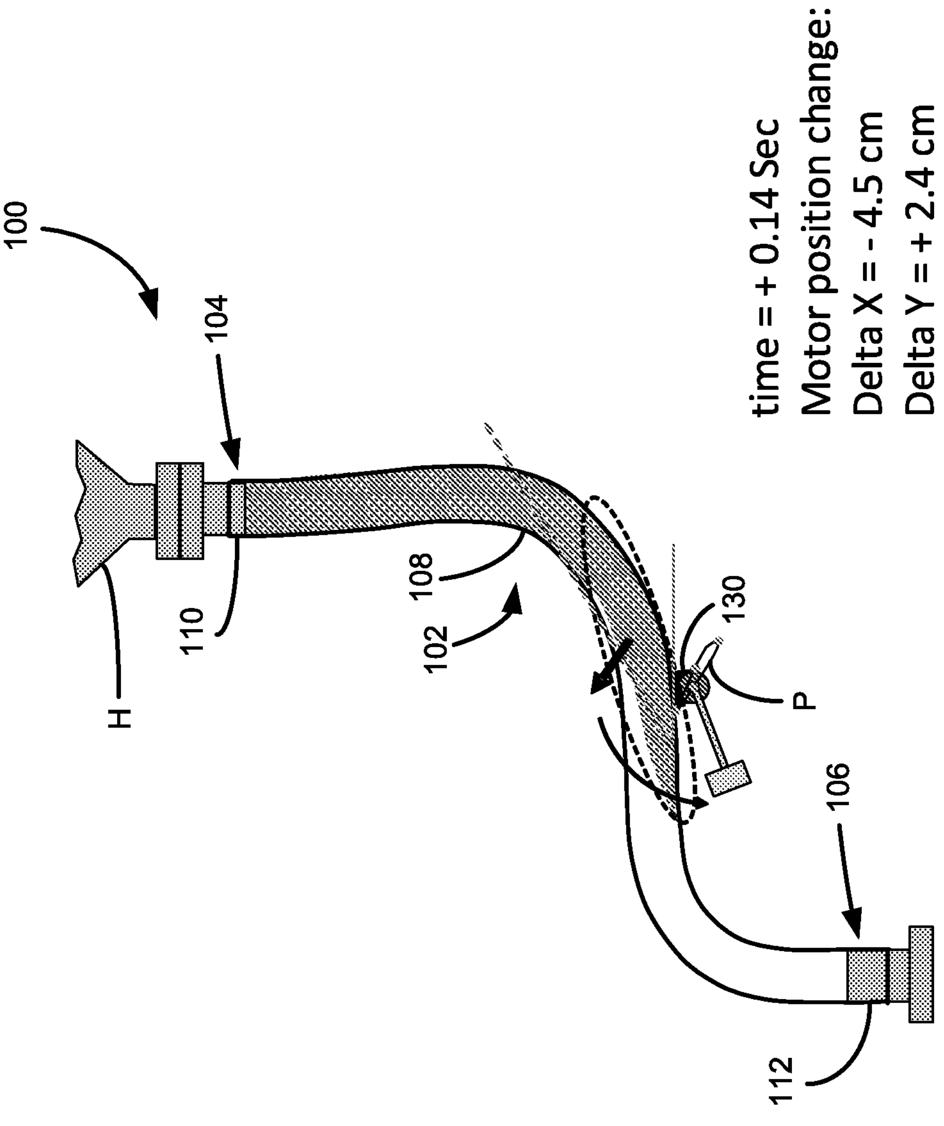
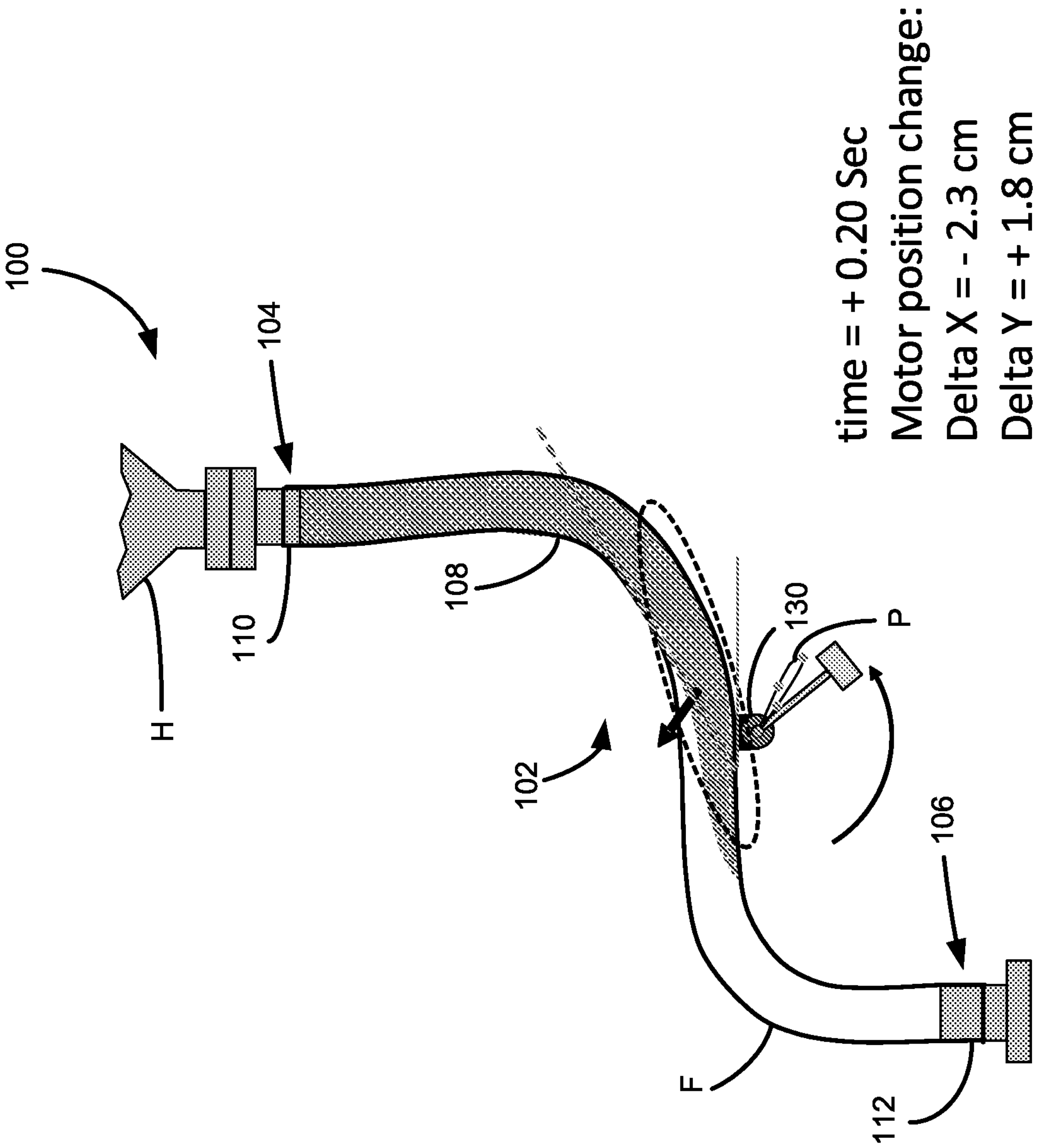
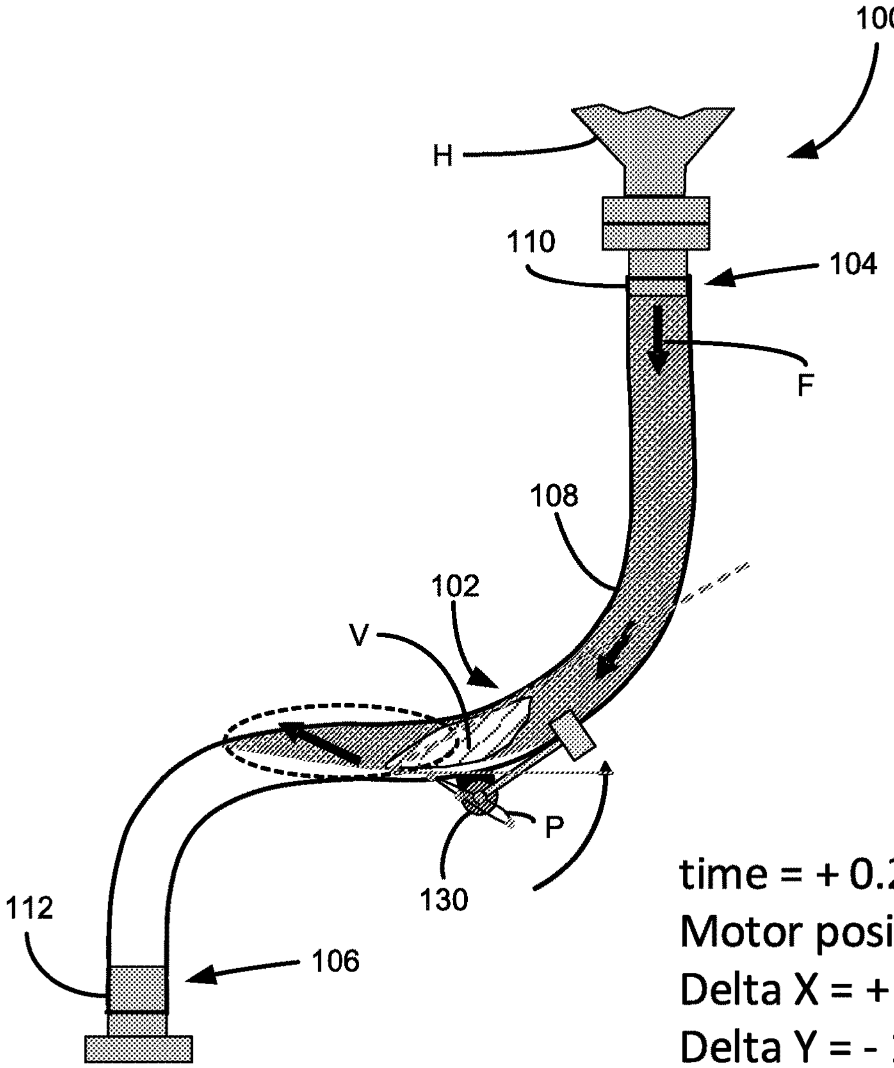

100
104
H
110
108
102
130
P
106
112
time = + 0.14 Sec
Motor position change:
Delta X = - 4.5 cm
Delta Y = + 2.4 cm

Fig. 3



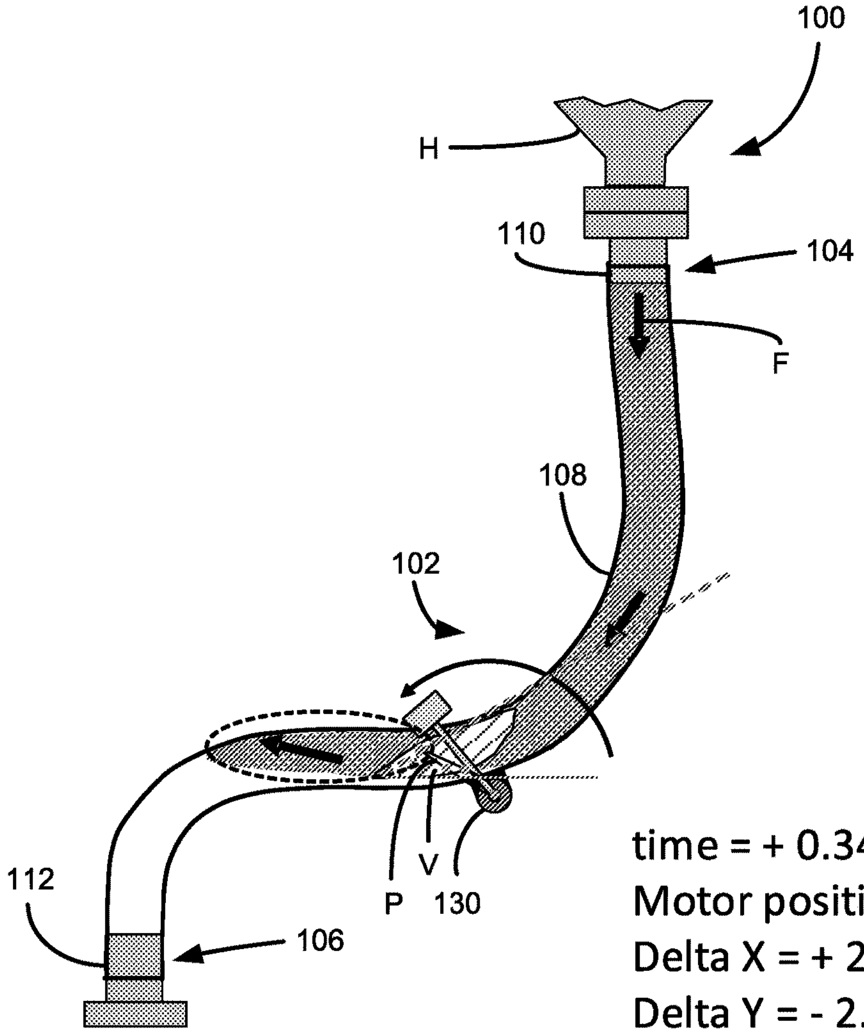
time = + 0.20 Sec
Motor position change:
Delta X = - 2.3 cm
Delta Y = + 1.8 cm

Fig. 4



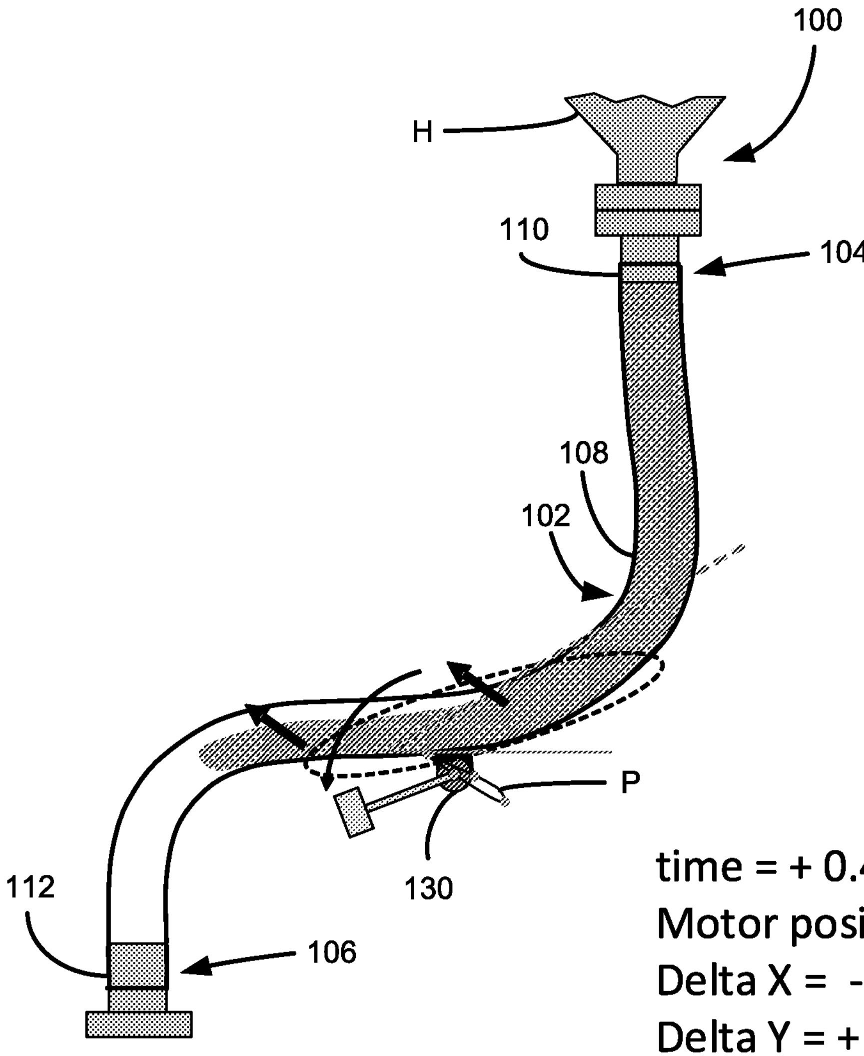
time = + 0.27 Sec
Motor position change:
Delta X = + 4.2 cm
Delta Y = - 1.8 cm

Fig. 5



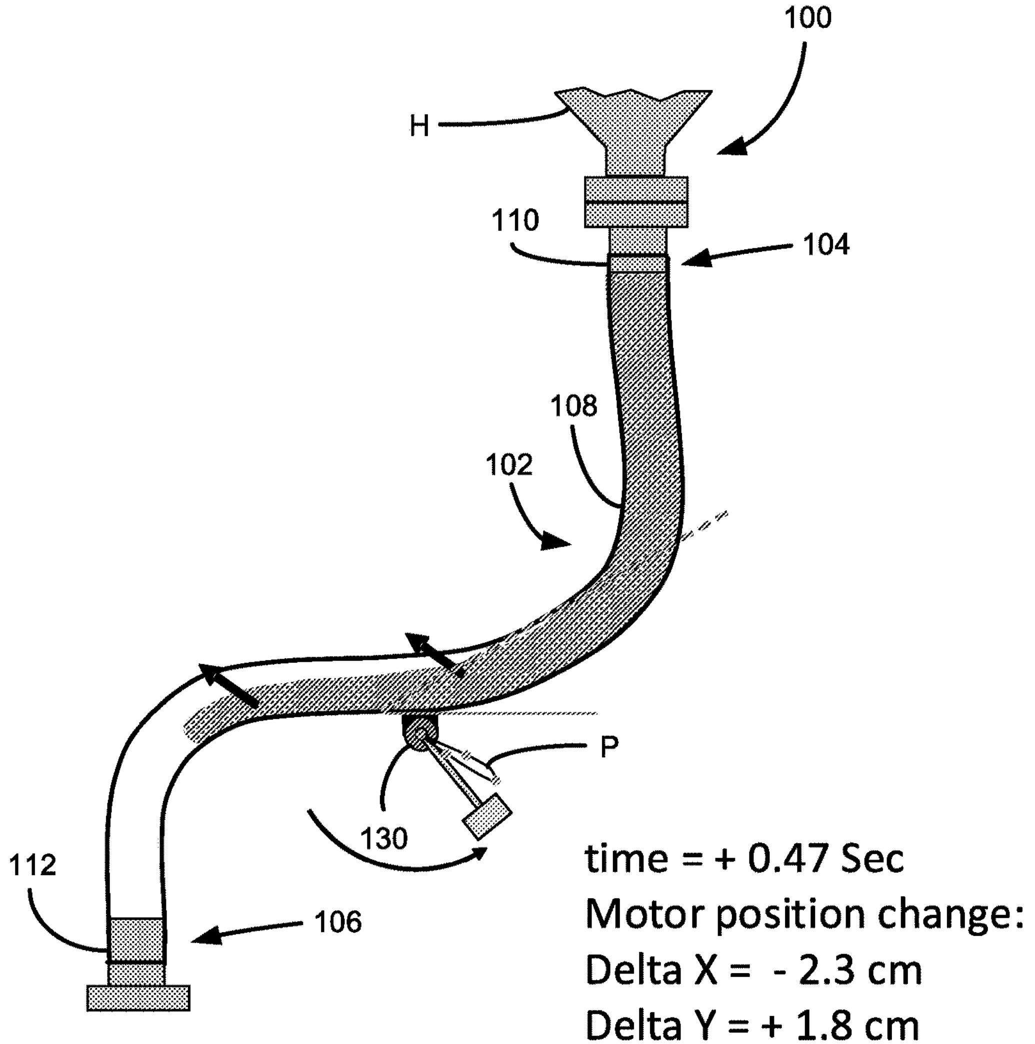
time = + 0.34 Sec
Motor position change:
Delta X = + 2.7 cm
Delta Y = - 2.3 cm

Fig. 6



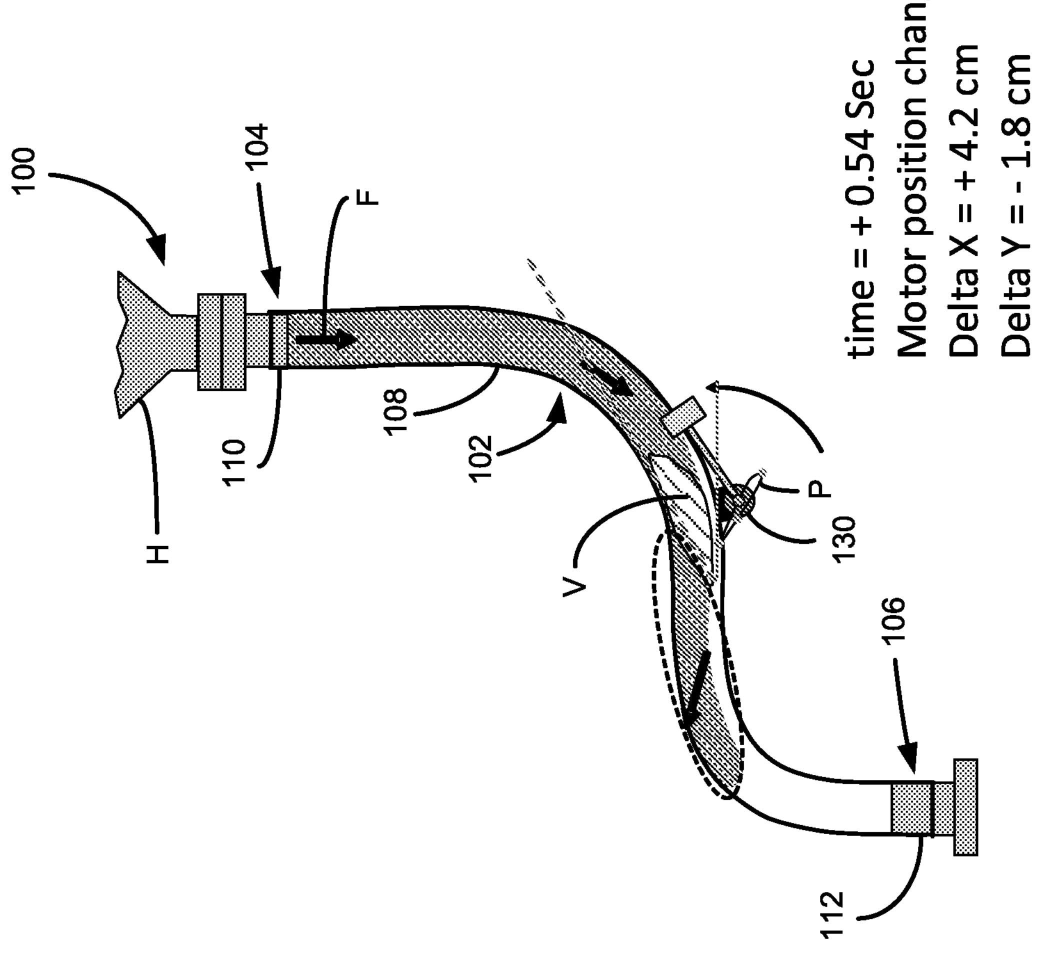
time = + 0.41 Sec
Motor position change:
Delta X = - 4.5 cm
Delta Y = + 2.4 cm

Fig. 7



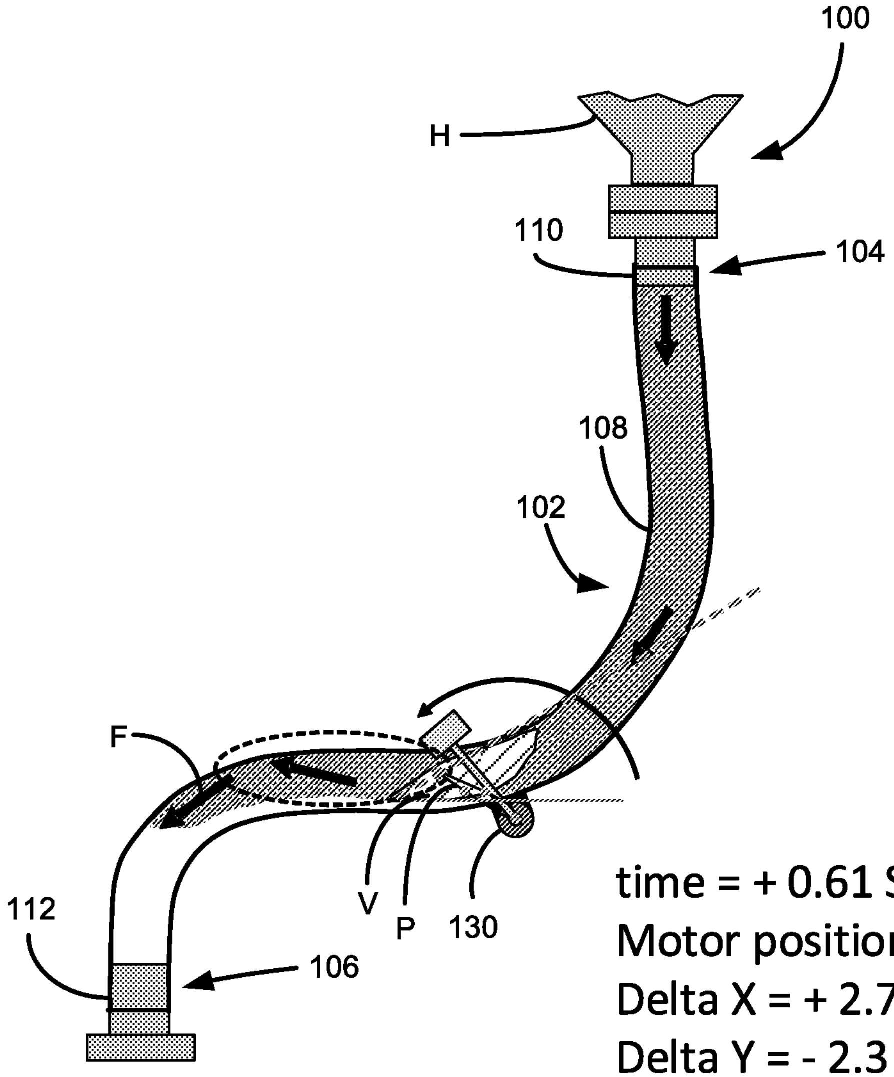
time = + 0.47 Sec
Motor position change:
Delta X = - 2.3 cm
Delta Y = + 1.8 cm

Fig. 8



time = + 0.54 Sec
Motor position change:
Delta X = + 4.2 cm
Delta Y = - 1.8 cm

Fig. 9



time = + 0.61 Sec
Motor position change:
Delta X = + 2.7 cm
Delta Y = - 2.3 cm

Fig. 10

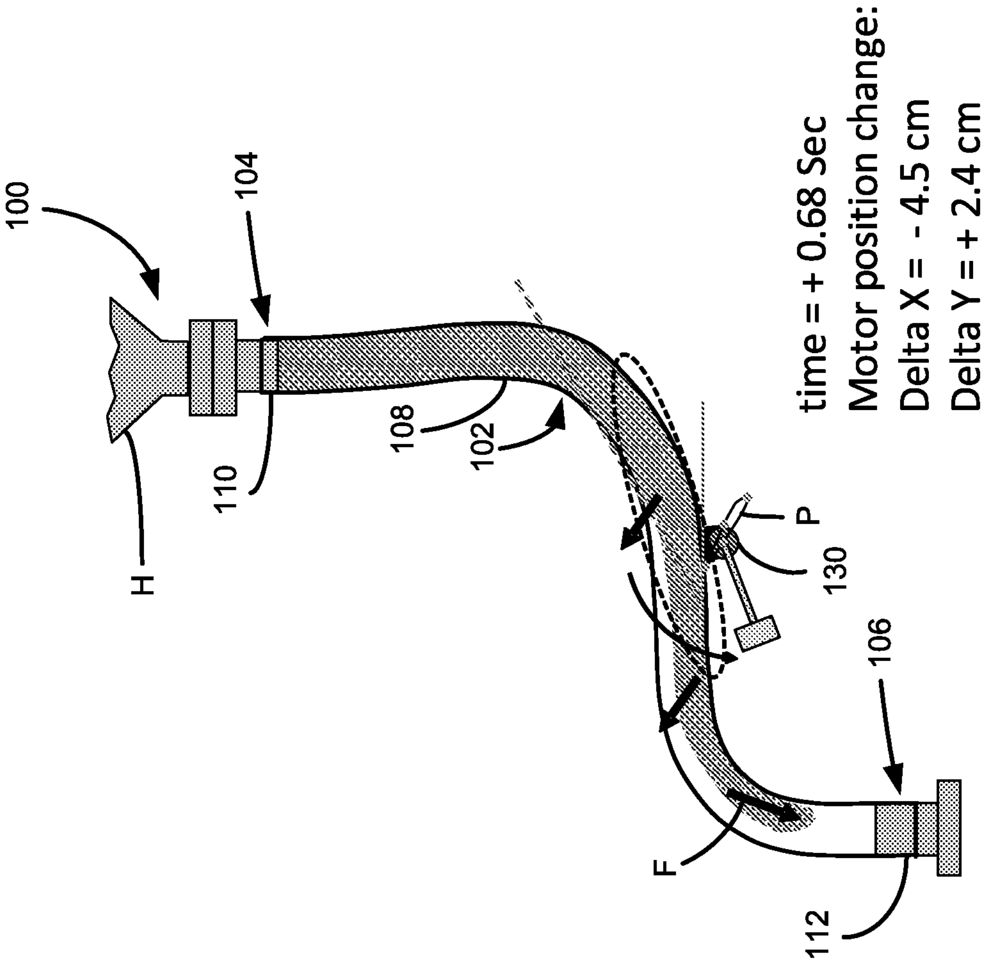

100
104
H
110
108
102
P
130
106
F
112
time = + 0.68 Sec
Motor position change:
Delta X = - 4.5 cm
Delta Y = + 2.4 cm

Fig. 11

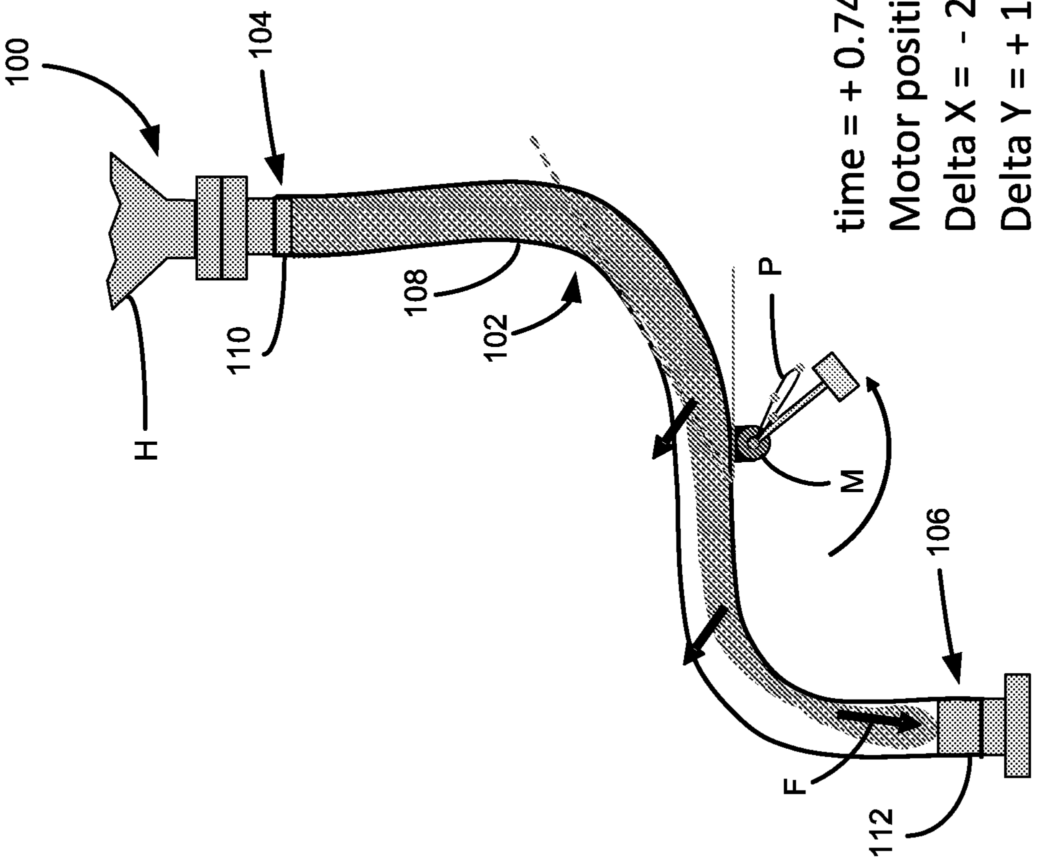
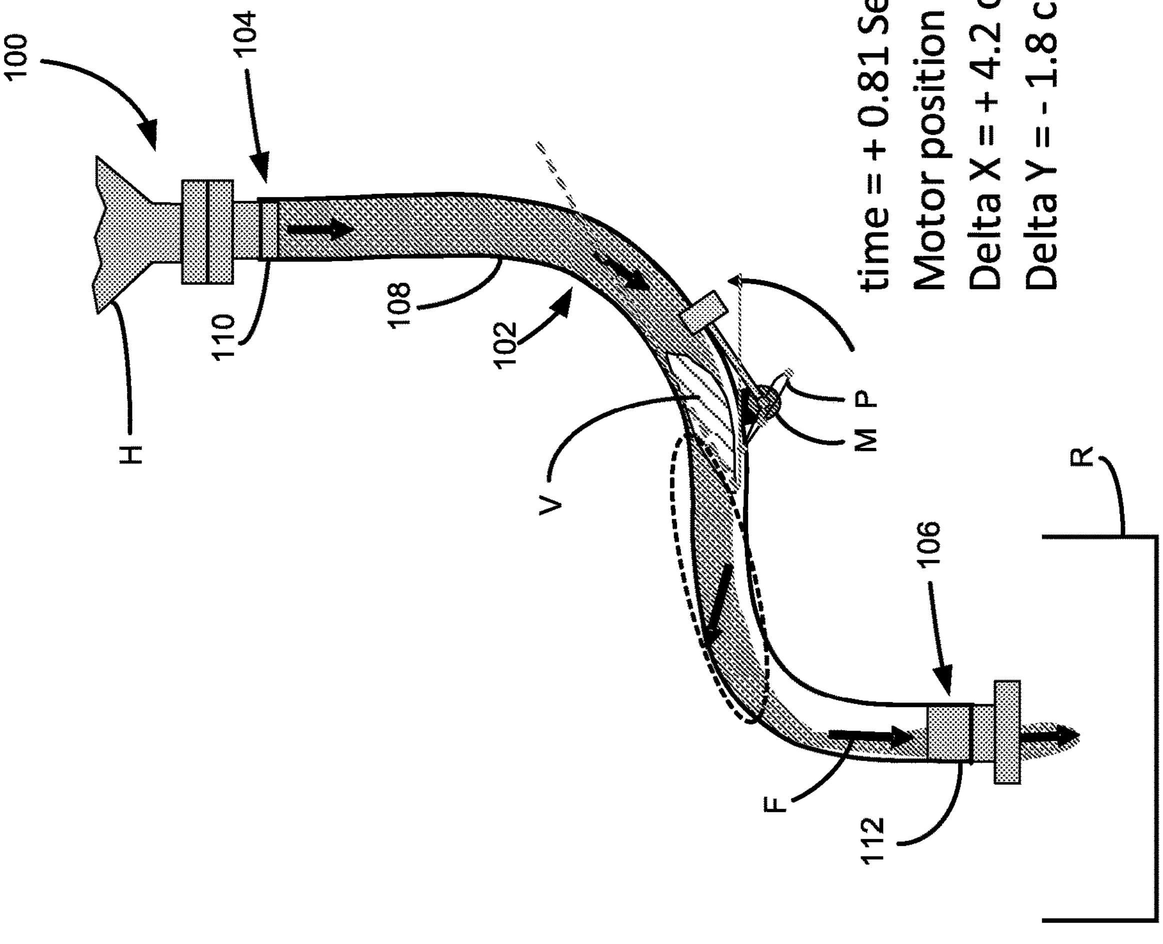

100
104
H
110
108
102
P
M
106
F
112
time = + 0.74 Sec
Motor position change:
Delta X = - 2.3 cm
Delta Y = + 1.8 cm

Fig. 12



time = + 0.81 Sec
Motor position change:
Delta X = + 4.2 cm
Delta Y = - 1.8 cm

Fig. 13

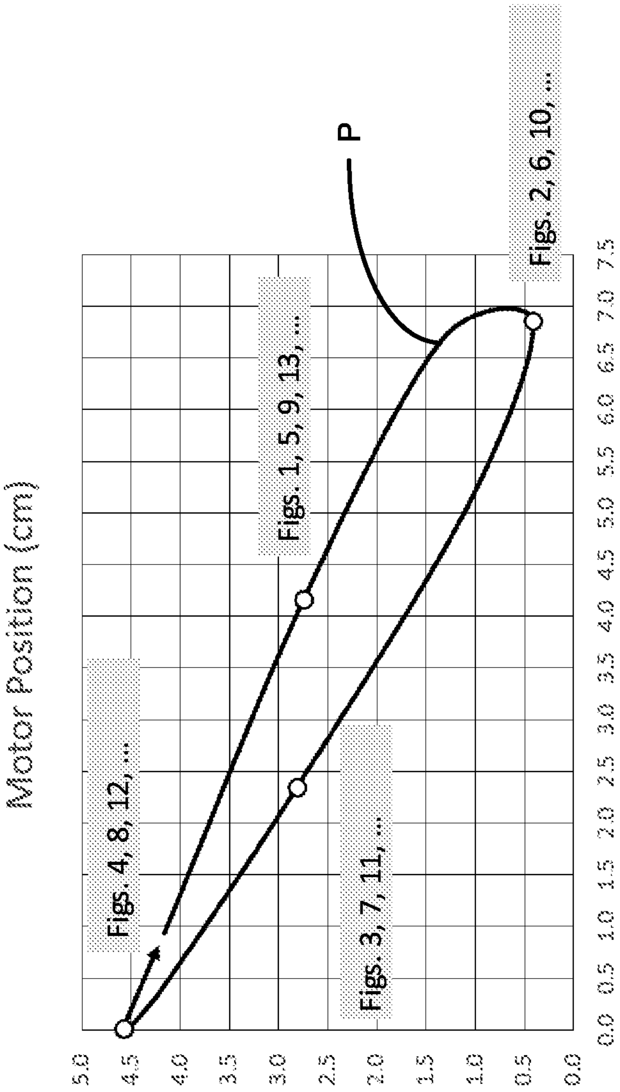

Motor Position (cm)
Figs. 4, 8, 12, ...
Figs. 1, 5, 9, 13, ...
Figs. 3, 7, 11, ...
Figs. 2, 6, 10, ...
P
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5

Fig. 14

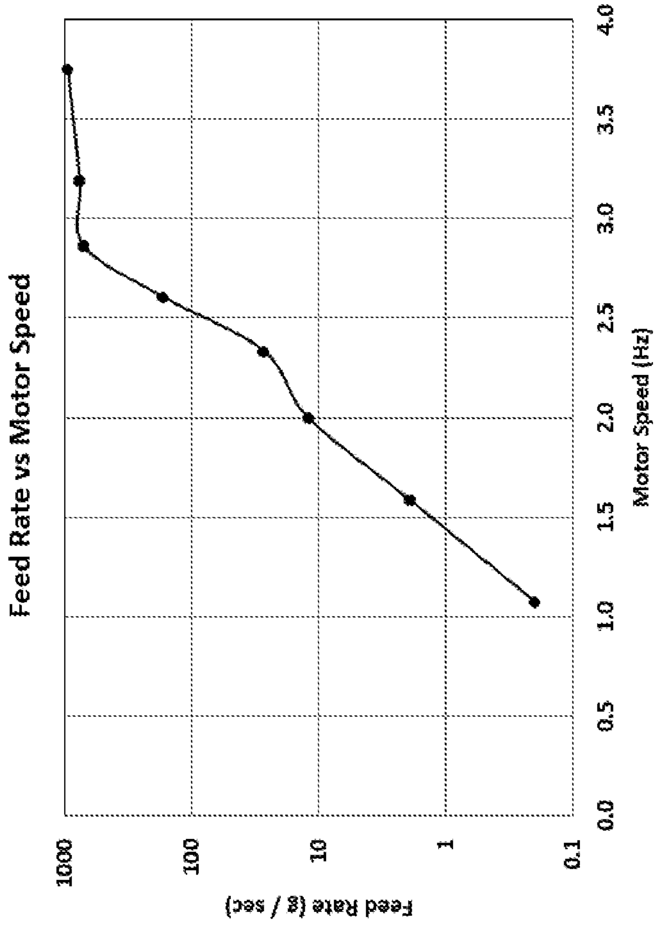

Feed Rate vs Motor Speed
Feed Rate (g / sec)
1000
100
10
1
0.1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Motor Speed (Hz)

Fig. 15

Motor Speed %	frequency (hz)	RPM	Force Amplitude (Newtons)	Feed Rate (g/sec)
100	3.75	225.0	23.35	942.0
90	3.20	191.7	16.69	764.0
80	2.87	171.9	13.62	712.0
70	2.61	156.5	11.74	169.0
60	2.34	140.1	10.00	27.0
50	2.00	120.0	6.83	12.1
40	1.59	95.1	4.35	1.9
30	1.08	64.7	2.10	0.2

Fig. 16

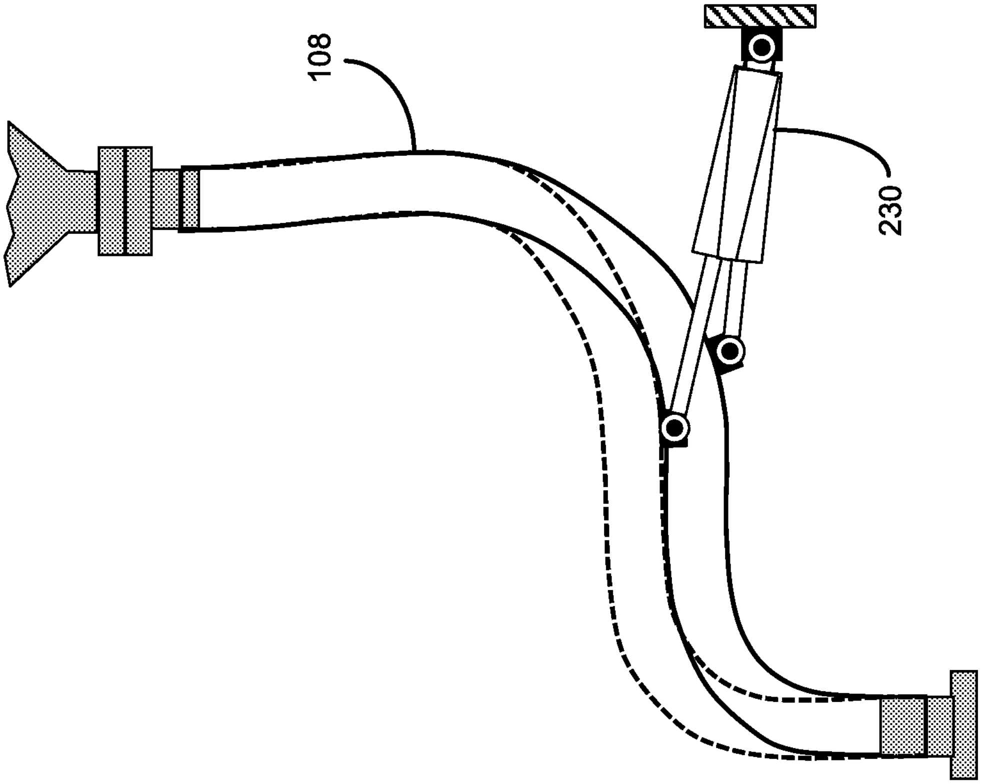


Fig. 18

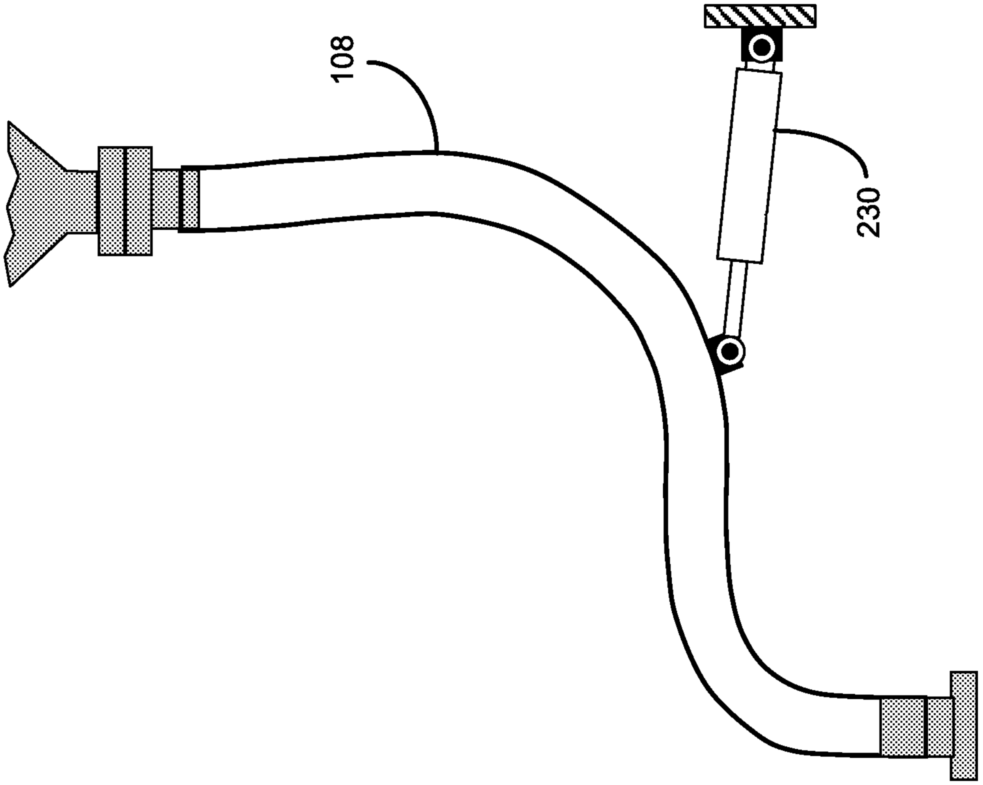


Fig. 17

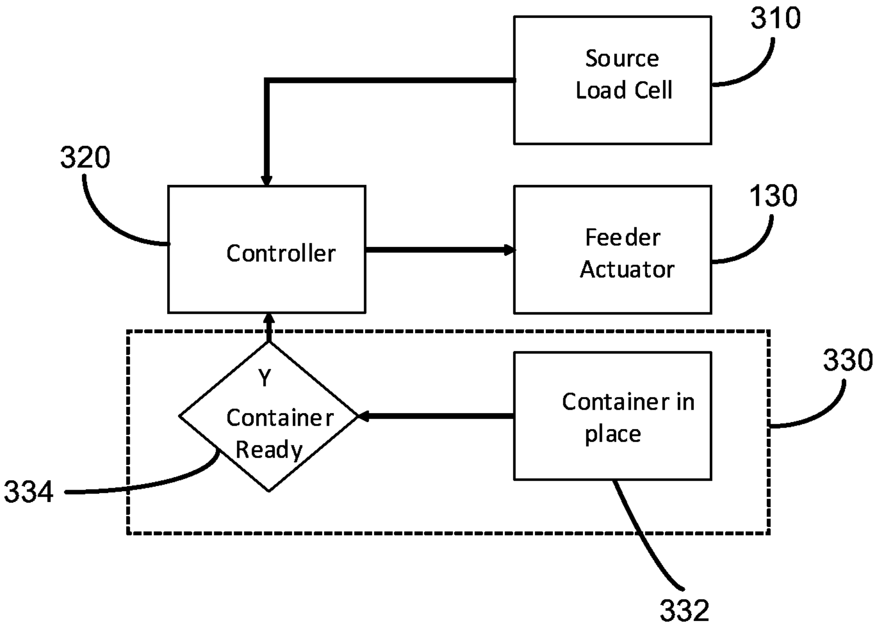

310
Source Load Cell
320
Controller
130
Feeder Actuator
330
Y
Container Ready
Container in place
334
332

Fig. 19

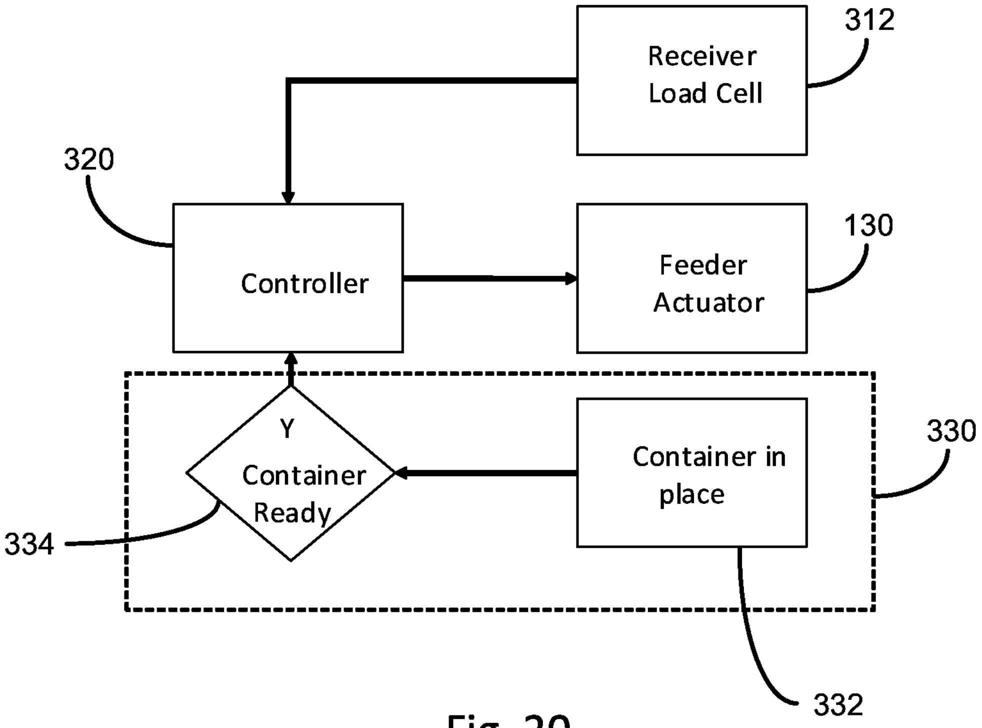

312
Receiver Load Cell
320
Controller
130
Feeder Actuator
330
Y
Container Ready
Container in place
334
332

Fig. 20

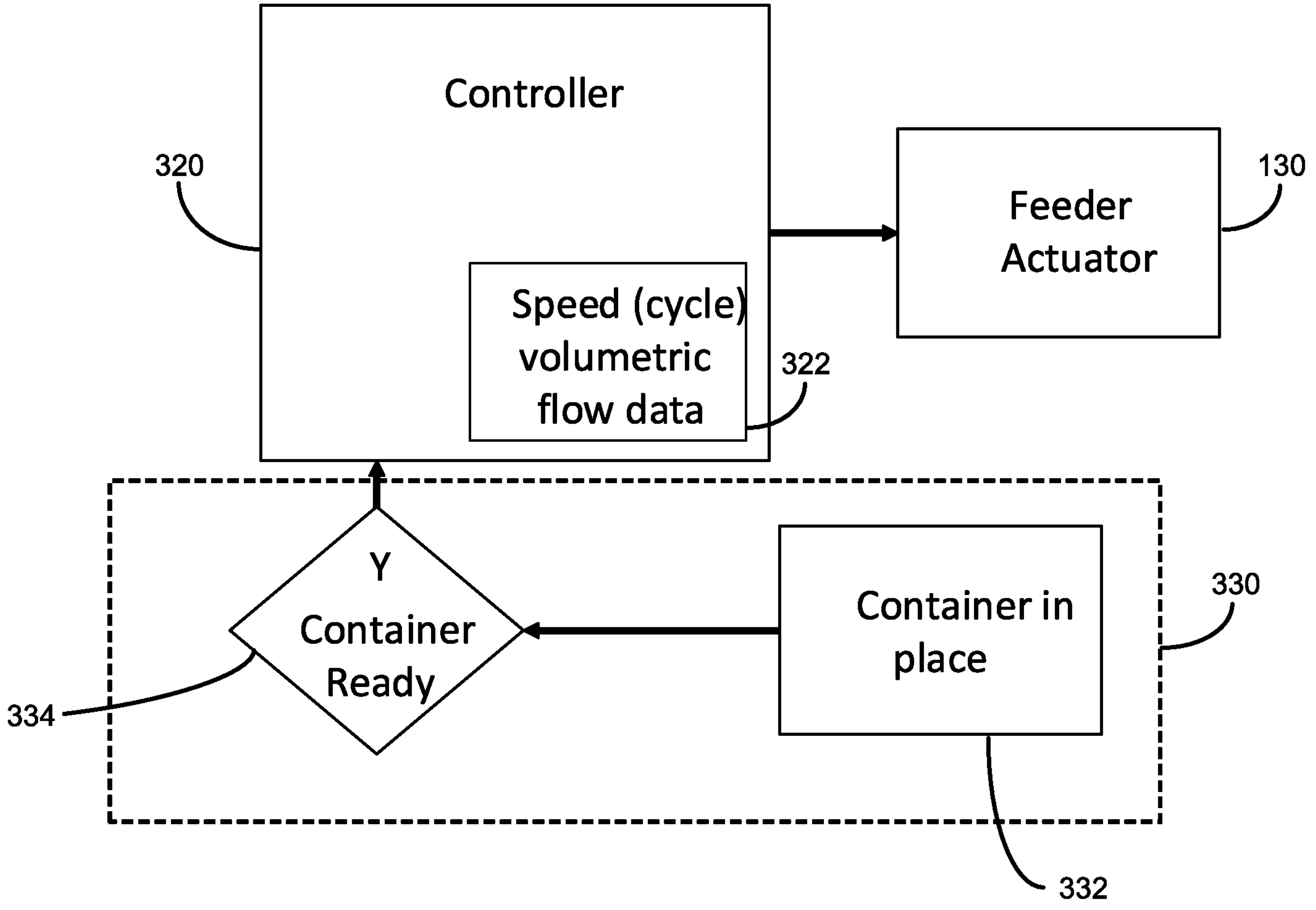

Controller
320
Speed (cycle) volumetric flow data
322
Feeder Actuator
130
Y
Container Ready
334
Container in place
332
330

Fig. 21

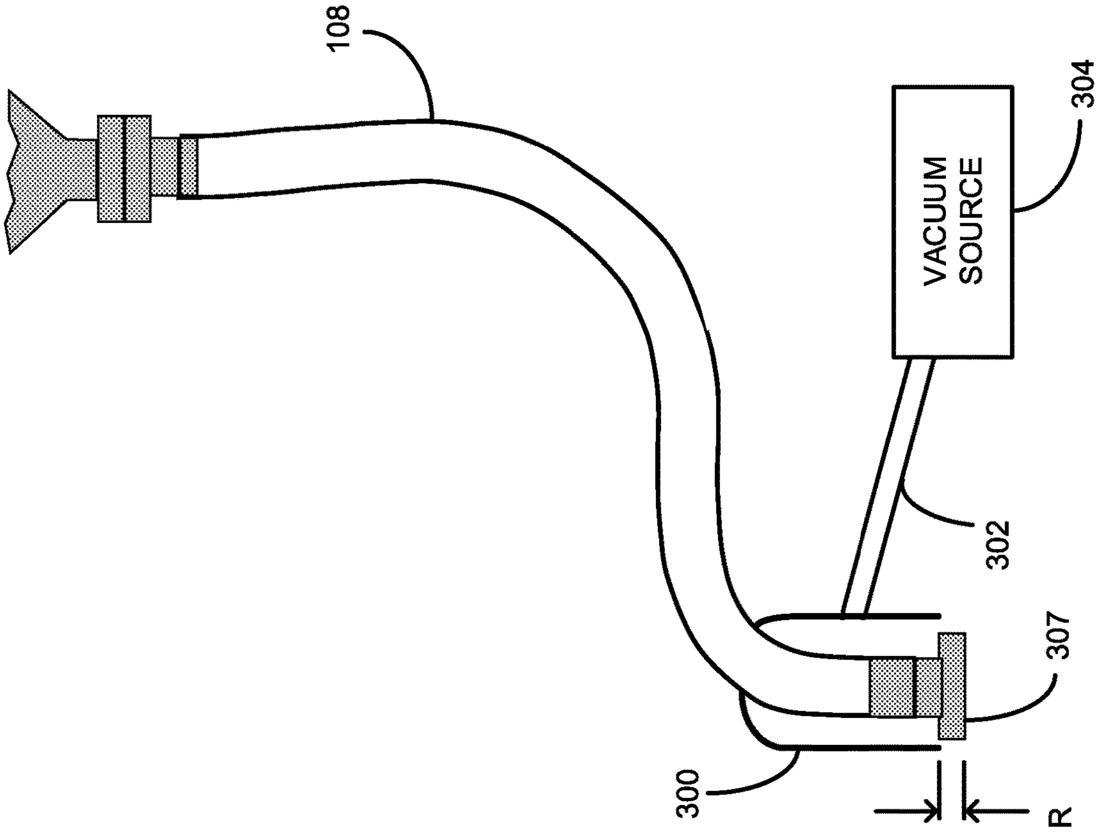


Fig. 22

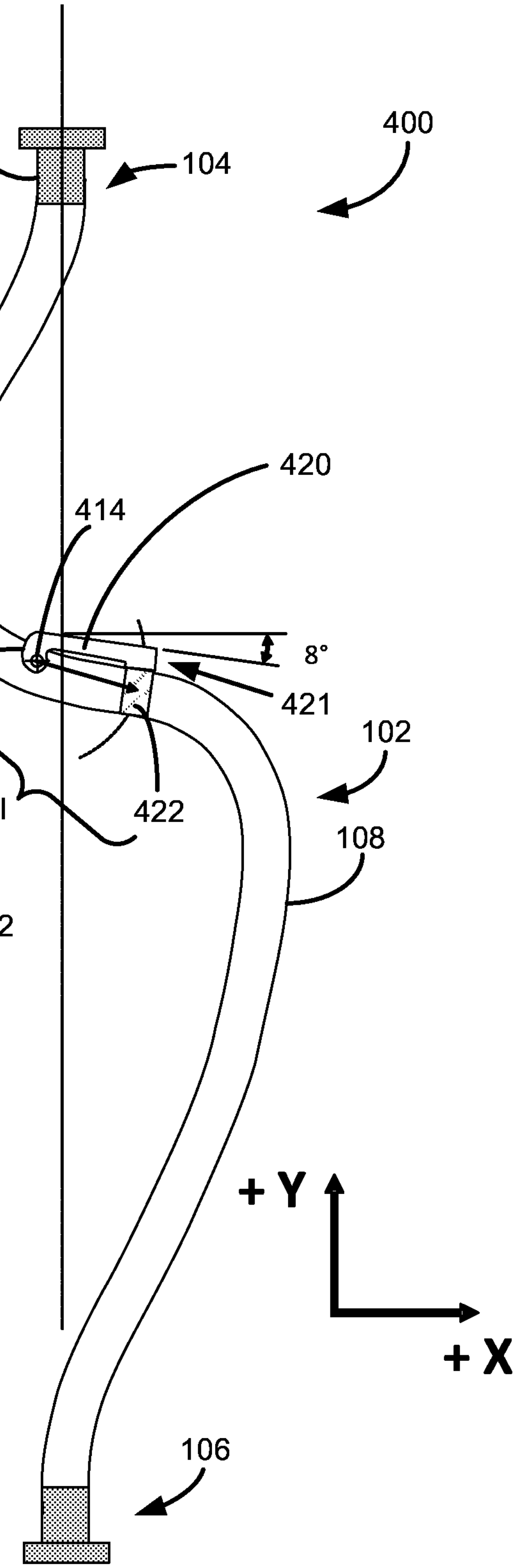


Fig. 23A

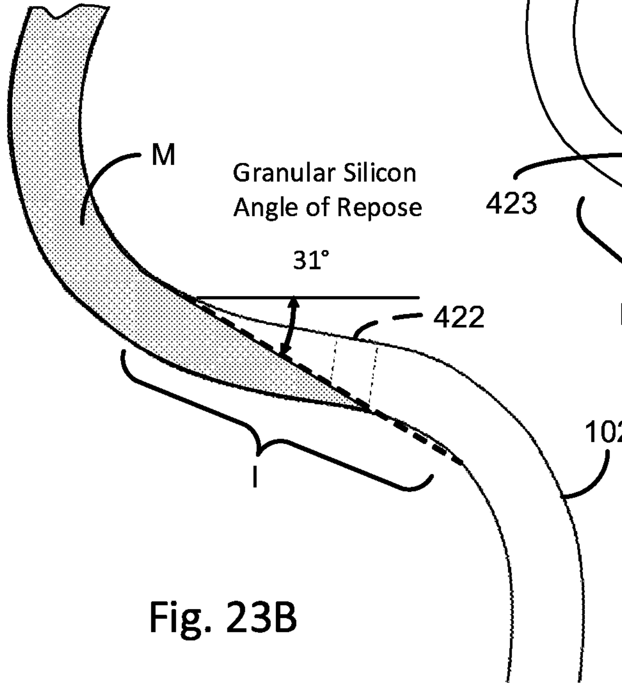


Fig. 23B

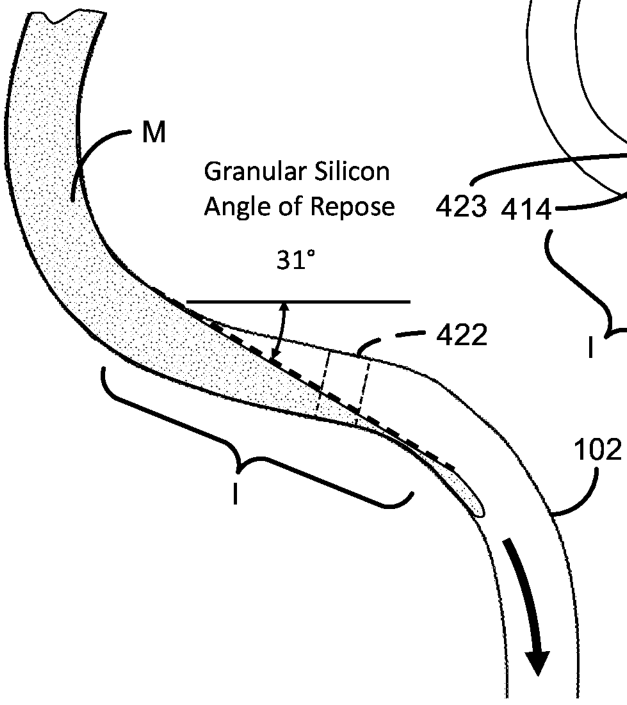


Fig. 24B

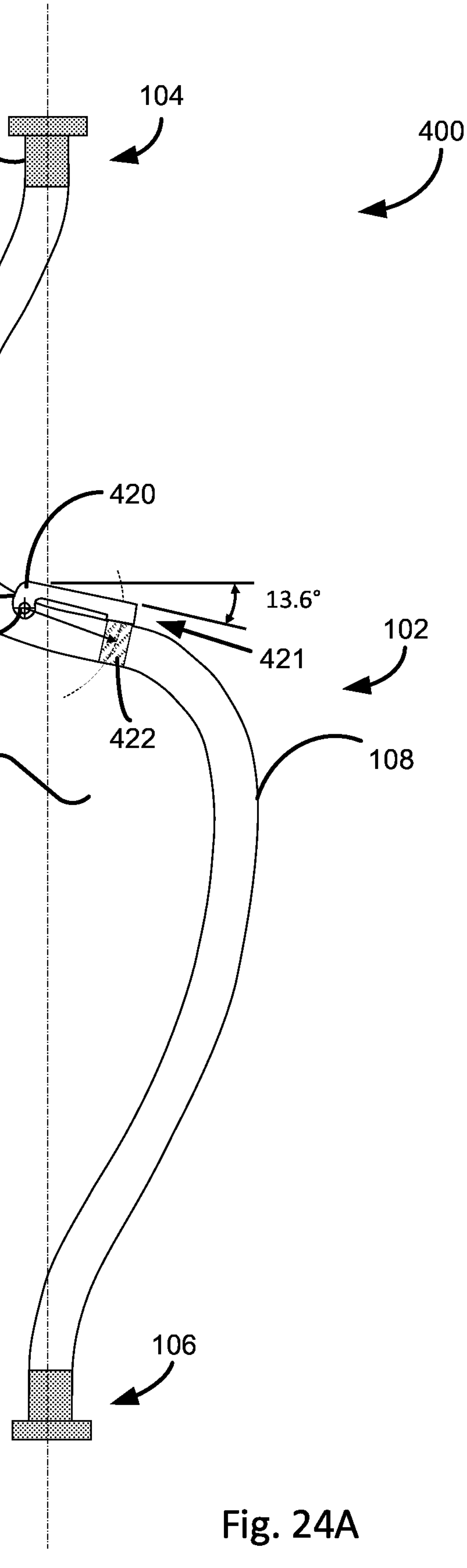


Fig. 24A

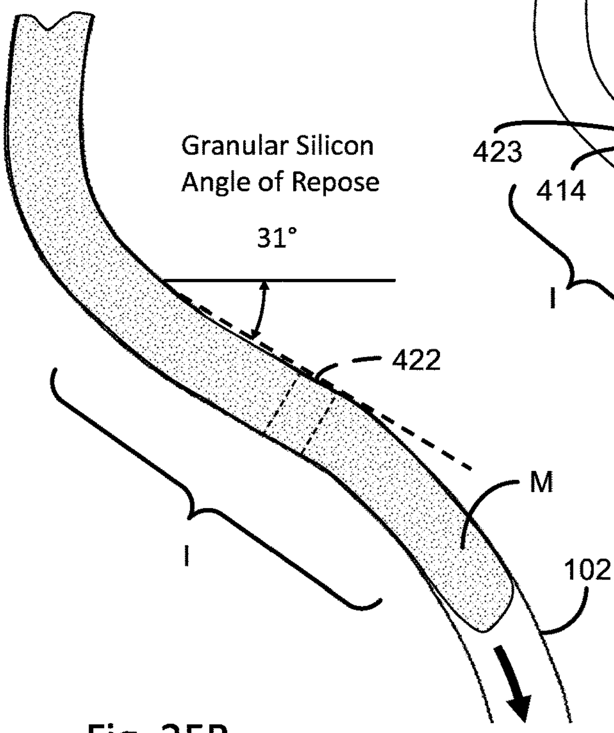


Fig. 25B

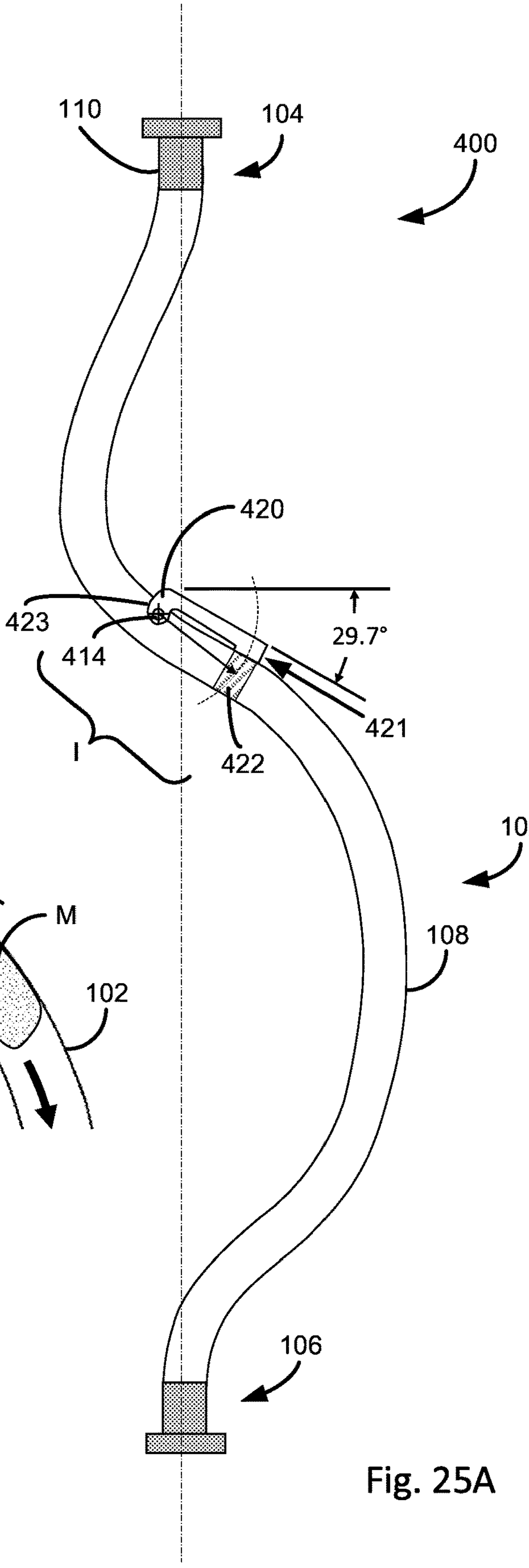


Fig. 25A

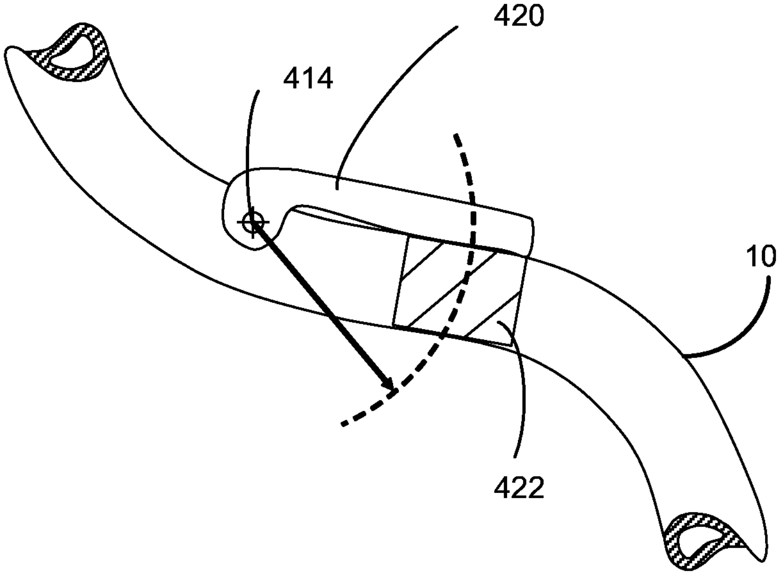


Fig. 26A

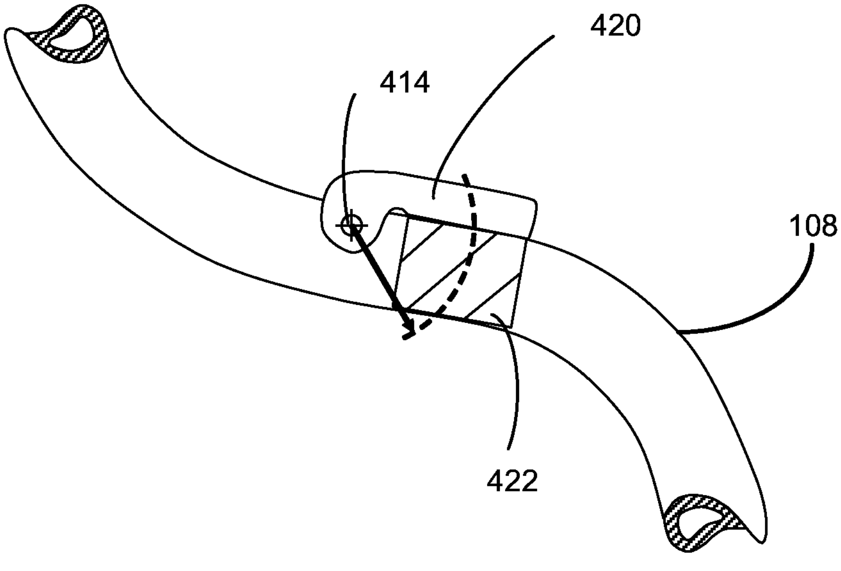


Fig. 26B

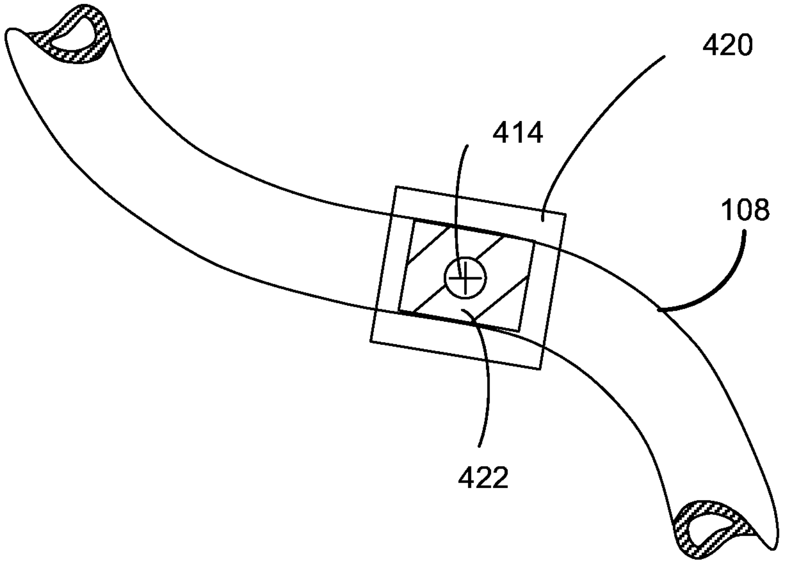


Fig. 27A

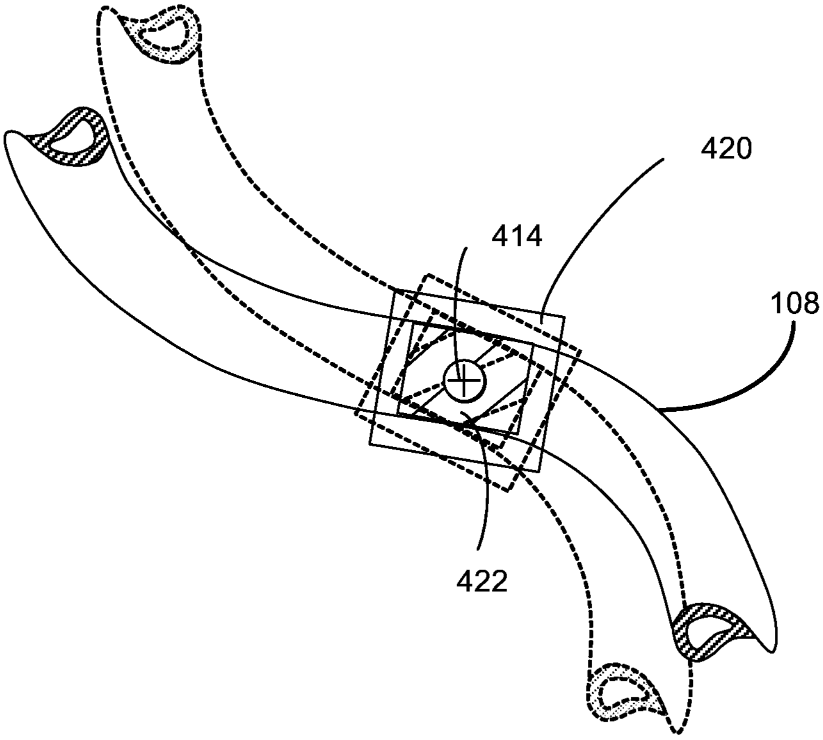


Fig. 27B

FEEDER

BACKGROUND

[0001] Silicon of ultra-high purity is used extensively in the electronics and photovoltaic industries. High purity granular polysilicon materials with only trace of amounts of contamination measured at the part per billion levels are often required. Producing such materials is possible, but then extreme care must be taken in any handling, packaging or transportation operations to avoid subsequent contamination.

[0002] Conventional feeding and flow control technologies used to convey granular polysilicon materials includes components having metal in their construction (e.g., valves, conduits, etc.). When protective coatings or linings are compromised, or when wear occurs at the interfaces of moving parts, for example, contamination from metal parts can occur, which is unacceptable.

[0003] Valves used to regulate the flow of granular materials that rely on components that move relative to the material being conveyed, such as butterfly dampers, pinch bladders, diaphragms, gates, etc., have a disadvantage of potentially crushing granules of the material, which can both reduce its value and potentially damage the components and other equipment.

[0004] In addition, conventional feeders may not provide sufficient control over the rate of flow granular polysilicon and/or the flow rate range. Conventional vibrating tray feeders may achieve a feed rate range between a lowest controllable feed rate and a highest controllable feed rate of only about 1:50, but a much higher feed rate range is desirable. Other conventional approaches allow higher feed rate ranges to be achieved, but only with apparatus having multiple parts within the control volume of the flowing material that must move relative to each other, such as auger screws, rotary vanes and other similar structures. Multiple parts in relative motion within the control volume, however, leads to a greater risk of contamination.

[0005] Also, such conventional feeders are difficult to purge with a suitable process gas and/or clean in part because of their complicated constructions. The multi-piece constructions typically require an extensive use of seals to prevent leakage through components that move relative to each other.

[0006] Conventional vibratory solids conveyors typically have a rigid container constrained by linkages and/or springs that can be driven by an eccentric weight assembly coupled to an electric motor or an electromagnetic drive in a desired motion, such as elliptical rotation that includes horizontal and vertical components.

[0007] Conventional approaches to conveying solids, including vibratory conveyors, screw augers, belt conveyors and other similar devices, are not capable of achieving high performance over a large range of flows while ensuring that ultrahigh purity is maintained.

SUMMARY

[0008] Described below are apparatus and methods that address some of the drawbacks in conventional approaches to feeding solids materials, including granular polysilicon.

[0009] According to a first implementation, a feeder operable to convey a divided solids material comprises a conduit and an actuator. The conduit has a hollow body with a length, a first end, a second end opposite the first end and a displaceable body segment defined along at least a portion of the length. The displaceable body segment has at least a first fixable location positionable at a first fixed location. The actuator is positioned to apply force to the conduit and controllable to cause selected flow of divided solids material in a feed direction extending generally from the first end to the second end.

[0010] In some implementations, the actuator is supported by the conduit and moves with the displaceable body segment during a feeding operation. The actuator can comprise a rotating offset mass, and the rotating offset mass can be operated to generate oscillating motion of the displaceable body segment and the attached actuator. The displaceable body segment can be cyclically displaced through a closed trajectory having at least one of a vertical component and a horizontal component.

[0011] In some implementations, the displaceable body segment has a second fixable location downstream of the first fixable location in the feeding direction and positionable at a second fixed location.

[0012] In some implementations, the displaceable body segment has a curved profile with a length longer than a shortest distance separating the first fixable location and the second end, and the actuator is attached to the displaceable body segment approximately at an inflection point for a curve of the curved profile.

[0013] In some implementations, the actuator is positioned stationarily and has a controllably movable element that contacts the displaceable body segment. In some implementations, the actuator comprises a linear actuator. In some implementations, the actuator comprises an elongate member having a distal end pivotable into contact with the displaceable body segment to selectively move the displaceable body segment and a proximal end pivotably connected to a pivot point.

[0014] In some implementations, the displaceable body segment comprises an intermediate section configured to collect a portion of the divided solids material when the displaceable body segment is at rest. The intermediate section can be configured to collect a leading edge of a flow of divided solids material received from the first end of the feeder.

[0015] In some implementations, the intermediate section is configured for positioning at a slight angle relative to horizontal, and there is a first upright section positioned upstream of the intermediate section and a second upright section positioned downstream of the intermediate section.

[0016] In some implementations, the conduit is made from a resilient material. In some implementations, the conduit comprises polyurethane hose material.

[0017] In some implementations, a feeder comprises a conduit and an actuator. The conduit has an inlet end, an outlet end opposite the inlet end and a displaceable body segment along a feeding direction between the inlet end and the outlet end. The inlet end is configured for connection to a source of material to be fed by the feeder. The outlet end is configured to convey divided solids material from the feeder to a location downstream of the feeder. The outlet end is positioning at a lower height than the inlet end. The displaceable body segment is sized to have a length longer than a shortest distance between the inlet end and the outlet end and to define a curved profile with at least one inflection point when installed. When installed, the displaceable body segment defines an intermediate section configured to support accumulated material therein at an angle of repose of the material, and to reduce movement of material in the feeding direction when the displaceable body segment is at rest. The actuator is connected to the displaceable body segment to controllably displace the displaceable body segment in a feeding operation.

[0018] In some implementations, the actuator is controllable to displace the displaceable body segment in an oscillating cycle. In some implementations, the actuator is manually operable. In some implementations, the displaceable body segment extends substantially from the inlet end and substantially to the outlet end.

[0019] In some implementations, the intermediate section is caused to be displaced from a substantially lateral position at which no flow occurs to a downwardly tilted position at which flow towards the outlet end occurs.

[0020] In some implementations, the actuator can be configured to move at a rate sufficient to cause displacement of the displaceable body section such that the solids material moves at a selected rate between a low trickle flow and a high bulk filling flow.

[0021] According to a method implementation, a method of conveying a divided solids material with a feeder comprises using a sensor to monitor an amount of the divided solids material being conveyed with the feeder, receiving signals from the sensor at a controller and sending control signals from the controller to the feeder to control a flow rate of the divided solids material over a flow rate range ratio of greater than 1:50 of a low flow rate to a high flow rate.

[0022] According to some implementations, using a sensor to monitor an amount of the solid material being conveyed can comprise configuring the sensor to measure a loss of weight of the solid material from a source of the material positioned upstream of the feeder. According to some implementations, using a sensor to monitor an amount of the solid material being conveyed comprises configuring the sensor to measure a gain in weight from the solid material conveyed to a receptacle positioned downstream of the feeder.

[0023] According to some implementations, the feeder can comprise a conduit segment for receiving the solid material and that is displaceable according to the control signals from the controller to achieve a desired flow rate of the material from the feeder. In some implementations, the flow rate range ratio is greater than 1:4000.

[0024] According to another method implementation, a method of conveying divided polysilicon comprises receiving divided polysilicon from a source into a conduit of a feeder, controllably moving the conduit through an operation path in which the conduit is positioned in at least a first position at which flow through the conduit occurs and a second position at which flow through the conduit is stopped, and receiving the divided silicon material flowing through the conduit, when the conduit is positioned at least in a first position, in a receptacle positioned downstream of an outlet end of the conduit.

[0025] Desirably, the feeding and flow control technologies described herein tend not to rely on reducing the cross section of the conduit, which reduces damage to the material being conveyed and the equipment.

[0026] The foregoing and other objects, features, and advantages will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. **1** is side elevation view of a representative implementation of a feeder in its at rest position.

[0028] FIGS. **2-13** are side elevation views of the feeder of FIG. **1** schematically showing the feeder of FIG. **1** and material being fed with the feeder in different positions throughout several cycles of motion.

[0029] FIG. **14** is a graph showing the trajectory of the motor and a segment of the body of the feeder through a cycle with reference to the positions shown in FIGS. **2-13**.

[0030] FIG. **15** is a graph of feed rate for the feeder vs motor speed.

[0031] FIG. **16** is a table of data used to plot the graph of FIG. **15**.

[0032] FIGS. **17-18** are side elevation views of another implementation of the feeder in which the actuator for moving the body is a double acting pneumatic cylinder.

[0033] FIG. **19** is a schematic block diagram of a representative control circuit for regulating operation of the feeder as a gravimetric feeder according to control based on a loss of weight.

[0034] FIG. **20** is a schematic block diagram of a representative control circuit for regulating operation of the feeder as a gravimetric feeder according to control based on a gain in weight.

[0035] FIG. **21** is a schematic block diagram of a representative control circuit for regulating operation of the feeder as a volumetric feeder.

[0036] FIG. **22** is a side elevation view of another implementation of the feeder in which a vacuum or suction device has been added to assist in controlling dust during feeding operations.

[0037] FIG. **23**A is a side elevation view of another implementation of the feeder in which an intermediate section is constrained to control flow as desired.

[0038] FIG. **23**B is an enlarged section view of a portion of the feeder of FIG. **23**A showing solids in the feeder at rest when the feeder is in a zero flow position.

[0039] FIG. **24**A is a side elevation view of the feeder of FIG. **23**A showing the feeder in a different position.

[0040] FIG. **24**B is an enlarged section view of a portion of the feeder of FIG. **24**A showing solids in the feeder beginning to flow.

[0041] FIG. **25**A is a side elevation view of the feeder of FIG. **23**A showing the feeder in another different position.

[0042] FIG. **25**B is an enlarged section view of a portion of the feeder of FIG. **25**B showing solids in the feeder and the feeder positioned for maximum flow.

[0043] FIGS. **26**A and **26**B are side elevation views showing variations of the feeder of FIG. **23**A having members of different lengths.

[0044] FIGS. **27**A and **27**B are side elevation views of the feeder of FIG. **23**A showing another variation in the member.

DETAILED DESCRIPTION

[0045] Referring to FIG. **1**, a side elevation view of a representative implementation of a feeder **100** through which material can be fed is shown. The feeder **100** has a body **102** that is generally tubular, which is also sometimes referred to herein as a conduit. Because the body **102** is tubular, it has a hollow cross section. The cross section of the body **102** may define an inner surface that is circular, elliptical, rounded or even multi-sided. The outer surface may have any suitable shape, and the wall(s) between the inner surface and outer surface may have any suitable thickness (constant or variable).

[0046] The body **102** has a first end **104** and an opposite second end **106**. Between the first and second ends **104**, **106**, there is a displaceable body segment **108** that can be caused to displace or move, or to vibrate or oscillate (and in some cases, to do so cyclically), as described below in greater detail, to cause material to be conveyed or fed from the first end **104**, through the body **102** and to the second end **106**. The body **102** is formed of one or more materials and to have selected dimensions such that it can be moved between different positions as desired, which is described below in more detail.

[0047] In some implementations, the material to be fed or conveyed is one or more solids materials comprising particles, such as a divided solids material. Polysilicon is one example of a material that can be provided as a divided solids or finely divided solids material. Other materials can also be fed using the described apparatus and methods. Also, the material to be fed can be a mixture of two or more different component materials.

[0048] A material is defined to be flowable if the bulk stress acting on the material exceeds the material's bulk strength. In the case of a granular material, one measurement used to indicate a material's ability to flow is the angle of repose of the material. The angle of repose of a granular material is the steepest angle of descent or dip relative to the horizontal plane to which the material can be piled without slumping (at this angle, the material on the slope face is on the verge of sliding). A material that has a lower tendency to flow may be comprised of particles with a relatively high degree of inter-particle friction, such as particles of a material having more angular shapes that tend to interlock with each other. In the same way, flowability of a material tends to be decreased if there is plastic deformation of particles, partial melting of particles, moisture present in and/or around particles and/or another factor tending to increase adhesion between particles.

[0049] In some cases, when particles of a material are at rest and not flowing, e.g., because the angle of repose for the material has not been exceeded, the particles can nevertheless be induced to flow by disturbing them, such as through applying energy to them, e.g., in the form of vibrations.

[0050] In the case of granular polysilicon (also sometimes referred to herein as granulate polysilicon and granules), the polysilicon particles are generally spheroids having an average diameter of 0.25 to 20 mm, such as an average diameter of 0.25-10 mm, 0.25-5 mm, or 0.25 to 3.5 mm. As used herein, "average diameter" means the mathematical average diameter of a plurality of granules. Individual granules may have a diameter ranging from 0.1-30 mm, such as 0.1-20 mm, 0.1-10 mm, 0.1-5 mm, 0.1-3 mm or 0.2-4 mm. The individual particles of any given material may have generally the same size and shape, or they vary in size and shape.

[0051] The open cross section of the tubular body **102** or conduit can sized to be at least 2-3 times greater than the major dimension of the largest target particle size such that flow of particles of such size through the feeder is facilitated. In specific examples, the major dimension is a diameter that is 2-3 times, 5 times, 10 times or 100 times the diameter of the largest target particle size of the material to be conveyed.

[0052] The first end **104** can be connected to an upstream source of material to be fed, such as a material comprising solids. In the illustrated implementation, the first end **104** is connected to the outlet end of a hopper H, which is stationary. Instead of the hopper H, the feeder **100** can be connected downstream of any other component or conduit that supplies material to be fed. The second end **106** can be connected to an outlet from which material fed by the feeder **100** is discharged as shown, or to any other downstream location. As shown in FIG. **13**, for example, the second end **106** can convey material to a receptacle R.

[0053] The displaceable body segment **108** can have a first fixable location **110**, e.g., a location that is positionable at a first fixed location. Similarly, the displaceable body segment **108** can have a second fixable location **112**, e.g., a second location that is fixable at a second fixed location. The first and second fixable locations **110**, **112** define the approximate ends of the displaceable body segment **108**. In the illustrated implementation, the first fixable location **110** is located in the area of the first end **104**, and second fixable location **112** is located in the area of the second end **106**. In other implementations, the first and second fixable locations **110**, **112** can be located at points spaced from the first and second ends **104**, **106**, respectively, to define displaceable body segments of different lengths and characteristics.

[0054] Typically, at least the displaceable body segment **108** is configured to be sufficiently flexible to be displaced as desired, such as by selecting appropriate material(s) and their dimensions. As one example, in the illustrated implementation, the body **102**, including the displaceable body segment **108**, is formed of a section of flexible polyurethane hose or conduit having an appropriate uniform diameter and wall thickness. In other implementations, one or more different materials may be used for the body **102** and/or displaceable body segment **108**, and/or non-uniform wall thicknesses and/or diameters may be used.

[0055] As shown in the implementation of FIG. **1**, there are no moving parts within the displaceable body segment **108**, i.e., there are no moving parts within the internal volume defined by the displaceable body segment **108**, which can be designated as part of the control volume for the feeder. This is advantageous because contact between solid material flowing through the displaceable body segment **108** and any moving parts or other sensitive areas causes wear and other problems, particularly with solid material such as granular polysilicon.

[0056] As also shown in FIG. **1**, the feeder **100** has an actuator, e.g., a motor **130** or other device configured to move the body **102**, and in particular the displaceable body segment **108**, to cause it to selectively oscillate or otherwise move, typically in a cyclical fashion. The motor **130** is positioned to impart motion to the displaceable segment **108**, such as by being mounted to the body **102** as shown (or having a component that contacts the body). The motor **130** can be an electric motor having an eccentric weight. As stated, any other type of actuator or other device sufficient to impart the desired motion to the displaceable body segment **108** could also be used, such as a pneumatic cylinder, a hydraulic cylinder, or a mechanical drive such as a rack and pinion assembly powered by a servo motor, as a few examples.

[0057] Referring to FIG. **1**, the body **102** has an S-shaped profile in elevation. In the vertical direction, the first end **104** is positioned at a level above the second end **106**. In the horizontal direction, the first and second ends **104**, **106** are offset from each other. The S-shaped profile of the body **102** has two curves bending in opposite directions in a single plane that meet at inflection point within the displaceable body segment **108**. Other configurations can also be used, depending on the particular operating requirements for the application. In the illustrated implementation, the motor **130** is positioned to have its rotational axis substantially perpendicular to the displaceable body segment **108**.

[0058] Referring again to FIG. **1**, the body **102** is shown as a transparent component to allow its interior and the material M to be illustrated. The feeder **100** is shown partially filled with material M that has come to rest at an intermediate point within the body **102**. A leading edge or head portion of the material M, which is inclined from left to right in FIG. **1**, in inclined at the material's angle of repose A. In the illustrated implementation, e.g., the angle of repose for the material M, such as granular polysilicon material, is approximate 31°. The section of the body **102** in FIG. **1** where the material M is at rest can be described as an intermediate section (also sometimes referred to as a repose section). The intermediate section can be approximately level in the downstream direction as shown (i.e., from right to left in FIG. **1**), angled upwardly or angled downwardly, together with any necessary change to the section's length to ensure that sufficient run out is provided, to assist in ensuring that no flow occurs when the feeder **100** is not operating. The segments adjacent the first and second ends **104**, **106** can be relatively upright as shown to have the material flowing into and out of the body **102** assisted by gravity to a maximum degree, but other configurations are also possible.

[0059] By displacing or moving the displaceable body segment **108** as described in more detail below, the material M can be moved or feed through the body **102** along a feed path as indicated generally by the arrows F (see, e.g., FIGS. **2**, **5**, **6**, **9-13**) and out through the second end **106** to a subsequent component and/or location.

[0060] The steady state cyclical motion of the feeder **100** in a representative operating scenario is shown in FIGS. **2-13**. Specifically, FIGS. **2-13** are additional side elevation views of the feeder **100** showing how operation of the motor **130** causes oscillatory motion of the displaceable body segment **108**. Referring to FIG. **2**, during steady state operation of the motor **130** at a speed of 225 RPM in the counterclockwise direction, the position of the motor **130** has moved to the right and down. Specifically, at a time of 0.07 seconds relative to an arbitrary starting point on the motor's steady state trajectory, the motor **130** has moved 2.7 cm to the right (Delta X=+2.7 cm) and 2.3 cm down (Delta Y=−2.3 cm). Because the motor **130** is attached to the displaceable body segment **108**, the displaceable body segment has substantially the same motion as the motor **130**.

[0061] As the displaceable body segment **108** moves down to the right, the material M, and specifically, the granules that make up the material M, have a relative velocity that is in a direction up to the left, thereby creating a void V in the material M as shown schematically in FIG. **2**. The growing void V is not constrained by the material's angle of repose, and so material will begin to flow from right to left, beginning in the intermediate section along the flow path F. As flow of material continues, the void V will be filled, and additional material from the hopper H will enter the body **102** to replace the material flowing away from the intermediate section. It can be said that the material being fed is entrained in pockets and sequentially moved throughout the feeding process. A profile or trajectory P of the cyclical motion of the motor **130**/displaceable body segment **108**, which is described below in greater detail in connection with FIG. **14**, is shown superimposed on the rotational axis of motor **130** in FIGS. **2-13**.

[0062] Subsequently, as shown in FIG. **3**, while the motor speed is maintained at 225 RPM and at 0.14 seconds, the displaceable body segment **108** and the material M are accelerated up to the left. The void V is collapsed, and the material M is once again constrained by its angle of repose, but at position farther along the flow path F. Flow from the hopper H is stopped. At the point shown in FIG. **3**, the motor **130**/displaceable body segment **108** have moved 4.5 cm to the left (Delta X=−4.5 centimeters), and 2.4 cm up (Delta Y=2.4 cm) from the position shown in FIG. **2**.

[0063] In FIG. **4**, at 0.20 seconds, the displaceable body segment **108** reaches its left most position, stops and starts to move down to the right again. The material M maintains its velocity in a direction up to the left. Relative flow between the hopper H and body **102** remains stopped. At this point, Delta X=−2.3 cm and Delta Y=1.8 cm relative to the position shown in FIG. **3**.

[0064] In FIG. **5**, at 0.27 seconds, the inertia of the material M causes continued motion up to the left with the displaceable body segment **108** moving down to the right. At this point, the relative velocity is at its maximum. The flow at the head portion of the material along with the displaceable body segment **108** moving down to the right produces a more rapidly growing void V. Because the material M is not constrained by its angle of repose, flow of material starts to fill the void V. Flow from the hopper H resumes to replace material flowing below. At this point, Delta X=4.2 cm and Delta Y=−1.8 cm relative to the position shown in FIG. **4**.

[0065] In FIG. **6**, at 0.34 seconds, the inertia of the material M allows continued motion up to the left at the head portion of the material. With the material continuing to flow, along with movement of the displaceable body segment **108** down to the right, voiding continues to take place. Because the material is not constrained by its angle of repose, flow continues to fill the void. Flow from the hopper H continues to replace material flowing below. At this point, Delta X=2.7 cm and Delta Y=−2.3 cm relative to the position shown in FIG. **5**.

[0066] In FIG. **7**, at 0.41 seconds, the head of the material M can be seen advancing along the flow path F. The displaceable body segment **108** and material M are accelerated up to the left. The void V has collapsed, and granular material is once again constrained by its angle of repose. Relative flow between this granular material and the downstream section of the displaceable body segment **108** has stopped. Flow from the hopper H has stopped. At this point, Delta X=−4.5 cm and Delta Y=2.4 cm relative to the position shown in FIG. **6**.

[0067] In FIG. **8**, at 0.47 seconds, the material M is advancing farther along the flow path F. The displaceable body segment **108** has reached its upper left most position. It will then stop, and start to move down to the right. The inertia of the material M remains in a direction up to the left. Relative flow in the downstream direction in the displaceable body segment **108** has stopped. Flow from the hopper H has stopped. At this point, Delta X=−2.3 cm and Delta Y=1.8 cm relative to the position shown in FIG. **7**.

[0068] In FIG. **9**, at 0.54 seconds, the displaceable body segment **108** is moving down to the right and has reached its maximum velocity. The flow in the displaceable body segment **108** produces a more rapidly growing void V. Because the material is not constrained by its angle of repose, material starts to fill the void. Flow from the hopper H resumes to replace material flowing below. At this point, Delta X=4.2 cm and Delta Y=−1.8 cm relative to the position shown in FIG. **8**, i.e., the same position as is shown in FIG. **5**. Thus, one cycle is depicted in the sequence from FIG. **5** through FIG. **9**.

[0069] In FIG. **10**, at 0.61 seconds, the inertia of the material M allows continued motion up to the left along the displaceable body segment **108** and into a discharge segment of the body **102**. The discharge segment can be positioned substantially upright as shown. With the material continuing to flow along the flow path, along with movement of the displaceable body segment down to the right, voiding continues to take place. Because material is not constrained by its angle of repose, flow continues to fill the void. Flow from the hopper H continues to replace material flowing below. At this point, Delta X=2.7 cm and Delta Y=−2.3 cm relative to the position shown in FIG. **9**.

[0070] In FIG. **11**, 0.68 seconds, the head portion of the flow of material along the flow path begins to fall from above through the discharge section toward the second end **106**. Material is also advancing elsewhere along the flow path. The displaceable body segment **108** and the material M are accelerated up to the left. The void has collapsed, and material is once again constrained by it angle of repose. Flow between the intermediate section and points downstream has stopped. Also, flow from the hopper H has stopped. At this point, Delta X=−4.5 cm and Delta Y=2.4 cm relative to the position shown in FIG. **10**.

[0071] In FIG. **12**, at 0.74 seconds, material at the head portion of the flow continues to fall toward the end **106**. Material is also advancing through intermediate points along the flow path. The displaceable body segment **108** has reached the upper left most position, stopped and started to move down to the right again. The material M has maintained its velocity up to the left. Flow between the angle of intermediate section and downstream segments has stopped. Flow from the hopper has stopped. At this point, Delta X=−2.3 cm and Delta Y=1.8 cm relative to the position shown in FIG. **11**.

[0072] In FIG. **13**, at 0.81 seconds, material at the head portion of the flow, continues to fall as accelerated by gravity through the second end **106** and is discharged from the feeder **100**. Material is advancing through the displaceable body segment **108** with the displaceable body segment **108** moving down to the right. The relative velocity of the displaceable body segment **108** is at its maximum. The flow in the intermediate section causes a void V to grow. Because the material is not constrained by its angle of repose, flow starts to fill the void. Flow from the hopper H resumes to replace material flowing below. At this point, Delta X=4.2 cm and Delta Y=−1.8 cm relative to the position shown in FIG. **12**.

[0073] As described above, FIG. **14** is a graph of X axis and Y axis motion of the motor **130** and the displaceable body segment **108** showing their trajectory P and including references to show how the positions of FIGS. **2**-**13** correlate to points on the trajectory. Although FIGS. **2**-**13** show specific times for convenience of illustration, the motion throughout the cycle continues smoothly between discrete points as indicated by the trajectory P. Although not specifically shown in the figures, there would typically be a smooth ramping up of speed to the desired operating speed (e.g., 225 rpm).

[0074] By maintaining the motion of the displaceable body segment **108** predominately in the XY plane, feeding efficiency is maximized, and potential drawbacks from motion with components in the Z direction (i.e., perpendicular to the page), which could introduce torsional vibrations adverse to feeding, can be avoided. Thus, the motor **130** (as well as the cylinder **230** described below) can be positioned such that the forces they produce act predominately in the XY plane. For the motor **130**, the mounting can also be configured so that the swinging mass does not introduce torsional vibration effects that would tend to counteract smooth feeding.

[0075] As described, the motion of the displaceable body segment **108**, and the resulting performance of the feeder, is influenced by a number of variables. One such variable is the direction in which the motor is rotated relative to the shape or profile of the displaceable body section **108**, including whether the motor's rotation tends constrict or relax the curved sections in the displaceable body segment **108**. Another variable concerns the magnitude and direction of residual forces in the displaceable body segment **108** tending to resist the action of the motor (e.g., due to the stiffness of the hose material and/or its configuration). Depending upon the particular needs for a specific situation, the user may determine that one direction of rotation is preferred over the other and/or that the displaceable body segment should be configured to have selected characteristics.

[0076] FIG. **15** is a graph showing how feed rate through the feeder **100** for the material (in g/second, and plotted on a logarithmic scale) increases as the rotational speed of the motor **130** (in Hz) is increased. FIG. **16** is a table providing data points for the graph of FIG. **15**. Overall, the feeder **100** shows excellent results with a predictably increasing feed rate as motor speed is increased, and a wide usable range. Repeated tests have shown that these results are reproducible and accurate.

[0077] At high speeds, the eccentric weight of the motor **130** provides both a high centrifugal force and a high frequency to produce a high feed rate. Conversely, at low speeds, the eccentric weight provides a low centrifugal force amplitude at a low frequency. The motion of a representative feeder was studied using video analysis. Feed rate data corresponding to the video analysis was obtained by evaluating a mass vs. time relationship of the feeder's discharge. The mass of the material collected from the discharge was weighed in a container supported by a load cell (such as, e.g., a Model RAP3 single point load cell provided by Loadstar Sensors of Fremont, Calif.). Comparisons of this measured feed rate data with a calculated feed rate based on modelling the feeder as a positive displacement pump show excellent agreement.

[0078] By way of contrast to conventional vibratory feeders, the feeder **100** operates in a different frequency-amplitude regime. Referring again to FIG. **16**, the feeder in a representative embodiment operates over a frequency range of 1.08-3.75 Hz and has a maximum amplitude of about 80 mm (at 100% speed, with the intermediate section at an average incline of about 30 degrees from horizontal). In contrast, a conventional electromagnetic driven rigid tray feeder operates over a frequency range of 20-60 Hz and an amplitude of 1-11 mm. Similarly, a conventional eccentric motor driven rigid tray feeder operates over a frequency range of 15-30 Hz and an amplitude of 1-10 mm. Likewise, another conventional mechanically driven rigid tray feeder operates over a frequency range of 5-15 Hz and an amplitude of 3-15 mm. Thus, the feeder operates over a much lower frequency range and reaches a much greater amplitude.

[0079] The electric motor **130** may be configured to be controlled by a variable frequency drive (VFD), either as a separate component or provided integrally with the motor. Such a VFD-controlled motor provides precise control over the speed of the motor, and thus allows a desired flow rate to be achieved. As a result of the frequency-amplitude control of the feeder, the feeder is capable of a flow rate range of 1:4700, which is far greater than the flow rate range of about 1:50 achievable with a conventional vibrating tray feeder.

[0080] Because the feeder **100** can achieve flow rates ranging from a trickle flow at very low motor speeds to very high flow rates at high motor speeds, it can be operated in a variety of different ways, which increases the flexibility of its use. As one example, in operating the feeder to reach a target weight of material to be output, the feeder can be operated at high speed for an initial period and then at low speed for a subsequent period as the target weight is approached. Thus, the feeder is very well suited for use in a continuous process where flow control of material is required. The feeder can be used as a gravimetric feeder in bulk filling applications.

[0081] FIG. **19** is a schematic block diagram of a control system for the feeder **100** configured as a gravimetric feeder. In gravimetric feeding, material is fed into a process at a constant weight per unit of time since weight is a variable that can be readily captured by a weighing module. According to the loss in weight type of gravimetric feeding of FIG. **19**, the amount of material fed into the process is weighed at a source of the material. Thus, there is a source load cell **310** coupled to a container representing the source of material (not shown, but generally located upstream of the feeder **100**) that is connected to a controller **320** to send signals corresponding to the container's loss in mass during a feeding operation. The controller **320** is connected to the feeder actuator (i.e., the motor **130**) or other moving mechanism to send control signals to carry out controlled operation of the feeder **100** in reaching a desired target, e.g., conveying a desired mass of the material, including through control of the flow rate of material. Additional feedback control could also be used.

[0082] As also shown in FIG. **19**, an optional logic circuit **330** with a container sensor **332** and a container sensor circuit **334** can be provided. If provided, the container sensor **332** can be configured to monitor whether a receiving container, such as the receptacle R in FIG. **13**, is in place. The container sensor circuit **334** can be configured to send a signal to the controller **320** to indicate that a receiving container is in place (container ready=Y) and that a feeding operation can be commenced.

[0083] FIG. **20** is similar to FIG. **19**, but shows a schematic block diagram for the feeder **100** configured as a gain in weight type gravimetric feeder. According to the gain in weight type of gravimetric feeding of FIG. **20**, the amount of material fed into a process is weighed at a receiving container. Thus, there is a load cell or other equivalent sensor **312** coupled to the receiving container (such as the receptacle R). The sensor **312** is connected to the controller **320** to send signals indicating the receiving container's gain in mass during a feeding operation. As above, the controller **320** carries out a feeding algorithm and sends control signals to the motor **130** or other mechanism. Also, the optional logic circuit **330** can be implemented, if desired.

[0084] FIG. **21** is similar to FIGS. **19** and **20**, but shows a schematic block diagram for the feeder **100** configured as a volumetric feeder instead of a gravimetric feeder. As indicated, the controller **320** is connected to send control signals to the motor **130** based on a control algorithm based on stored data **322**, such as speed (cycle) volumetric flow data describing a relationship between operating speed of the motor and flow rate. Also, the optional logic circuit **330** can be implemented, if desired.

[0085] Another implementation of the feeder can be described in connection with FIGS. **23**A-**25**B. Referring first to FIG. **23**A, a feeder **400** has the first end **104** of the body **102** at a first fixed location **110** similar to the feeder **100**, but has an elongate member **420** proximate to at least a segment of the body **102**, generally between its ends **104**, **106**. The member **420** is operable to apply a force and/or torque to the segment of the body **102** (and thus can be described as another form of "actuator"), as well as to constrain the body **102** to move on a selected path. In most cases, the force and/or torque produces at least some displacement in the body **102** along all points that are not fixed. Thus, the displaceable body segment **108** of the body **102** in the feeder **400** can be defined as extending from close to the first end **104** to close to the second end **106** (if fixed) or to the second end (if free to move). In certain implementations, there could be multiple displaceable body segments.

[0086] The member **420** has a distal end **421** that is configured to contact the body **102** within the displaceable body segment **108**, and an opposite proximal end **423**. The proximal end **423** of the member **420** is pivotably supported to pivot about a pivot point **414**. As is described below in more detail, it is only the member **420** that is connected at the pivot point **414**, and not any part of the body **102**. Rather, the displaceable body segment **108** of the body **102** is contacted by the distal end **421** of the member **420**. In the illustrated implementation, the displaceable body segment **108** is contacted by a band clamp **422** that at least partially encircles it and extends lengthwise from the distal end **421** proximally over a length of the band clamp **422**.

[0087] By moving the member **420**, e.g., by pivoting the member **420** about the pivot point **414**, the displaceable body segment **108** is moved and more specifically, an intermediate section I thereof can be rotated to a selected angle, such as to shut off feeding (zero feed rate), to allow for feeding at a maximum rate and/or to allow for feeding at rates between the zero feed rate and the maximum feed rate. In some implementations, the member **420** extends along the displaceable body segment over at least a portion of the length of the member **420**.

[0088] The pivoting operation can be accomplished in discrete operations or as in cyclical operations. Further, the rotation of the intermediate section I can be accomplished manually or as step in an automatic feeding process. In the illustrated implementation, the member **420** has a forked end (not shown) that straddles the body **102** and is pivotably supported at the pivot point **414**.

[0089] The intermediate section I (which tends to move greater distances that other sections of the displaceable body segment **108** during operation) is shown schematically in FIG. **23**A to include the section contacted by the band clamp **422**, and adjacent sections upstream and downstream thereof. Depending upon a variety of factors, almost any point along the body **102** except the first end **104** (which is fixed) may undergo at least a small displacement during pivoting and thus is considered part of the displaceable body segment **108**.

[0090] The geometry of the intermediate section I, including its slope, the radii of its bends and inflection point, are selectively controlled by a number of factors, including the length and path of the body **102**/displaceable body segment **108**, the location of the pivot point **414** (i.e., the vertical distance of the pivot point **414** below and the horizontal distance offset from the first end **104**), the geometry of the member **420**, the angle of rotation of the member **420** and the flexural properties of the body **102**. For a displaceable body segment **108** formed of a length of hose, the flexural properties of the body account for the type of hose, the thickness of the hose material and other similar properties. Desirably, moving the member **420** to cause the intermediate section I to rotate as described does not collapse displaceable body segment **108** or otherwise interfere with feeding taking place within it except as intended.

[0091] In the feeder **400**, the second end **106** of the body **102** can be fixed or movable. If the second end **106** is fixed, it may be relatively aligned in the vertical direction with the first end **104** as shown in FIG. **23**A, or it may be horizontally offset from the first end **104**.

[0092] The member **420** can be described as defining an offset radius (or pivot length) between the point at which it acts on the displaceable body segment **108** (i.e., at the member/body interface, which is at the location of the band clamp **422** in the illustrated implementation) and the pivot point **414**. FIG. **26**A is an enlarged side elevation view showing a member **420** having approximately the same offset radius as in FIG. **23**A. FIG. **26**B is an enlarged side elevation view showing a member **420** defining a shorter offset radius.

[0093] Overall, the geometry of the member **420** and the location of the pivot point **414** are influenced by the design envelope of the feeder **400**. As shown in FIGS. **23**A and **23**B, a design goal of the feeder **400** is to provide a minimum height difference between the first end **104** and point at which the member **420** contacts the displaceable body segment **108** (i.e., the member/body interface, which is at the location of the band clamp **422** in the illustrated implementation) to achieve a compact configuration, while at the same time allowing the displaceable body segment **108** to achieve the necessary geometries for both the shut off and maximum flow positions. To accommodate the change between these geometries while respecting the constraints of the body **102**/displaceable body segment **108**, such as conservation of length (not requiring the hose to stretch or compress) and minimum bend radius (not requiring the hose to bend too tightly as to risk kinking it), and to reduce the amount of stress on the body, the resulting positions of the member/body interface (band clamp **422**) can be varied in both height and horizontal location. To work within the constraints of the displaceable body segment **108** while permitting the second end **106** to move, a convenient method of moving the member/body interface (band clamp **422**) along an arc to achieve precise shutoff, intermediate, and maximum flow geometries influenced the selected geometry of the member **420**.

[0094] Given a larger allowed envelope in which to provide flexing of the body **102** between at least the first fixed end **104** and the member/body interface (as well as between the member/body interface and any downstream fixed point, such as a fixed second send **106**, if present), the length of the body **102**/displaceable body segment **108** could be extended, permitting the member/body interface (band clamp **422**) to be positioned to coincide with the pivot point **422**. In this case, the member **420** is configured to rotate about itself without changing in height or horizontal position (i.e., a zero radius offset), while at the same time keeping stresses experienced in the body within acceptable levels. For example, as shown in FIG. **27**A, the member/body interface (band clamp **422**) of the member **420** is positioned to coincide with the pivot point **414**. FIG. **27**B is similar to FIG. **27**A, and shows schematically how the geometry of the displaceable body segment is changed by rotating of the member **420** acting on the body through the member/body interface (band clamp **422**) at the pivot point **414**.

[0095] Instead of the member **420**, other arrangements can be used. For example, an actuator similar to the actuator **230** could be configured to move the displaceable body segment **108**. Other approaches to generating an appropriate torque and/or force applied at a suitable location(s) are also possible. As another example, it is also possible to have the force or torque applied very close to or at the pivot point **414**.

[0096] In one operation mode, the member **420** is moved manually to change the angle of the intermediate section I of the body **108**. FIG. **23**B is an enlarged sectioned depiction of a portion of the body **108** of the feeder **400** of FIG. **23**A, including the intermediate section I, that is shown schematically to be filled with granular material M, such as granular silicon. (The member **420** has been excluded from FIG. **23**B for clarity.)

[0097] As illustrated in FIG. **23**B, the granular material M is not flowing because it is constrained at the limit of its angle of repose (in the case of granular silicon, the characteristic angle of repose is) 31°. Thus, the gravitational force that would tend to cause the granular silicon to flow farther through the body is balanced by the material's tendency to accumulate at its angle of repose, so the material M remains stationary. The dashed line illustrates schematically that the angle of repose for a leading edge of the material M intersects with a lower side of the hose, so no flow is possible. The position illustrated in FIGS. **23**A and **23**B is referred to as the shutoff position. In the specific example of FIG. **23**A, with a hose having a diameter of 1.5 inches and being positioned as shown, and the member **420** being configured as shown, the member **420** was moved to a position 8° below horizontal to achieve the precise shutoff position shown in FIG. **23**B.

[0098] In FIGS. **24**A and **24**B, the positioning of the body **108** to achieve a minimum flow condition is shown. By moving the member **420** to a position 13.6° below horizontal, the leading edge of the accumulated material M in the intermediate section shown by the dashed line now extends beyond a drop-off point and within an open area of the body **108**, and so the material M just begins to flow.

[0099] In FIGS. **25**A and **25**B, the body **108** has been positioned as shown to achieve a maximum flow condition.

By moving the member **420** to an angle of 29.7° below horizontal, maximum flow is achieved. It was observed that greater angles below horizontal (i.e., making the hose more vertical) did not achieve a higher flow rate because of limiting upstream flow resistance (flow friction and/or pressure balance).

[0100] In the representative implementation of FIGS. **23**A-**25**B, it was possible to achieve highly controllable flow rates for granular silicon material across a range from 11 grams per second to 740 grams per second. Further, the flow rates were consistent as a function of time.

[0101] As stated, the feeder **400** can be implemented for manual operation, e.g., using a lever or other device to move the intermediate section as desired. Thus, the feeder **400** can be controlled manually to shutoff flow, to deliver maximum flow or to deliver material at any intermediate flow rate. Optionally, such a manual implementation could be achieved without requiring a source of power or any control circuit.

[0102] In other implementations, the feeder **400** can be implemented with a system having at least some automated control of feeding. For example, the member **420** or other device could be configured for control by a control circuit and one or more servo motors to control the angle of the member **420**, which could optionally be varied during a feeding cycle.

[0103] In the described feeder implementations, only the segments of the body and structures attached to it (such as a motor or a member) move during operation, so there are no internal moving parts. In the illustrated implementations, the feeders typically eliminate at least one valve, which is one specific component having internal moving parts. As a result, the feeders tend to be less costly to produce and maintain and more reliable than conventional feeding technologies having internal parts. Many internal parts are subject to fouling during operation and are prone to wear faster, particularly in applications where feeding of granular polysilicon material is involved. Maintenance or repair of such internal parts requires considerable downtime.

[0104] In the described feeder, there are fewer components and fewer different materials that contact the material being fed than in conventional feeders. As a result, there is a much lower risk of contamination to the material being fed. In some implementations of the feeder used for feeding high purity granular polysilicon, the body **102** is made of a single length of polyurethane hose that poses little contamination risk.

[0105] As stated, at least the displaceable body segment **108**, or the entire body **102**, can be configured to be flexible so that it can be resiliently deformed or distorted, e.g., through the positions shown in FIGS. **2**-**13** and the trajectory P of FIG. **14**. In some implementations, the body is made of a section of flexible hose, such as a hose made of polyurethane material having sufficient thickness to withstand selected operating requirements. Suitable polyurethane hose suppliers include, e.g., Kuriyama of America, Inc. (see, e.g., Tigerflex Model VOLT200 at http://products.kuriyama.com/category/tigerflex-thermoplastic-industrial-hoses), Masterduct Inc. (https://www.masterduct.com/material-handling-hoses), Hosecraft USA (https://www.hosecraftusa.com/application/Material_Handling_Hoses) and Norres Schlauchtechnik GmbH (http://www.norres.com/us/products/industrial-hoses-technical-hoses/). It is of course possible to use other materials (such as, e.g., EPDM rubber, Styrene-butadiene rubber, natural rubber, other elastomeric materials, other resilient materials, etc.) to achieve the desired flexibility of the displaceable body segment **108**. In addition, it would be possible to configure the body to have multiple segments of different materials and/or to have multiple layers. Further, in some implementations, it may be desirable to include a bellows section along a section of the displaceable body segment. As stated, contact metal contamination of the material being fed can be reduced by using components and/or coatings made of selected materials, including polyurethane.

[0106] FIGS. **17** and **18** are schematic illustrations of an alternative implementation in which a double acting pneumatic cylinder **230** or other linear actuator is used to impart the desired motion to the displaceable body segment **108** or body **102** instead of the motor **130**. As shown in FIG. **17**, the movable end of the cylinder **230** is connected to the displaceable body segment, and the opposite stationary end is connected to a fixed location. The cylinder **230** would also be supplied by suitable fluid source to move back and forth and to pivot to achieve the desired motion (such as is shown schematically in FIG. **18**) and corresponding desired feed rate. Of course, mechanisms other than the motor **130** and the cylinder **230** could be used to move the displaceable body segment.

[0107] FIG. **22** is a schematic illustration of another alternative implementation in which a source of vacuum or suction force is used in the area near the outlet **307** of the feeder to help control dust that may arise during feeding operations. In some situations, e.g., if material is being fed from a higher fall height, a dust cloud can form from the falling material impacting a surface and/or previously fed material. To address this situation, which is usually undesirable, a suction hood **300** can be positioned to at least partially surround the outlet **307**. The suction hood **300** can be connected via a flexible supply line **302** to a vacuum or suction source **304**. In use, a vacuum or suction force at the suction hood **300** is set to be sufficient to assist in withdrawing dust into the hood **300**, but without adversely affecting the feeding of material in a substantially opposite direction through the outlet **307**.

[0108] In the illustrated implementation, the suction hood **300** is positioned recessed from the outlet **307** by a selected distance R, which also helps adjust the effect of the suction force to prevent it from adversely affect the feeding of material. In some implementations, the suction hood **300** is recessed from the end of the outlet by about 0.5 inch.

[0109] In view of the many possible embodiments to which the disclosed principles may be applied, it should be recognized that the illustrated embodiments are only preferred examples and should not be taken as limiting in scope. Rather, the scope is defined by the following claims. I therefore claim all that comes within the scope and spirit of these claims.

1. A feeder operable to convey a divided solids material, comprising:
- a conduit having a hollow body with a length, a first end, a second end opposite the first end and a displaceable body segment defined along at least a portion of the length;
- the displaceable body segment having at least a first fixable location positionable at a first fixed location;
- an actuator positioned to apply force to the conduit and controllable to displace the displaceable body segment

to cause selected flow of divided solids material within the conduit in a feed direction extending generally from the first end to the second end.

2. The feeder of claim **1**, wherein the actuator is supported by the conduit and moves with the displaceable body segment during a feeding operation.

3. The feeder of claim **2**, wherein the actuator comprises a rotating offset mass, and wherein the rotating offset mass is operated to generate oscillating motion of the displaceable body segment and the attached actuator.

4. The feeder of claim **2**, wherein the displaceable body segment is cyclically displaced through a closed trajectory having at least one of a vertical component and a horizontal component.

5. The feeder of claim **2**, wherein the displaceable body segment has a second fixable location downstream of the first fixable location in the feeding direction and positionable at a second fixed location.

6. The feeder of claim **1**, wherein the displaceable body segment has a curved profile, wherein the curved profile has a length longer than a shortest distance separating the first fixable location and a second fixable location, and wherein the actuator is attached to the displaceable body segment approximately at an inflection point for a curve of the curved profile.

7. The feeder of claim **1**, wherein the actuator is positioned stationarily and has a controllably movable element that contacts the displaceable body segment.

8. (canceled)

9. The feeder of claim **1**, Wherein the actuator is an elongate member having a distal end pivotable into contact with the displaceable body segment to selectively move the displaceable body segment and a proximal end pivotably connected to a pivot point.

10. The feeder of claim **1**, wherein the displaceable body segment comprises an intermediate section configured to collect a portion of the divided solids material when the displaceable body segment is at rest.

11. The feeder of claim **10**, wherein the intermediate section is configured to collect a leading edge of a flow of divided solids material received from the first end of the feeder.

12. The feeder of claim **1**, wherein the displaceable body segment comprises an intermediate section configured for positioning at a slight angle relative to horizontal, a first upright section positioned upstream of the intermediate section and a second upright section positioned downstream of the intermediate section.

13. (canceled)

14. (canceled)

15. A feeder, comprising:

a conduit having an inlet end, an outlet end opposite the inlet end and a displaceable body segment defined along a feeding direction between the inlet end and the outlet end;

the inlet end being configured for connection to a source of material to be fed by the feeder;

the outlet end being configured to convey divided solids material from the feeder to a location downstream of the feeder, wherein the outlet end is configured for positioning at a lower height than the inlet end;

the displaceable body segment being sized to have a length longer than a shortest distance between the inlet end and the outlet end and to define a curved profile with at least one inflection point when installed;

the displaceable body segment when installed defining an intermediate section configured to support accumulated divided solids material therein at an angle of repose of the material, and to reduce movement of material in the feeding direction when the displaceable body segment is at rest; and

an actuator connected to the displaceable body segment to controllably displace the displaceable body segment during a feeding operation.

16. (canceled)

17. (canceled)

18. (canceled)

19. The feeder of claim **15**, wherein the intermediate section is caused to be displaced from a substantially lateral position at which no flow occurs to a downwardly tilted position at which flow towards the outlet end occurs.

20. The feeder of claim **15**, wherein the actuator is configured to move at a rate sufficient to cause displacement of the displaceable body section such that the solids material moves at a selected rate between a low trickle flow and a high bulk filling flow.

21. A method of conveying a divided solids material with a feeder, comprising:

using a sensor to monitor an amount of the divided solids material being conveyed with the feeder;

receiving signals from the sensor at a controller;

sending control signals from the controller to the feeder to control a flow rate of the divided solids material over a flow rate range ratio of greater than 1:50 of a low flow rate to a high flow rate.

22. The method of claim **21**, wherein using a sensor to monitor an amount of the solid material being conveyed comprises configuring the sensor to measure a loss of weight of the solid material from a source of the material positioned upstream of the feeder.

23. The method of claim **21**, wherein using a sensor to monitor an amount of the solid material being conveyed comprises configuring the sensor to measure a gain in weight from the solid material conveyed to a receptacle positioned downstream of the feeder.

24. The method of claim **21**, wherein the feeder comprises a conduit segment for receiving the solid material and that is displaceable according to the control signals from the controller to achieve a desired flow rate of the material from the feeder.

25. The method of claim **21**, wherein the flow rate range ratio is greater than 1:4000.

26. A method of conveying divided polysilicon, comprising:

receiving divided polysilicon from a source into a conduit of a feeder;

controllably moving the conduit through an operation path in which the conduit is positioned in at least a first position at which flow through the conduit occurs and a second position at which flow through the conduit is stopped; and

receiving the divided silicon material flowing through the conduit, when the conduit is positioned at least in a first position, in a receptacle positioned downstream of an outlet end of the conduit.

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