US 20120085341A1

(19) United States

(12) Patent Application Publication

Britland

(10) Pub. No.: US 2012/0085341 A1

(43) Pub. Date: Apr. 12, 2012

(54) SOLAR THERMAL SYSTEM

(76) Inventor: **Curtis Britland**, Lexington, KY (US)

(21) Appl. No.: **13/219,606**

(22) Filed: **Aug. 27, 2011**

Related U.S. Application Data

(60) Provisional application No. 61/390,862, filed on Oct. 7, 2010.

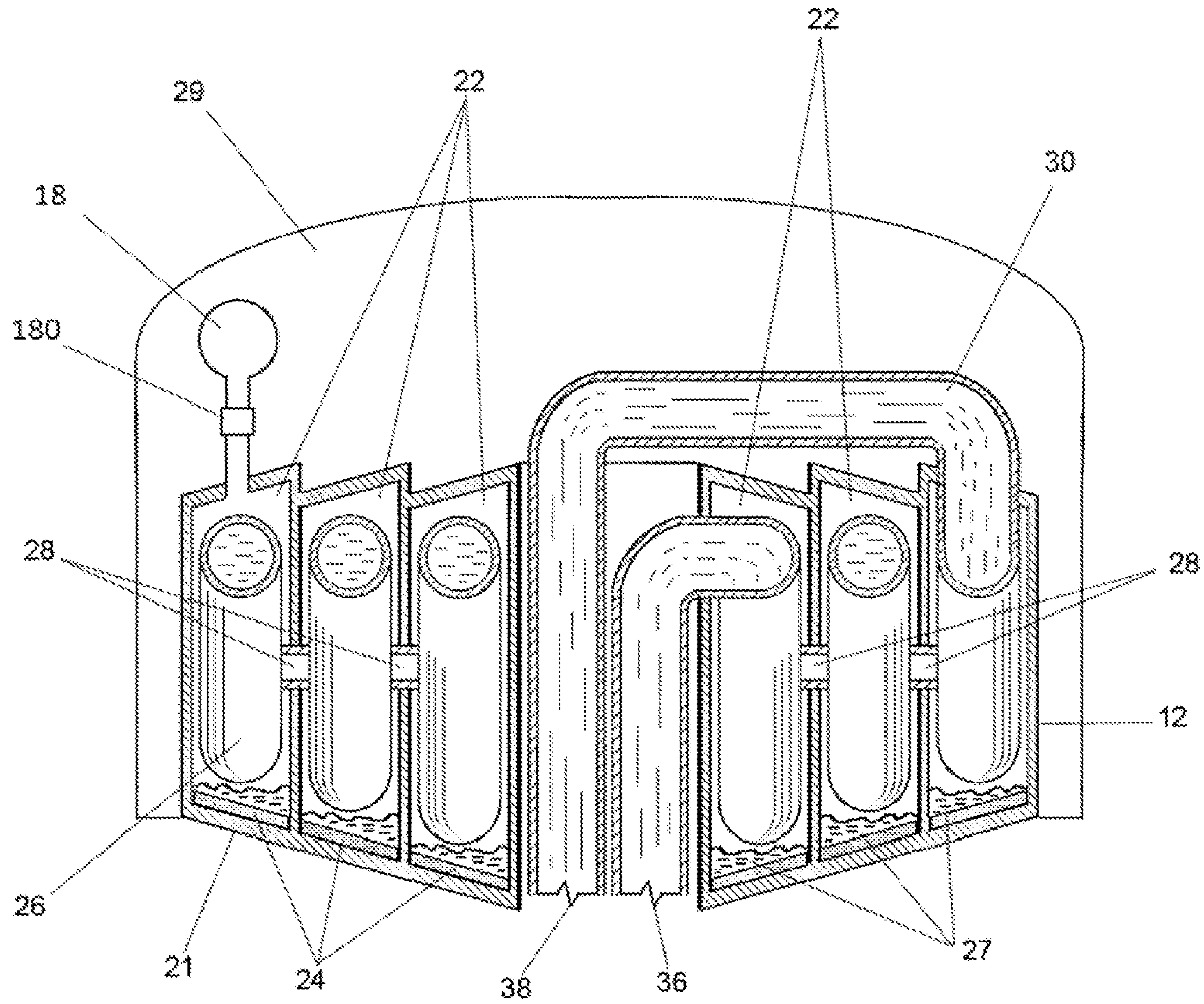
Publication Classification

(51) **Int. Cl.**
F24J 2/04 (2006.01)
F24J 2/38 (2006.01)

(52) **U.S. Cl.** **126/604**; 126/640

(57) **ABSTRACT**

A solar thermal power system with associated heat exchanger, variable focus heliostat, and a heliostat stand with a pneumatic piston for shock absorption and positioning is disclosed. The heat exchanger is a solar receiver possessing a beveled bottom substantially perpendicular to the angles of the reflected light from the surrounding heliostats.



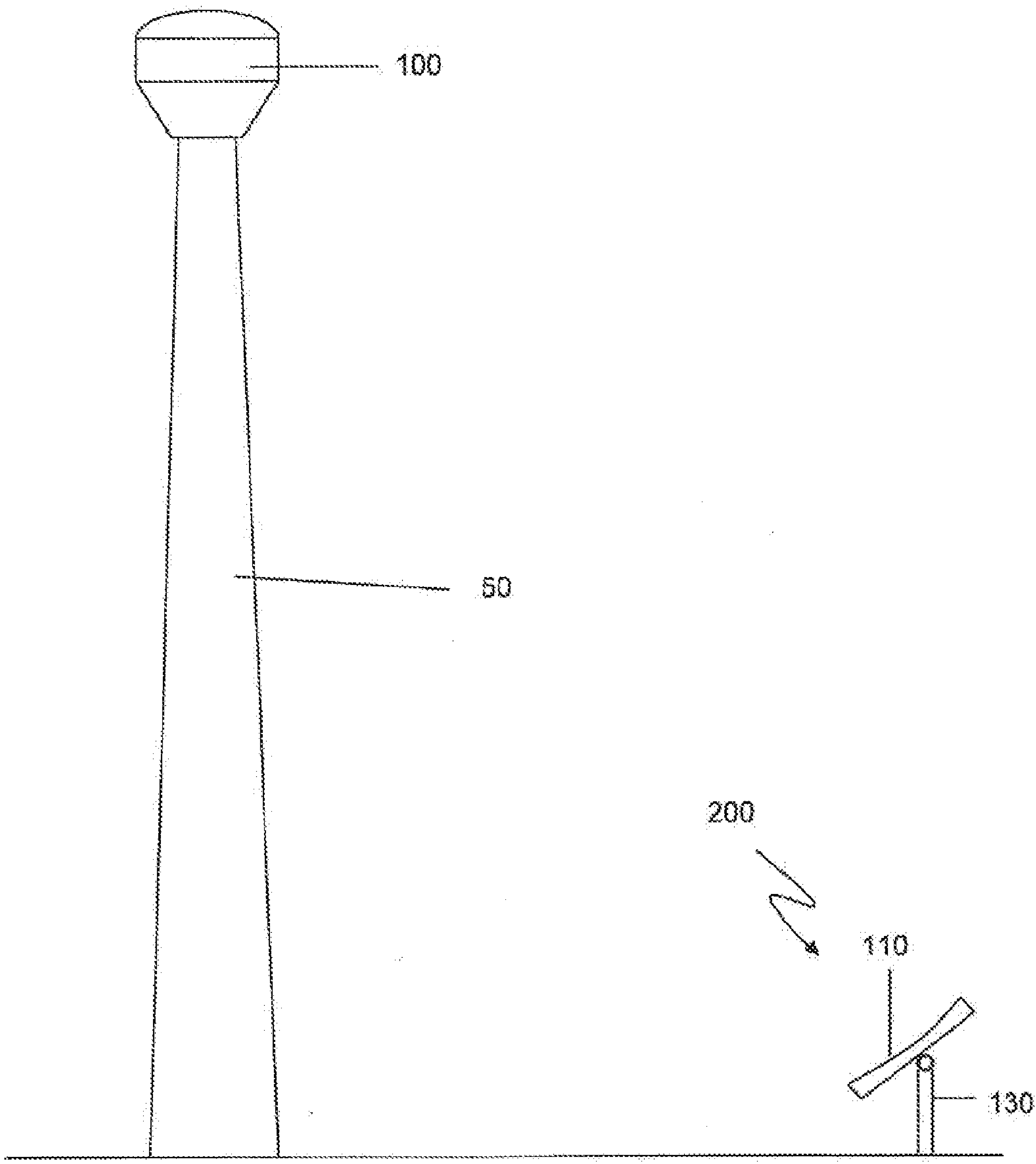


FIG. 1

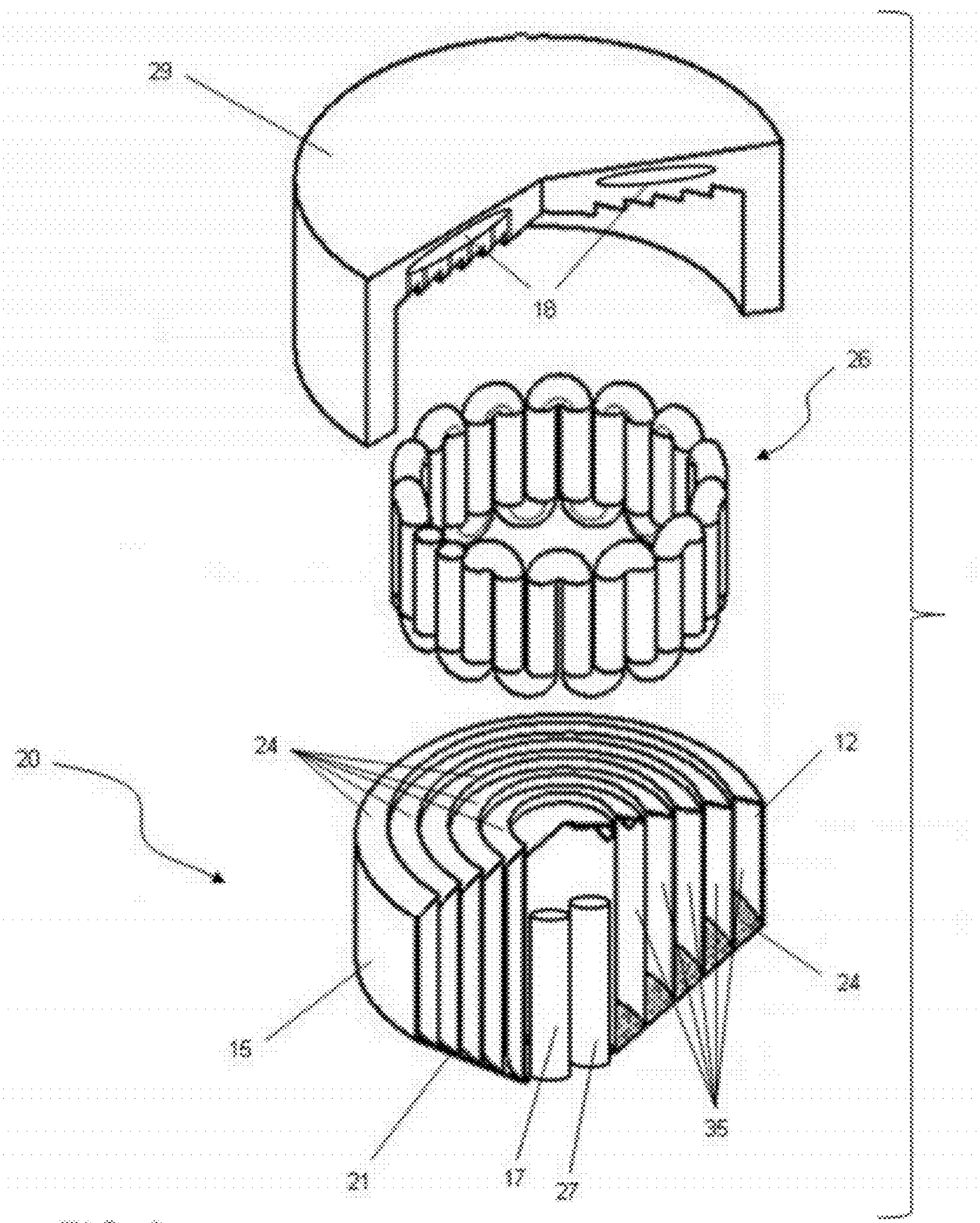


FIG. 2a

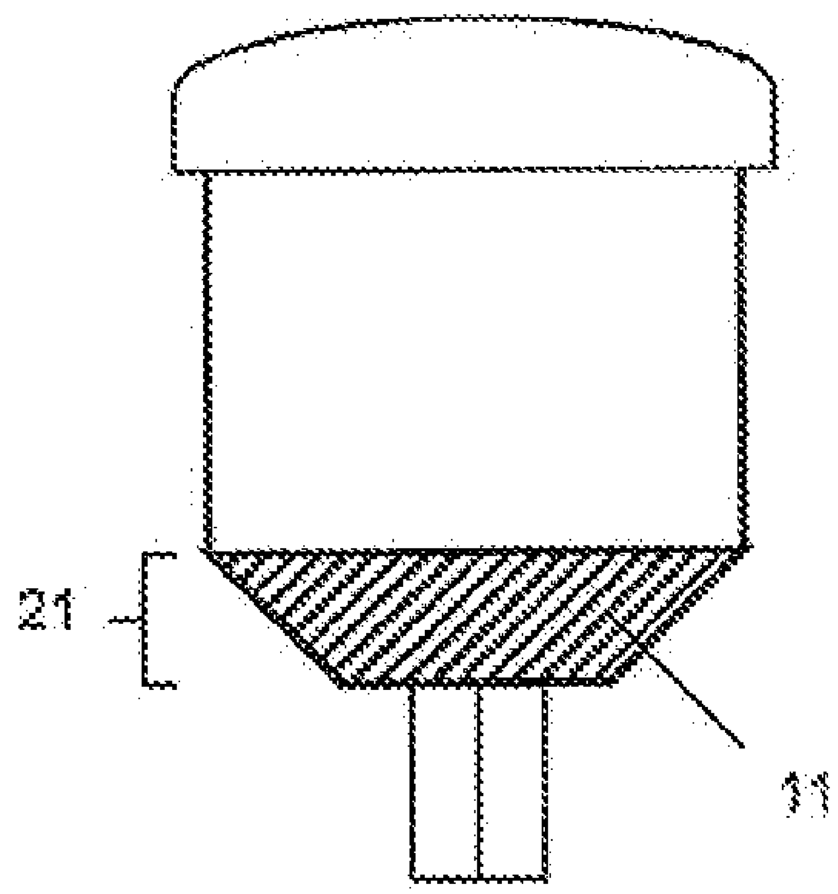


FIG. 2b

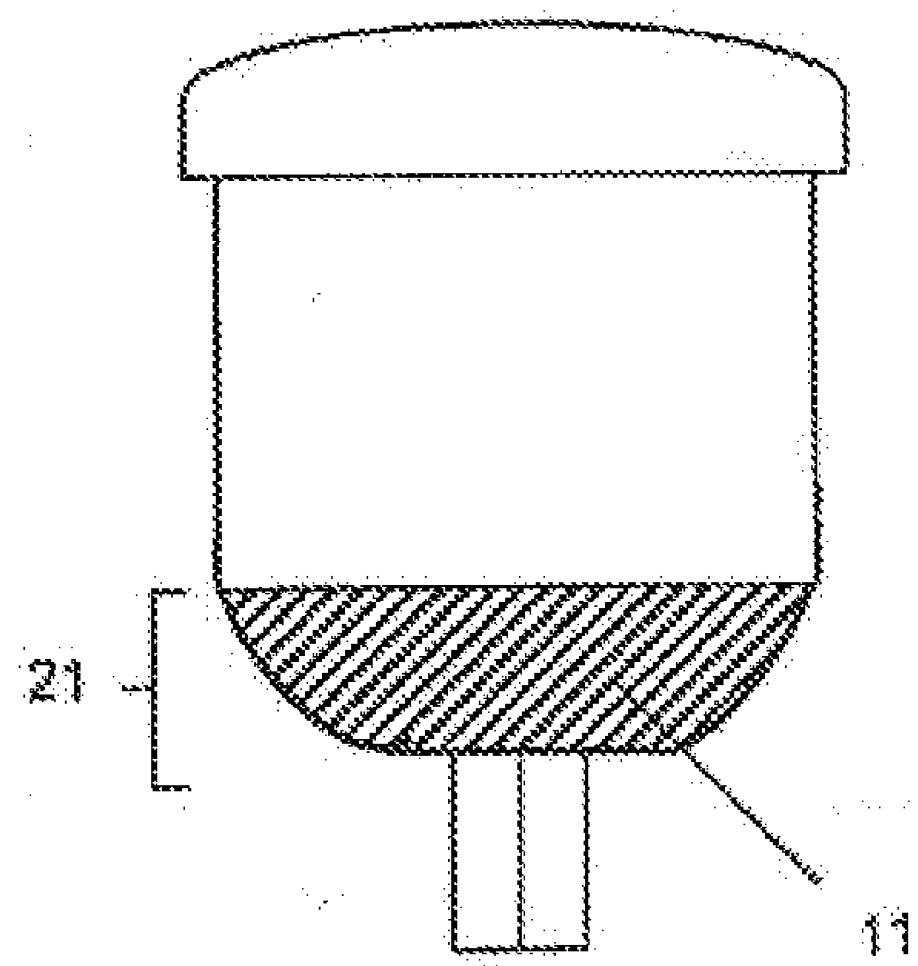


FIG. 2c

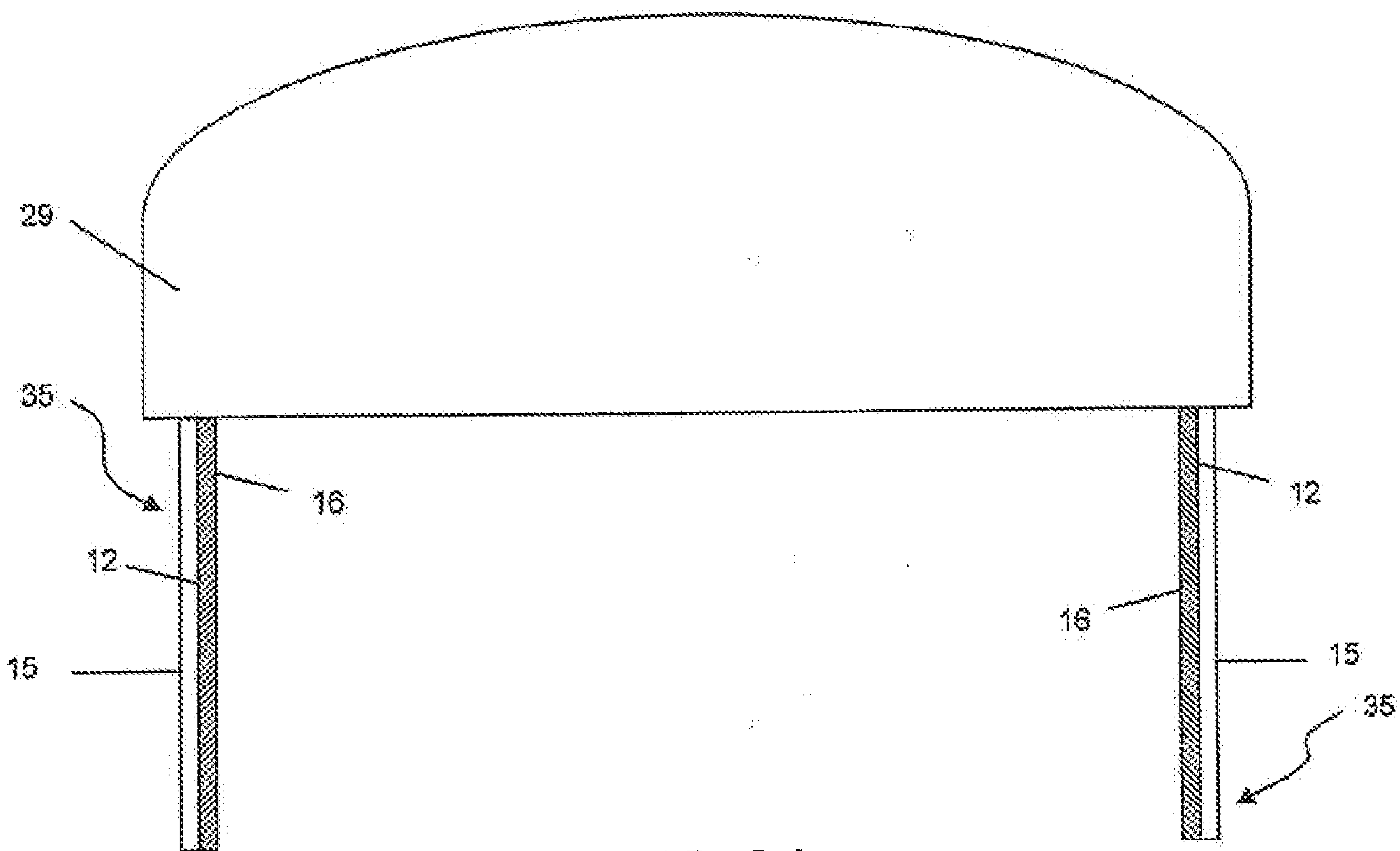


FIG. 2d

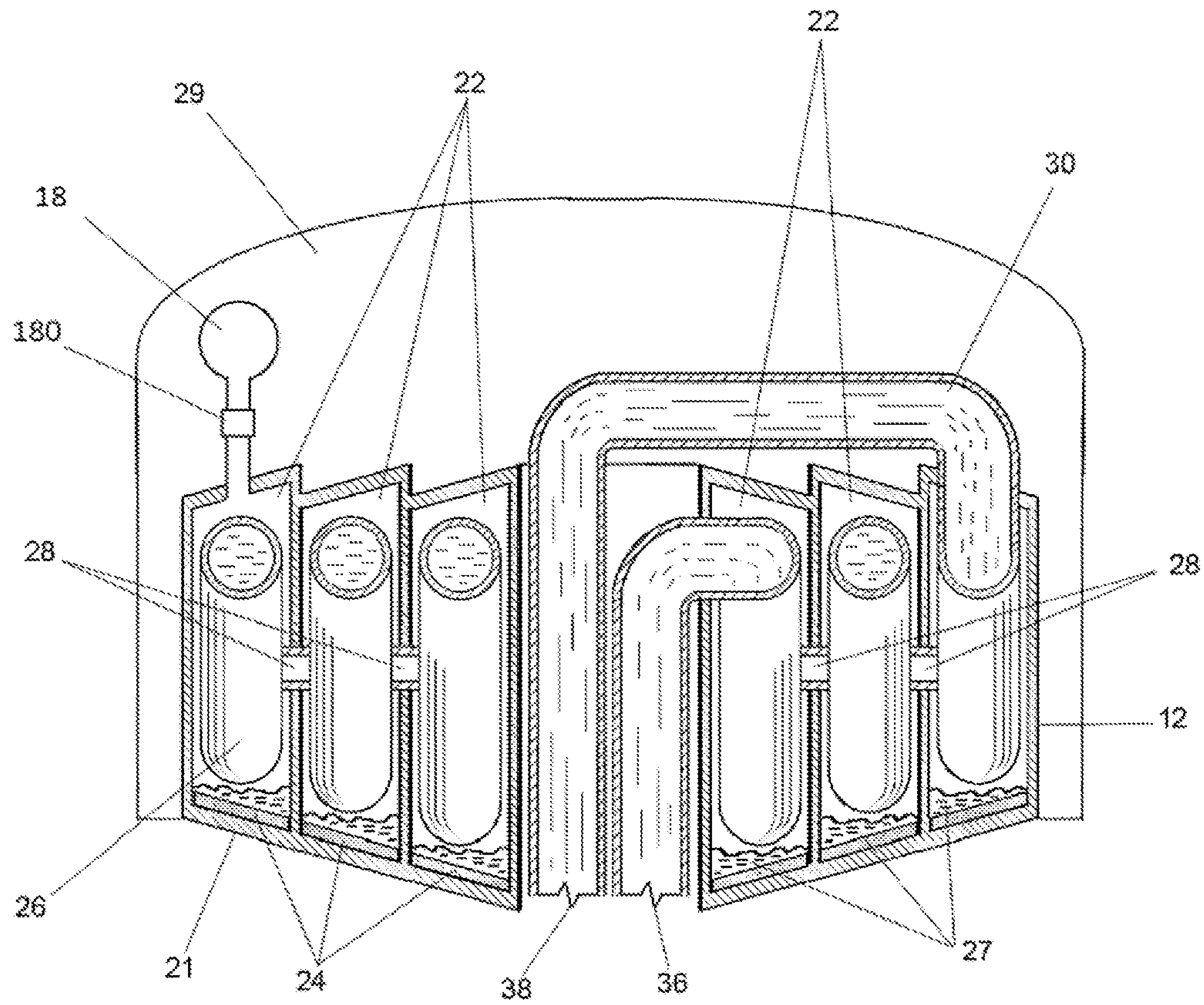


FIG. 2e

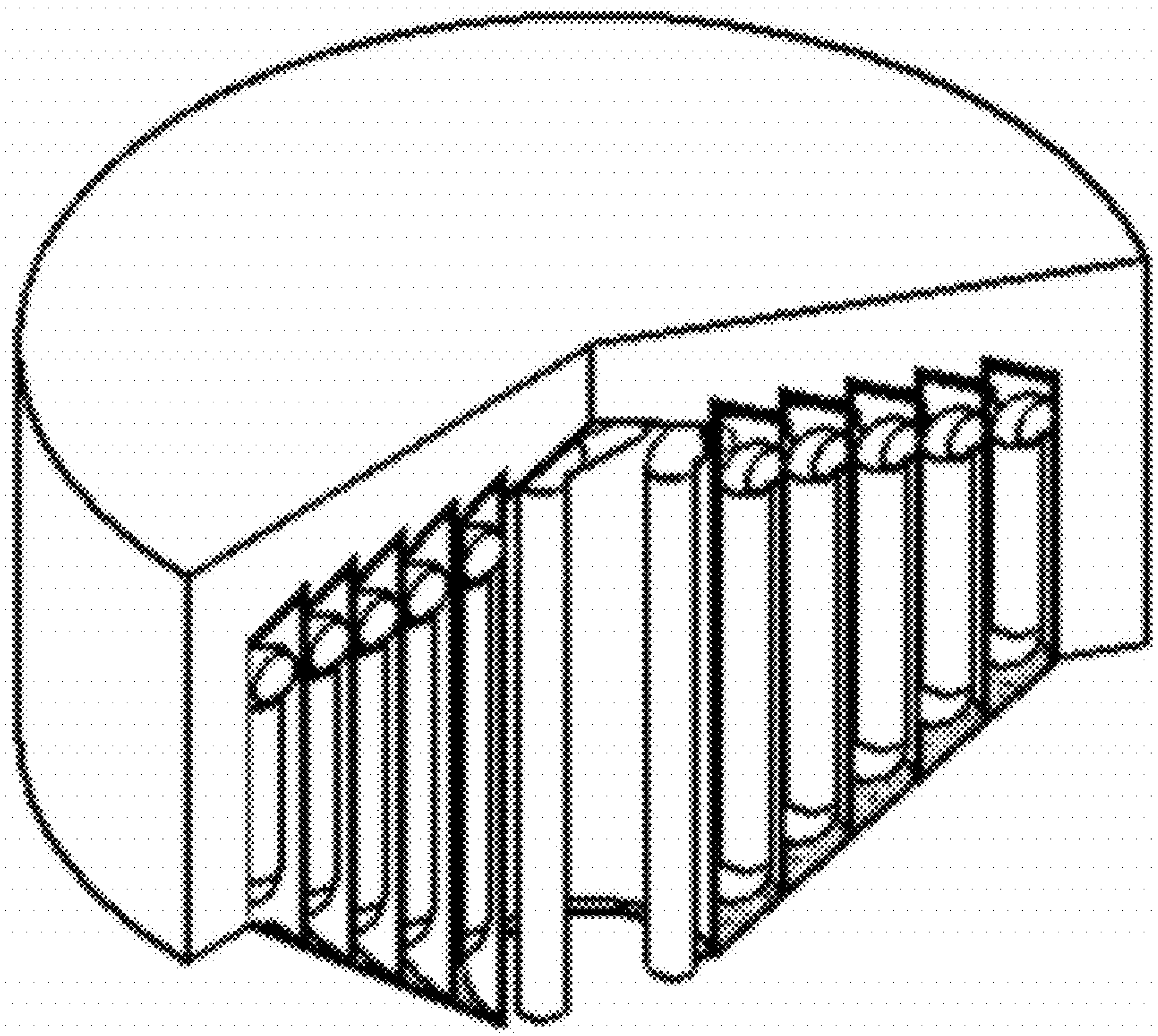


FIG. 2f

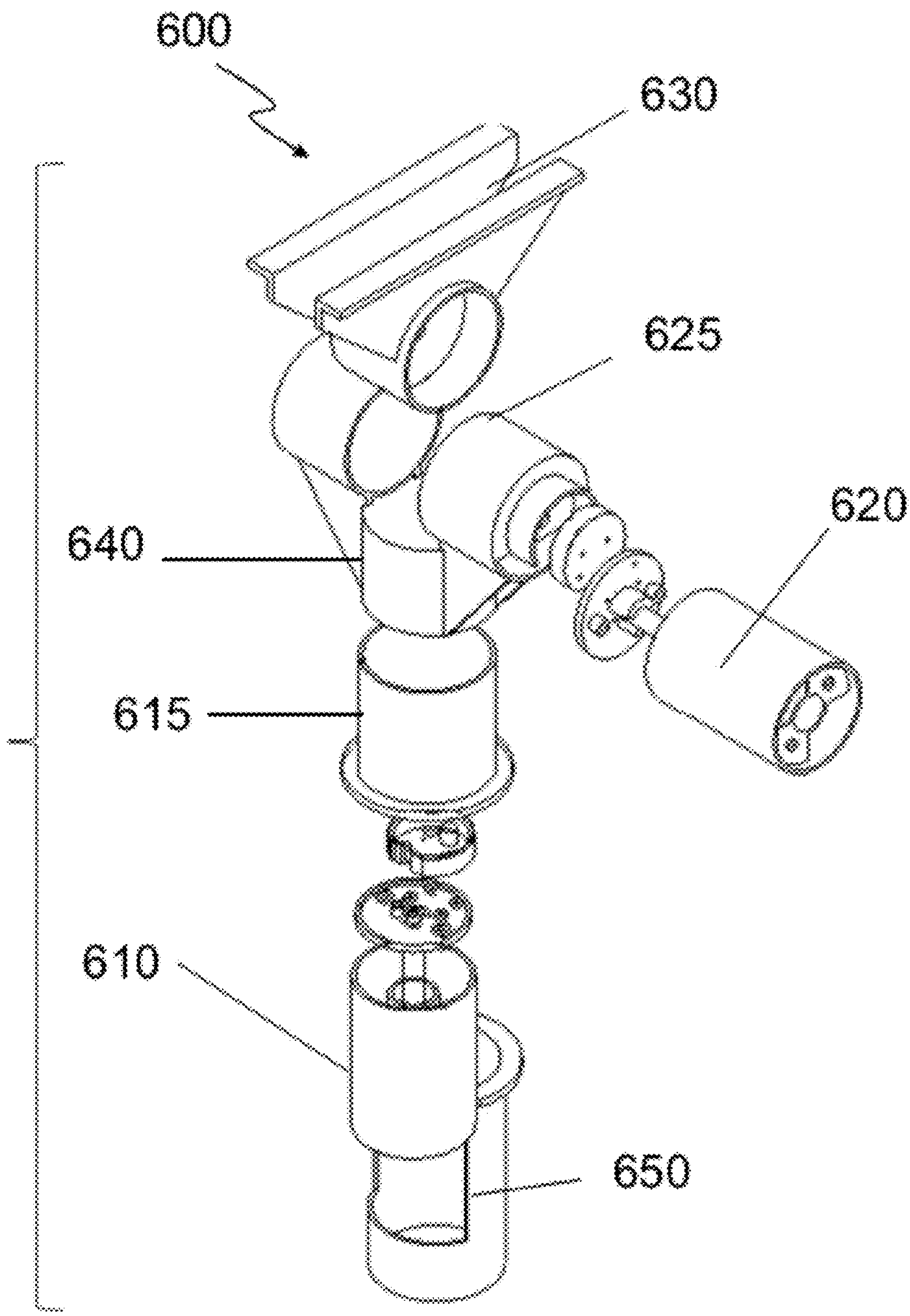


FIG. 3

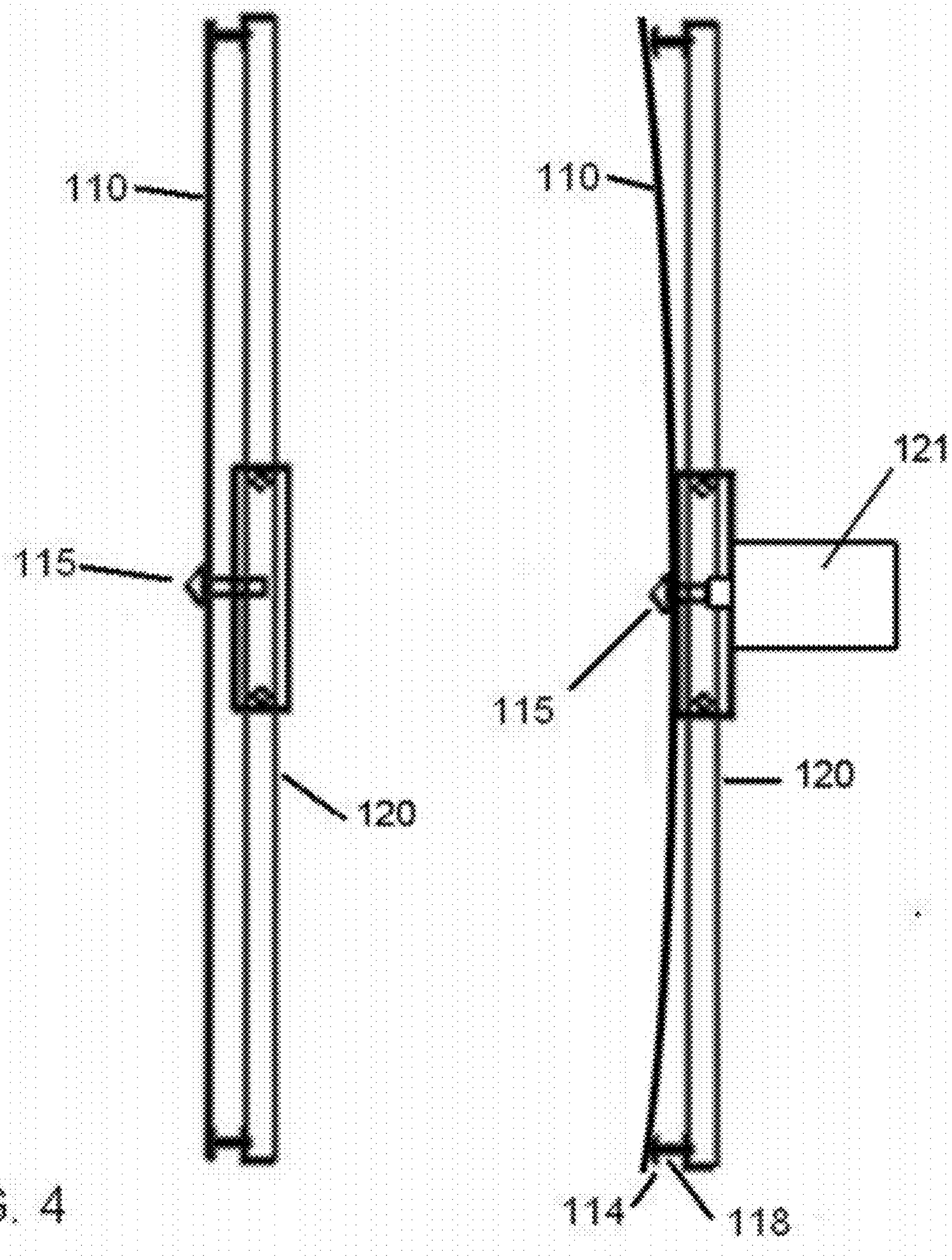


FIG. 4

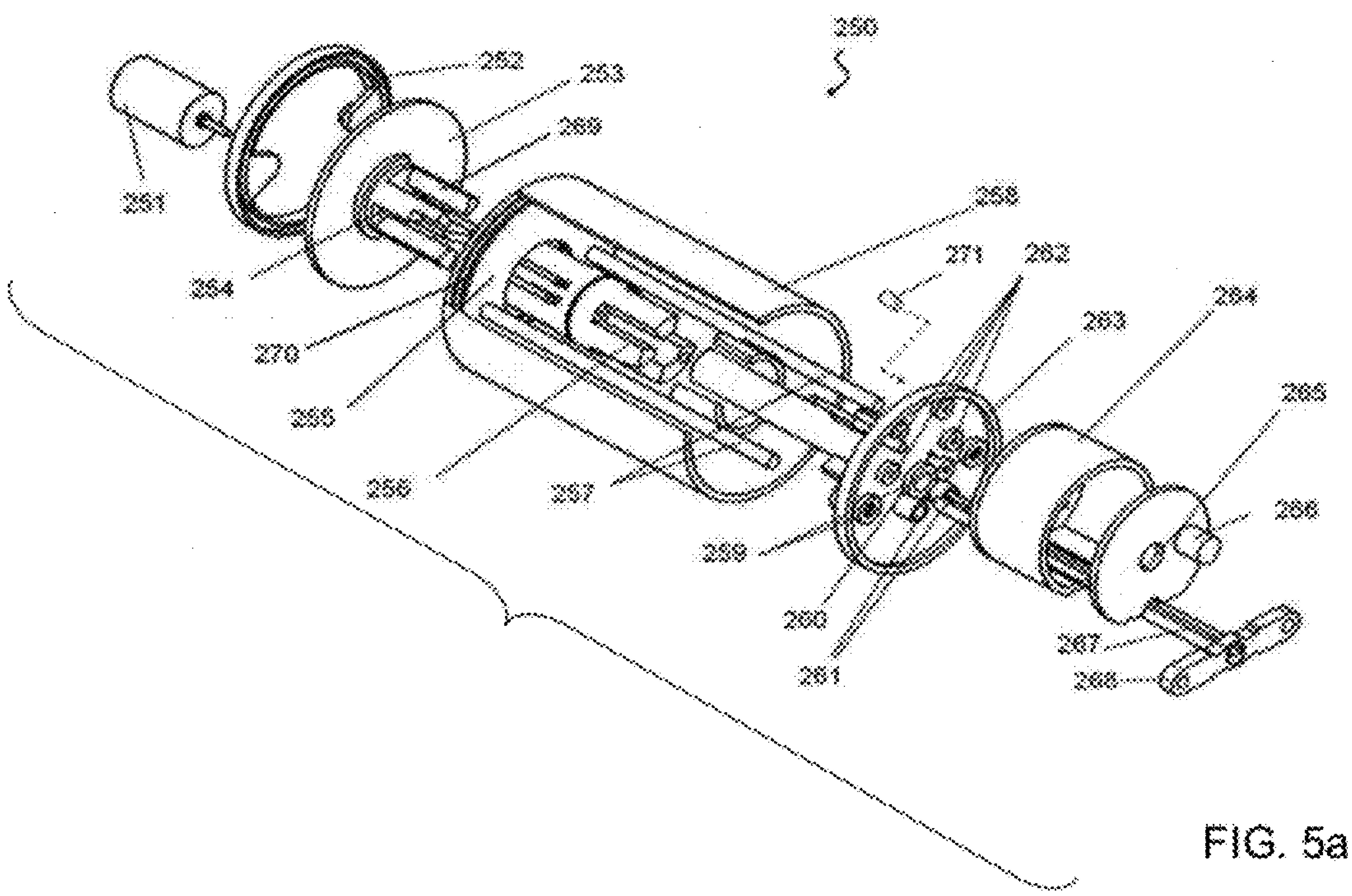

250
251
252
253
269
254
270
255
256
257
258
271
262
263
264
265
266
259
260
261
267
268

FIG. 5a

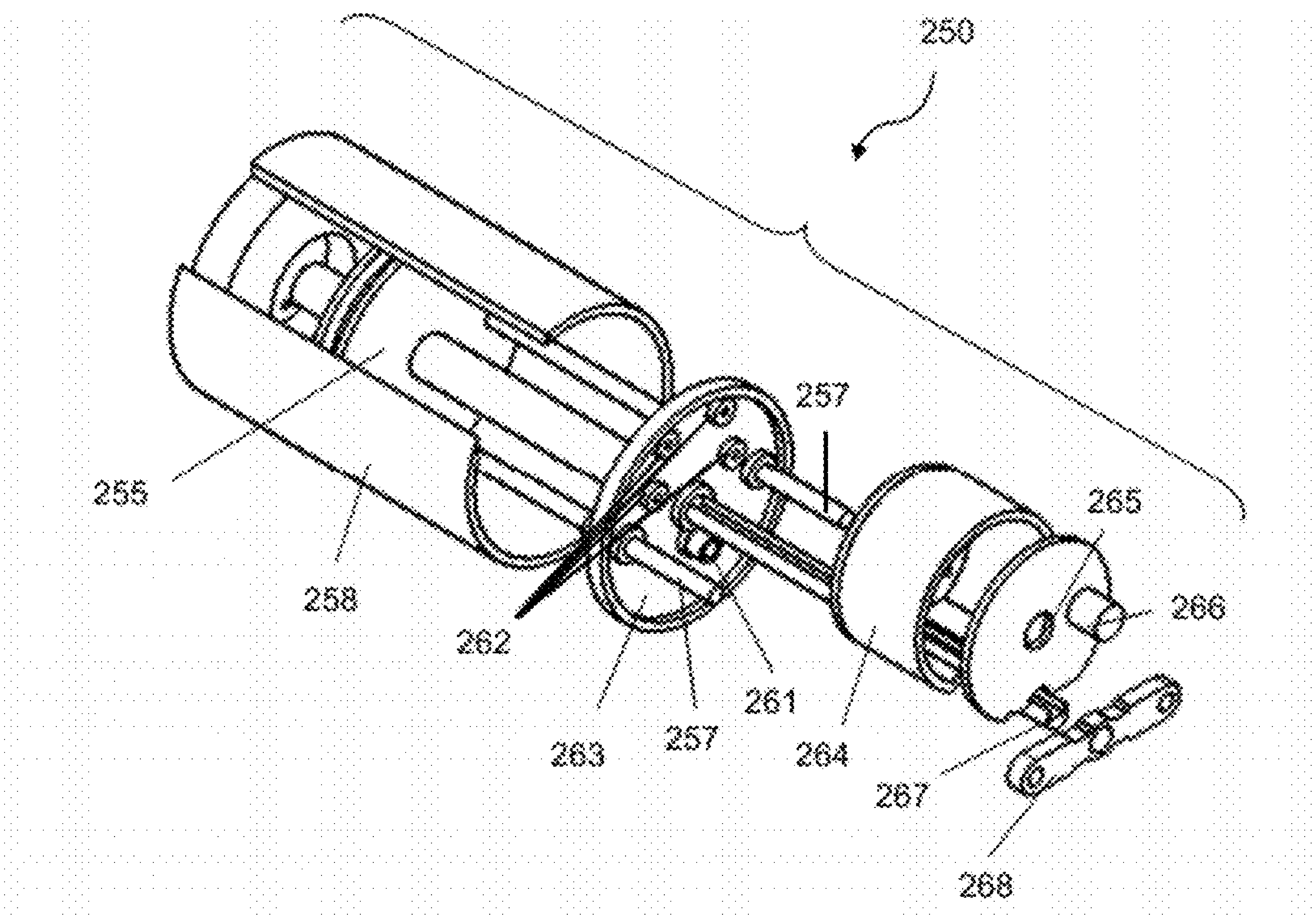


FIG. 5b

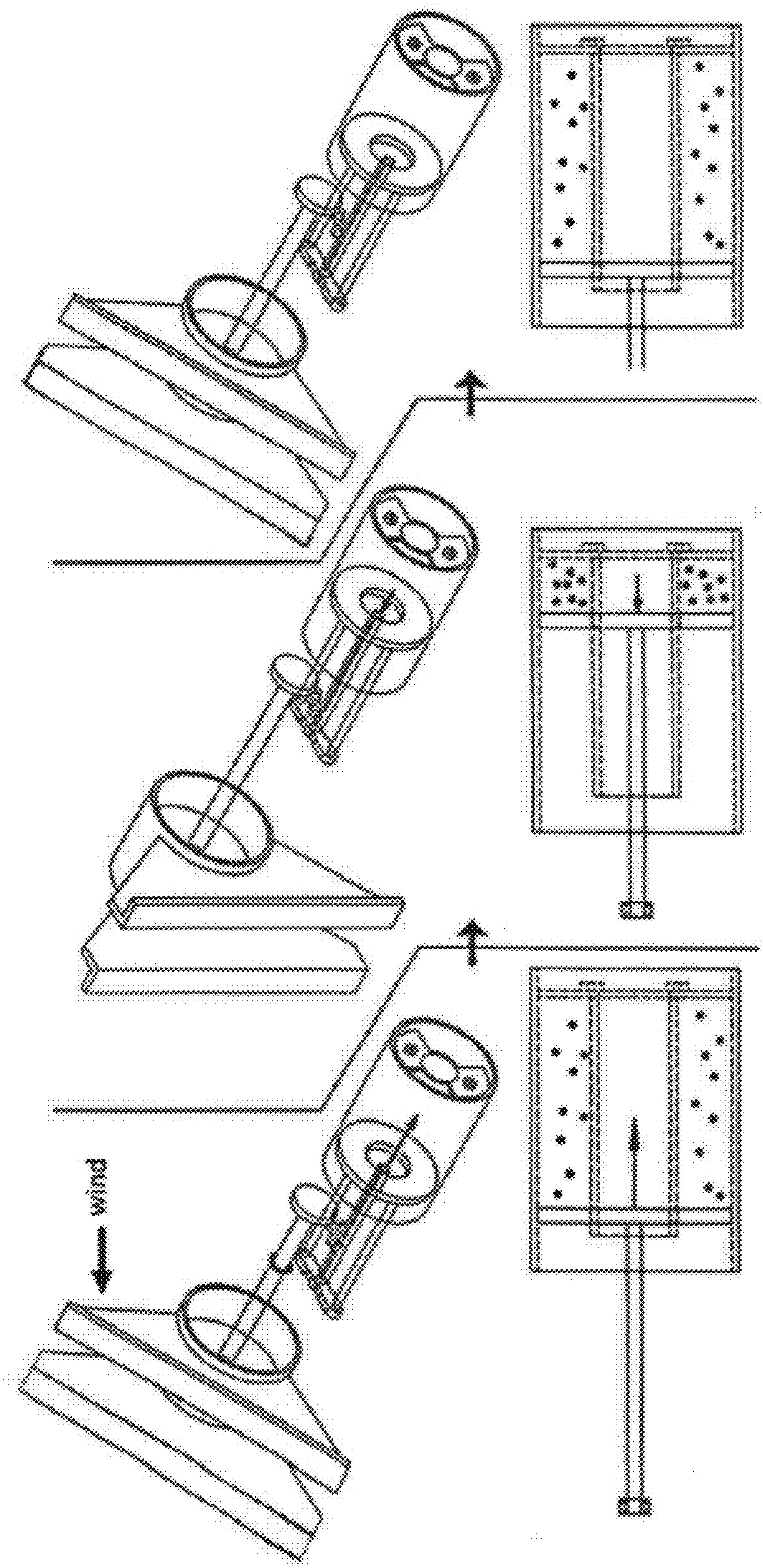


FIG. 6c

FIG. 6b

FIG. 6a

Fig. 7a

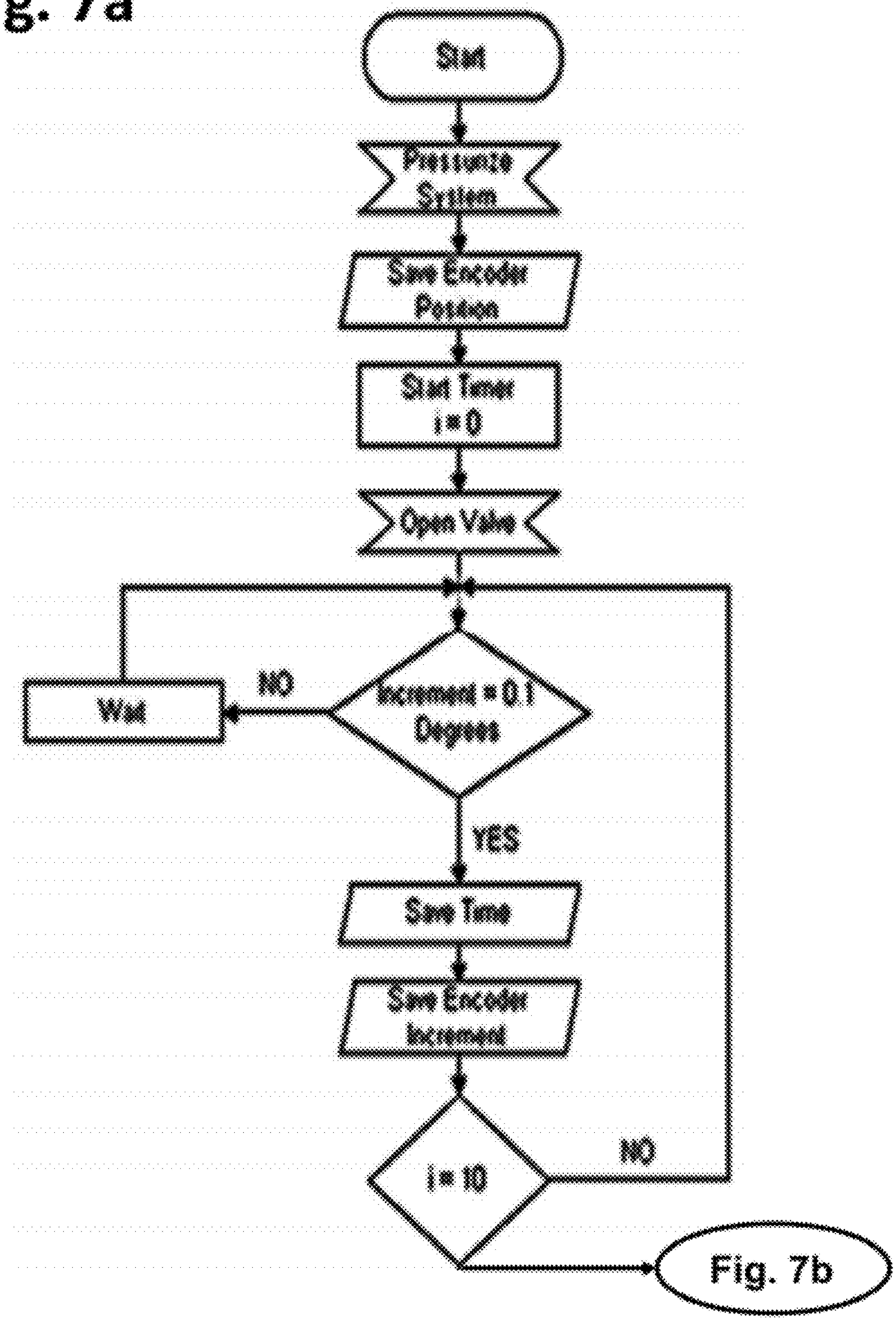

Start
Pressurize System
Save Encoder Position
Start Timer
i = 0
Open Valve
Wait
NO
Increment = 0.1 Degrees
YES
Save Time
Save Encoder Increment
i = 10
NO
Fig. 7b

Fig. 7b

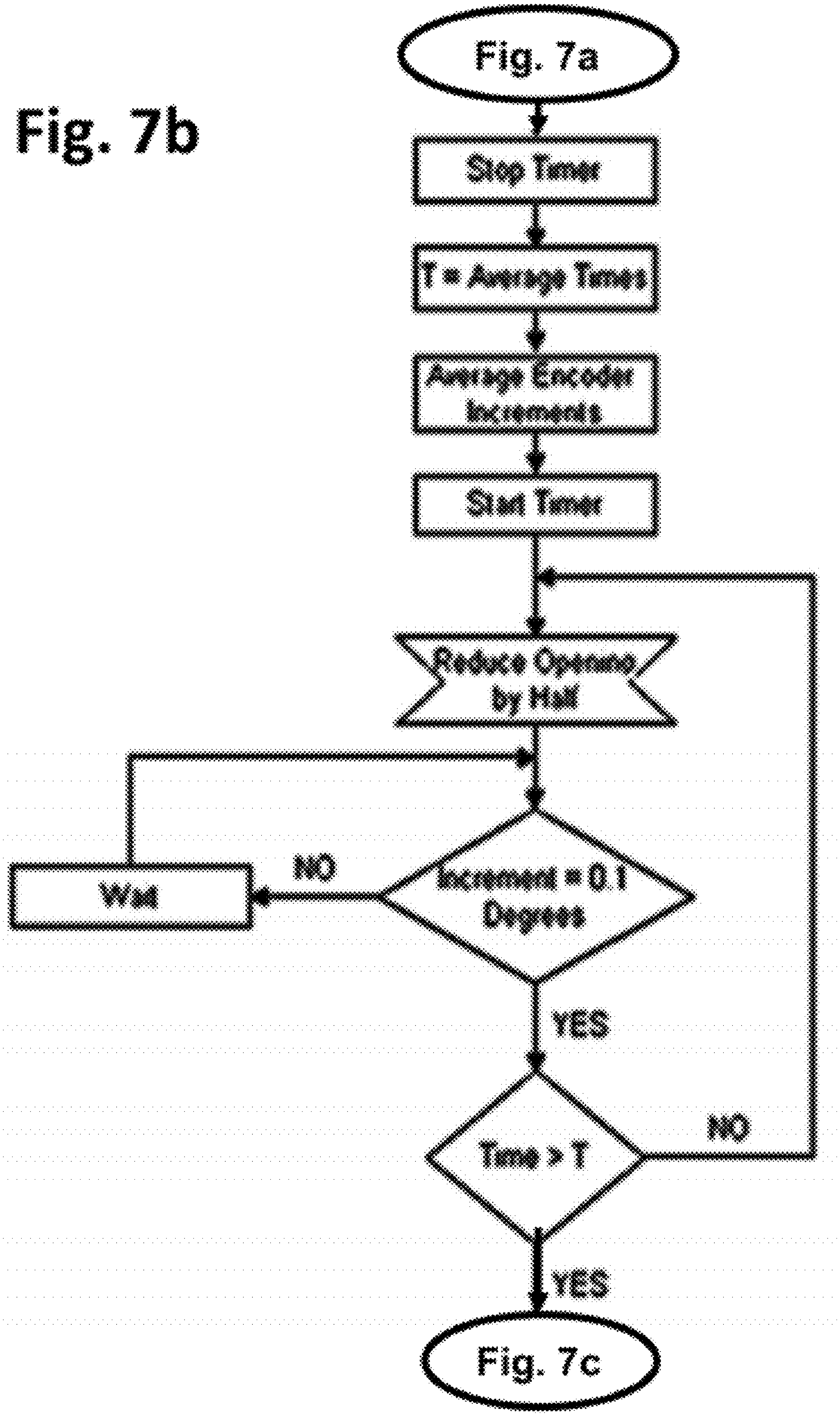


Fig. 7a
Stop Timer
T = Average Times
Average Encoder Increments
Start Timer
Reduce Opening by Half
NO
Wait
Increment = 0.1 Degrees
YES
Time > T
NO
YES
Fig. 7c

Fig. 7b

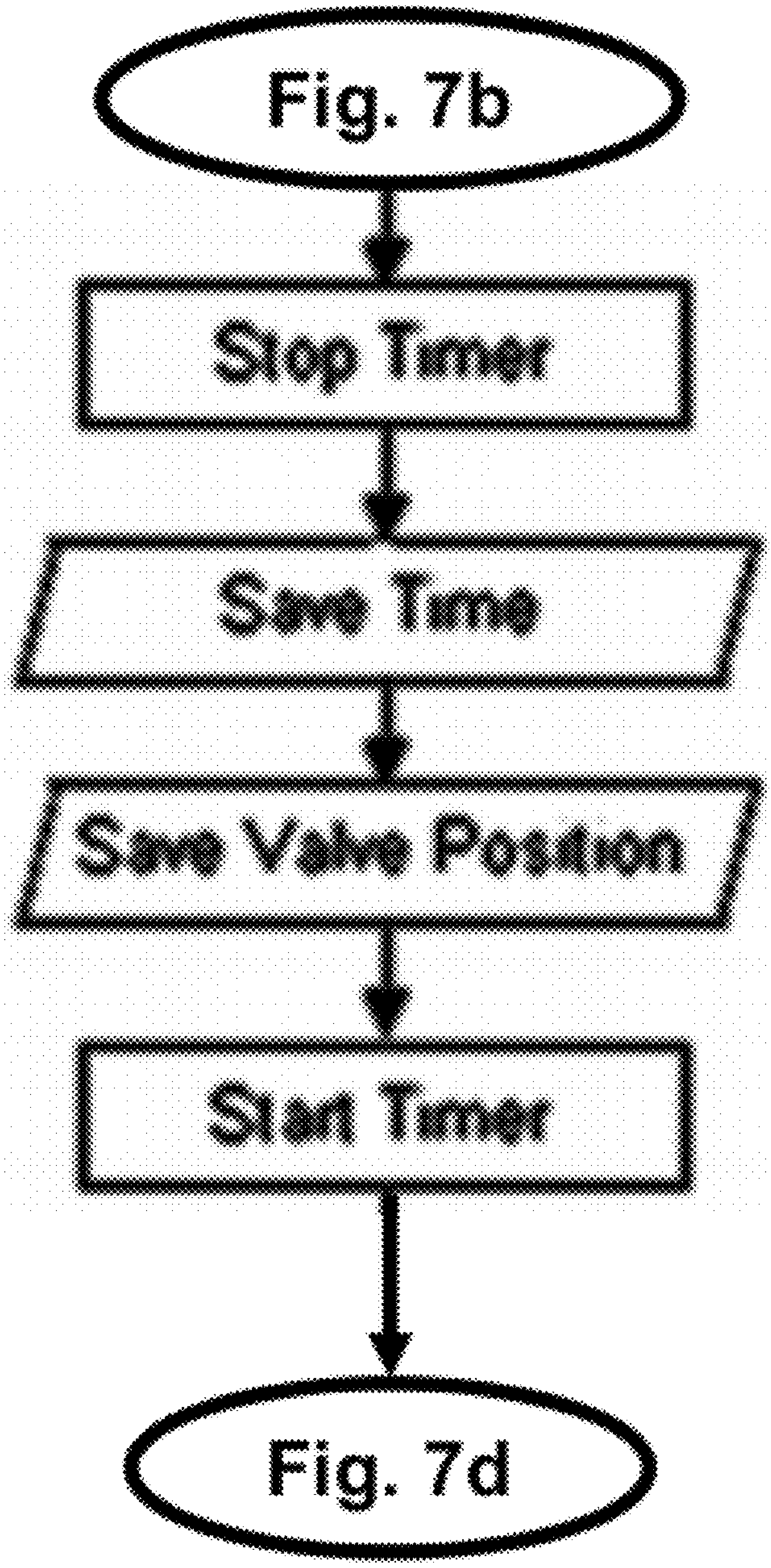


Fig. 7b
Stop Timer
Save Time
Save Valve Position
Start Timer
Fig. 7d

Fig. 7d

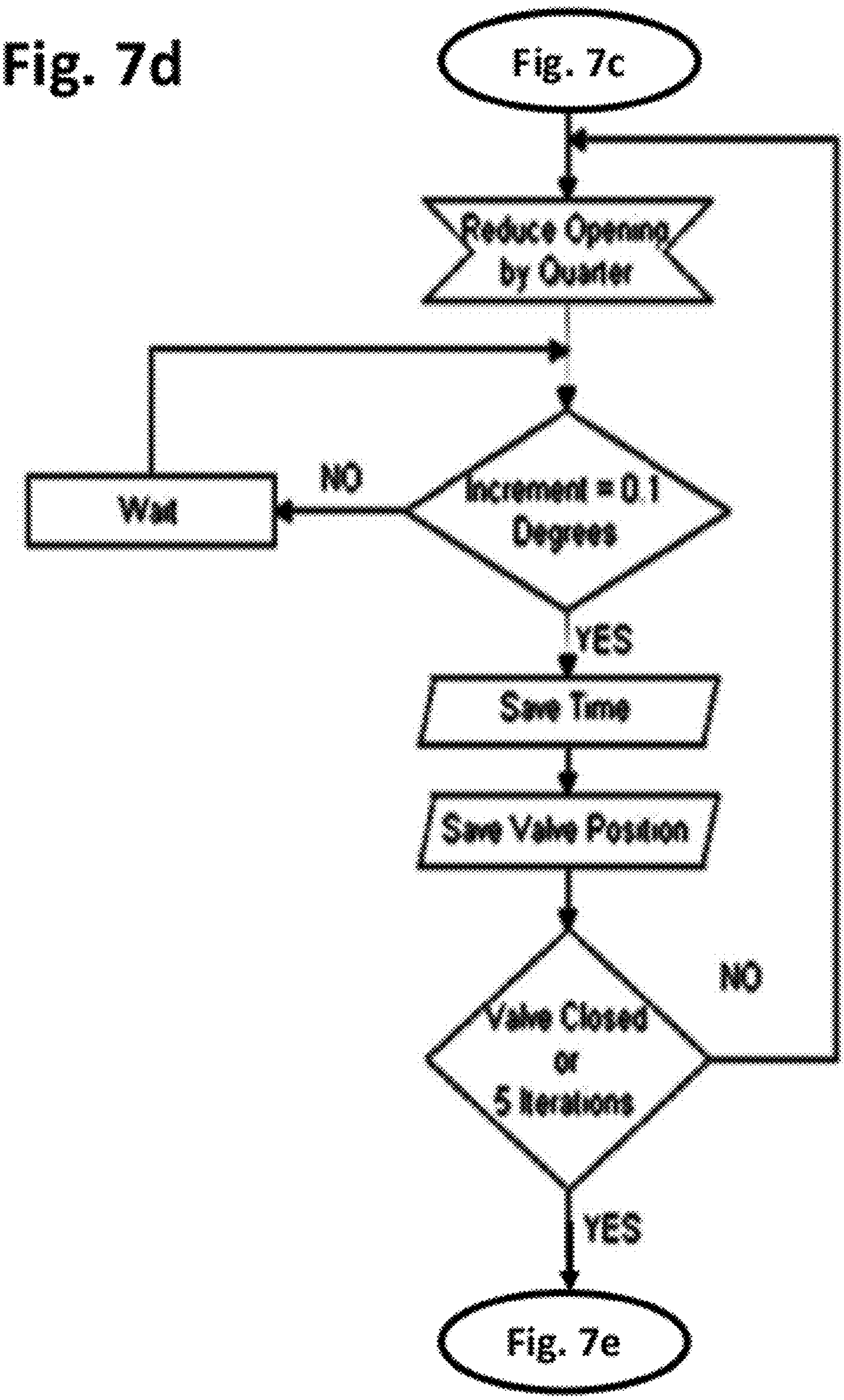


Fig. 7c
Reduce Opening by Quarter
NO
Wait
Increment = 0.1 Degrees
YES
Save Time
Save Valve Position
NO
Valve Closed or 5 Iterations
YES
Fig. 7e

Fig. 7e

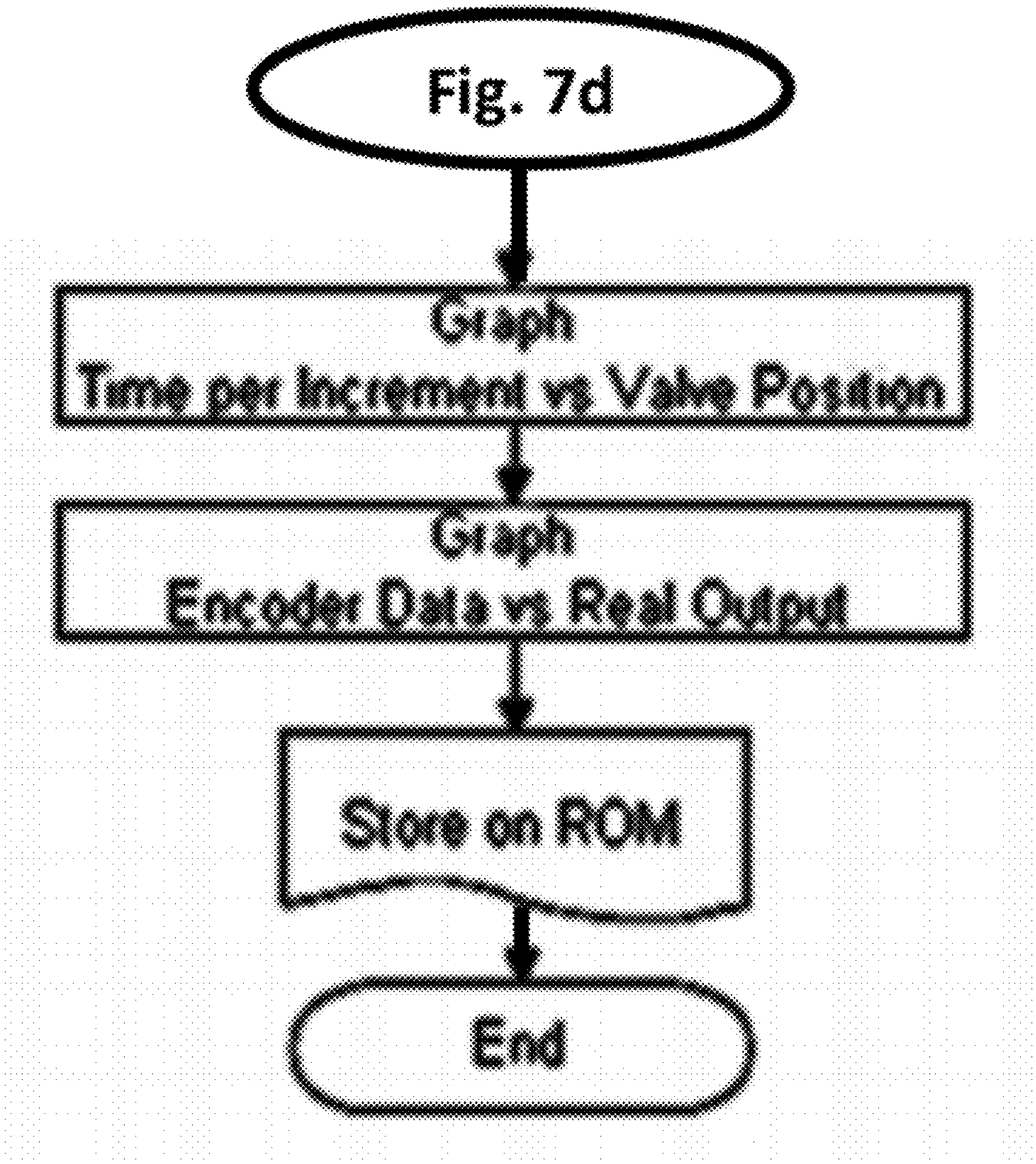


Fig. 7d
Graph
Time per Increment vs Valve Position
Graph
Encoder Data vs Real Output
Store on ROM
End

SOLAR THERMAL SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/390,862, entitled "Solar Thermal System" filed Oct. 7, 2010, hereby incorporated by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The system disclosed in this application relates to renewable energy systems. More particularly, this application discloses a solar thermal system and tower mounted solar receiver for converting solar energy into electricity.

[0004] 2. Background of the Technical Field

[0005] Solar thermal systems utilize solar energy in conjunction with heat exchangers to create superheated steam either in the heat exchanger itself or indirectly through the heating of a intermediate such as a molten salt. A solar thermal system is comprised of a tower mounted solar receiver with rows of heliostats which focus reflected sunlight onto the surface of the solar receiver to heat the water or the heat transfer fluid contained therein. A heat transfer fluid with the appropriate properties can be pumped out of the heat exchanger into a storage facility where it acts to store the thermal energy until it can be utilized. The thermal energy collected is used to convert water into steam for the purpose of driving a steam turbine to create electricity.

[0006] Currently available solar furnaces require large arrays of heliostats, i.e. mirrors, to focus sufficient light to heat the contents of the power tower. The solar receiver itself is typically a large cylinder housing a heat transfer material through which a heat transfer fluid is pumped through internal conduits.

SUMMARY

[0007] Disclosed herein is a solar thermal power system with associated heat exchanger, variable focus heliostat, and a heliostat stand with a pneumatic piston for shock absorption and positioning. The heat exchanger is essentially a solar receiver mounted onto a tower. In one embodiment, the solar receiver possesses a beveled surface at the bottom to create a vessel floor that is substantially perpendicular to the angles of the reflected light from the heliostats. An increase in the amount of incoming light striking the vessel floor perpendicularly, the greater the efficiency of the system. The vessel is sealed and contains a heat transfer fluid that can be either water or a molten salt.

[0008] One type of molten salt utilized is a typically mixture of 60 percent sodium nitrate and 40 percent potassium nitrate. In an alternative embodiment, calcium nitrate is included in the salt mixture. In one embodiment, the salt melts at 220° C. and is kept liquid at 290° C. in an insulated storage tank. Solar thermal systems de-couple the collection of solar energy from producing power by storing thermal energy. Electricity can be generated in periods of inclement weather or even at night using the stored thermal energy in the hot salt tank. Tanks are insulated and can store energy for approximately one week.

[0009] In various embodiments of the disclosed system, a compressed air piston, i.e. pneumatic piston, is used as a shock absorber on the stand to minimize breakage from wind gusts and for positioning the heliostat. An additional embodiment of a configurable reflective surface of a heliostat panel employs a reflective film and a means to modify the curvature of the surface from flat to parabolic.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** depicts an exemplary arrangement of a solar receiver mounted on a tower with associated heliostats.

[0011] FIG. **2***a* depicts an exploded cut-away view of an embodiment of the solar receiver.

[0012] FIGS. **2***b* and **2***c* depict embodiments of the solar receiver.

[0013] FIG. **2***d* depicts a cross sectional view of the outer walls of a solar receiver above the base.

[0014] FIG. **2***e* depicts a cross sectional view of an embodiment of the solar receiver.

[0015] FIG. **2***f* depicts a cut-away view of an embodiment of the solar receiver.

[0016] FIG. **3** depicts an exploded view of an embodiment of the heliostat stand with pneumatic pistons.

[0017] FIG. **4** depicts a heliostat with a flexible reflective surface.

[0018] FIG. **5***a* depicts an exploded cutaway view of an embodiment of the valved heliostat pneumatic piston.

[0019] FIG. **5***b* depicts an exploded cutaway view of an embodiment of the valved heliostat pneumatic piston.

[0020] FIGS. **6***a*, **6***b*, and **6***c* detail a stepwise progression of using the pneumatic pistons to absorb the shock of wind loading on the heliostats.

[0021] FIGS. **7***a* and **7***b* depict a the logic flow of the control system.

DETAILED DESCRIPTION

[0022] The disclosed thermal solar system is designed for placement between 37° latitude North and 37° latitude South. An embodiment of the solar thermal system of the present application, as depicted in FIG. **1**, includes a plurality of heliostats **200**, i.e. heliostat panels **200**, individually arranged to reflect and focus solar energy to the base **21** of a solar receiver **100**. The solar receiver **100** acts as a heat exchanger and is elevated above a field of heliostats **200** atop a solar receiver tower **50**. Each heliostat **200** is of, at a minimum, a reflective surface **110** and a heliostat support **130**. The solar receiver **100** is configured with a base **21** that is essentially an inverted hollow frustum of a cone arranged to minimize skewing of the reflected light from a heliostat **200** across the surface area of the base **21**. The base **21** is preferably beveled but could also be bulbous. The disclosed base **21** configurations allow for the solar energy reflected from a heliostat **200** to be concentrated across a smaller surface area and allows for a minimization of the size the solar receiver **100**.

[0023] The solar receiver **100**, as depicted in FIGS. **2***a* and **2***e*, possesses a vessel **20** that functions to contain the solar receiver heat transfer material **27**, a heat transfer fluid conduit **26** which functions to permit the heat transfer fluid **30** to travel in a sealed manner into, through, and out of the solar receiver **100** so as to absorb heat from the heat transfer material **27**, and a cap **29** which serves to seal and insulate the vessel **20**. The vessel **20** is optimally substantially configured of a substantially rigid material having sufficiently high softening and melting points, preferably copper at 1/16 of an inch thickness reinforced by carbon foam, and having a base **21** that, in some embodiments, is substantially an inverted hollow frustum of a cone that tapers down to a substantially central plane beneath the cylinder of the solar receiver **100** so as to leave a vessel port **23** at the bottom. The outer wall **15** of the base **21** is preferably coated with a carbon based solar selective material to improve the absorption of light and subsequent transfer of thermal energy into the vessel **20**. In one embodiment, the total surface area of the solar receiver **100** is approximately 2.3 square meters and the solar receiver **100** has an internal volume of approximately 1.6 cubic meters. Optimally, the solar receiver **100** is designed to operate at temperatures of at least 600° C. and at pressures of 250 to 300 bar. Flow through the conduit **26** can be adjusted to assist in control of the solar receiver's **100** temperature, but is optimal at 1.7 m^2/s when the operating temperature is 600° C. Higher flow rates require greater residence time within the solar receiver **100** and lower flow rates would require less residence time. Residence time can be controlled by adjusting the pump speed or by increasing the height of the solar receiver **100** and the height/length of an enclosed heat transfer fluid conduit **26**. The longer the length of the conduit **26**, the longer the residence time within the solar receiver **100**.

[0024] The vessel **20** possesses a plurality of compartments **22** segregated by compartment walls **35** concentrically arranged about the vessel port **23**. The cap **29** is configured so as to receive the compartment walls **35** and seal the individual compartments **22** across the top of the compartment walls **35**. Preferably, the compartment walls **35** are constructed from copper, carbon foam, or carbon foam applied to copper. The inner surface **95** of the solar receiver **100** is preferably lined with carbon foam for structural support as well as to facilitate the distribution of heat throughout the solar receiver **100**. As shown in FIG. 2*e*, the cap **29** also contains a reservoir **18** and boiler relief valve **180** for bleeding off pressure from the vessel as needed.

[0025] The solar receiver **100** utilizes a heat transfer fluid conduit **26** configured in an annular serpentine arrangement within the concentrically arranged annular compartments **22** to circulate a heat transfer fluid **30** through the solar receiver **100** and back out through an outlet conduit **27** which passes through the vessel port **23**. The sealed compartments **22** contain the serpentine conduit **26** and a heat transfer material **27**. The conduit **26** is arranged in connected concentric rows, each row residing within a compartment **22**. The heat transfer fluid **30** enters the conduit **26** at the vessel port **23** where it is directed to the outer ring of serpentine conduit **26**. Ideally the conduit **26** is fashioned from RA **330** or **321** stainless steel due to its strength and oxidation resistance, but other useful materials known to those skilled in the art may be substituted.

[0026] The heat transfer fluid **30** is preferably a molten salt or water. The heat transfer material **25** is preferably carbon foam, cadmium, or zinc. The internal temperature of the solar receiver **100** must stay below the melting point of the copper alloy utilized, e.g. 1075° for C18100. The use of serpentine conduit **26** increases the residence time of the heat transfer fluid **26** in the heat transfer material **27** and solar receiver **100**. When a liquid/molten heat transfer material **25** is used within the solar receiver **100**, a wicking layer **24**, e.g. a stainless steel felt, is used to inhibit pooling of the heat transfer material **25** and to facilitate the migration of a liquid heat transfer material **25** via capillary action. The integrity of the solar receiver **100** is also maintained by the transfer of heat from the solar receiver **100** to the heat transfer fluid **30** circulating through the solar receiver **100** in the conduit **26** and out through the vessel port **23**. The conduits **26** are connected through the compartment walls **35** and the heat transfer fluid travels through the conduit **26** from the vessel port **23** to the outer ring of conduit **26** and then circulates progressively inward through the concentrically arranged annular conduit **26** rows before exiting the solar receiver **100** through conduit exiting the vessel port **23**.

[0027] The connection between each annular conduit **26** row allows the heat transfer fluid **30** inside the conduit to flow from conduit **26** ring to conduit **26** ring, but each compartment that contains a serpentine conduit **26** ring is sealed around the conduit **26** as it passes through the compartment wall **35**, preferably by welding, brazing, or application of a seal, e.g. an o-ring, fastened or clamped to the compartment wall, to keep the compartments **22** separated. Because of the vessel's **20** conical shape, a liquid heat transfer material **27** will be prone to flow to the bottom corner of each compartment **22**. The wicking layer **24** on the bottom of the compartment will facilitate the distribution of the heat transfer material **27** on the essel's **20** inner surface. As the heat transfer material **27** evaporates from the base **21** of the vessel **20**, it keeps the inner vessel **20** surface at an optimal temperature and prevents breaches resulting from overheating and transfers heat to the conduit **26** and its heat transfer fluid **30**. The vaporized heat transfer material **27** condenses on the conduit **26** and drips back to the base **21** of the vessel **20**.

[0028] The heliostats **200** are deliberately spaced to minimize shadowing, reflective blocking, and mechanical blocking. The furthest mirror in the field is placed at approximately 102 m from the base of the approximately 60 m high solar receiver tower **50**. The optimal spacing between the rows is 2 m. With this configuration, the minimum incoming and outgoing ray angle at the last row of heliostats approximately 30° from vertical.

[0029] The angle of each reflective surface **110** on heliostats **200** in the last row of the heliostat **200** field is between approximately 31° and approximately 29° depending on the altitude angle of the sun. The tilt angle of the reflective surface **110** is substantially 60°+/−2°. The height of the heliostat **200** with a reflective surface **110** tilt angle of approximately 60° is 0.87 meters. This configuration results in approximately 0.03 meters of shadowing on the bottom of each heliostat **200** reflective surface **110** furthest from the solar tower **50**. At approximately 100 meters from the tower, the shadowing effect will no longer occur. The annual light losses from shadowing are approximately 1 percent. Adjacent heliostats **200** are spaced 0.25 meters from each other to avoid mechanical blocking. As heliostats **200** get progressively closer to the tower, their angle of inclination increases so as to maintain focus on the base **21** of the vessel **20** of the solar receiver **100**.

[0030] The energy loss in solar thermal systems due to atmospheric attenuation is estimated to be approximately 6 percent and the loss due to the cosine effect is estimated to be approximately 23.4 percent. The loss of efficiency is further aggravated by typical reflective losses of 6 percent for standard reflective coatings. The total expected efficiency of the solar thermal field of heliostats **200** is estimated to be approximately 67 percent.

[0031] Heliostats **200** are commonly designed with flat or slightly curved mirrors **110**, i.e. reflective surfaces **110**, which are able to direct light at a specified target. These mirrors **110** are typically constructed using aluminum or glass. Common mirror **110** sizes range from 2 to 10 meters square. In order to collect the light from the mirrors **110**, the solar receiver **100**

needs to have at least as much surface area as a mirror **110**. In order to reduce the size of the solar receiver **100**, each heliostat **200** needs to be able to focus the light on the base **21** of the vessel **20** of the solar receiver **100**. Each heliostat **200** requires a different focal point to accurately concentrate the light on the base **21**. Heliostats **200** have not been designed to efficiently focus solar energy on a small target in this way because each reflective surface **110** would need to be uniquely manufactured to with the appropriate focal length.

[0032] The reflective panels **110** on the heliostats **200** can be conventional reflective mirrors used in existing solar collection fields, but equipped with shock loaded pistons and motors. Alternatively, the reflective panels **110** can be frames equipped with a solar mirror reflective film such as 3M® Solar Mirror Film 1100™. The foregoing embodiments permit the reflective panels **110** to be repositioned and/or reshaped so as to optimize solar energy reflection to the appropriate focal point.

[0033] As depicted in FIG. **4**, the use of a solar mirror film as a reflective surface **110** permits the reflective surface to be reconfigured to optimize reflection of solar energy to the base **21** of the vessel **20** by adjustment of the concavity of the reflective surface **110**.

[0034] The frame of the heliostat **200** is designed to allow it to flex while keeping it secure against high winds. The mirror **110** is mounted along the edges of the reflective surface **110** to a reflective surface frame **120** using anchors **118** that pivot and rubber bushings **114** to allow the mirror **110** to move while being adjusted.

[0035] The adjuster bolt **115** is placed at the middle of the mirror **110** and is used to pull the center of the reflective surface **110** back toward the panel frame **112** in order to create a parabolic shape. The adjuster bolt **115** is positioned by a motor **121**.

[0036] The heliostat drive uses components that are specialized for high accuracy actuation in applications where high mechanical resistance and sudden shock frequently occur. The configuration is designed for low cost manufacturing and minimal maintenance. The actuator uses a bidirectional pneumatic piston **250** that is coupled with a gear box **264** to deliver the power output and accuracy that is necessary in solar applications. The pneumatic piston **250** described herein to drive the solar actuator delivers high power output and acts as a shock absorber to protect the gear box **264** and reflective surface **110** of the heliostat panel **200**.

[0037] As depicted in FIGS. **5***a* and **5***b*, a pneumatic piston **250** is utilized for both shock absorption and movement. As shown in FIGS. **6***a*, **6***b*, and **6***c*, the pneumatic piston **250** is pressurized to induce movement as well as to provide the cushioning effect of a shock absorber should a wind gust jar a heliostat panel **140**. A centralized compressor pressurizes the pneumatic piston **250** typically to between thirty and ninety psi. The air flowing from the compressor will flow through a manifold to each of the actuator blocks. The manifold will select the actuator that is being manipulated. Air flowing into a block preferably containing between five and twenty actuators will pass through an electro-pneumatic regulator after which it will pass to a cylinder control valve. In one embodiment, as shown in FIG. **5***a*, the electro-pneumatic regulator is optimally a four port, two position valve arranged outside the pneumatic piston, which extends or retracts the cylinder. The pneumatic piston **250** will permit some movement of the heliostat panel **140** along a path that is perpendicular to the general plane of the reflective surface **110** so as to relieve some of the stress from wind loading. Alternatively, the heliostat panel **140** can be rotated so as to minimize the surface area of the panel **140** facing the wind. The use of pneumatic pistons **250** to drive movement of the panels increases the longevity of the heliostats and drive components **200**.

[0038] The two pneumatic pistons **250** are utilized to control the position of their respective rack gears which rotate the heliostat **200** about vertical and horizontal axes. An electronic control system selects appropriate actuators using the manifold and supplies the appropriate airflow and pressure using the electro-pneumatic flow control. The electronic control system monitors and responds to the heliostats **200** position using an encoder that is connected to the gearbox via an encoder mount. This configuration would step the rotation of each heliostat **200**. FIGS. **7***a* and **7***b* depict the logic flow of the control system.

[0039] An individual pneumatic piston **250** is typically driven at 35 psi by a compressor. A valved pneumatic piston **250** is depicted in FIG. **5***a*. A valveless pneumatic piston **250** is depicted in FIG. **5***b*. Each pneumatic piston **250**, i.e. actuator **250**, is equipped with a motor **251** controlling the flow of air to a four port, two position valve **256** that regulates the piston's **255** rate of movement and controls the direction of movement. The piston barrel **258** is sealed at one end by the bottom cap **253** and at the other end by the top cap **263**. The bottom cap possesses an exhaust port **254** integrated into the valve seat **269**. A bottom seal **252** provides an airtight seal for the piston barrel **258**. A piston seal **270** segregates the piston **255** into airtight compartments below and above the piston **255**. Piston guides **257** facilitate the movement of the piston across the piston barrel and keep it aligned. A pressure relief valve **271** is affixed to the inlets **262** in the top cap **263** of the pneumatic piston **250** to prevent pressure fluctuations in the pneumatic system that could be caused by sudden wind loading.

[0040] The pressure delivered to each pneumatic piston **250** is dependent upon wind conditions and optimized to lower energy consumption on calm weather days and reduce wear on components. As the piston **250** is actuated, a rack gear **267** that is attached to a piston rod **267** rotates the main drive via the gearbox **264**. This translates the linear motion of the piston **250** into rotary motion for the heliostat panel **200**. The gearbox **264** is preferably machined from steel, and serves as the mount for the pneumatic piston **250**. At 35 PSI with a head diameter of 3 inches and 6:1 gearbox **264**, the system will produce approximately 1500 lbs of torque. The pressure, head/bore diameter, and gearbox ratio are configurable to meet different operational and space requirements. The drive gear is monitored using an encoder **266** in electronic communication with a means for controlling the pneumatic piston **250**, e.g. a control system, computer with instructions acting as a control system written in a machine readable language in non-volatile memory, so that the position of the heliostat panel **200** is available to the system. If sudden wind loading changes the position of the heliostat panel **200**, the encoder **266** will provide feedback to the control system to allow it to correct the position of the heliostat panel **200**. The system will track adjustments to each flow valve **256** and use an incremental encoder to determine output performance. Electronic encoders **266** measure the performance output of the pneumatic pistons **250** and are assigned unique addresses, e.g. serial numbers, MAC addresses, or IP addresses for identification. The data and addresses allow tracking software used by the control system to manipulate each pneumatic piston **250** individually to achieve optimal positioning of the individual heliostat panels **200**.

[0041] The position of the heliostat panel **200** is monitored and controlled by the aforementioned control system through manipulation of an altitude actuator **620** and an azimuth actuator **610**, each being a pneumatic piston **250** and associated components. As depicted in FIG. **3**, A heliostat panel mounting bracket **630** engages the piston head **268** of the altitude actuator **620** in a fixed arrangement by means of a altitude actuator gearbox mount **625** so as to translate the rotational movement of the piston head **268** into rotational movement of the heliostat panel mounting bracket **630** about a substantially horizontal axis. The altitude actuator gearbox mount **625** is coupled to the azimuth actuator gearbox mount **615** so as to translate rotational movement of the piston head **268** of the azimuth actuator **610** into rotational movement of the heliostat panel **200** about a substantially vertical axis. The azimuth actuator **610** is mounted into a heliostat stand base **650** for support.

[0042] A motorized drive mechanism that rotates the adjuster bolt is mounted to the heliostat panel **140**. During the calibration of the heliostats **200**, the drive motor is connected to a mobile calibration unit, or "MCU", that is used to power and control the motors. This MCU is equipped with a generator, plugs for the motors, and a computer that monitors the mirror adjustments and wirelessly communicates with the central heliostat **200** control system. When the reflective surface **110** of the heliostat **200** are being adjusted, the central control system for the field will target the boiler one mirror at a time. Once the reflective surface **110** of the heliostat **200** is directing light on the base **21** of the vessel **20**, the focal adjuster will begin to alter the focal point for optimum concentration. A fixed camera may be utilized to observe the base **21** of the solar receiver **100** to determine proper alignment of the reflective surface **110** of the heliostat **200**. Once the heliostat **200** has been adjusted, the adjuster bolt **115** is locked in place and the drive motor is removed. The adjuster motor **118** can be reattached if the focal point of the heliostat **200** needs further adjustment.

What is claimed is:

1. A solar receiver comprising:

a. a vessel for holding a heat transfer material, said vessel being configured as a substantially vertical cylindrical wall with a bottom edge and a top edge affixed to a base substantially configured as an inverted hollow frustum of a cone having an internal surface, an external surface, a base top connected to said bottom edge of said vertical cylindrical wall of said vessel, and a base bottom having a conduit port sealed about a inlet conduit segment and an outlet conduit segment to permit the entry and exit of a heat transfer fluid through a heat transfer fluid conduit;

b. a cap having a bottom face in a sealed arrangement with said top edge of said cylindrical wall; and

c. concentrically arranged compartments within said vessel separated by substantially annular compartment walls, said compartment walls extending from said bottom face of said cap to said internal surface of said base so as to seal each compartment, said compartments having heat transfer fluid conduits arranged as an annular ring in each compartment, and said annular rings connected so as to permit progressive flow from an outermost ring to an innermost ring through conduit ports in said compartment walls.

2. The solar receiver of claim **1**, wherein a reservoir contained within said cap is connected to said vessel by a valve which provides pressure relief for said vessel.

3. The solar receiver of claim **1**, wherein said annular rings are arranged in a vertically looping serpentine configuration within each said compartment.

4. The solar receiver of claim **1**, wherein said base is beveled above said port.

5. The solar receiver of claim **1**, wherein said base is bulbous above said port.

6. The solar receiver of claim **1**, wherein said vessel and said base are constructed of a copper alloy.

7. The solar receiver of claim **6**, wherein said heat transfer fluid conduit is constructed of a material selected from the group consisting of a copper alloy, stainless steel, and galvanized steel.

8. The solar receiver of claim **1**, wherein said heat transfer material is selected from the group consisting of carbon foam, cadmium, and zinc.

9. The solar receiver of claim **8**, wherein said heat transfer fluid is selected from the group consisting of water and molten salt.

10. The solar receiver of claim **9**, wherein said molten salt is a mixture of 60 percent sodium nitrate and 40 percent potassium nitrate.

11. The solar receiver of claim **10**, wherein said mixture contains calcium nitrate.

12. The solar receiver of claim **1**, wherein at least part of said internal surface of said base is covered by a layer of a wicking material that extends under at least part of said compartment walls from said conduit port to said cylinder wall.

13. The solar receiver of claim **1**, wherein said wicking material is a stainless steel felt.

14. A heliostat drive comprising:

a. a plurality of pneumatic pistons, wherein a first said piston engages a heliostat panel support about a horizontal axis and a second pneumatic piston engages a pneumatic piston support affixed to said first piston and arranged along a substantially vertical axis;

b. a heliostat panel support, said heliostat panel having a substantially planar heliostat support for engaging a heliostat panel, engaged with a drive mechanism which is driven by and engages a distal end of a pneumatic piston;

c. means to control said drive mechanism through the actuation of said plurality of pneumatic pistons; said means to control said drive mechanism controlling the flow of air to said plurality of pneumatic pistons so as to cause said pistons to move linearly along a pneumatic piston barrel and convert said linear movement of said piston into rotational movement of a drive mechanism by means of gears driven by a piston rod, said gears engaging a drive shaft at a distal end of each of said plurality of pneumatic pistons so as to provide linear to rotational translation of said linear motion of each said pneumatic piston; and

d. means for coupling said plurality of pneumatic pistons and said heliostat panel support.

15. The heliostat drive of claim **14**, wherein said drive is remotely controlled.

16. The heliostat drive of claim **14**, wherein said means to control said drive mechanism is a computer having machine readable instructions written in non-volatile memory to control said plurality of pneumatic pistons through the control of air flow to said plurality of pneumatic pistons.

17. A solar thermal system comprising:

a. a vessel for holding a heat transfer material, said vessel being configured as a substantially vertical cylindrical wall with a bottom edge and a top edge affixed to a base substantially configured as an inverted hollow frustum of a cone having an internal surface, an external surface, a base top connected to said bottom edge of said vertical cylindrical wall of said vessel, and a base bottom having a conduit port sealed about a inlet conduit segment and an outlet conduit segment to permit the entry and exit of a heat transfer fluid through a heat transfer fluid conduit;

b. a cap having a bottom face in a sealed arrangement with said top edge of said cylindrical wall;

c. concentrically arranged compartments within said vessel separated by substantially annular compartment walls, said compartment walls extending from said bottom face of said cap to said internal surface of said base so as to seal each compartment, said compartments having heat transfer fluid conduits arranged as an annular ring in each compartment, and said annular rings connected so as to permit progressive flow from an outermost ring to an innermost ring through conduit ports in said compartment walls;

d. a heliostat drive comprised of a plurality of pneumatic pistons, wherein a first said piston imparts rotation to a heliostat panel about a substantially horizontal axis and a second pneumatic piston imparts rotation to a heliostat panel about a substantially vertical axis; and

f. means to control said heliostat drive through the actuation of said plurality of pneumatic pistons; said means to control said drive mechanism controlling the flow of air to said plurality of pneumatic pistons so as to cause said pistons to move linearly along a pneumatic piston barrel and convert said linear movement of said piston into rotational movement of a drive mechanism by means of gears driven by a piston rod, said gears engaging a drive shaft at a distal end of each of said plurality of pneumatic pistons so as to provide linear to rotational translation of said linear motion of each said pneumatic piston.

* * * * *