



(22) **Date de dépôt/Filing Date:** 2015/10/30

(41) **Mise à la disp. pub./Open to Public Insp.:** 2016/04/30

(45) **Date de délivrance/Issue Date:** 2018/01/09

(30) **Priorité/Priority:** 2014/10/31 (US62/073,587)

(51) **Cl.Int./Int.Cl.** *F03D 9/00* (2016.01),
F03D 3/00 (2006.01), *F03D 9/25* (2016.01),
F24J 2/00 (2014.01)

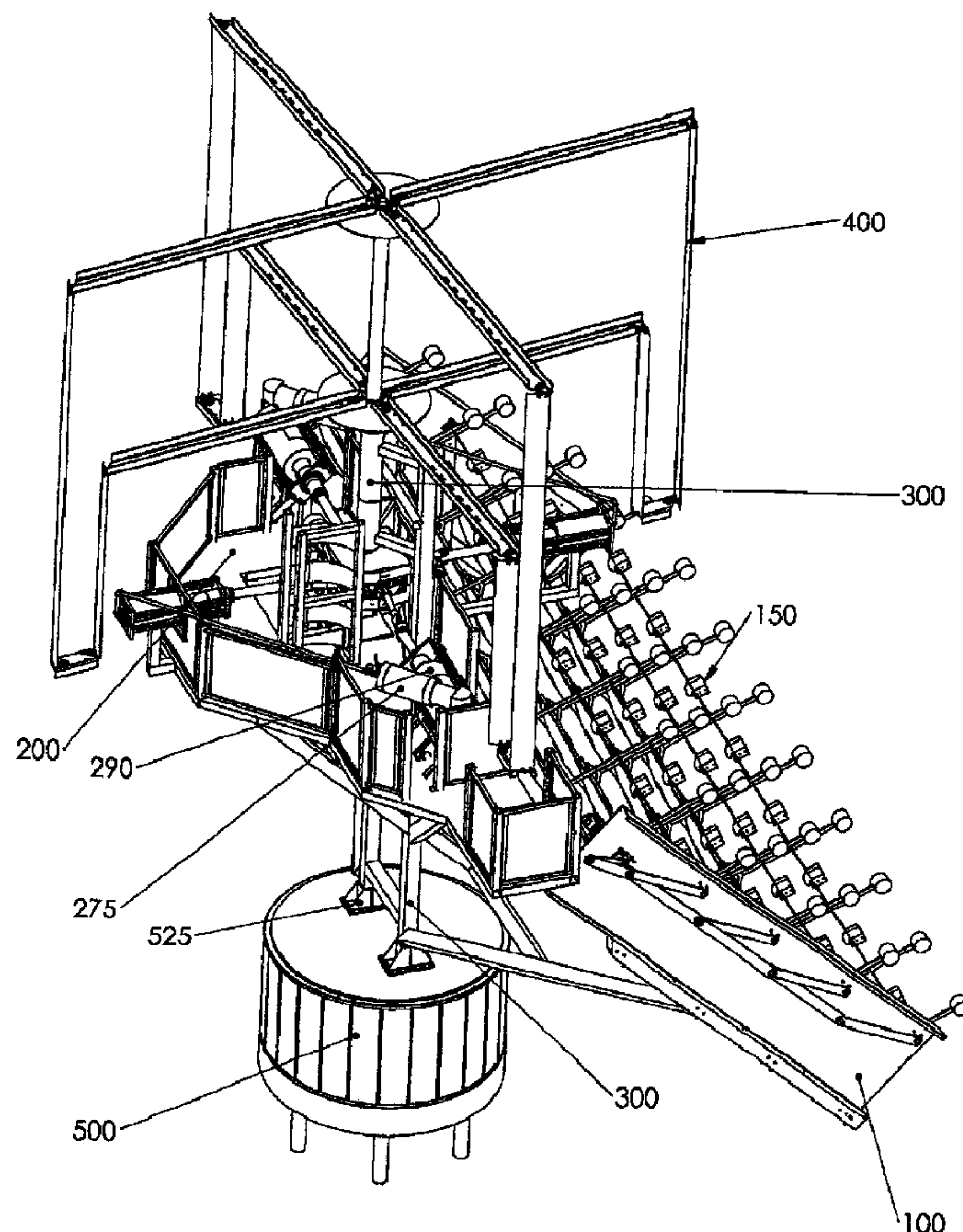
(72) **Inventeur/Inventor:**
ARMSTRONG, ROSS D., CA

(73) **Propriétaire/Owner:**
SOLAR WIND RELIANCE INITIATIVES (SWRI) LTD.,
CA

(74) **Agent:** MERIZZI RAMSBOTTOM & FORSTER

(54) **Titre :** SYSTÈME DE PRODUCTION COMBINÉE D'ÉNERGIE SOLAIRE ET D'ÉNERGIE ÉOLIENNE

(54) **Title:** COMBINED WIND AND SOLAR POWER GENERATING SYSTEM



(57) **Abrégé/Abstract:**

An integrated wind and solar solution is provided, including a solar energy collection assembly (100) and a vertical axis wind turbine (400), combined to provide an integrated power output. In preferred embodiments, the vertical axis wind turbine is positioned

(57) Abrégé(suite)/Abstract(continued):

above the solar energy collection assembly. Concentrating solar mirror collectors (116) are used to direct sunlight to a heat engine (250), which converts the collected heat energy into rotary motion. Rotary motion from the heat engine and from the vertical axis wind turbine preferably are on the same rotating axis (600), to facilitate load sharing between these two sources. A dual axis azimuth-altitude solar panel alignment tracking system is used in order to boost the energy conversion capability of the solar energy collectors.

ABSTRACT

An integrated wind and solar solution is provided, including a solar energy collection assembly (100) and a vertical axis wind turbine (400), combined to provide an integrated power output. In preferred embodiments, the vertical axis wind turbine is positioned above
5 the solar energy collection assembly. Concentrating solar mirror collectors (116) are used to direct sunlight to a heat engine (250), which converts the collected heat energy into rotary motion. Rotary motion from the heat engine and from the vertical axis wind turbine preferably are on the same rotating axis (600), to facilitate load sharing between these two sources. A dual axis azimuth-altitude solar panel alignment tracking system is used in order
10 to boost the energy conversion capability of the solar energy collectors.

COMBINED WIND AND SOLAR POWER GENERATING SYSTEM**BACKGROUND OF THE INVENTION**

This invention relates to an electrical generating and storage system which uses both wind and solar energy to produce electricity.

5 In recent years, as the need for green technology solutions has become more apparent, electricity generating system installations have gone through a dramatic evolution away from carbon-based industrial generating systems towards solar energy and wind energy solutions. While solar energy and wind energy solutions both have well-established benefits in regards to carbon dioxide emission reduction, the variability of electricity generated from
10 these devices has been a problematic concern for governments and other organizations charged with making electricity generation infrastructure decisions to balance electricity demand with the supply availability. An important concept in this context is “dispatchability”. Dispatchable energy sources are energy resources that can be ramped up or shut down in a short amount of time in response to demand.

15 It is well known that a negative statistical correlation exists between wind energy and solar energy on all time scales. For example, on a daily time scale, solar energy is only generated in daylight hours, with a peak generating capability when the sun has reached its peak altitude near the noon hour; whereas wind energy generation is possible throughout the entire day, but tends to peak in the late evening and non-daylight hours. On a monthly time
20 scale, in a northern hemisphere country such as Canada, solar energy production peaks in July and is at its least in January. Wind energy on the other hand is observed to peak in the winter months or coldest climate, when air density is at its highest, and is at its least in the summer months, when temperatures are at their highest, and air density is at its lowest.

It follows that marrying wind and solar into one system could have significant advantages.
25 However, wind energy systems and solar energy systems currently in use tend to be separate. Wind energy systems consist primarily of stand-alone horizontal axis wind turbines (HAWT) solutions, and stand-alone vertical axis wind turbine (VAWT) solutions. Similarly, solar collection systems consist primarily of stand-alone of photovoltaic solutions and concentrated solar power solutions.

There have been some field installations in which stand-alone horizontal axis wind turbine solutions and photovoltaic solutions have been combined, and share real estate area. The inherent benefits of such installations have been publicly cited, fundamentally that greater power is generated per unit of area, and that the impact of windmill shadows on solar collector performance is relatively insignificant when compared with the power generation benefit gain. However, these systems tend not to be well integrated with each other and tend to operate as if they were stand-alone units just sharing the same real estate.

To date, there do not appear to be any effective systems offering a well-integrated approach towards combining the capture of both wind and solar energy.

10 **BRIEF SUMMARY OF THE INVENTION**

In the invention, an integrated wind and solar solution is provided. A solar energy collection assembly and a vertical axis wind turbine are combined to provide an integrated power output.

In preferred embodiments, the vertical axis wind turbine is positioned above the solar energy collection assembly in order to take advantage of the direct correlation between wind speed and height above ground level.

The invention preferably uses concentrating solar mirror collectors, and a heat engine used to convert the collected heat energy into rotary motion. The heat engine preferably also has a thermal storage element to store energy and thus enhance dispatchability of the system.

20 Rotary motion from the heat engine and from the vertical axis wind turbine preferably are on the same rotating axis, to facilitate load sharing between these two sources via a common output driveshaft connected to a generator.

Preferably, a dual-axis azimuth-altitude solar panel alignment tracking system is used in order to boost the energy conversion capability of the solar energy collectors by generally tracking the sun.

Embodiments of the invention may be scaled up or down over a wide range. In one version with circular parabolic mirrors, it is contemplated that the height from the base of the

concrete footing to the top of the upper windmill beam will be 11.23 meters, the width across the array of solar collectors will be approximately 10.0 m, and the depth from the back of windmill blade to the front counterbalancing weight of the solar array will be approximately 8.74 m. Currently estimated power production for such an installation could
 5 be 3700 kwh/month or 45,000 kwh per year using circular mirrors, or up to 5000 additional kwh per year if rectangular or square parabolic mirrors are used instead.

In another version, with rectangular or square mirrors, it is contemplated that the height from ground level to the top of the upper windmill beam will be approximately 8.43 m, the width across the array of rectangular or square solar collectors will be approximately 5.38
 10 m, and the depth from the back of the windmill blade to the front of the parabolic mirror will be approximately 4.80 m. Current estimates of power production for such an installation would be 15,300 kWh per year.

In a photovoltaic variation, it is contemplated that the height will be approximately 8.20 m, the width across the array of photovoltaic solar panels will be approximately 5.38 m, and
 15 the depth from the back of the windmill blade to the front of the photovoltaic panels will be approximately 5.56 m. Current estimates of power production for such an installation would be 16,000 kWh per year. In this variation, the solar energy generated uses separate electrical infrastructure (for example a solar string inverter which converts DC energy generated into AC energy).

20 Benefits of the invention may include but are not limited to the following:

The generation of electrical energy where wind speeds are less than 5 metres per second. These wind conditions have a probability of occurrence of greater than 50% of the time in many areas, and, while not in use today with stand-alone devices, can be used to generate low-level electrical energy. Stand-alone HAWT
 25 and VAWT applications are not normally capable of cost-effective operation at these low wind speeds.

By using a load sharing approach, both wind energy and solar energy yield a common rotary motion interface, and are combined to raise induction generator operating efficiency levels. Flexibility can be further enhanced if the design

incorporates a dual induction generator approach, and better decision processes can be made as to when to actuate either a single or dual induction generator.

Greater levels of power generating ability per unit of area are possible through the adoption of careful product sharing integration strategies.

5 Effective rotating equipment maintenance strategies can be developed by designing in appropriate access to the key equipment requiring ongoing maintenance; and through the development of all appropriate equipment safeguards.

10 A thermal storage element can be easily incorporated and size scaled to facilitate electrical equipment dispatchability.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a perspective view of a preferred embodiment of the invention, showing a vertical axis windmill positioned above an assembly with circular concentrating solar mirror collectors, and using a heat engine to drive an output shaft.

15 Figure 2 is another perspective view of the preferred embodiment, from a different angle.

Figure 3A is a side view of the preferred embodiment.

Figure 3B is a front view of the preferred embodiment.

Figure 3C is a top view of the preferred embodiment.

20 Figure 3D is a side view of the preferred embodiment, with the C-channel side rail removed to show the linkage operation more clearly. The parabolic mirrors are shown in a low-angle or dawn/dusk position.

Figure 3E is a side view corresponding to Figure 3D, but with the parabolic mirrors in a high angle or mid-day position.

25 Figure 4A is a front view of the altitude or horizontal axis linkage adjustment system for the solar mirror collectors, showing the mirrors in their high angle position.

Figure 4B is a more detailed view of area B of Figure 4A.

Figure 5 is a front view showing light energy concentrated and redirected to a thermal storage compartment.

Figure 6 shows an alternate mirror embodiment with a square shape.

5 Figure 7 shows the internal mechanism of the main optical shaft subassembly.

Figure 8A shows the main optical shaft subassembly with the mirror in dawn and dusk position.

Figure 8B corresponds to Figure 8A, and shows the mirror in its highest (mid-day) position.

Figure 9 is a top view of the heat engine.

10 Figure 10A is a front view of the heat engine.

Figure 10B is a detailed view of area A of Figure 10A.

Figure 10C is a detailed view of area B of Figure 10A.

Figure 11A shows the regenerator assembly.

Figure 11B is a cross-section at A-A of Figure 11A.

15 Figure 11C is a cross-section at D-D of Figure 11B.

Figure 11D is a cross-section at B-B of Figure 11A.

Figure 11E is a detailed view of area C of Figure 11C.

Figure 12A shows the heat engine storage compartment assembly.

Figure 12B is a cross-section at A-A of Figure 12A.

20 Figure 12C a detailed view of area C of Figure 12B.

Figure 12D is a cross-section at B-B of Figure 12A.

Figure 13A is a view of the left side of the regenerator and cylinder assembly.

Figure 13B a detailed view of area A of Figure 13A.

Figure 13C is a cross-section at B-B of Figure 13A.

Figure 14A is a top view of the main maintenance platform assembly.

5 Figure 14B is a cross-section at B-B of Figure 14A.

Figure 15A is a top view of the main mast and frame assembly.

Figure 15B is a front view of the main mast and frame assembly.

Figure 16A is a perspective view of the vertical axis windmill arm and blade assembly.

Figure 16B a detailed view of area A of Figure 16A.

10 Figure 16C a detailed view of area B of Figure 16A.

Figure 17 is a perspective view of the base rotator assembly with its baseplate removed to show the internal components associated with azimuth axis rotation.

Figure 18A is a top view of the rotator baseplate assembly associated with Figure 17.

Figure 18B a corresponding bottom view.

15 Figure 19 is a perspective view showing an alternative embodiment of a heat engine collector compartment, assuming the delivery of heat through a heat pipe delivery system.

Figure 20 is a perspective view showing an alternative embodiment of a heat pipe attachment support structure for direct mounting to the parabolic mirror frame assembly.

20 Figure 21 is a perspective view of the preferred embodiment of the invention, but using square parabolic mirrors instead of circular ones.

Figure 22 is a front view corresponding to Figure 21.

Figure 23 is a top view corresponding to Figure 21.

Figure 24A is a side view corresponding to Figure 21.

Figure 24B is a side view corresponding to Figure 21, with the C-channel side rail removed to show the linkage operation more clearly. The parabolic mirrors are shown in a low-angle or dawn/dusk position.

- 5 Figure 24C is a side view corresponding to Figure 24B, but with the parabolic mirrors in a high angle or mid-day position.

Figure 25A is a front view of an alternative beta-type dual Stirling engine and a central rotator mechanism for the conversion of linear motion into rotary motion for direct engagement with the vertical axis wind turbine and speed increaser interface.

- 10 Figure 25B is a corresponding top view.

Figure 25C is a cross-section at A-A of Figure 25B.

Figure 26A is a front view of an alternative main optical shaft subassembly which controls the motion of the hyperbolic mirror assembly and its individually paired square parabolic mirror subassembly, showing the mirrors at their mid-day position.

- 15 Figure 26B is a cross-section at A-A of Figure 26A.

Figure 26C a front view similar to Figure 26A, but with the mirrors at their dawn and dusk positions.

Figure 26D is a cross-section at B-B of Figure 26C.

- 20 Figure 27 is a perspective view of the alternative base rotator substructure assembly with covering baseplate and driveshaft removed.

Figure 28A is a perspective view of an alternative windmill arm and blade assembly with three blades and an airfoil beam design.

Figure 28B is a detailed view of area A of Figure 28A.

Figure 29A is a detailed view of area B of Figure 23.

Figure 29B is a cross-section at C-C of Figure 29A, showing an alternative central rotator mechanism for the conversion of linear motion into rotary motion, for direct engagement with the vertical axis wind turbine and speed increaser which converts rotation speeds above the synchronous speed of the induction generator.

5 Figure 29C is a detail of the circled area in Figure 29B.

Figure 30 is a perspective view of a variation of the invention, using a photovoltaic solar delivery system, and overhead vertical axis wind turbine combined energy delivery solution.

Figure 31 is a front view of the Figure 30 variation.

Figure 32 is a side view of the Figure 30 variation.

10 Figure 33A is a side view of the Figure 30 variation.

Figure 33B is a side view of the Figure 30 variation, with the C-channel side rail removed to show the linkage operation more clearly. The photovoltaic panels are shown in a low-angle or dawn/dusk position.

Figure 33C is a side view corresponding to Figure 33A, but with the photovoltaic panels in a
15 high angle or mid-day position.

DETAILED DESCRIPTION

Overview

Figures 1 to 3E show the overall system. The solar collection array **100** is supported structurally by the main mast and frame assembly **300**. Concentrated solar energy is
20 redirected to heat engine storage compartments **290,290'**, which act as heat sources for the heat engine **250**, mounted on the main maintenance platform assembly **200**. Efficiency of the heat engine is significantly increased by regenerators **275,275'** incorporated into the heat engine design.

The main mast and frame assembly **300** also provides structural support for the vertical axis
25 wind turbine assembly (windmill arm and blade assembly) **400**. The windmill arm and blade

assembly rotate on the main vertical driveshaft **600**. Structural moment and axial support of the main mast and frame assembly is provided by the rotator baseplate **525**. Vertical axis or azimuth control for the entire assembly is provided by the base rotator assembly **500** which supports the rotator baseplate **525**.

- 5 Electricity is produced from an electric induction generator **205** (see Figures 14A and 14B) driven by both the heat engine **250** and the wind turbine **400**, as will be explained in detail below.

Solar collection array

- 10 **Figures 4A to 6** show a solar collection array, namely an array of circular parabolic mirrors **116** mounted within a rigid frame assembly **119** with counterbalance weights **118**. The mirrors and rigid frame assembly rotate about a horizontal shaft axis **110**. This shaft has a larger diameter, torque-transferring portion at its outer extremities, and a smaller diameter central portion to rotate the optical shaft subassembly **150**. This horizontal axis of rotation is the axis of altitude adjustment, and is situated at an appropriate distance away from the
- 15 parabolic mirrors **116**, i.e. at a distance from the mirrors that results in the concentration of the sunlight from the parabolic mirrors onto individual hyperbolic mirrors **180,181, 189 and 194** (see Figure 4A and 4B), to an approximate concentration diameter of 7.5cm. The hyperbolic mirrors are mounted in an off-axis manner, aligned so that the individual hyperbolic mirrors reflect and further concentrate the light energy to one of sixteen 5 cm
- 20 target zones situated on a copper spreader plate of heat storage compartment **290**. The individual hyperbolic mirrors are individually incorporated into the optical shaft subassembly **150**, whose function will be further explained later below. The four leftmost hyperbolic mirrors are aimed at the targets on the heat storage front plate **290** on the left side, and the four rightmost hyperbolic mirrors are aimed at the targets on the heat storage
- 25 front plate **290'** on the right side. The heat storage compartments **290,290'** act as the heat sources for the heat engine **250**, which converts linear motion into rotary motion at a common rotary interface to the windmill arm and blade assembly **400** just below the windmill piloted flange bearing supports **303,303'** (see Figure 15). The common rotary interface **263** (see Figure 10) drives a speed increaser **203** (see Figures 14A and 14B) which
- 30 in turn drives an induction generator **205** thereby producing electricity. Affixed to the

generator is a brake **206** to facilitate stopped rotation conditions. The entire top level assembly is supported by a base rotator assembly **500** which provides vertical axis or azimuth axis control for the entire system.

Horizontal axis (solar collectors altitude angle control)

5 **Figure 4A** is a view of a C-channel side rail **101** with the cover removed to expose the linkage system controlling the altitude axis adjustment of the solar collection system. The horizontal shaft axes **110** are supported by flange pillowblock bearings **122** mounted within the C-channel side rail. An electric motor **104** with brake provides rotation to a gear reducer **103** which slows the speed of rotation and increases the motor's output torque as required to
10 rotate the individual horizontal shaft axes. The torque requirement is lessened by the counterbalance weights **118** that are incorporated into the rigid frame assembly **115,119,120**.

Figure 3D is a side view of the preferred embodiment, with the C-channel side rail **101** removed to show the linkage operation more clearly. The parabolic mirrors are shown in a
15 low-angle position. **Figure 3E** is a side view corresponding to **Figure 3D**, but with the parabolic mirrors in a high angle position.

As observed in **Figure 4A**, the C-channel side rail **101** is supported by a frame member **304** which is a key structural element of the main mast and frame assembly **300** (see **Figures 15A** and **15B**). The frame member **304** is oriented at a 45-degree angle from horizontal.

20 The gear reducer **103** is mounted outside the C-channel side rail **101**, and is structurally supported by it. The gear reducer's output shaft resides inside the C-channel side rail, and rotates the crank **102** to drive the linkage assembly. The crank starts in the position shown in **Figure 3D**, and moves counter-clockwise in increments until it reaches the position shown in **Figure 3E**. It then moves clockwise in increments, back to the **Figure 3D** position at the
25 end of the day. The crank in turn drives the secondary linkage **105**. The secondary linkage in turn controls the rotation of the first of four rotation linkages **106** which in turn rotationally controls the highest horizontal shaft axis **110''**. The secondary linkage also is connected to and controls the motion of the first connector linkage **107**. The connector linkage connects to a second connector linkage **107'** and also to the second of the four rotation linkages **106'**

which in turn rotationally controls the second highest horizontal shaft axis **110''**. In turn, the second connector linkage **107'** connects to the third and final connector linkage **107''** and as well as to the third of the four rotation linkages **106''** which in turn rotationally controls the second lowest horizontal shaft axis **110'**. The third and final connector linkage **107''** is
 5 connected only to the final rotation linkage **106'''** which in turn rotationally controls the lowest horizontal shaft axis **110**.

The secondary linkage **105** is responsible for translating rotational motion delivered by the gear reducer **103** and electric motor **104** into a horizontal shaft axis **110** rotational swing of 50 degrees. This in turn controls the rotation of the rigid frame assembly **120** and the
 10 parabolic mirrors **116** that it supports, making the angular adjustment equal and common for all rigid frame assemblies and parabolic mirrors. The median horizontal angle of the parabolic mirrors **116** in the design is 45 degrees, which coincides with the same horizontal angle of the frame member **304** supporting the C-channel side rail **101**. Given the 50 degrees of rotational motion flexibility of the design, the parabolic mirrors **116** are thus
 15 capable of being rotated between an altitude of 20 degrees from horizontal to 70 degrees from horizontal. This meets the site-specific geographically imposed altitude alignment requirements of most solar panel installations. Obviously, the degree of rotation can be varied as desired, with minor design changes within the scope of the invention. The 45-degree median angle, and the 50 degrees of rotation, are for this specific example.

20 In a preferred example, the crank starts at dawn in the same position as at dusk. It rotates incrementally counter-clockwise to its highest angle (mid-day) position, and then clockwise back to its lowest angle (dusk/dawn) position.

Alternatively, the crank could go through a complete rotation of 360 degrees so it returns to the 8:30-9:00 pm position at dusk. In such a version, in order to complete a full daily cycle of
 25 sun rotation from dusk to dawn, the gear reducer **103** needs only to complete one 360-degree revolution.

Start and stop times for the operation of the electric motor **104** are controlled by a programmable controller, programmed to turn the motor on for only a few milliseconds at a time every 15 minutes or so throughout the day. The daily sequence of start and stop times

will vary depending on the site-specific needs, and the particular time and date when solar tracking is occurring. The brake incorporated on the electric motor **104** assists in improving the precision of the start and stop sequence. In one example of the invention, the crank **101** is approximately 41 cm long (pivot point to pivot point), and the secondary linkage **105** is approximately 52 cm, such that the ratio of the crank length to secondary linkage length is approximately 0.79. In another example, the respective dimensions are approximately 58 cm and 70 cm, and the ratio is approximately 0.83. In general, suitable ratios may be in the range of 0.75 to 0.85. These dimensions and ratios control the angle of rotation of the parabolic mirrors. In the first example (the Figure 1 to 20 embodiment), there is 50 degrees of rotation. In the second example (the Figure 21 to 29 embodiment), there is 74 degrees of rotation. Varying the dimensions and ratios varies the range of rotation.

Light energy redirection to the heat engine storage compartment

Figure 5 illustrates how the array of parabolic mirrors **116** focuses and redirects light to the heat engine storage compartments **290**. The light from the parabolic mirrors **116, 116'** focuses the energy onto the individual hyperbolic mirrors **180, 181** which redirect and further concentrate the light towards the heat engine storage compartment **290**.

Alternative mirror configuration

Figures 6 and 21 to 24C show a square mirror **116A** as an alternative to the circular parabolic mirrors **116**. These mirrors can be used within basically the same equipment form factor. The advantage is that 27% more light energy per mirror can be captured and redirected towards the heat engine storage compartment **290**. It should be understood that non-square rectangular mirrors could be used with the same effect, square just being a special case of rectangular. Where the word "rectangular" is used in this specification, it should be interpreted to indicate either a square or non-square rectangle unless the context indicates otherwise.

Hyperbolic mirrors and optical shaft sub-assembly kinematics discussion

Referring to **Figures 7 to 8B**, the main optical shaft subassembly **150**, situated on the horizontal or altitude axis of alignment, is responsible for redirecting the solar energy from

the rotating parabolic mirrors **116** to the fixed location individual targets at the heat storage compartment **290**. The main optical shaft subassembly **150** is fixed in position laterally, held in place by the rigid frame assembly **115,119,120**. Similarly, the individual targets on the heat storage compartment **290** are fixed in position. Consequently, there is no need for any variation in the axial position of the hyperbolic mirrors (**180,181,189 and 194 of Figure 4**), and they can be mounted in fixed positions.

Regarding radial movements of the horizontal axis of alignment, since the parabolic mirrors **116** are moving radially about the horizontal axis, and since the individual targets on the heat storage compartment **290** remain in a fixed position, there is a need for an offsetting adjustment in the angular position of the hyperbolic mirrors. Assuming the hyperbolic mirrors' position of reflection is located on the horizontal axis of alignment, the amount of offsetting adjustment is equivalent to one half of the angular movement of the parabolic mirror **116**. This offsetting adjustment is accomplished automatically and continuously using the mechanism incorporated within the main optical shaft subassembly **150**.

Figure 7 and 8 illustrate the function of this optical shaft subassembly **150**. The device is structurally held by the optical main shaft **151,152** which has its outboard ends structurally affixed to the rigid frame assembly **119,120**. The inboard ends of the optical main shaft **151,152** are structurally affixed to the optical equipment cover **159**.

Within the optical equipment cover **159** resides the equipment required to facilitate the offsetting adjustment. Two light duty flange bearings **157** support the keyed optical mirror shaft **153** which is permitted to rotate freely and independently of the rotation of the optical main shaft **151** and optical main shaft **152**. This keyed optical mirror shaft **153** can be but is not necessarily collinear with the optical main shaft **151, 152**. Also mounted on the optical mirror shaft **153** is a synchronous drive sprocket component **156** with 32 sprocket teeth. Also mounted on two individually fixed small sprocket shafts **154 and 154'** are two additional synchronous drive sprocket components **155 and 155'** each with sixteen sprocket teeth. Mounted between the three sprockets is a dual-sided synchronous serpentine belt drive **158**. The outermost small sprocket shaft **154** located on the external edge of the optical equipment cover **159** is structurally affixed to a side plate **160**. This side plate **160**

also provides linear guidance for a sprocket belt tightening device **161** which facilitates the tightening of the dual-sided synchronous belt drive **158**.

Referring to **Figure 8A**, a distinctly designed hyperbolic mirror **180** is also mounted to the optical mirror shaft **153** and is fixed axially by shaft collars and fixed radially by the keyed
5 nature of the optical mirror shaft **153**.

The above described construction details, results in a radial movement path of the hyperbolic mirror **180** which is opposite in direction and is one half of the angular movement of the optical main shaft **151, 152**. So while during any given day, there could be a 50-degree rotation of the optical main shaft **151, 152**, the hyperbolic mirror **180** would see
10 an equal and opposite adjustment of up to 25 degrees.

The extents of this level of rotation are observed by the two mirror positions observed in **Figure 8A and 8B**. The circle exhibited on the hyperbolic mirror **180** is an indication of the extents of the parabolic mirror's **116** light energy being concentrated to a diameter of 7.5 cm onto the hyperbolic mirror **180**, and where it would reside on the hyperbolic mirror at
15 different times of the day, depending on the parabolic mirrors' **116** likely angular position at that point in time.

Heat engine design and linear to rotary motion converter

Figures 9 ,10A, 10B and 10C provide a detailed description of the complete heat engine **250** Design. **Figures 11A to 11E** provide a more comprehensive description of the regenerator
20 assembly **275** used in the heat engine. **Figures 12A to 12D** provide a more comprehensive description of the heat engine storage compartment assembly **290'**. **Figures 13A to 13C** provide a more comprehensive description of the regenerator and cylinder assembly used within the heat engine **250** design.

We start the discussion on the heat engine **250** design by discussing the design of the heat
25 engine storage compartment assembly **290'** as detailed in **Figure 12A to 12D**.

As discussed above, the parabolic mirrors' **116,116'** concentrate the sunlight onto the individual hyperbolic mirrors (**180 and 181 respectively of Figure 4A**) to an approximate concentration diameter of 7.5 cm. The individual hyperbolic mirrors then reflect and further

concentrate the light energy to one of sixteen 5 cm target zones situated on the copper spreader plate described as the heat storage compartment front plate **267'**.

In **Figures 12A to 12D**, the heat engine storage compartment is further defined. The sixteen individual sunlight target zones are evenly distributed on the copper spreader plate **267'**.

5 The spreader plate **267'** is metallurgically bonded to the copper folded fin **292'** which acts as the heat transfer mechanism for the solar salts situated within the heat storage compartment. The solar salt composition to be used in the storage area will be optimized to have the lowest liquidus temperature, a composition such as the following (Li – 33% mol, K- 48%mol, and Na – 19%mol). The galvanized storage chamber **291'** houses the solar salt
10 composition. The galvanized storage chamber **291'** is encased in a suitable insulation material **296'** on three sides. There is a removal access plate **294'** into the galvanized storage chamber **291'** in order to access the chamber and fill with the solar salt composition. This removal access plate **294'** can be accessed only after removing the separate insulation material compartment **295'** above it. The galvanized storage chamber
15 **291'** is a scalable design, which can be made larger if greater thermal storage capability is a customer requirement, and smaller if lesser thermal storage capability is required.

Referring to **Figure 9**, a hot piston **251,251''** pressurized with helium gas resides within each of the two heat storage compartments **290,290'**. During the hot piston compression cycle, the heated helium gas exits from the hot piston and passes through the hot insulated exit
20 pipe **261,261'**, then through the regenerator assembly **275,275'** which acts as a temporary heat storage device. The hot helium then begins to cool by passing through the uninsulated pipe **252,252'** to the cold piston **251',251'''**. The cold piston **251',251'''** has an aggressive folded-fin heat sink assembly **258,258'** metallurgically bonded to it. As the vertical axis wind turbine blade **400** passes by the cold piston **251',251'''**, it initiates a localized pressure drop
25 condition that results in the development of airflow velocity that passes through the folded fin heat sink assembly, thereby cooling the cold piston and significantly increasing the temperature differential between the hot piston and the cold piston. As the cold piston **251',251'''** completes its compression cycle, the cooled helium gas in the piston passes back through the uninsulated pipe **252,252'** and back through the regenerator assembly
30 **275,275'**, where the stored heat begins to reheat the helium gas. The heated gas then passes through the hot insulated exit pipe **261,261'** and once again into the hot piston

251,251". The regenerator assembly **275,275'** plays an efficiency improvement role in this heat engine **250**; the greater the effectiveness of the regenerator **275,275'** in heating and cooling in the helium gas, the greater the efficiency of the heat engine design.

The heat engine is comprised of two pairs of hot piston **251,251"**, 2 regenerator assemblies
5 **275,275'** and two pairs of cold pistons **251'251'"**.

The piston rod **253** that exits each of the hot piston **251,251"** and cold piston **251'251'"** is connected to a rotator cylinder linkage **254,254'255,255'**. All four rotator cylinder linkages are connected to a Stirling engine rotator pin **263** situated between the top and bottom heat engine rotator wheels **256,256'**. The centre hub of the top heat engine rotator wheel
10 **256** connects directly with the main driveshaft **600**. The bottom heat engine rotator wheel **256'** connects directly to the speed increaser input shaft **203**. This describes the rotary motion interface for both the vertical axis wind turbine **400** and the solar collector array **100**.

Figure 13A to 13C describes through the use of a top view and detailed and sectional view
15 describes in more detail the function of the regenerator and cylinder assembly. The heat engine **250** is comprised of two of these linear motion actuating devices. Starting from the cold piston rod end **253'**, the piston rod **253'** passes through a gland **267'** that is supported by the cold piston front plate **269**. A series of 8 tension rods **268', 268"** provide a compressive load on the cold piston front plate and the cold piston back plate **262'**, ensuring
20 a pressurized seal is maintained. The piston rod **253'** then enters into the body of the cold piston **251'**. The cold piston **251'** is supported by two cold piston support structures **257"',257'"**. The wind turbine end of the cold piston **251'** contains a shrouded cover **258'** encompassing an aggressively constructed folded fin heat sink **271** which is metallurgically bonded to the cold piston **251'**. The cold piston back plate **262'** has configured openings in
25 the plate to ensure airflow from the vertical axis wind turbine **400** is unobstructed and able to pass through the aggressively constructed folded fin heat sink **271** freely. The cold piston **251'** exit is connected to the uninsulated return pipe **252**. Situated adjacent to the regenerator assembly **275** is a pressure gage **259** and a valve **260** for pressurizing the regenerator and cylinder assembly with helium gas. Adjacent to the valve **260** is the
30 regenerator assembly **275**, which is followed by the insulated return pipe **261**, that sits at

the entrance of the hot piston **251**. The hot piston back-plate **272** resides at the back plate of the hot piston **251**, which is encased in insulation material in order to minimize heat loss. Adjacent to this hot piston back-plate **272** sits the heat storage compartment assembly **290**. At the opposite end of the hot piston **251** resides the hot piston front plate **270**. A series of
 5 8 tension rods **268** provide a compressive load on the hot piston front plate **270** and back plate **272**. The hot piston front plate **270** supports a gland **267** which supports the piston rod **253** which exits the hot piston **251**.

Figure 10A to 10C describes the front view of the heat engine **250** four piston design and it describes a few detailed features of the design to a greater extent than the other views.

10 **Detail A** shows the copper spreader plate with the sixteen sunlight target zones **267'**, which is the heat source for the heat storage compartment assembly **290'**. A thermocouple embedded within the copper spreader plate **267'** monitors temperatures of the spreader plate throughout the day. When the temperature of the spreader plate reaches a certain minimum temperature threshold, the linear actuator **265'** is activated, and the insulator
 15 front plate **266'** is linearly raised to cover the copper spreader plate **267'**. This action minimizes heat losses within the heat storage compartment assembly **290**. Similarly, a thermocouple is also embedded within the insulator front plate **266'** at a strategic location, and when the thermocouple reaches a certain minimum threshold temperature the linear actuator **265'** is once again activated and the insulator front plate **266'** is linearly lowered
 20 thereby exposing the copper spreader plate **267'**. This above described process identifies a strategy to minimize thermal compartment heat losses during the evening periods, and high cloud-cover periods which arise during the variable solar collection conditions experienced.

Detail B shows a partial front view of the device which converts linear motion into rotary motion. The front cold piston assembly of the heat engine covers the centre region,
 25 however what is observed is the rotator cylinder linkage **255** connection to the heat engine rotator pin **263**. The **Detail B** view also partially communicates how the general space, other than the Stirling engine rotator pin **263**, is clear and unobstructed in between the top rotator wheel **256**, and the bottom rotator wheel **256'** so as not to restrict rotation of the four rotator cylinder linkage **254,254',255,255'** components connected to it.

Figure 11A to 11E provides a sectional and detailed view of the regenerator assembly 275,275' construction. The regenerator is a key component of the heat engine design. It needs to be effective at temporarily storing the heat from the hot helium gases which enters and exits the unit during the hot piston compression cycle; and it in turns needs to be effective in reheating the cold helium gases during the cold piston compression cycle upon their return through the regenerator. Pressure drop is also an appropriate consideration in determining the design of this device, as pressure drop will also lessen the efficiency of the heat engine.

The regenerator assembly is encased in insulation 276 around its circumference. As well the end units are encased in Insulation 280,280'. The regenerator assembly 275,275' has a standard pipe inlet which is transitioned in the end cap assembly 281,281' as the gases are routed circumferentially around a central copper regenerator core 279. The copper regenerator core is held in position concentrically by two regenerator hanger supports 282,282' located within the endcap assembly 281,281' region of each end. A highly dense aluminum (or copper) lanced folded fin 278 is metallurgically joined to the central copper regenerator core 279. The central copper regenerator core 279 and highly dense lanced folded fin 278 is held in place by an outer pipe 277 which is welded to the end cap assemblies and pressurized to ensure no gaseous leaks.

Main maintenance platform assembly

Figure 14A is a top view of the main maintenance platform assembly 200.

The main purpose of this main platform assembly 200 is to provide human access to the heat engine 250 equipment and rotating equipment so as to facilitate the ongoing maintenance needs of the top level assembly. Human access is provided through the access opening 207 where access is achieved through a pull down ladder.

Human safety is achieved through restricting access to the pull down ladder through the use of a lock. When the lock is removed, and when the ladder is pulled down, a proximity sensor receives an alert, which completes one of three actions; i) it energizes the brake 206 which restricts the rotation of the vertical axis wind turbine 400, ii) it activates a second proximity sensor which ensures that the vertical axis windmill blade 400 is not blocking any access to

the outer platform defined by the perimeter safety walls **216, 217 and 218**, and iii) it energizes the motor **104** actuating the horizontal or altitude axis and the motor **506** actuating the vertical or azimuth axis, and instructs these motors to park in a mode that minimizes solar collection activities. The goal of these actions would be to shut down all
 5 rotating equipment prior to the human reaching the platform, thereby placing human safety as a priority over energy collection activities.

Human safety is also achieved through the use of access opening guarding **208** protecting the human from rotating equipment, safety perimeter walls
210,211,212,213,214,215,216,217,218, 219 and 220) around nearly the entire platform, and
 10 by providing a bearing maintenance stepper plate (not shown in the accompanying drawings) which covers the mechanism that translates linear motion into rotary motion, and provides access to the vertical axis wind turbine support bearings **303,303'** (see Figure 1).

The maintenance platform assembly **200** also provides maintenance access to the speed increaser **203** that multiplies the vertical axis wind turbine **400** and heat engine **250** rotary
 15 speed inputs, and increases them to an rpm which is above the synchronous slip speed of the generator **205**. The brake **206** is incorporated into the back end of the generator **205**. A coupling **204** connects the speed increaser **203** with the generator **205**.

The windmill will operate best within a certain range of tip speed ratios. Tip speed ratio is defined as the ratio between the tangential speed of the tip of a blade and the actual
 20 velocity of the wind. The tip speed ratio is related to efficiency, with the optimum varying with blade design. In this example, a tip speed ratio of 3 to 6 is the preferred target, and a range of operating speeds between 120 and 180 rpm. The larger the unit and the windmill diameter becomes, the slower the operating rpm of the unit becomes. Operating rpm may be varied in the design at relatively low changeover cost.

25 The maintenance platform design facilitates an optional dual generator, by incorporating a lower maintenance access region as described by **202**. As a result, the speed increaser **203**, the coupling **204** and the generator **205** can be duplicated. In such an application, the speed increaser **203**, would need to have a dual output shaft design, and would require an electro-mechanical clutch in between the top speed increaser **203** and the bottom speed increaser

203', so that activation or deactivation of the bottom speed increaser could be controlled by energy generation control software.

Given this dual generator **205,205'** option (as observed in Figure 14B), in peak periods of energy collection when there is a period of extremely high wind speeds, the dual generator
 5 **205,205'** control design can be actuated, thereby facilitating a higher level of electricity output. Decisions relating to when to activate or deactivate the second drive could be automated and programmed into the control software.

Main mast and frame assembly

Figure 15A and 15B describes the main mast and frame assembly **300** used in this design.
 10 This element of the design is the fundamental structural skeleton of the top level assembly. Two main mast vertical square columns **301,301'** provide the main lower connection to the base rotator assembly **500** (see Figure 18).

The lower hanging members of the main mast support the frame member **304,304'**. Frame member **304,304'** provides the primary structural support for the array of solar collectors
 15 and the C-channel side rail sub-assembly **100** as indicated in **Figure 1**.

As was discussed earlier, the heat engine storage compartment **290** per **Figure 1** is situated at a 45-degree angle from horizontal, so as to be perpendicular to these frame members **304,304'**. This orientation best facilitates the solar collector's heat transfer process.

The structural elements identified as **305,305',307,307',306,306',308,308',309** and **310** are
 20 the structural frame elements which provide overall support for the main maintenance platform subassembly **200** (see **Figure 14**).

The cylindrical tube **302** and piloted flange bearings **303,303'** are the primary structural elements which support the driveshaft **600** driving the windmill arm and blade assembly **400**
 (see **Figure 16**), and facilitates its rotation. Through rotation, the windmill arm and blade
 25 assembly **400** derives mechanical torque from wind energy through the use of an intermediary driveshaft component **600**.

Windmill arm and blade assembly

Figures 16A to 16C show a four-blade windmill arm and blade assembly **400**.

The design has two windmill arm support plate assemblies **403,403'**. The top windmill arm support assembly **403** rigidly supports four upper windmill arm beams **402** and also
 5 facilitates static and dynamic balancing adjustments of the complete windmill arm and blade assembly **400**. The upper windmill arm beam **402** in turn supports a blade inner support assembly **410** which has blade pitch angle feature adjustments incorporated into the design. The blade inner support assembly **410** in turn is fastened to the windmill blades **401** at the top.

10 Between the two windmill arm support plate assemblies **403,403'** is a windmill support tube **404** which provides an interim structural support role for the complete windmill arm and blade assembly prior to its final installation. The two windmill arm support plate assemblies **403,403'** have a concentric keyed interface with a keyed driveshaft **600** that passes through the complete assembly and which is structurally held by the piloted flange bearings **303,303'**
 15 as indicated in the main mast and frame assembly **300** (see Figure 15). The opposite shaft end has a keyed connection with the top rotator wheel **80** (indicated in Detail B of Figure 10A), transferring torque generated from the windmill arm and blade assembly to this top rotator wheel **256**.

The bottom windmill arm support plate assembly **403'** rigidly supports four lower windmill
 20 arm beams **405**. The windmill arm support plate assembly **403'** also facilitates static and dynamic balancing adjustments as was the case in the upper assembly. The lower windmill arm beam **405** in turn supports a blade inner support assembly **410** which also has blade pitch angle feature adjustments. The blade inner support assembly **410** in turn supports the windmill blade **406**.

25 At the base of the windmill blades, the inner windmill blade **406** is rigidly connected to the bottom blade inner support assembly **411**. This bottom blade inner support assembly is fastened to the lower windmill arm beam **407**, which also has an outer perimeter connection to the blade outer support assembly **410**. The blade outer support assembly **410** is in turn fastened to the outer windmill blades **401** at the bottom.

Preferably, the windmill blades have an airfoil shape to optimize performance.

The design of this windmill arm and blade assembly offer several design benefits to the implementer. They are described as follows:

5 The blade profile has high coefficient of lift characteristics versus coefficient of drag characteristics for airfoil performance installations operating at Reynolds numbers approximating the realm of stand-alone vertical axis wind turbines installations of this nature.

10 The blade connection design offers a relatively clean and unobstructed blade connection design and does not require any mid-span connection requirements, which, if they existed could significantly impede wind turbine performance.

 The blade connection design facilitates the flexibility of differing blade pitch angles which is helpful in optimizing the design's performance.

15 The windmill arm support assembly design facilitates static and dynamic balancing adjustments to the windmill arm and blade assembly thereby minimizing vibrational concerns associated with unbalance.

20 The windmill arm and blade assembly provides a dual blade design that offers three functional benefits: 1) it increases blade torque generating performance, 2) it keeps the floorplan area associated main maintenance platform assembly area primarily free from safety concerns associated with the rotating windmill, and 3) the inner blade design acts as a functional assist in facilitating heat removal within the cold piston design, thereby increasing the temperature differentials between the hot and cold pistons, and increasing the heat engine's operating efficiency.

Base rotator assembly facilitating azimuth or vertical axis control

25 **Figure 17** describes the base rotator assembly **500** with the rotator baseplate assembly **525** removed. **Figure 18A and 18B** describes the rotator baseplate assembly **500** and its function.

The base rotator assembly **500** describes a concrete footing **501** which can include concrete piles or posts that extend deeper into the ground.

Affixed to the top of the concrete footing **501** are two wall c-channel frames **502** which are fastened to the concrete footing. Seated within the wall c-channel frames **502** resides a
 5 multitude of base wall sections **503** which surround the entire perimeter of the concrete footing and conceals the internal equipment of the base rotator assembly. At the top of the Wall C-channel frames **503** resides a Wall C-channel top frame **511** supporting the top portion of the Wall C-channel frames **503**. Parts of the C-channel top frame **511** are removable, thereby facilitating the removal of some of the base wall sections **503** facilitating
 10 access to the infrastructure equipment for maintenance purposes.

Within the base rotator assembly **500** resides a large foundation baseplate **510** which is capable of resisting a significant structural moment. A vertical shaft **504** with a keyed output facilitates the rotation of the rotator baseplate assembly's keyed welded hub **530** (see **Figure 18**). The vertical shaft with the keyed output is supported by two pillowblock
 15 bearings **515,515'** which are sized to resist the structural moment of the top level assembly. The vertical shaft with a keyed output **504** is driven by a large synchronous sprocket **508** through the synchronous belt drive **509** that is wrapped around a smaller synchronous driver sprocket **516**. The smaller synchronous driver sprocket **516** is driven by the output shaft of the gear reducer **505**; the gear reducer **505** is driven by the electric motor input
 20 **506**. Loosening and tightening of the synchronous belt drive **509** is facilitated by a take-up frame **507** which moves the gear reducer **505** and motor **506** towards the vertical shaft **504** for loosening and away for tightening.

An alternative structure is used for the management of the significant infrastructure weight of the top level assembly. Three structural base members with trunnion baseplate and
 25 columns **515,515',515''** are mounted on the concrete footing **501** at three 120-degree radially centric locations. On top of the trunnion baseplate and columns **515,515',515''** is seated a fixed pillowblock rolling bearing **513,513',513''** and a floating roller pillowblock roller bearing **514,514'514''**. Between the two bearings resides a trunnion wheel **512,512',512''** mounted on a shaft running between the two pillowblock roller bearings **513**

and **514**. The three trunnion wheels **512,512',512"** are oriented such that they can rotate tangentially in the direction of motion of the vertical shaft with keyed output **504**.

The rotator baseplate assembly **525** bottom view (see figure 18A and 18B) is mounted to the base rotator assembly **500** such that the vertical shaft with keyed output **504** (see figure 5 17), seats within the keyed welded hub **530** on the baseplate **526**, and provides the necessary delivered torque to rotate the rotator baseplate assembly **525**, and therefore provide azimuth axis or vertical axis control to the top level assembly. The three trunnion wheels **512,512',512"** also provide planar support for the rotator baseplate assembly **525** and each trunnion wheel **512,512',512"** rotates as the plate rotates. The point of contact of 10 the trunnion wheels **512,512',512"** is in the flat circumferential band identified as **526** in the bottom view.

On the top view of the rotator baseplate assembly **525**, the large base moment support plates **527,527'** reside and are structurally supported by a multitude of structural hex bolts **528**. These large base moment support plates **527,527'** support the two main mast vertical 15 square columns **301,301'** that is noted on the main mast and frame assembly **300** (see Figure 15A and 15B).

The base rotator assembly **500** is responsible for providing azimuth axis control to the top level assembly. It being the lowest component, it is also responsible for managing the structural weight and structural moment associated with the complete structure. Given that 20 the infrastructure weight of a combined wind and solar energy generator such as this is significantly higher than the standard weights of just a stand-alone solar energy device, the design has been radically revised in order to meet the weight challenge of this device.

In order to activate azimuth axis control for the entire system, the system needs to rotate less than a full revolution for the entire daily cycle. To facilitate the precision of its angular 25 control, the gear reducer **505** and synchronous drive (**508,509,516**) reduces the speed of output down to a low speed of revolution. In order to accomplish angular control, this system needs to be activated for only a few milliseconds every 5 or 10 minutes, so the duty cycle on the power transmission components is extremely low.

Alternative embodiment using heat pipes as a heat transfer mechanism in place of hyperbolic mirrors.

Figure 19 and Figure 20 communicate alternative embodiments using heat pipes that could be used in place of an hyperbolic mirror in transferring heat energy derived from the concentrated parabolic mirror **116** to the heat storage compartment **290A** driving the hot piston **251** of the heat engine **250**. Heat pipes are a phase change device which starts with a liquidus material, which when heated converts to a gaseous material. Extremely high levels of heat transfer rates are possible with heat pipes **181A, 182A**, possibly as high as or higher than 200,000 Watts per meter Kelvin (W/Mk). This compares to the heat transfer capability of metallic elements such as copper which is reputed to have the highest level of heat transfer but is limited to 400 W/Mk heat transfer rates. Heat pipes work best in an environment where heat needs to travel to a higher elevation, and the liquidus arising during cooling, can travel by gravity down to the lower position. These environmental conditions are present in the current invention general design concepts.

Figure 19 identifies an array of heat pipes **181A, 182A** that are initiated at the focal point of the parabolic mirrors **116** (see **Figure 4**) and end at the heat engine storage compartment **290A**. The heat pipes **181A, 182A** collect heat at a lower elevation, and transport it to the heat engine storage compartment which is elevated relative to the parabolic mirrors **116**. The heat pipes **181A, 182A** are encased in a circumferential layer of insulation **181B, 182B**, to minimize heat transfer losses. The heat engine storage compartment **250A** is supported by a structural cage design **277A** which would mount to the main maintenance floor panel. The heat engine storage compartment **250A** would provide the source of heat required to heat the hot piston gases which would be positioned in its centre piston **291A**.

Figure 20 identifies a heat pipe attachment support structure for mounting the heat pipe **181A** to the parabolic mirror rigid frame assembly **119** (see **Figure 4**). In this figure, the heat pipe **181A** is exposed and is positioned in the region where the parabolic mirror **116** focal point is situated. Insulation **181B** surrounds the heat pipe so as to minimize heat transfer losses. A special structural frame **151A** is used in order to brace the heat pipe **181A** and insulation **181B**. Four flexible braces **156A, 156A', 156A'' and 156A'''** are wrapped around the circumference of the insulation **181B** and supports it rigidly against the structural frame

151A. The base of the structural frame **151A** has an attachment device **152A, 153A** which mounts directly to the parabolic mirror rigid support frame **119**.

Referring to **Figures 21 to 24C**, an alternative hybrid system is described that consists of a solar collection array with altitude axis control **100-A**, that is supported structurally by a main mast and frame assembly **300-A**. Concentrated solar energy is re-directed to the heat engine solar targeting zone **290-A, 290'-A** which acts as a heat source for the heat engine **250-A**; in this embodiment there is no main maintenance platform observed in the design. The efficiency of heat engine **250-A, 250'-A** is significantly increased through the incorporation of a regenerator assembly **275-A, 275'-A** which is identical in design to **Figure 11A to 11E** details. The main mast and frame assembly **300-A**, also provides superstructure support for the windmill arm and blade assembly **400-A**, and eliminates the need for guide wire support. Windmill arm and blade assembly **400-A** rotation is facilitated through the main vertical driveshaft **600-A**. Structural moment and axial support of the main mast and frame assembly **300-A** is facilitated by the rotator baseplate **525-A**, moment connection plates **527-A** as well as a new torsional beam connection element **531-A**. Vertical axis or azimuth control for the entire assembly is provided by the base rotator assembly **500-A** which supports the rotator baseplate **525-A**.

Beta-type dual heat engine design 250-A, 250'-A

Figure 25A to 25C indicates a top and sectional view of the beta-style dual heat engine design being used in the alternative hybrid system, each engine comprising a hot piston and a cold piston all housed within a common core, with a separate connection loop that includes the heat engine's regenerator assembly.

In **Figure 25A** we describe an alternative heat engine construction which is considerably more compact, and economical in design than the alpha-style heat engine described in **Figures 9, 10, 11 and 13**. In this design both the hot piston core **298-A, 298'-A** and the cold piston core **297-A, 297'-A** reside within one of two piston cylinders **251-A, 251'-A** respectively; in contrast, the alpha-style heat engine design had four piston cylinders - **251, 251', 251"**, and **251'''**.

In **Figure 25A to 25C**, the linear motion of the beta-style dual heat engine **250-A, 250'-A** is described in the following manner. Starting with the cold piston rod **253'-A, 253'''-A**, it passes through a gland **267-A, 267'-A** that is supported by the cold piston front plate **269-A, 269'-A**. A series of 8 tension rods, **268** provide a compressive load on the combined cold

5 piston front plate **269-A, 269'-A** and the hot piston back plate **272-A, 272'-A**, ensuring a pressurized seal is maintained. The piston rod **253'-A, 253'''-A** then connects to the cold piston **297-A, 297'-A**. A tightly packed aluminum folded fin heat sink **271-A, 271'-A** is linearly positioned on either side of the cold piston core, and is metallurgically bonded to the cold piston **251-A, 251'-A**. These folded fin elements **271-A, 271'-A** act, in combination with

10 windmill assisted airflow to actively cool the cold piston and increase the observed temperature gradient between the hot piston **298-A, 298'-A** and the mating cold piston **297-A, 297'-A**, thereby improving the operational efficiency and performance of the heat engine. The cold piston **297-A, 297'-A** pushes the cold air into the uninsulated return pipe **252-A, 252'-A** respectively. This return pipe passes by a valve **260** used for pressurizing the

15 regenerator and heat engine assembly with helium gas. Adjacent to the valve **260** is a pressure gauge **259**. Adjacent to the pressure gage **259** is the regenerator assembly **275-A, 275-A'** with construction as described in **Figure 11**. As the cold gas passes through the regenerator it is heated up. It then passes through an insulated hot pipe **261-A** which returns the hot gases into the hot piston core **298-A, 298'-A**, expanding the hot chamber.

20 These gases are heated by the solar energy being directionally concentrated onto the hot cylinder, and expands until it reaches its peak expansion point. The hot piston core is connected to a hot piston connecting rod **253-A, 253''-A** which has a clearance fit with the cold piston rod **253'-A, 253'''-A**, enabling the hot piston rod **253-A, 253''-A** to operate with a motion which is independent of the cold piston rod. When the hot piston core **298-A, 298'-A**

25 reaches its peak expansion point, it reverses direction forcing the gases to follow a reverse cycle back towards the cold piston core **297-A, 297'-A**.

Figure 25A to 25C does not indicate the presence of a heat storage compartment assembly **290** as is noted in **Detail A** of **Figure 10** and describe by **Figures 12A to 12D** of the initial design. The thermal storage device is viewed to be optional equipment in the design, and is

30 not likely to be present on smaller energy based designs.

Figures 26A to 26D show an alternative embodiment of the hyperbolic mirror and optical shaft sub assembly with a function similar to what is described in **Figure 7** and **Figures 8A** and **8B**. This embodiment differs in several ways.

The optical equipment cover **159-A** has been designed in a more compact, and simple to
 5 manufacture manner in an attempt to minimize the shadow effect of the cover on the mating square parabolic mirror **100-A**, and to lower manufacture costs.

The optical main shaft **151-A** and **152-A** has been reconfigured from a single shaft design to a dual shaft support design with greater level of structural rigidity both in flexural bending and torsional torque transfer. This more structural design has been accomplished without
 10 any increase in shadow effect on the parabolic mirror. The axis of rotation of the optical main shaft **151-A** and **152-A** has also been moved forward away from the centre of the optical equipment cover **159-A** towards its outer perimeter. This is in an effort to reposition the axis of rotation nearer to the centroid of the hyperbolic mirror **180-A**.

The shape of the hyperbolic mirror elements **180-A** has also been redesigned to facilitate
 15 new heat engine solar targeting points on the hot piston **250-A**, **250'-A**. The hyperbolic mirror elements **180-A** have also been redesigned so that the mirrors primarily rotate outside of the optical equipment cover, **159-A**, so as to minimize any boundary constraints imposed by the new smaller optical equipment cover **159-A** design. The hyperbolic mirror elements **180-A** have been trimmed in size, so that the only portion of the mirror present in
 20 the design is required for the mirrored reflection of solar rays emanating from its mating square parabolic mirror **100-A**.

Figure 26A and 26B show the rotational extents of this design which facilitates parabolic mirror rotation from a mid-day sun altitude position of 17 degrees above horizontal. **Figure 26C** and **26D** reflect the rotational extents of the alternative design from a dawn or dusk sun
 25 altitude position of 93 degrees. In this design a total altitude rotation of 76 degrees is achieved with the parabolic mirror **100-A**, and a counter-rotating extent of 38 degrees for the optical shaft sub-assembly **150-A**, reflecting peak solar sun positions at latitudes above 40 degrees north. The above 90-degree dawn or dusk position, prohibits the buildup of snow or rain in the parabolic mirror in evening overnight conditions, thereby minimizing

detrimental operating conditions which might arise especially in wintry climates due to snow accumulation conditions.

Figure 27 describes the alternative base rotator assembly **500-A** with the rotator baseplate assembly **525-A** removed. This substructure houses the azimuth axis rotating equipment,
5 and dual axis solar control equipment.

Affixed to three concrete footings and column structures **501-A** is a triangular shaped structural frame **502-A** which provides general structural support for the complete alternative structure. Affixed to the structural frame are base wall sections **503-A** which completely surround the enclosed equipment. At the three internal triangular vertices of
10 the general support structure **502-A**, three structural columns **515-A** are positioned. Seated on top of each of the three structural columns **515-A**, is a baseplate and a fixed pillowblock roller bearing **513-A** and a floating pillowblock roller bearing **514-A**. Between the two bearings resides a trunnion wheel **512-A** mounted on a shaft running between the two pillowblock roller bearings **513-A,514-A**. Each of the three trunnion wheels **512-A** are
15 oriented such that they can rotate tangentially in the direction of motion of the central vertical shaft **504-A**. These three trunnion wheels provide the structural support for the dead weight of the entire structure and of the rotator baseplate assembly **525-A** (as observed in **Figures 21 to 24C**).

A geared speed reducer and motor **505-A** is mounted in the base of the internal
20 compartment of the base rotator assembly **500-A**. Affixed to the output shaft of the geared speed reducer and motor **505-A** is a spacer coupling **520-A** which connects directly to the central vertical shaft **504-A** which provides azimuth rotational capability to the design. The central vertical shaft **504-A** is supported by an upper floating pillowblock roller bearing **517-A** and lower fixed pillowblock roller bearing **518-A**. The upper floating pillowblock roller
25 bearing **517-A** is supported by a structural support beam **510-A** which is connected to two of the three structural columns **515-A**. The lower fixed pillowblock roller bearing is supported by a second structural support beam **510'-A** which is connected also to two of the three structural columns **515-A**. The two inner pillowblock roller bearings **517-A,518-A** are responsible for the support of the vertical shaft, the support of the shaft's weight, and for
30 the resistance of the structural moment associated primarily with the levered dead weight

of the array of solar collectors, and any wind loads or snow loads associated with environmental operating conditions. The pillowblock roller bearings **517-A, 518-A** are oriented in a manner which ensures that the primary radial loads are resisted by the base or side bodies of the pillowblock roller bearings **517-A, 518-A**.

- 5 A separately framed control cabinet **522-A** is positioned at the front of the base rotator assembly **500-A**. This control cabinet **522-A** houses the motor portion of the geared speed reducer and motor **505-A**, all electrical wiring emanating from the altitude control gear motor **104**, and from the Induction generator **205-A**. This control cabinet **522-A** also houses the PLC control equipment that controls the motion of the dual axis rotating invention.
- 10 **Figure 28A** and **28B** describe a three-blade windmill arm and blade assembly **400-A** used in the alternative design.

- There are two windmill arm support plate assemblies **403-A, 403'-A**. The top windmill arm support assembly **403-A** rigidly supports 3 upper windmill arm beams **402-A**, and also facilitates static and dynamic balancing adjustments of the complete windmill arm and
- 15 blade assembly **400-A**. The upper windmill arm beam **402-A** in turn supports a blade inner support assembly **410-A** which has blade pitch angle feature adjustments incorporated in to the design. The blade inner support assembly **410-A** in turn is fastened to the windmill blades **401-A** at the top.

- In between the two windmill arm support plate assemblies **403-A, 403'-A** resides a windmill support tube **404-A** which provides some rigidity and support for the complete assembly.
- 20 The two windmill arm support plate assemblies **403-A, 403'-A** have a concentric keyed interface with the keyed driveshaft **600-A** that resides within the windmill support tube **404-A**. The keyed driveshaft **600-A** is structurally supported by a fixed and floating pillowblock bearing structure residing within the main mast and frame assembly **300-A**.

- 25 The bottom windmill arm support plate assembly **403'-A** rigidly supports three lower windmill arm beams **405-A**. The windmill arm support plate assembly **403'-A** also facilitates static and dynamic balancing adjustments as is the case with the upper assembly. The lower windmill arm beam **405-A** in turn supports a blade inner support assembly **410-A** which also

has blade pitch angle feature adjustments. The blade inner support assembly **410-A** in turn is fastened to the inner windmill blade **406-A**.

At the base of the windmill blades, the inner windmill blade **406-A** is rigidly connected to the blade inner support assembly **411-A**. This blade inner support assembly **411-A** is
 5 connected to the lower windmill arm beam **407-A** which also has an outer perimeter connection to the blade support assembly **410-A**. The blade support assembly **410-A** is in turn fastened to the windmill blade **401-A** at the bottom.

The base of driveshaft **600-A** has a keyed connection with the top rotator wheel **256-A** (See
 10 **Figure 29B**), transferring generated torque from the windmill arm and blade assembly **400-A** to this top rotator wheel **256-A**.

The mechanical design of this alternative windmill arm and blade assembly offers several design benefits in addition to those already noted above.

The three double blade design facilitates an inner support infrastructure design such as the dual roller bearing support of the main mast and frame assembly
 15 **300-A**, thereby eliminating the need for guide wires in the design.

The upper windmill support beam **403-A** and the lower windmill support beam **407-A** have adapted a blade profile design as well, thereby improving the power coefficient of the overall windmill arm and blade assembly **400-A** enhancing its performance.

20 The lower windmill support beam **407-A** works in concert with the folded fin elements **271-A,271'-A** in the dual heat engine design **250-A,250'-A**, providing windmill assisted airflow to actively cool the cold piston and increase the observed temperature gradient between the hot piston **298-A,298'-A** and the mating cold piston **297-A,297'-A**, thereby improving the operational efficiency
 25 and performance of the heat engine design **250-A,250'-A**.

Figures 29A and 29B provides a more comprehensive sectional view of the alternative rotator assembly and how it is coupled to the vertical axis wind turbine and to the speed

increaser driving the solar-wind generator. **Figure 29C** is a close-up view of the circled area in **Figure 29B**, showing the multitude of folded heat exchange fin elements.

In Figure 29B, the rotator assembly is described, which has the function of translating the linear motions of the beta style dual heat engine **250-A,250'-A** into rotary motion with
 5 identical characteristics to the rotary motion observed by the main power transmission driveshaft **600-A**, and the vertical axis wind turbine **400-A** that it is connected to.

Connected to the wind turbine driveshaft **600-A** is the top rotator wheel **256-A**. Interfacing with the top rotator wheel is a specially designed heat engine rotator pin **263-A** which has the quality of having a top mounted pin, which is radially offset from the bottom mounted
 10 pin by a fixed angular difference, and with an intermediary connecting plate, specially designed to ensure no interference conditions arise during a normal 360-degree rotation of the vertical axis wind turbine **400-A**. Rotator cylinder linkage **254-A** and rotator cylinder linkage **255'-A** are connected in a clearance fit manner to the top mounted pin of the heat engine rotator pin **263-A**. Rotator cylinder linkage **254'-A** and rotator cylinder linkage **255-A**
 15 are connected in a clearance fit manner to the bottom mounted pin of the heat engine rotator pin **263-A**.

The individual rotator assembly connections are described as follows:

For the top mounted pin of heat engine rotator pin **263-A**: Rotator cylinder linkage **254-A** is pin connected to the left side hot piston connecting rod **253''-A**, thereby allowing the
 20 rotator cylinder **254-A** to rotate freely relative to the linearly fixed cold piston connecting rod **253'''-A**. Rotator cylinder linkage **255'-A** is pin connected to the right side cold piston connecting rod **253'-A** in a manner that allows rotator cylinder linkage **255'-A** to rotate freely relative to the linearly fixed cold piston connecting rod **253'-A**.

For the bottom mounted pin of heat engine rotator pin **263-A**: Rotator cylinder linkage **255-A**
 25 **A** is pin connected to the left side cold piston connecting rod **253'''-A**, thereby allowing the rotator cylinder **255-A** to rotate freely relative to the linearly fixed cold piston connecting rod **253'''-A**. Rotator cylinder linkage **254'-A** is pin connected to the right side hot piston connecting rod **253-A** in a manner that allows rotator cylinder linkage **254'-A** to rotate freely relative to the linearly fixed hot piston connecting rod **253-A**.

The bottom mounted pin of the heat engine rotator pin **263-A** is then connected to the bottom rotator wheel and shaft Subassembly **256'-A**.

An appropriately torque sized coupling **204-A** connects the bottom rotator wheel and shaft subassembly **256'-A** to the appropriately sized gearing speed increaser **203-A** . A

- 5 synchronous belt drive then connects speed increaser **203-A** to the induction generator **205-A**. An appropriately sized holding brake **206-A** is mounted on the input side of the induction generator **205-A**, in order to facilitate windmill stoppage conditions in excessively high wind speed environments.

Systemic Control of the Invention

- 10 While it is desirable that the windmill be self-starting in design, this is not an essential aspect of the invention. Similarly, the heat engine does not necessarily contain any speed control elements. In the versions of the invention described here, the windmill and the heat engine do not move independently, i.e. they operate in concert with each other.

- A preferred form of systemic control, although not necessarily the most economical, is
15 through the use of a regenerative drive to control the induction generator. Regenerative drives are equipped with an active supply unit, capable of signal conditioning of the output electricity. The regenerative drive allows full power flow both in motoring and generative modes, and is available as a solution at voltages ranging from 208V to 690V, 3 phase, and at module sizes as small as 5.5 kW. An example of such a commercially available product is the
20 ACS800-11 ABB Industrial Regenerative Drive. The regenerative drive facilitates a variable speed windmill design. The merit of a variable speed windmill design is that the windmill operating speed can be adjusted to facilitate optimal tip speed ratios and operating efficiencies at varying wind speeds; wind speed could in fact be treated as an input factor in the control of the drive in such a situation. The drive also facilitates regenerative braking in
25 high wind speed shut down situations, offering energy savings when compared with other braking methods such as mechanical braking.

A more cost effective form of systemic control that could be used in single phase applications, is through the use of a separate industrial drive controlled induction motor and clutch unit that could be used to initiate electricity generation in the induction generator. In

this situation, the induction generator would be accelerated to a speed that exceeds the synchronous speed plus slip of the motor. In the case of the typical four pole induction generator, such a speed would likely be above 1,850 rpm. While a typical induction motor operating across the line at 60 Hz would operate at its synchronous speed less the slip speed
 5 of the motor, or approximately 1750 rpm, the standard industrial drive controlling it could operate at a frequency of 64 Hz, and provide the speed necessary to initiate electricity generation. The motor and clutch unit could then be appropriately programmed to activate and engage when the speed had reached a minimum point of operation. In such a control situation, the windmill would operate as a fixed speed design, offering perhaps a lower
 10 overall operating windmill efficiency level.

Photovoltaic solution

Referring to **Figures 30 to 33C**, a second alternative hybrid system is described that consists of a solar collection array with altitude axis control **100-B**, that is supported structurally by a main mast and frame assembly **300-A**. In this embodiment photovoltaic solar energy is
 15 generated by two individual rows of five photovoltaic panels **100-B**, and the DC electricity generated is redirected to a DC to AC solar string inverter **590-B** for conversion to AC electricity. The main mast and frame assembly **300-A**, continues to provide superstructure support for the windmill arm and blade assembly **400-A** and solar collection array **100-B**, and eliminates the need for guide wire support. Windmill arm and blade assembly **400-A**
 20 rotates on the main vertical driveshaft **600-A**. Structural moment and axial support of the main mast and frame assembly **300-A** is via the rotator baseplate **525-A**, moment connection plates **527-A** as well as a new torsional beam connection element **531-A**. Vertical axis or azimuth control for the entire assembly is provided by the base rotator assembly **500-A** which supports the rotator baseplate **525-A**. This second alternative design shares
 25 many of the design elements of the first alternative design, and altitude axis control of the individual rows of photovoltaic panels is handled in a similar manner. There is no need for a heat engine **250-A**, **250'-A** in this design so these design elements have been removed.

Figure 33A is a side view of the Figure 30 variation. **Figure 33B** is a corresponding view, but with the C-channel side rail removed to show the linkage operation more clearly. The
 30 photovoltaic panels are shown in a low-angle position. **Figure 33C** is a side view

corresponding to Figure 33B, but with the photovoltaic panels in a high angle position. This is essentially the same linkage arrangement and mechanism for vertical angle adjustment as in the preferred embodiment.

Conclusion

5 The above description relates to preferred and alternative embodiments of the invention. However, many variations may be apparent to those knowledgeable in the field of the invention, within the broad scope of the invention as may be discerned from the description and/or the accompanying drawings. Such variations may include, but are not limited to, the following:

- 10 a) Variations in the size and shape of various elements;
- b) Variations in the number of mirrors and configuration of the mirror array;
- c) Variations in the external diameter and height of the vertical axis wind turbine;
- d) Variations in the speed of rotation of the vertical axis wind turbine and heat engine;
- e) Variations in the length of the linear stroke of the heat engine;
- 15 f) Variations in the pressurization of the helium filled heat engine (psi);
- g) Variations in the presence of a heat engine storage compartment (See Figure 12), and in the general size of such a compartment, which impacts the amount of energy storage incorporated into the device.
- h) Variation in the use of a single or dual speed increaser/induction generator in the
- 20 design.

CLAIMS:

1. An electrical generating system comprising:
at least one heat engine;
5 a solar energy collection assembly, comprising an array of parabolic mirrors arranged to collect and transmit solar energy to each heat engine, to drive each heat engine;
a vertical axis wind turbine mounted above the solar energy collection assembly,
comprising a number of vertical windmill blades laterally displaced from and rotatable around a central axis;
10 a common output driveshaft on the same axis as said central axis of said vertical axis wind turbine, connected to be driven by said vertical axis wind turbine and by each said heat engine; and
electricity generation means connected to said common output driveshaft to produce electricity.
15
2. A system as in claim 1, wherein the parabolic mirror array comprises at least one generally horizontal row, and wherein each row is rotatable about a generally horizontal axis in a frame, and wherein the frame is rotatable about a generally vertical axis, and wherein rotation about these axes is controlled and programmable so as to cause the parabolic mirrors to generally
20 track the sun.
3. A system as in claim 2, wherein each row being rotatable is by a linkage assembly driven by a motor connected to a crank, which in turn connects to a secondary linkage, which in turn connects to connector linkages connected to rotation linkages, which in turn are connected to
25 said horizontal axes to produce rotation as said motor operates said crank.
4. A system as in claim 3, wherein the ratio of crank length to secondary linkage length is in the range of 0.75 to 0.85.
- 30 5. A system as in any one of claims 1 to 4, wherein each parabolic mirror focuses solar energy on a respective hyperbolic mirror positioned above each parabolic mirror, the hyperbolic

mirrors in turn directing the solar energy towards at least one central heat-storage element, each heat-storage element providing heat to at least one said heat engine to drive said at least one heat engine, each said heat engine driving said common output driveshaft via conversion of linear motion of a piston in each said heat engine to rotary motion of said common output driveshaft.

5

6. A system as in claim 5, wherein said heat-storage element includes a storage chamber containing a salt composition.

7. A system as in claim 1, where the windmill blades are supported at upper and lower ends thereof by windmill support struts.

10

8. A system as in claim 1 or claim 7, where there are both inner and outer windmill blades.

9. A system as in claim 7 or claim 8, where at least one of: (a) the windmill blades; and (b) the windmill support struts; is/are airfoil shaped.

15

10. A system as in claim 9, wherein the parabolic mirror array comprises at least one generally horizontal row, and wherein each row is rotatable about a generally horizontal axis in a frame, and wherein the frame is rotatable about the same generally vertical axis as the vertical axis of the wind turbine, and wherein rotation about these axes is controlled and programmable so as to cause the parabolic mirrors to generally track the sun.

20

11. A system as in claim 10, wherein each row being rotatable is by a linkage assembly driven by a motor connected to a crank, which in turn connects to a secondary linkage, which in turn connects to connector linkages connected to rotation linkages, which in turn are connected to said axes to produce rotation as said motor operates said crank.

25

12. A system as in claim 11, wherein the ratio of crank length to secondary linkage length is in the range of 0.75 to 0.85.

30

13. A system as in claim 7, wherein a lower inner blade or support is configured to facilitate airflow through heat sinks around a cold piston of the heat engine.

14. A system as in any one of claims 1 to 13, wherein the parabolic mirrors are circular.

5

15. A system as in any one of claims 1 to 13, wherein the parabolic mirrors are rectangular or square.

16. An electrical generating system comprising:

10

a solar energy collection assembly ;

at least one heat engine driven by heat from solar energy collected by said solar energy collection assembly and transmitted to each said heat engine;

a vertical axis wind turbine mounted above the solar energy collection assembly;

a common output driveshaft on the same axis as said vertical axis wind turbine,

15

connected to be driven by each said heat engine and by said vertical axis wind turbine;

electricity generation means connected to said common output driveshaft to produce electricity;

wherein the solar energy collection assembly comprises an array of parabolic mirrors arranged to deliver solar energy to the heat engine; and

20

wherein the parabolic mirror array comprises at least one generally horizontal row, and wherein each row is rotatable about a generally horizontal axis in a frame, and wherein the frame is rotatable about a generally vertical axis, and wherein rotation about these axes is controlled and programmable so as to cause the parabolic mirrors to generally track the sun.

25

17. A system as in claim 16, wherein each row being rotatable is by a linkage assembly driven by a motor connected to a crank, which in turn connects to a secondary linkage, which in turn connects to connector linkages connected to rotation linkages, which in turn are connected to said horizontal axes to produce rotation as said motor operates said crank.

30

18. A system as in claim 17, wherein the ratio of crank length to secondary linkage length is in the range of 0.75 to 0.85.

19. A system as in any one of claims 16 to 18, wherein each parabolic mirror focuses solar energy on a respective hyperbolic mirror positioned above each parabolic mirror, the hyperbolic mirrors in turn directing the solar energy towards at least one central heat-storage element, each heat-storage element providing heat to at least one said heat engine to drive said at least one heat engine, each said heat engine driving said common output driveshaft via conversion of linear motion of a piston in each said heat engine to rotary motion of said common output driveshaft.
20. A system as in claim 19, wherein said heat-storage element includes a storage chamber containing a salt composition.
21. A system as in claim 16, wherein the wind turbine comprises a number of vertical windmill blades laterally displaced from and rotatable around a central axis, connected to drive said common output driveshaft, where the windmill blades are supported at upper and lower ends thereof by windmill support struts, and where at least one of: (a) the windmill blades; and (b) the windmill support struts; is/are airfoil shaped.
22. A system as in claim 21, where there are both inner and outer windmill blades.
23. A system as in claim 21, where the frame is rotatable about the same generally vertical axis as the vertical axis of the wind turbine, and wherein rotation about these axes is controlled and programmable so as to cause the parabolic mirrors to generally track the sun.
24. A system as in claim 23, wherein each row being rotatable is by a linkage assembly driven by a motor connected to a crank, which in turn connects to a secondary linkage, which in turn connects to connector linkages connected to rotation linkages, which in turn are connected to said axes to produce rotation as said motor operates said crank.
25. A system as in claim 24, wherein the ratio of crank length to secondary linkage length is in the range of 0.75 to 0.85.

26. A system as in claim 21, wherein a lower inner blade or support strut is configured to facilitate airflow through heat sinks around a cold piston of the heat engine.

27. A system as in any one of claims 17 to 26, wherein the parabolic mirrors are circular.

5

28. A system as in any one of claims 17 to 26, wherein the parabolic mirrors are rectangular or square.

1/56

FIGURE 1

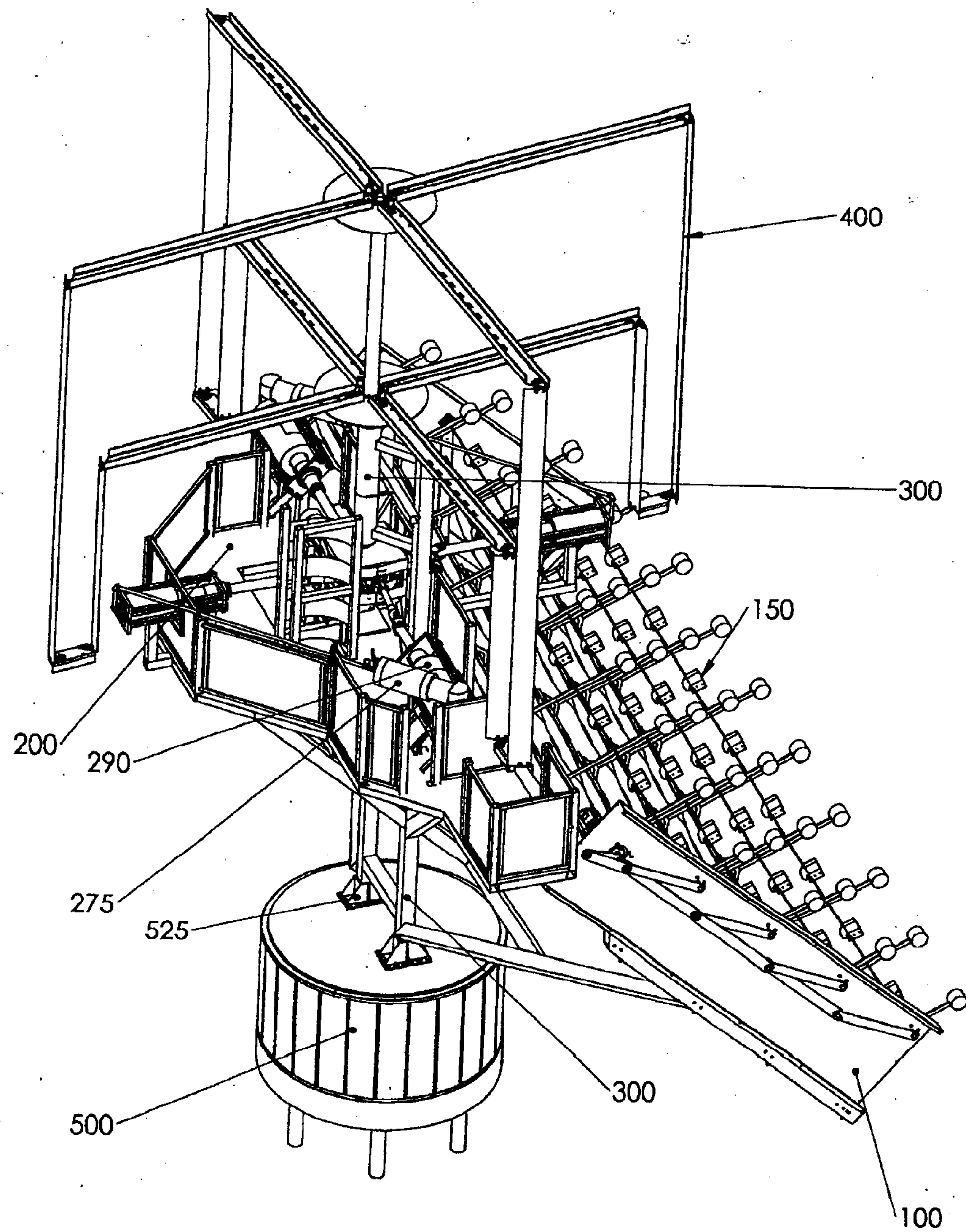


FIGURE 2

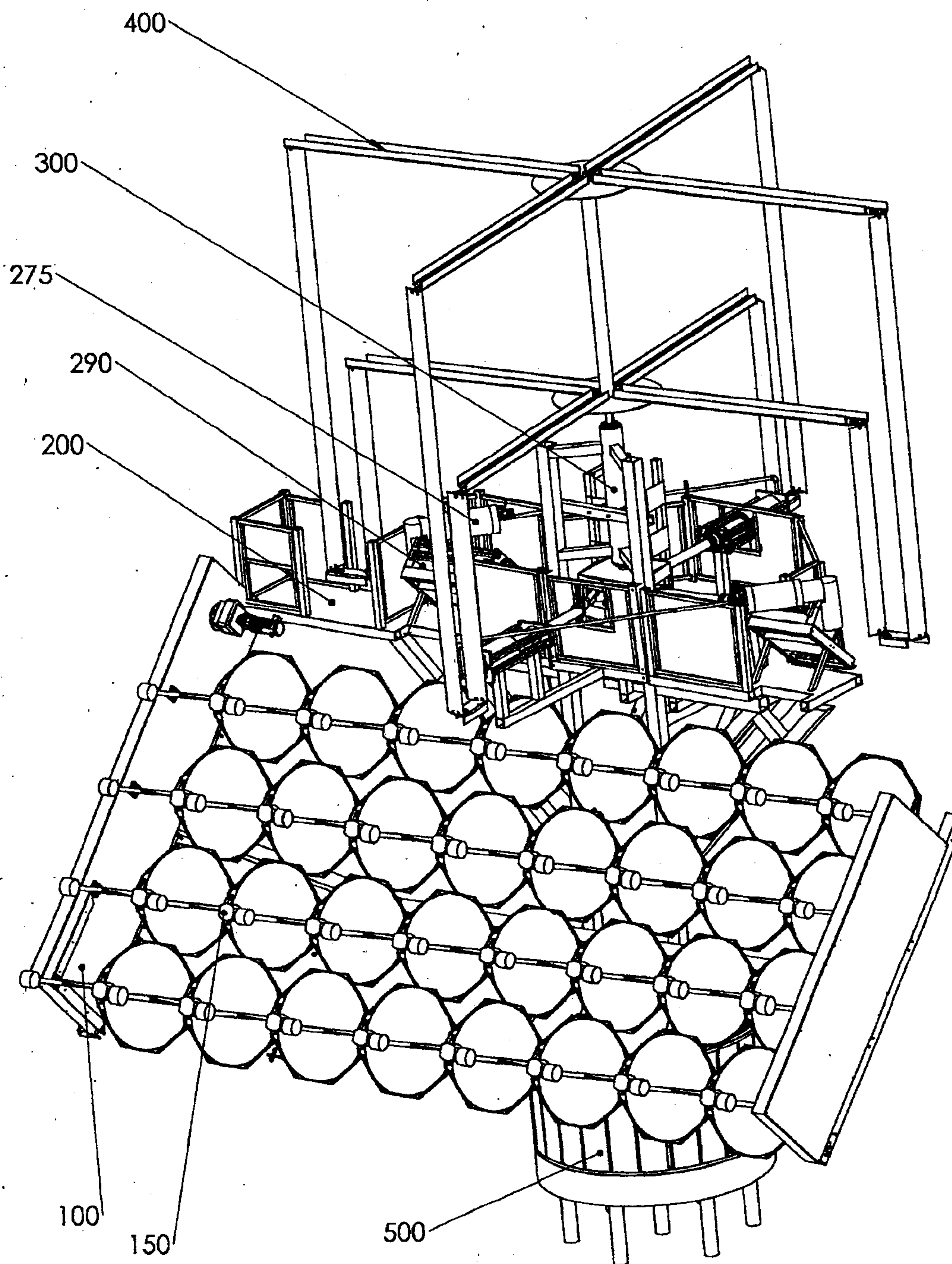


FIGURE 3A

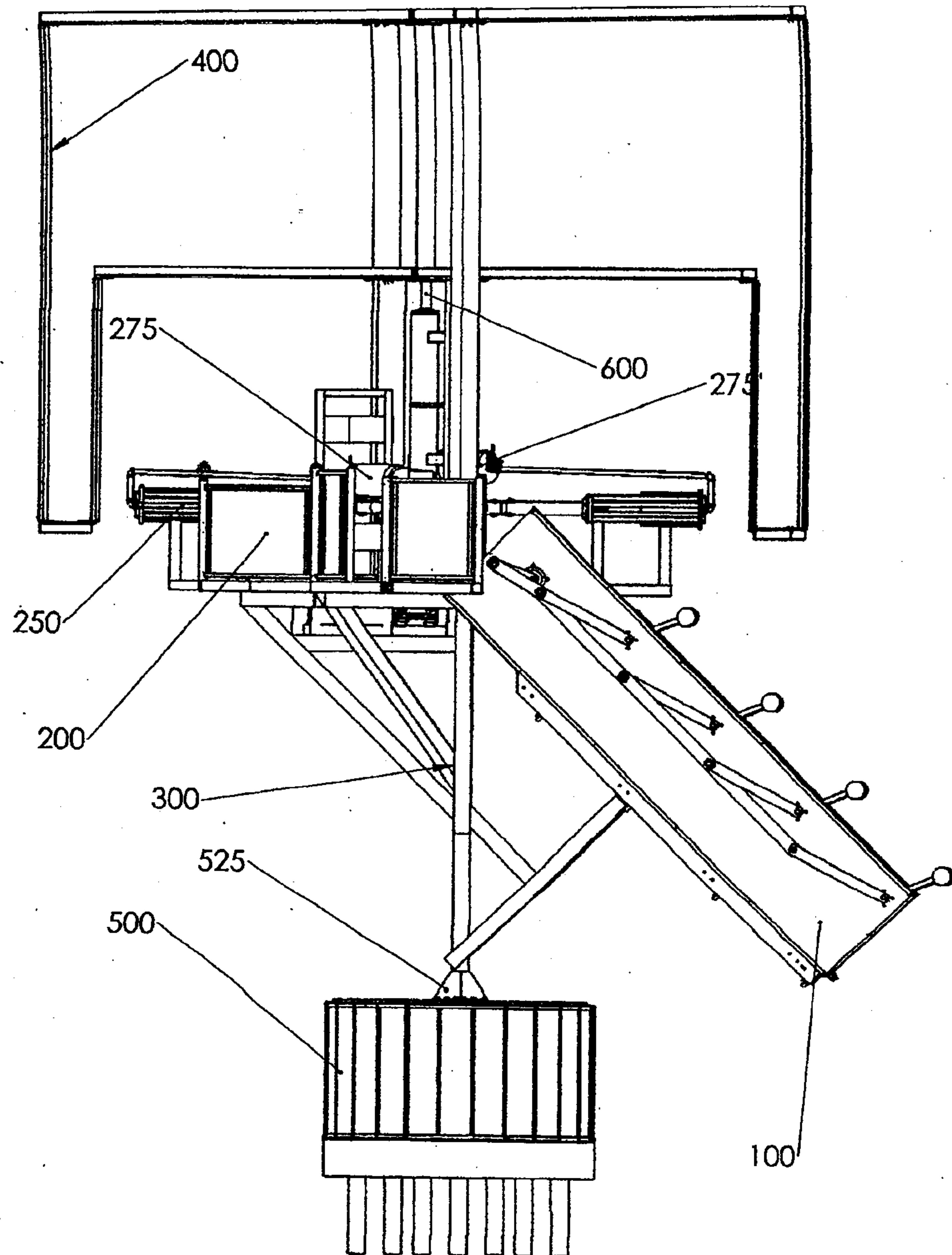


FIGURE 3B

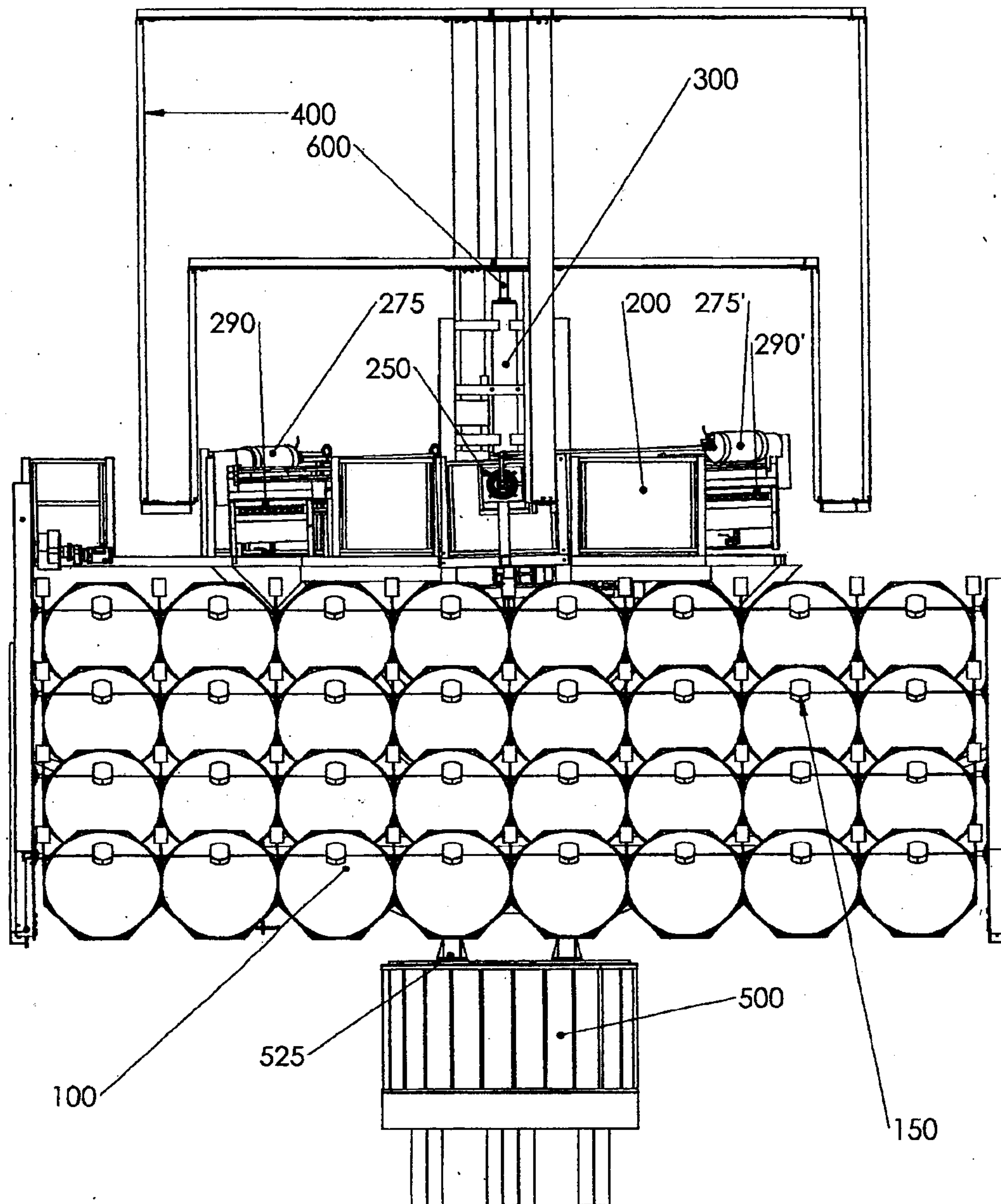
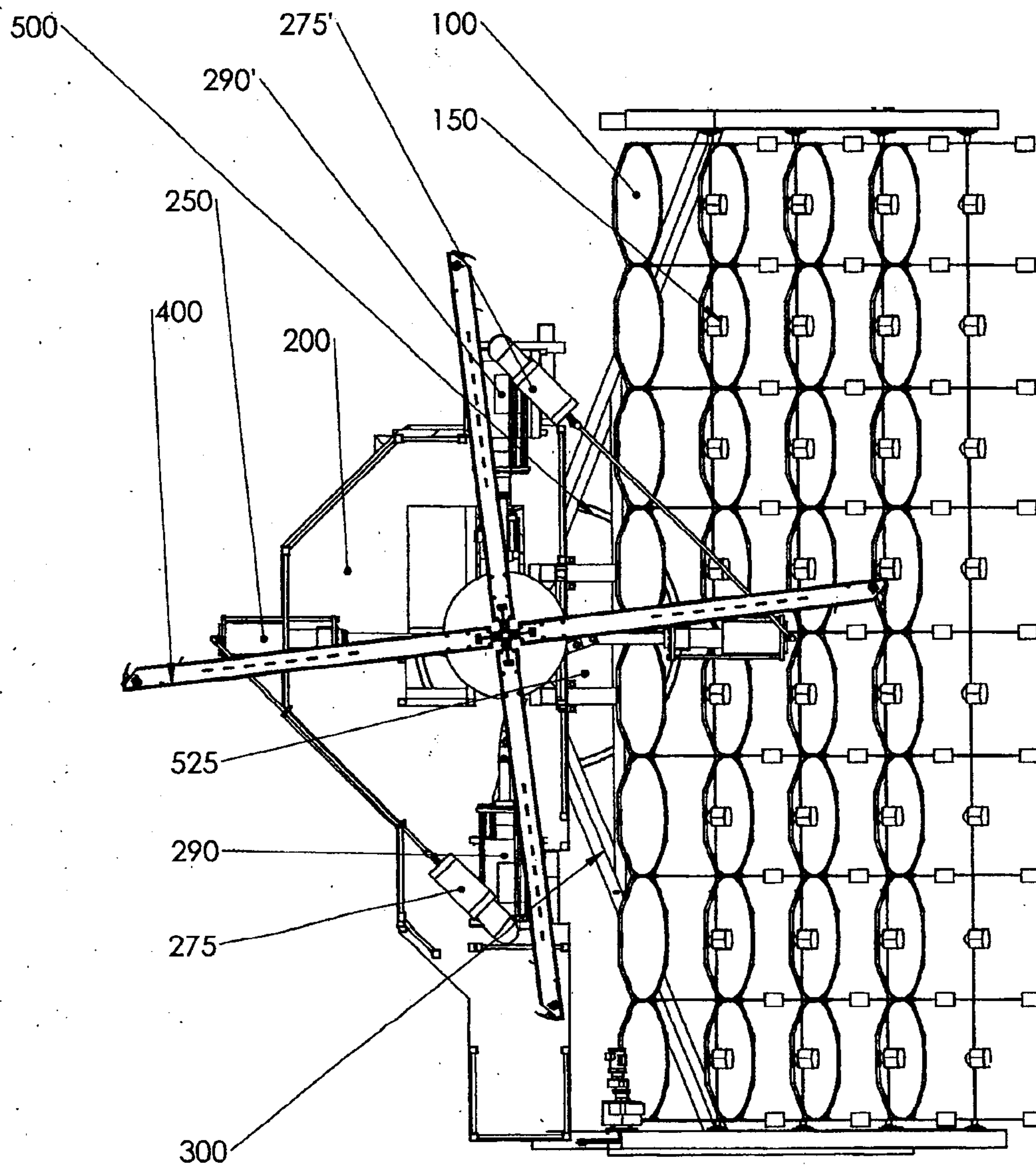
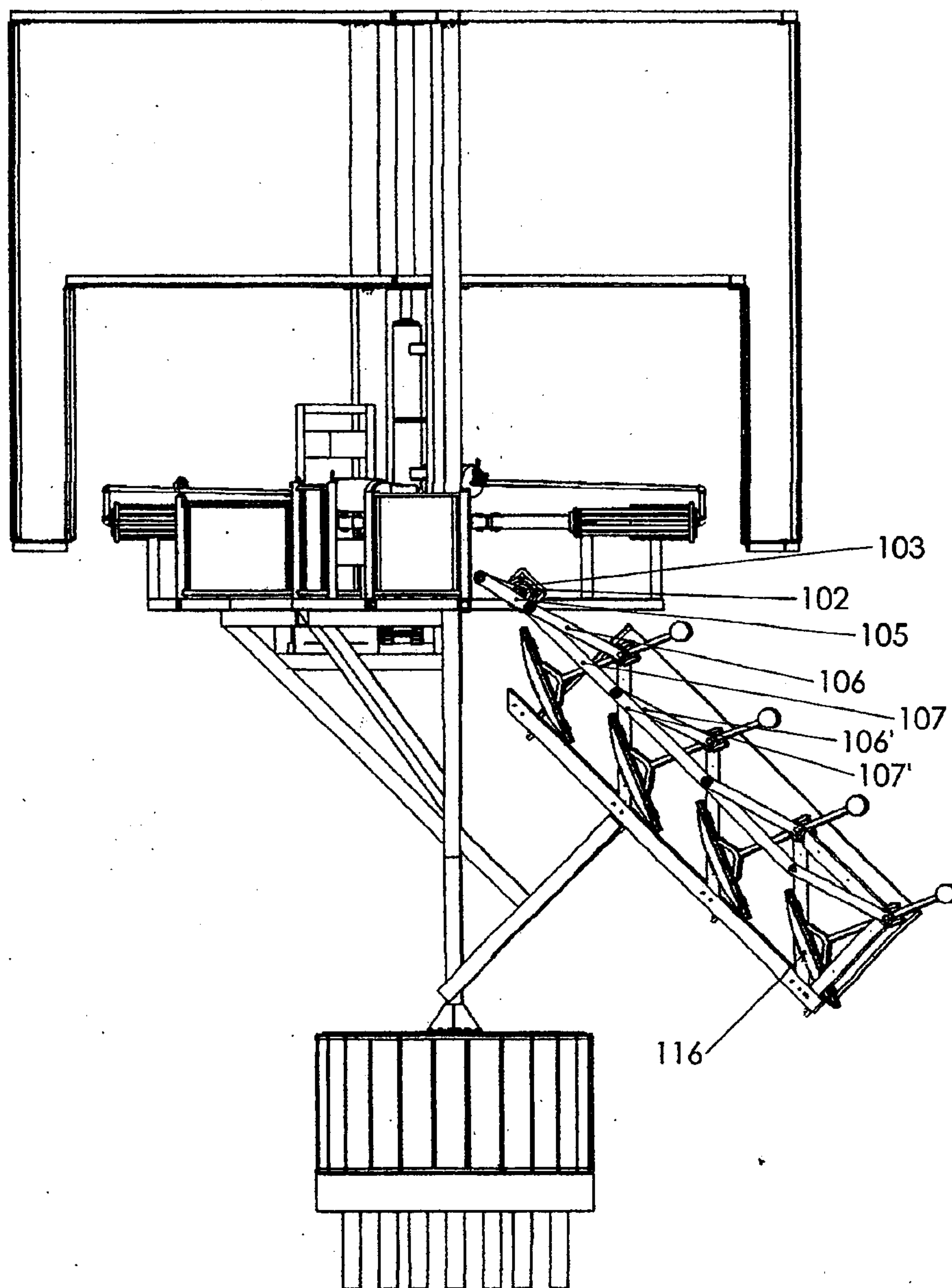


FIGURE 3C



6/56

FIGURE 3D



7/56

FIGURE 3E

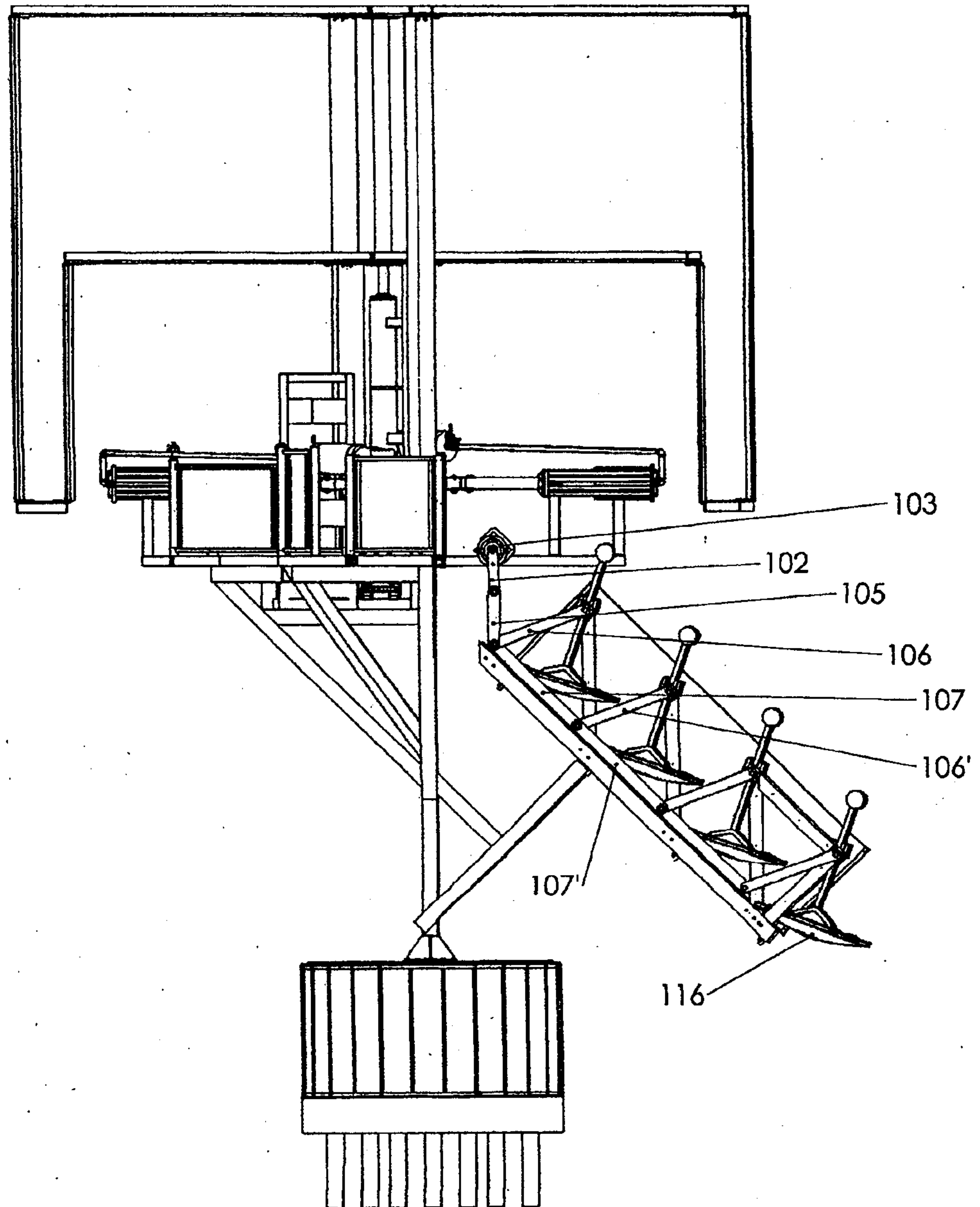
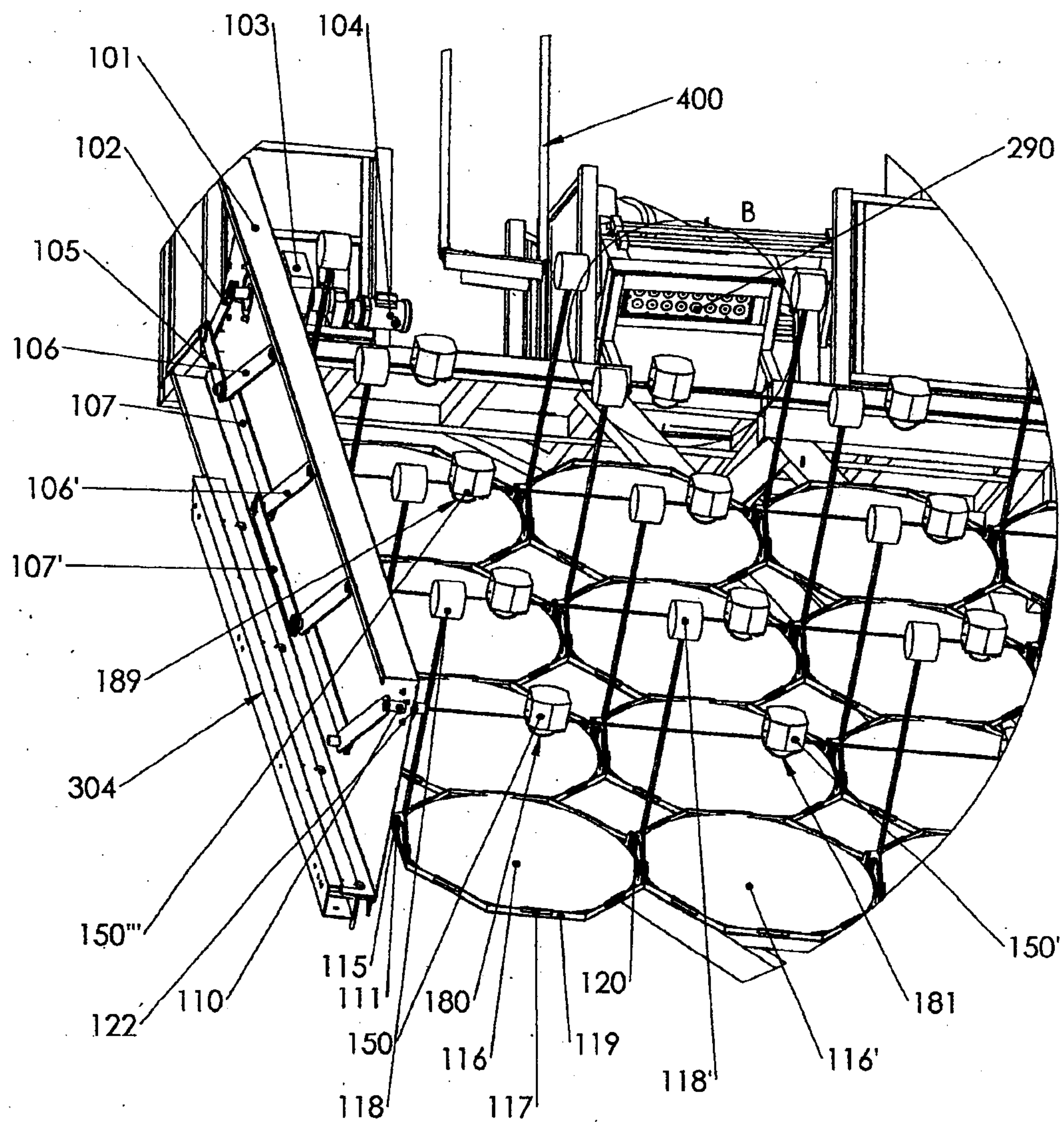
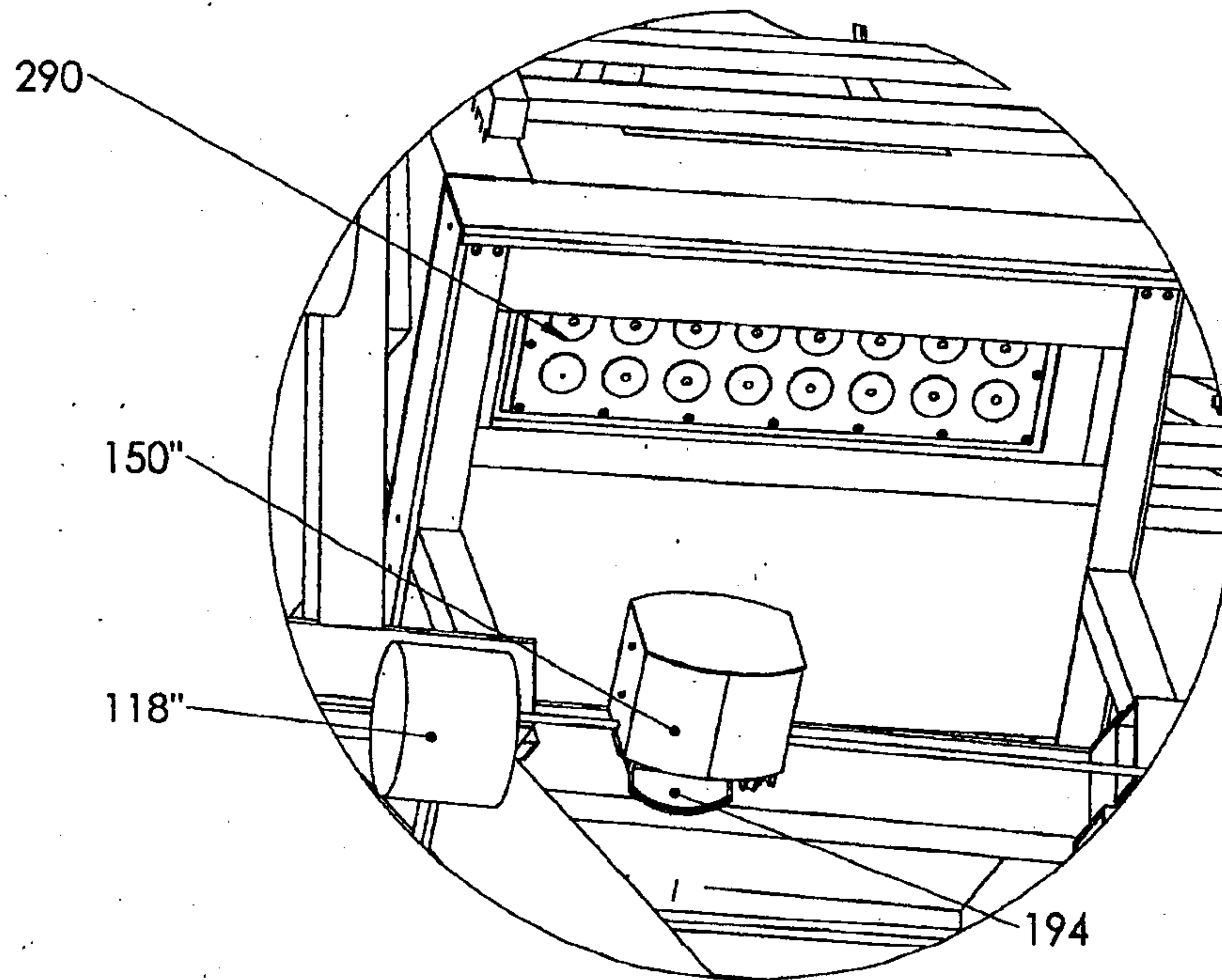


FIGURE 4A



9/56

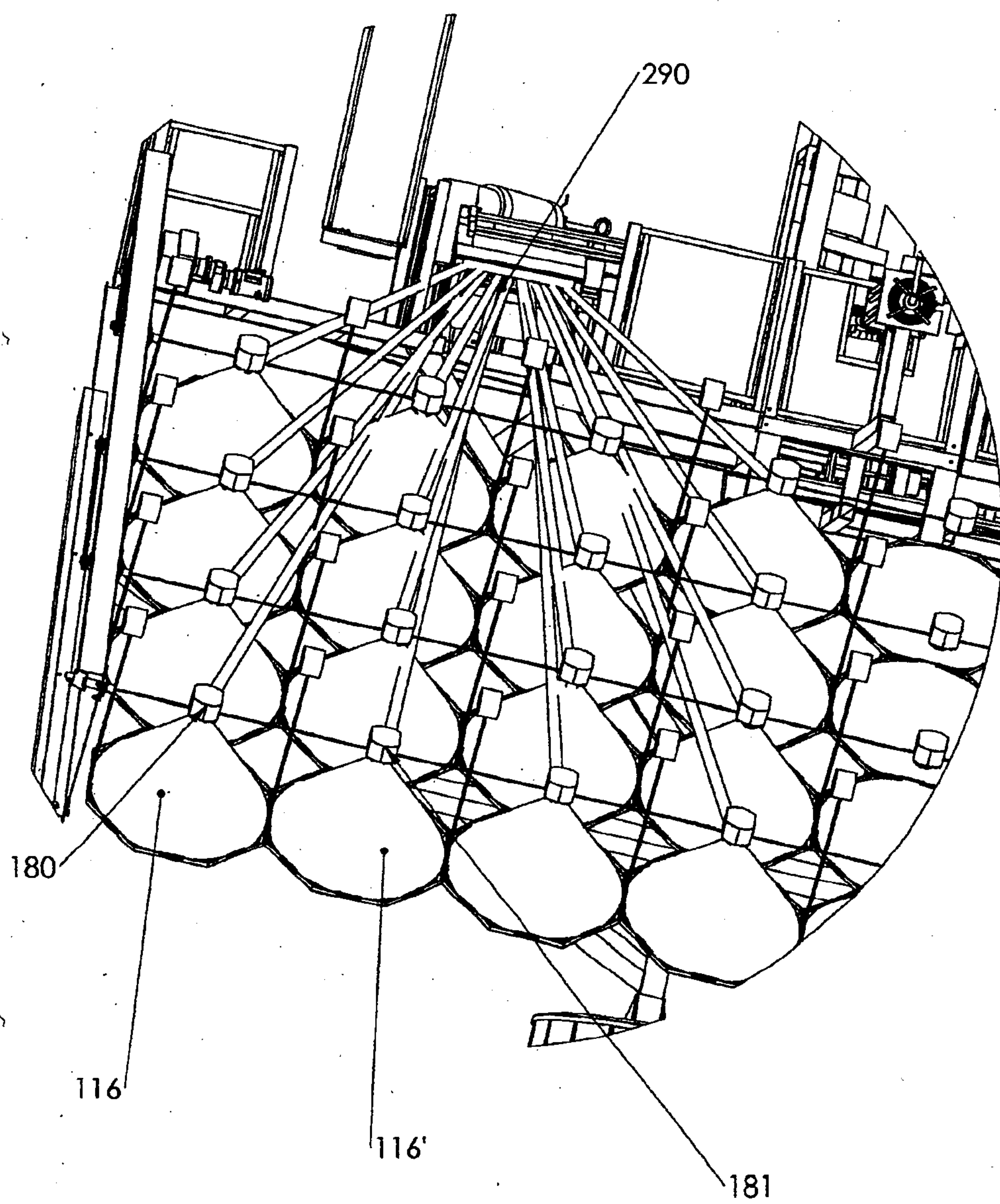
FIGURE 4B



DETAIL B

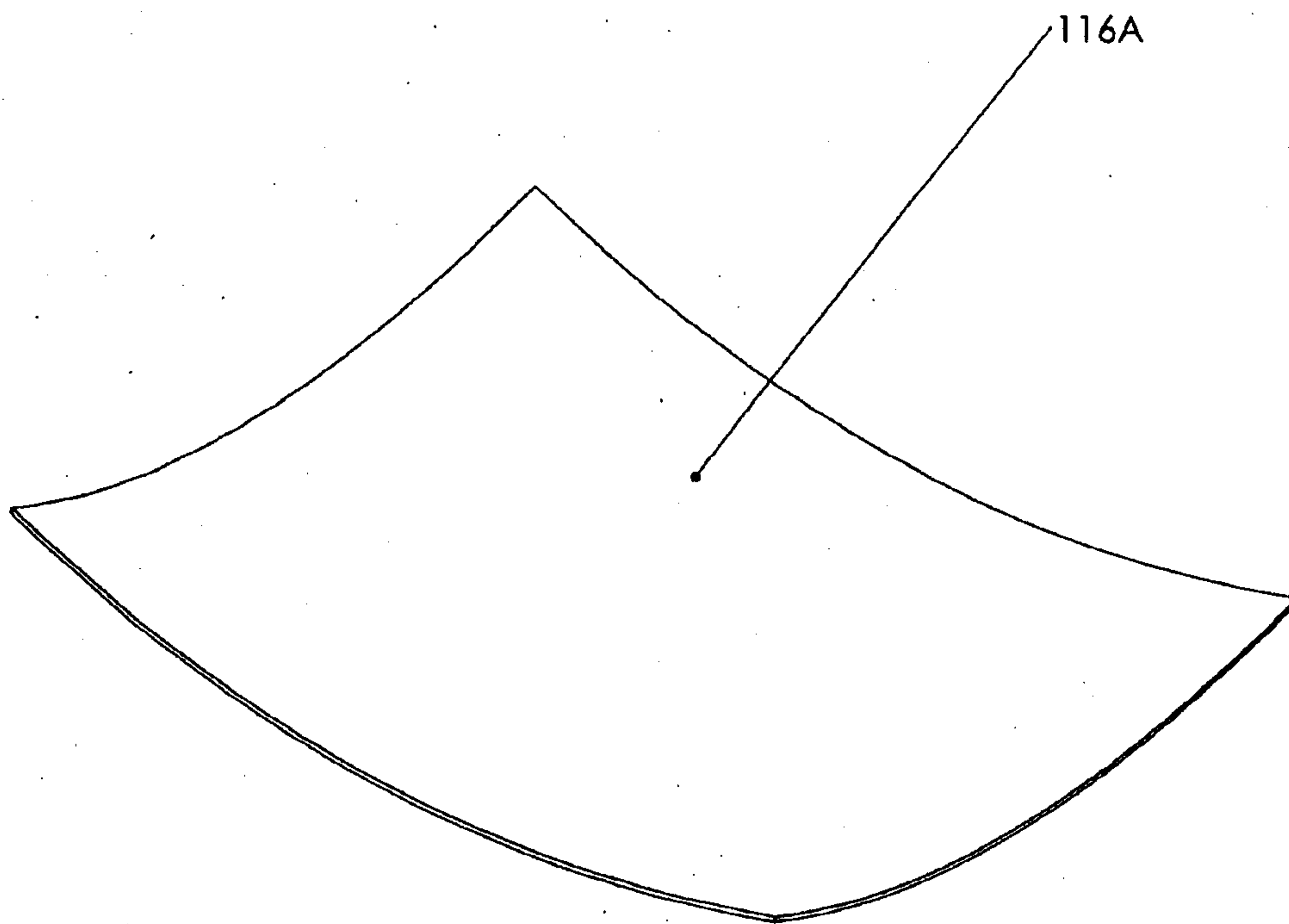
10/56

FIGURE 5



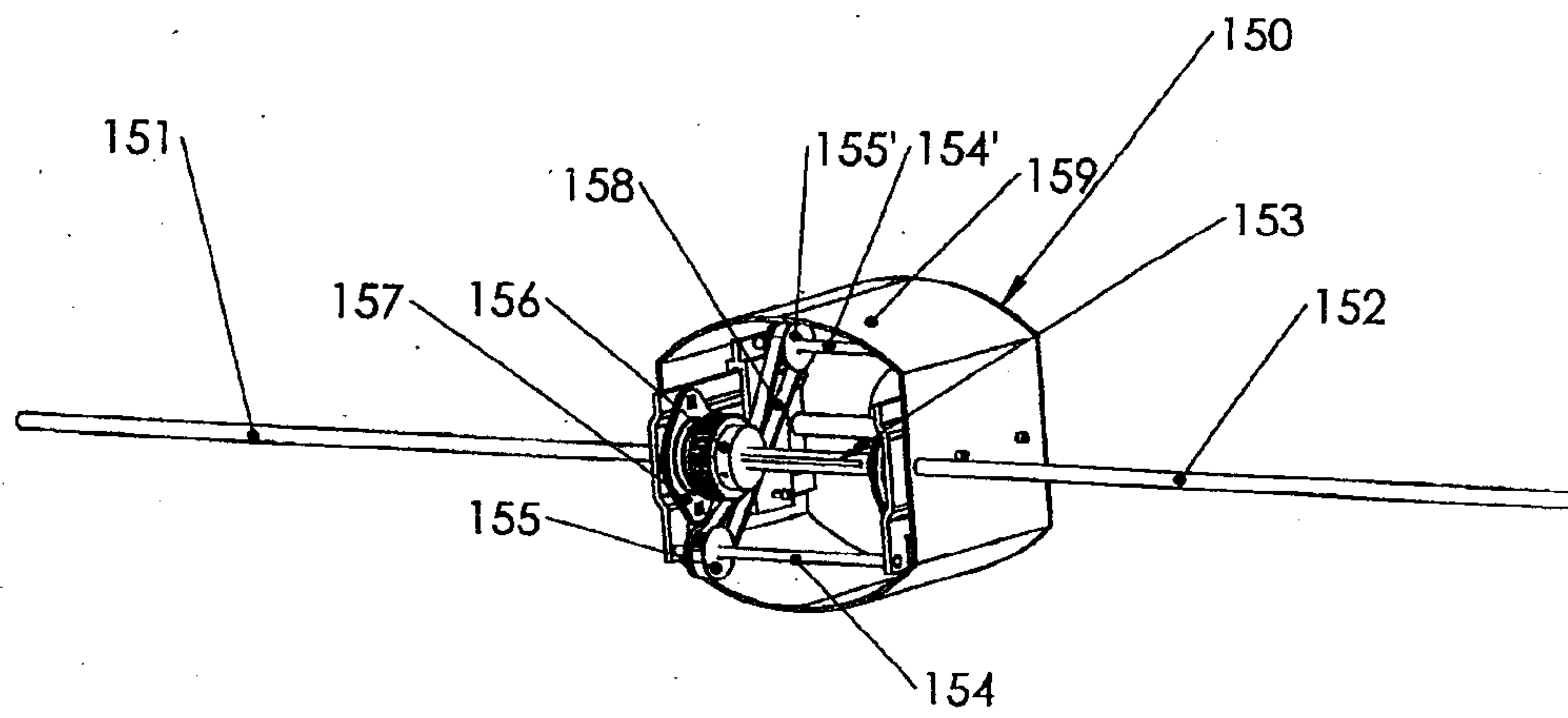
11/56

FIGURE 6



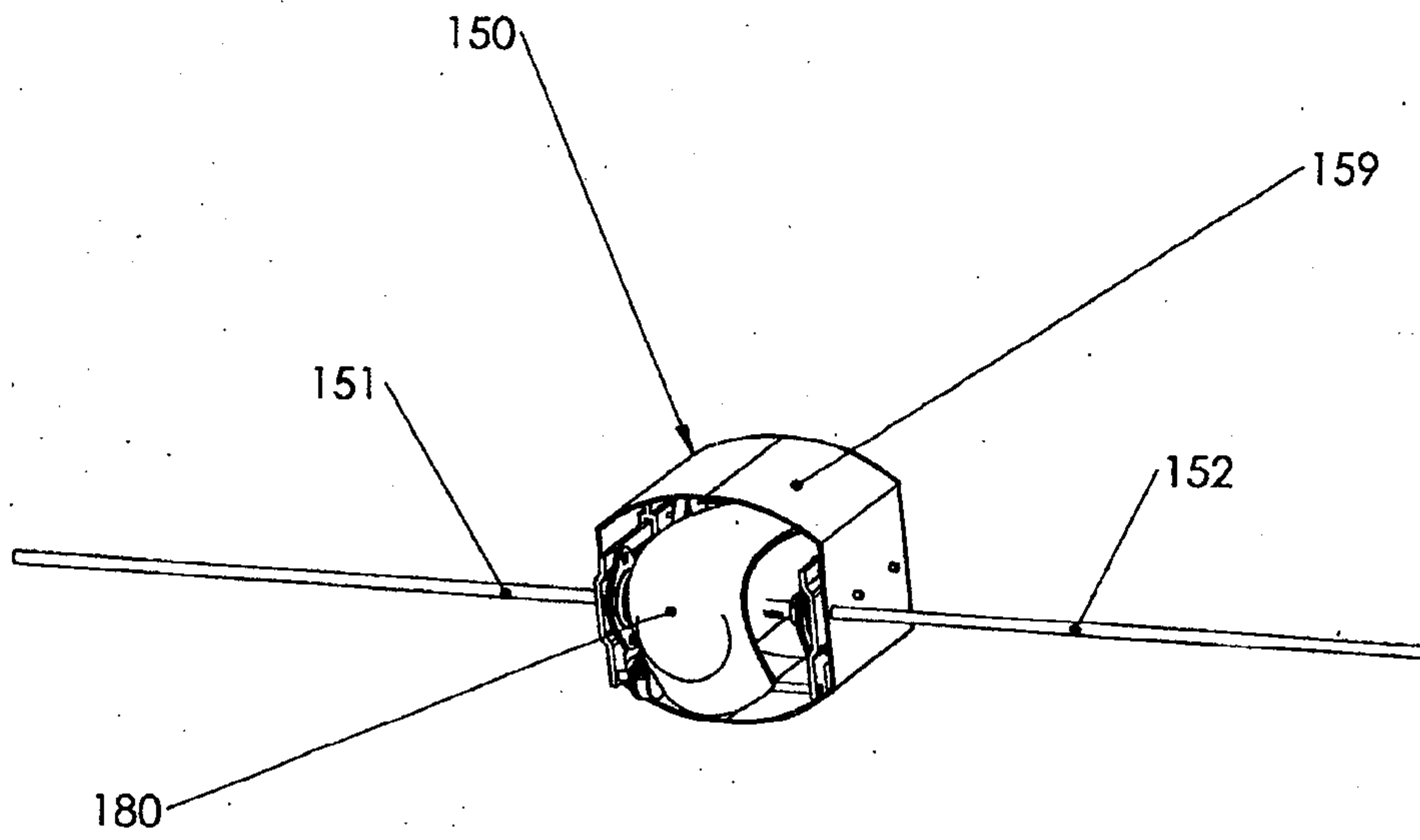
12/56

FIGURE 7



13/56

FIGURE 8A



14/56

FIGURE 8B

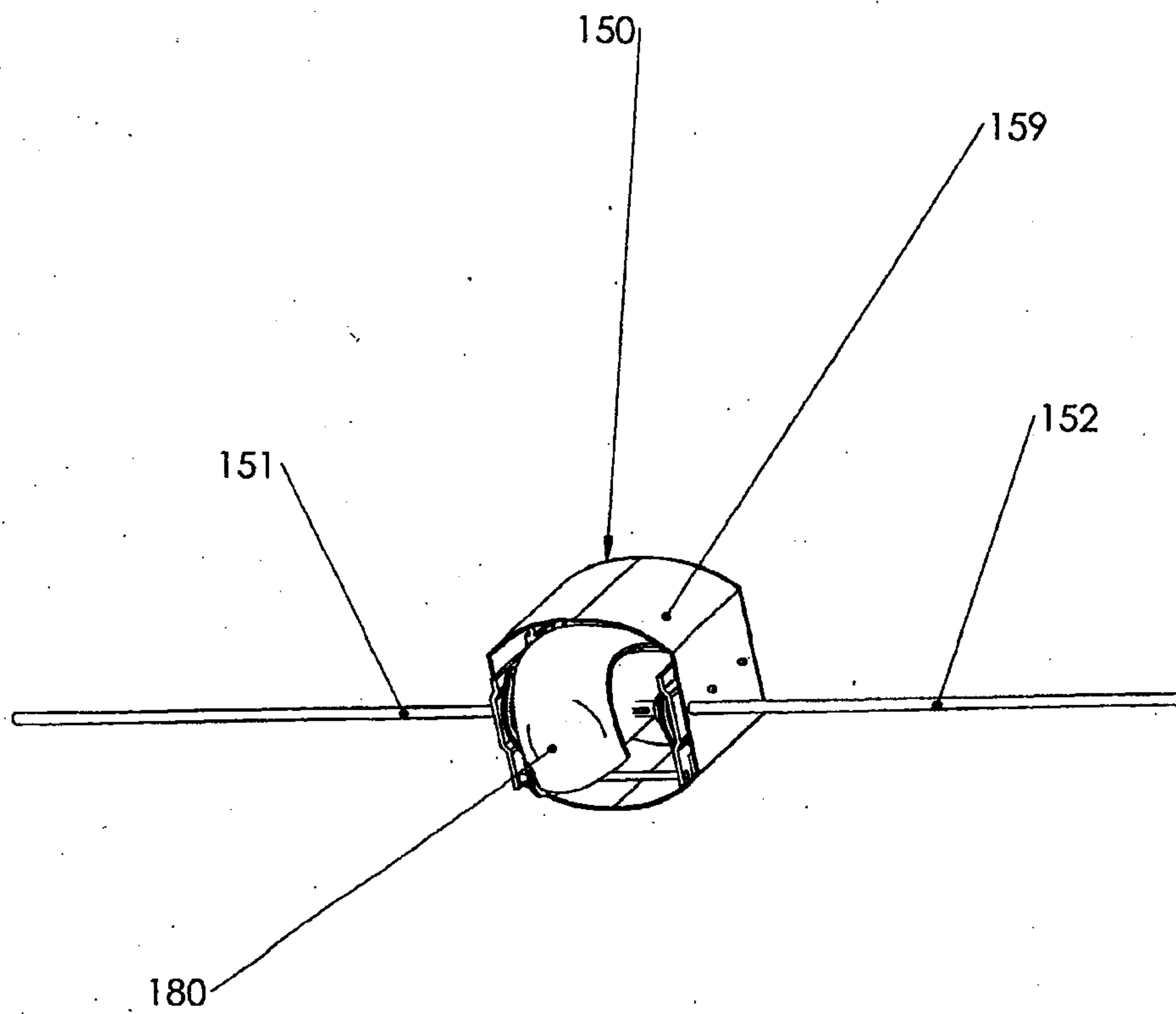
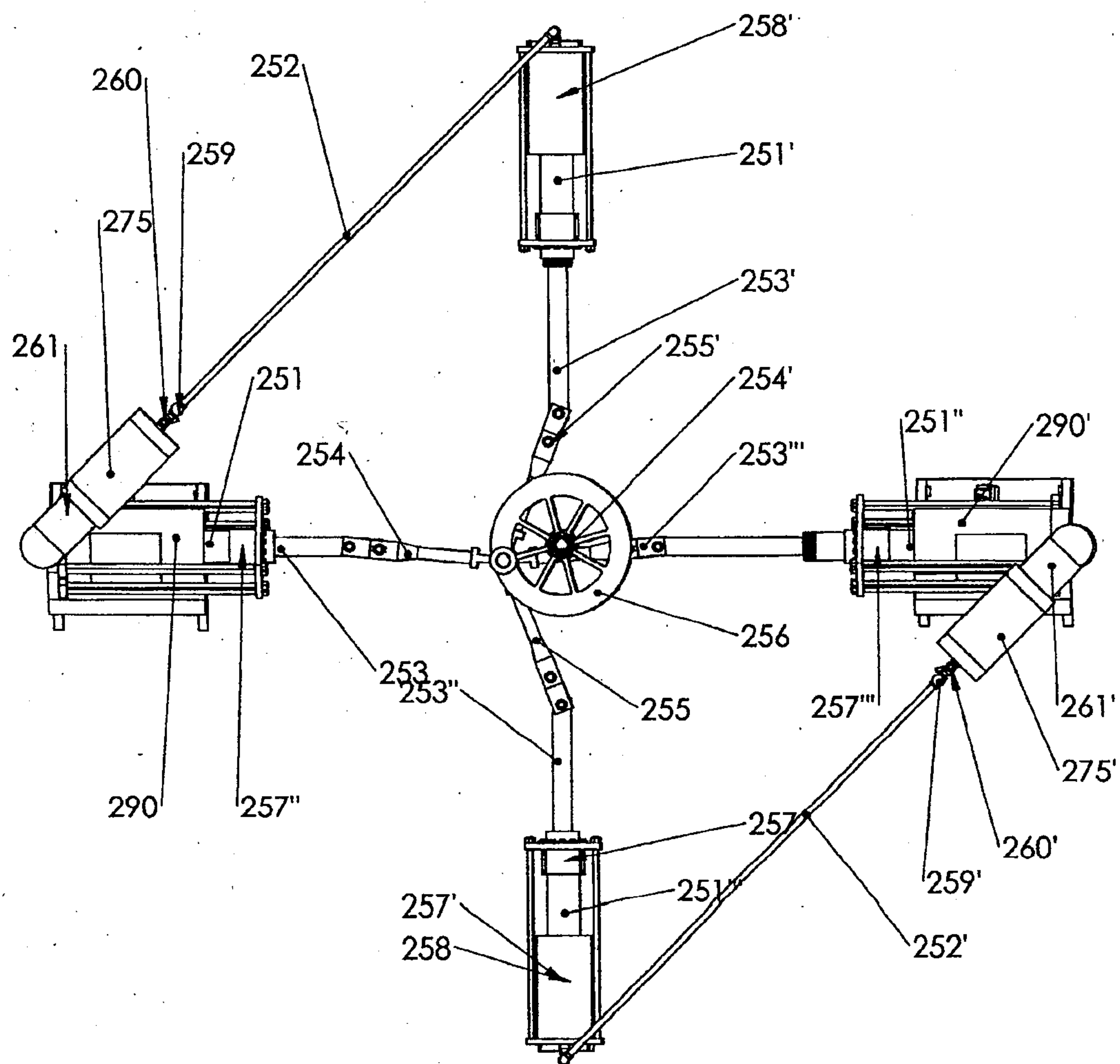
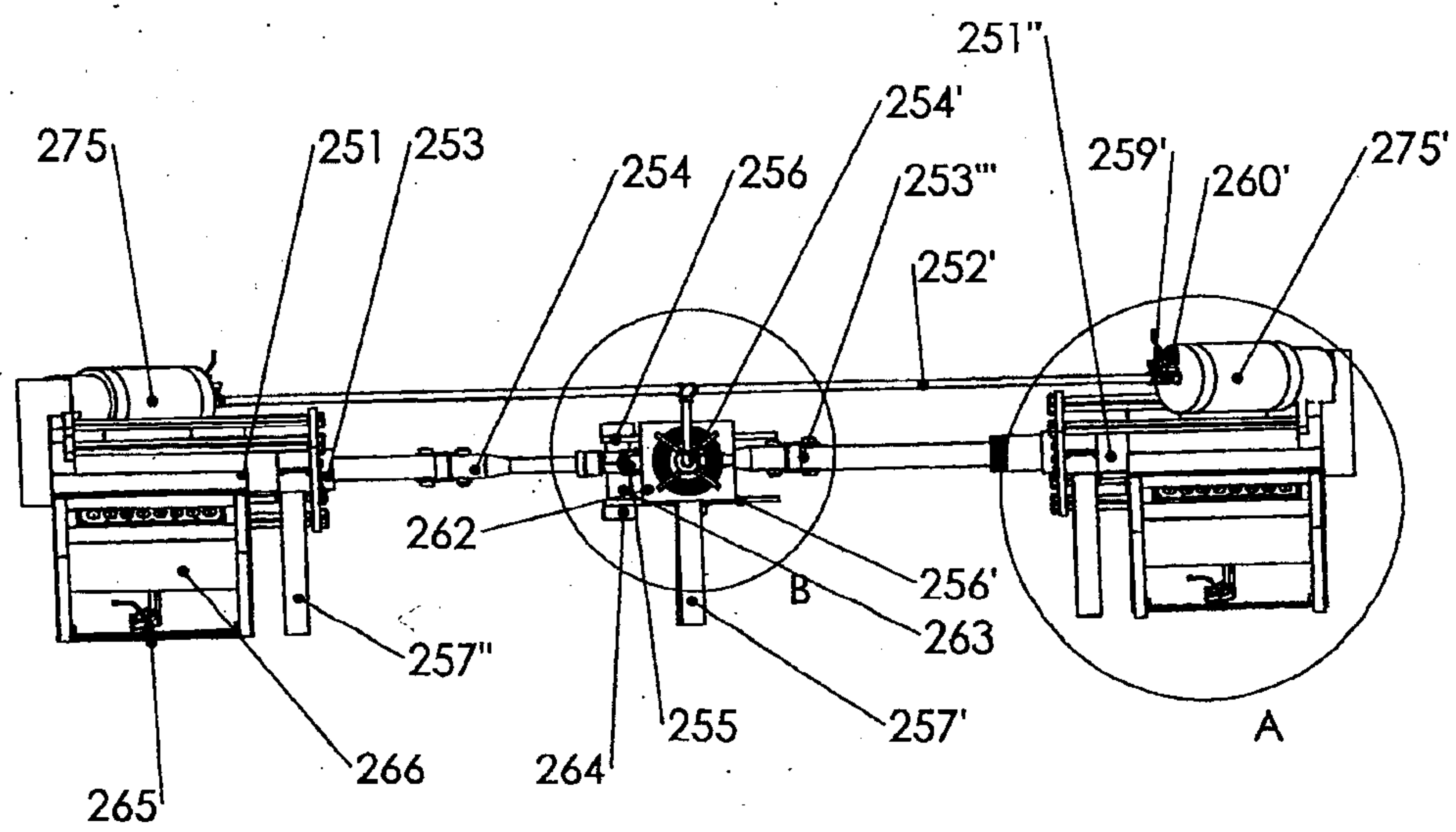


FIGURE 9



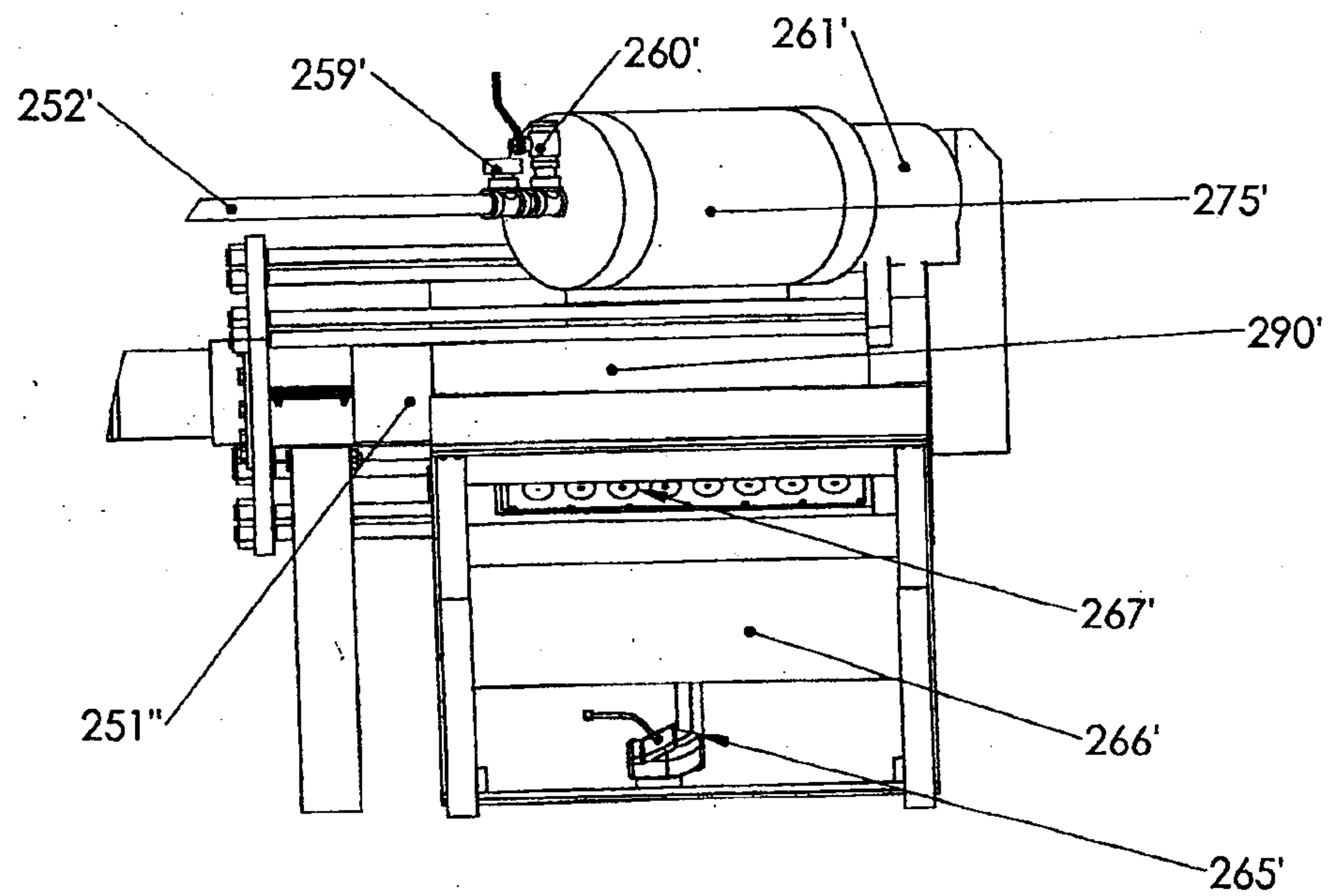
16/56

FIGURE 10A



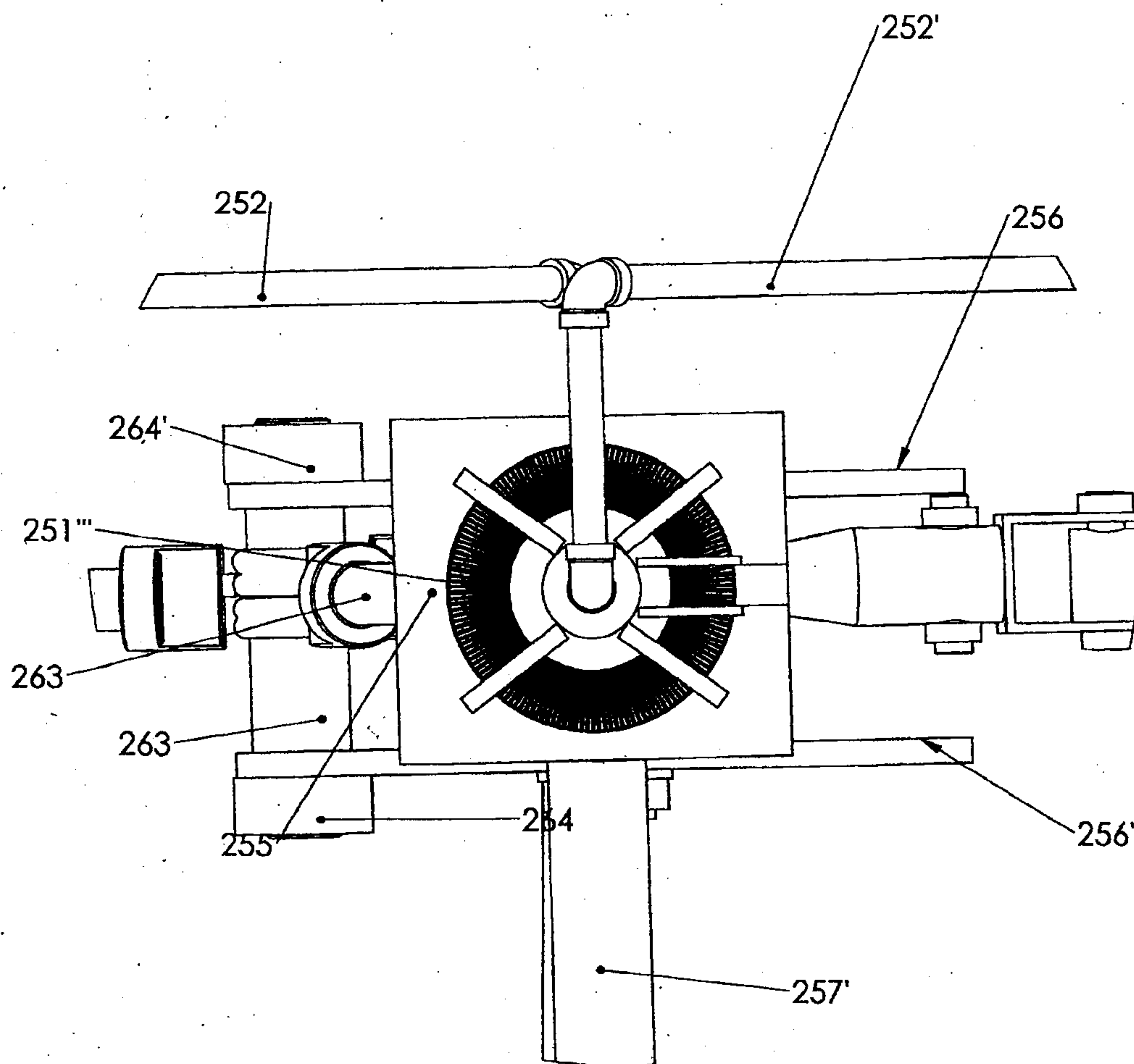
17/56

FIGURE 10B



DETAIL A

FIGURE 10C



DETAIL B

19/56

FIGURE 11A

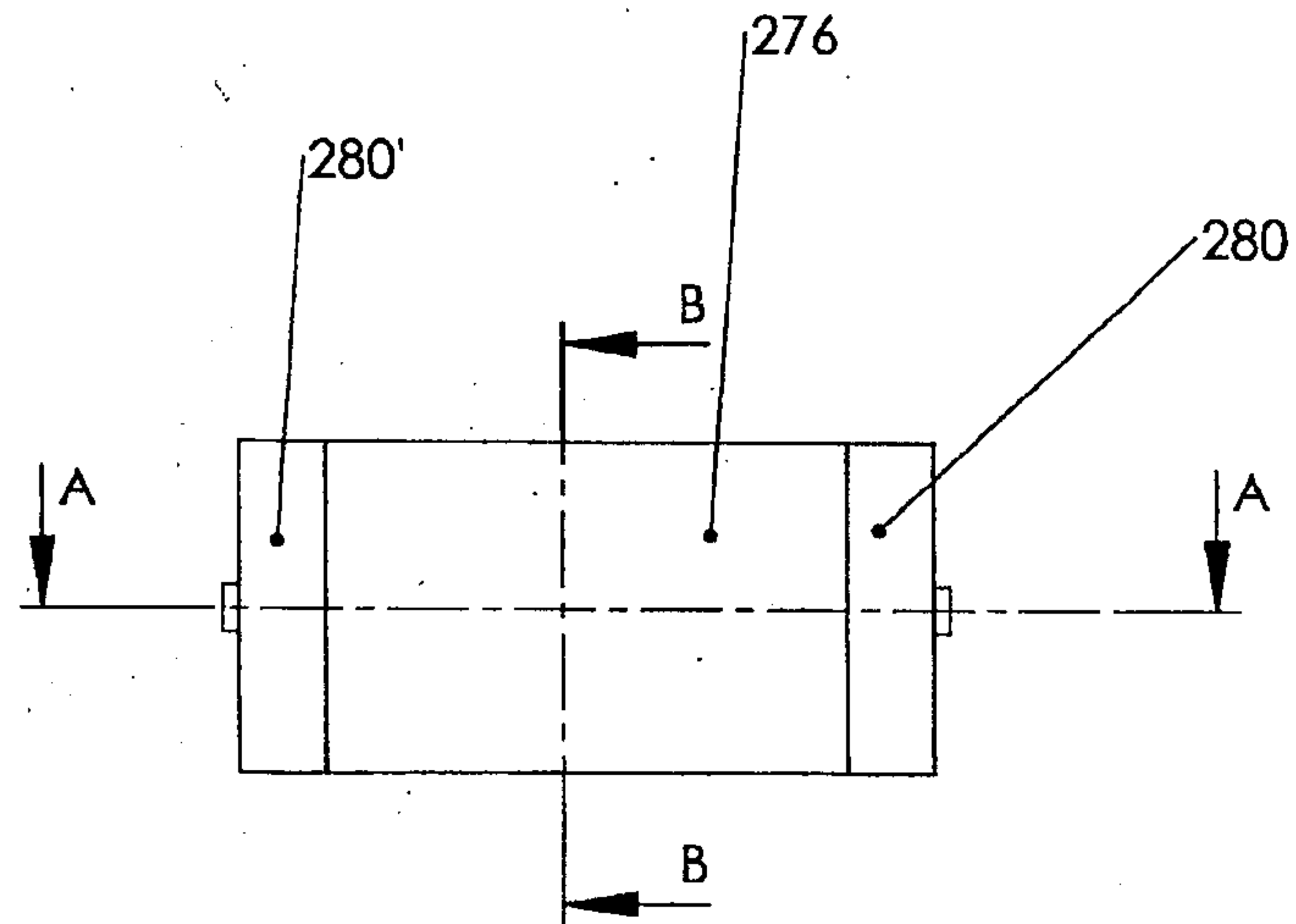
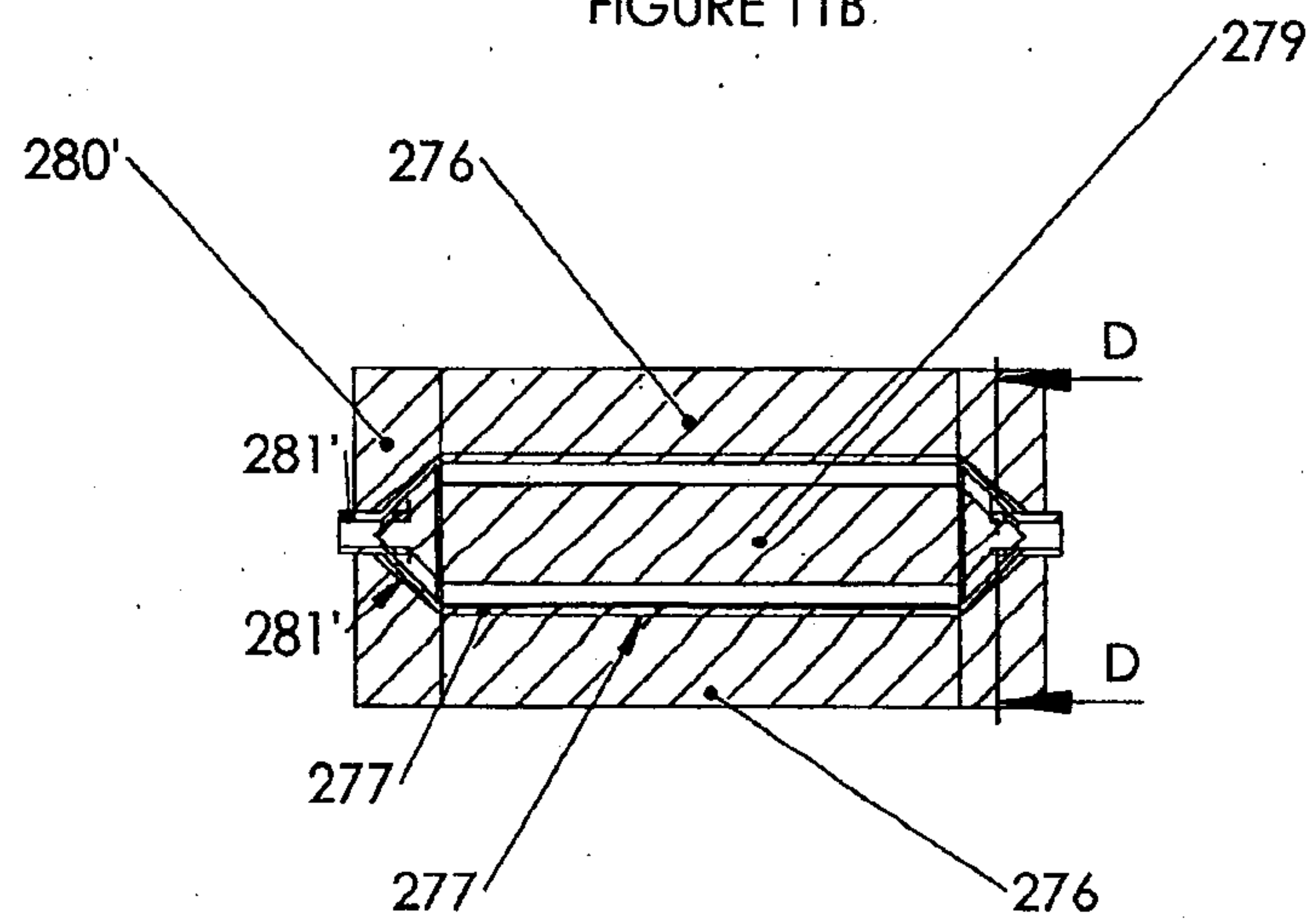


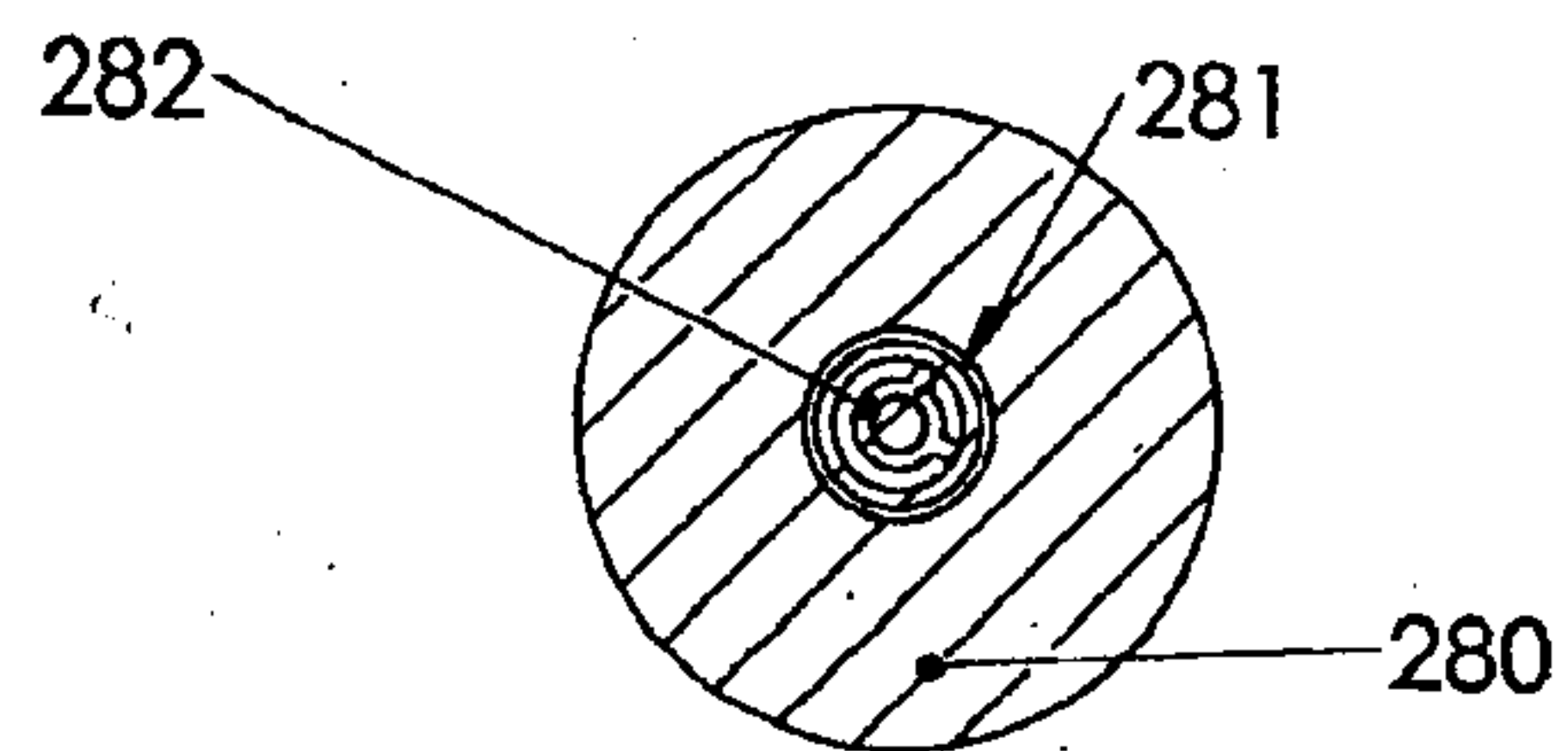
FIGURE 11B



SECTION A-A

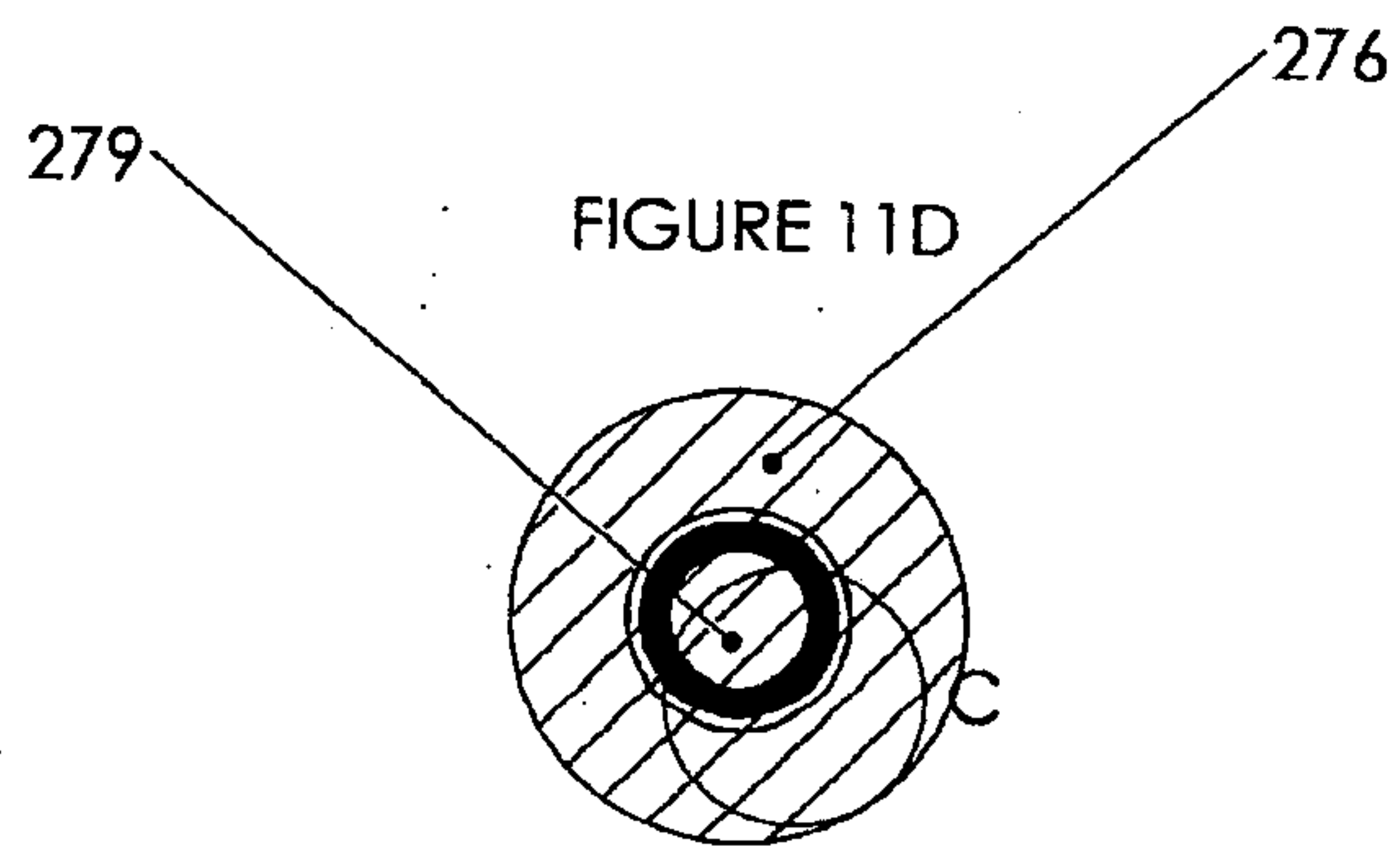
20/56

FIGURE 11C



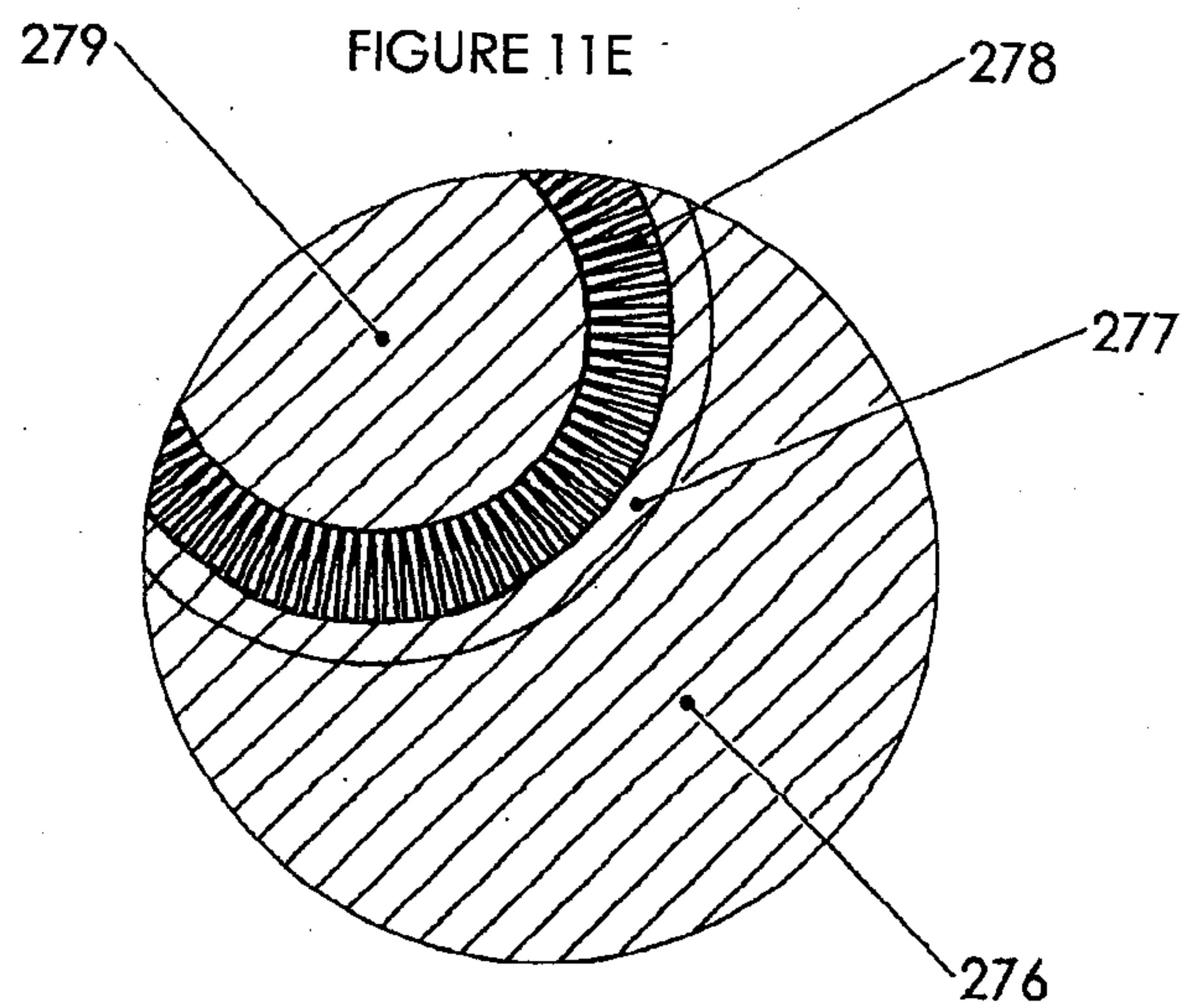
SECTION D-D

FIGURE 11D



SECTION B-B

FIGURE 11E



DETAIL C

21/56

FIGURE 12A

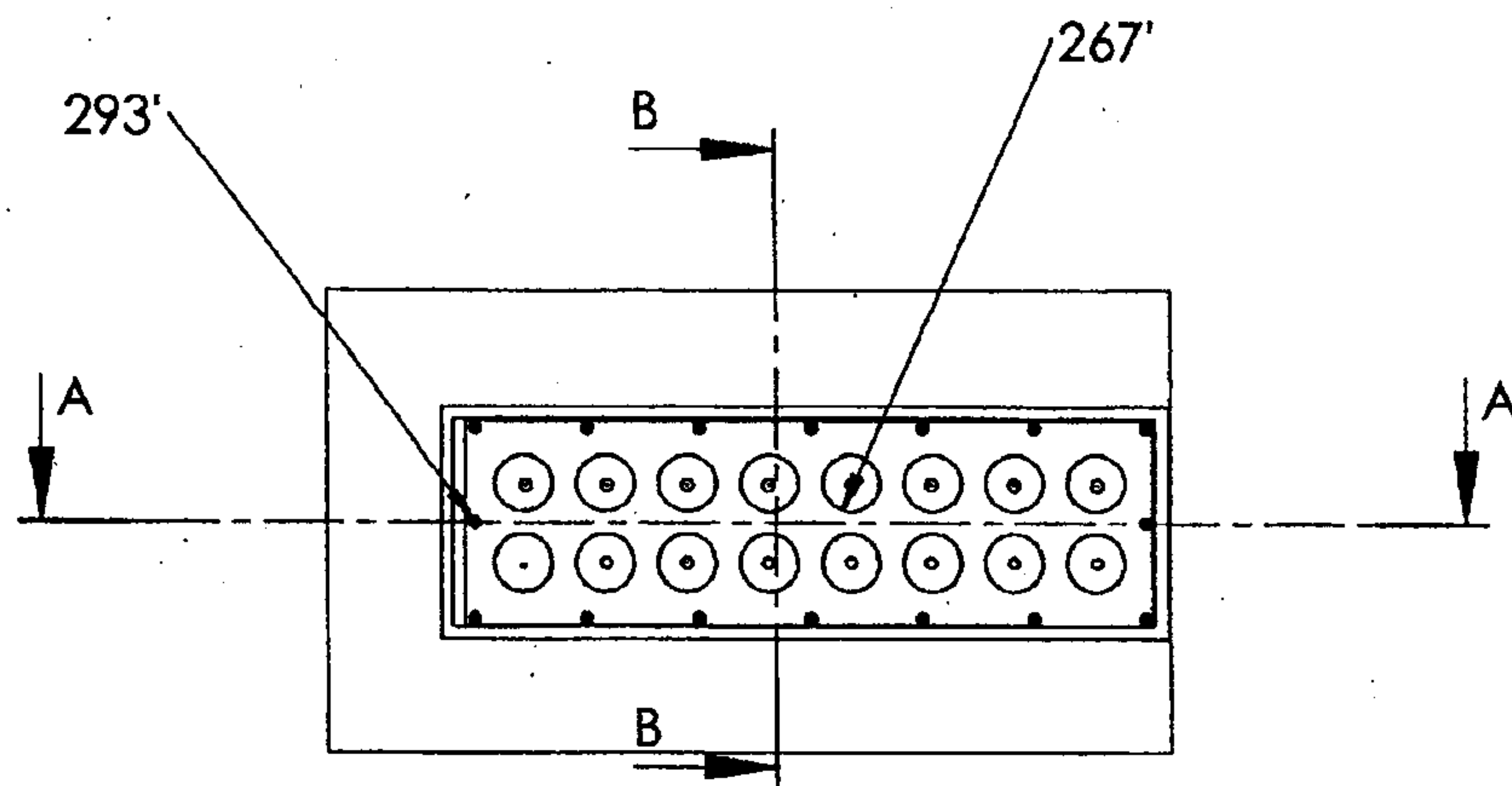
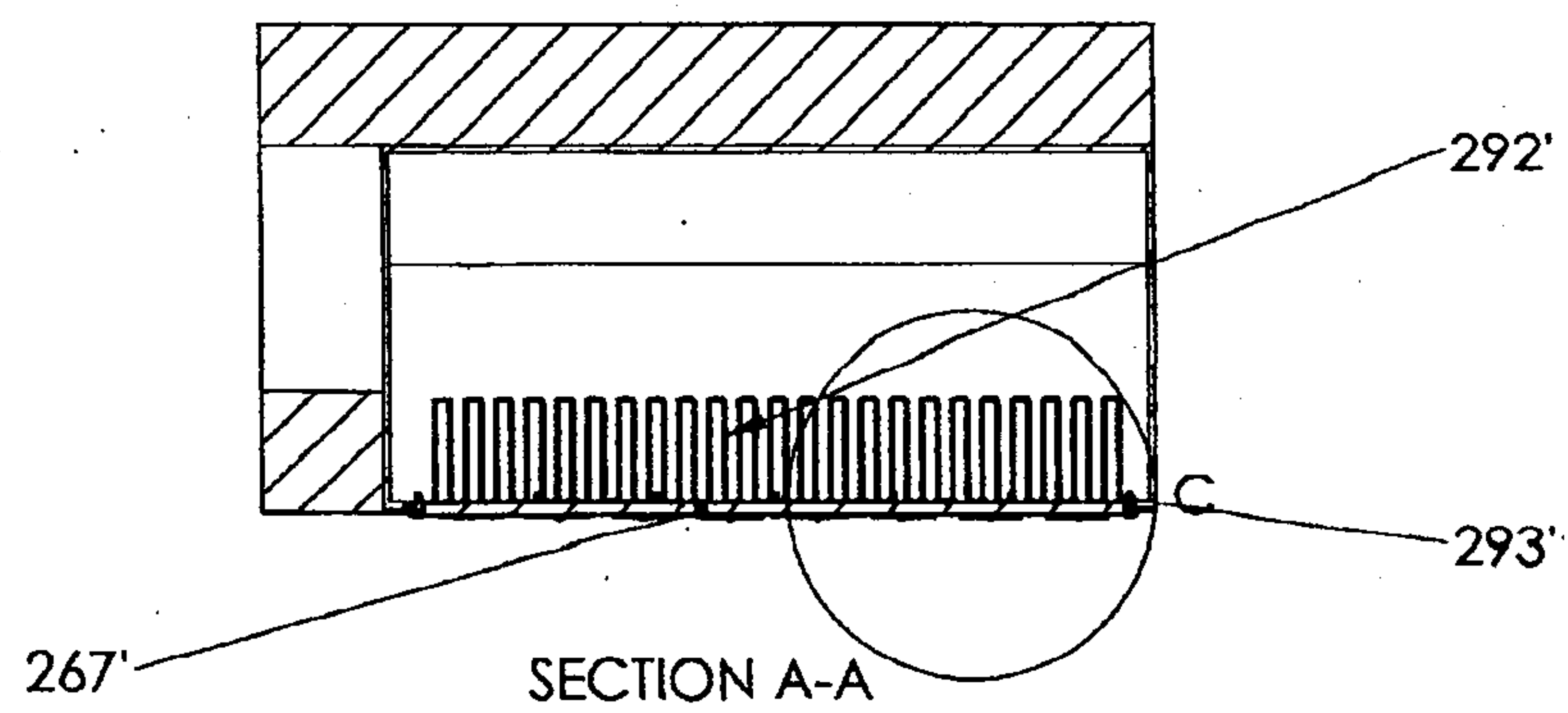
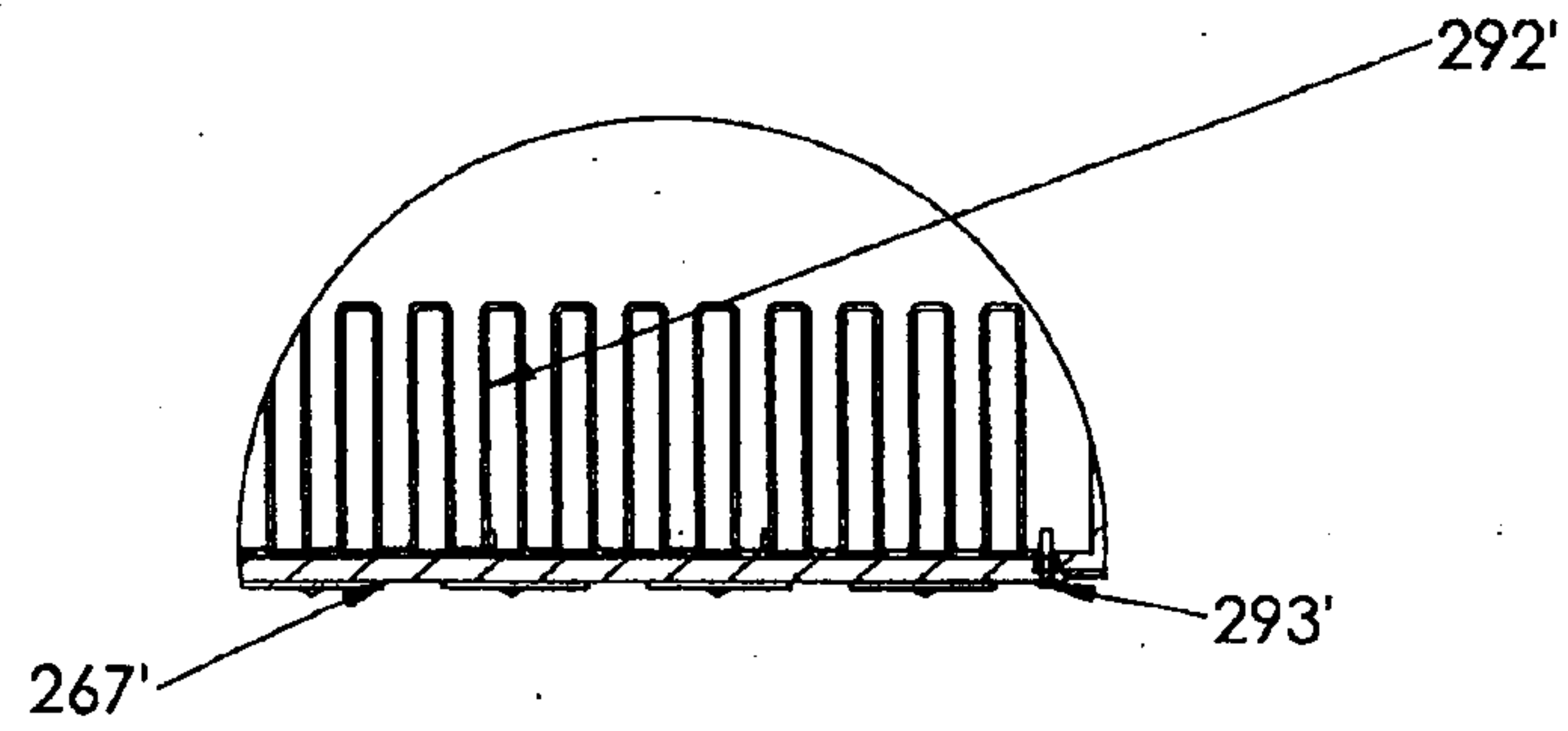


FIGURE 12B



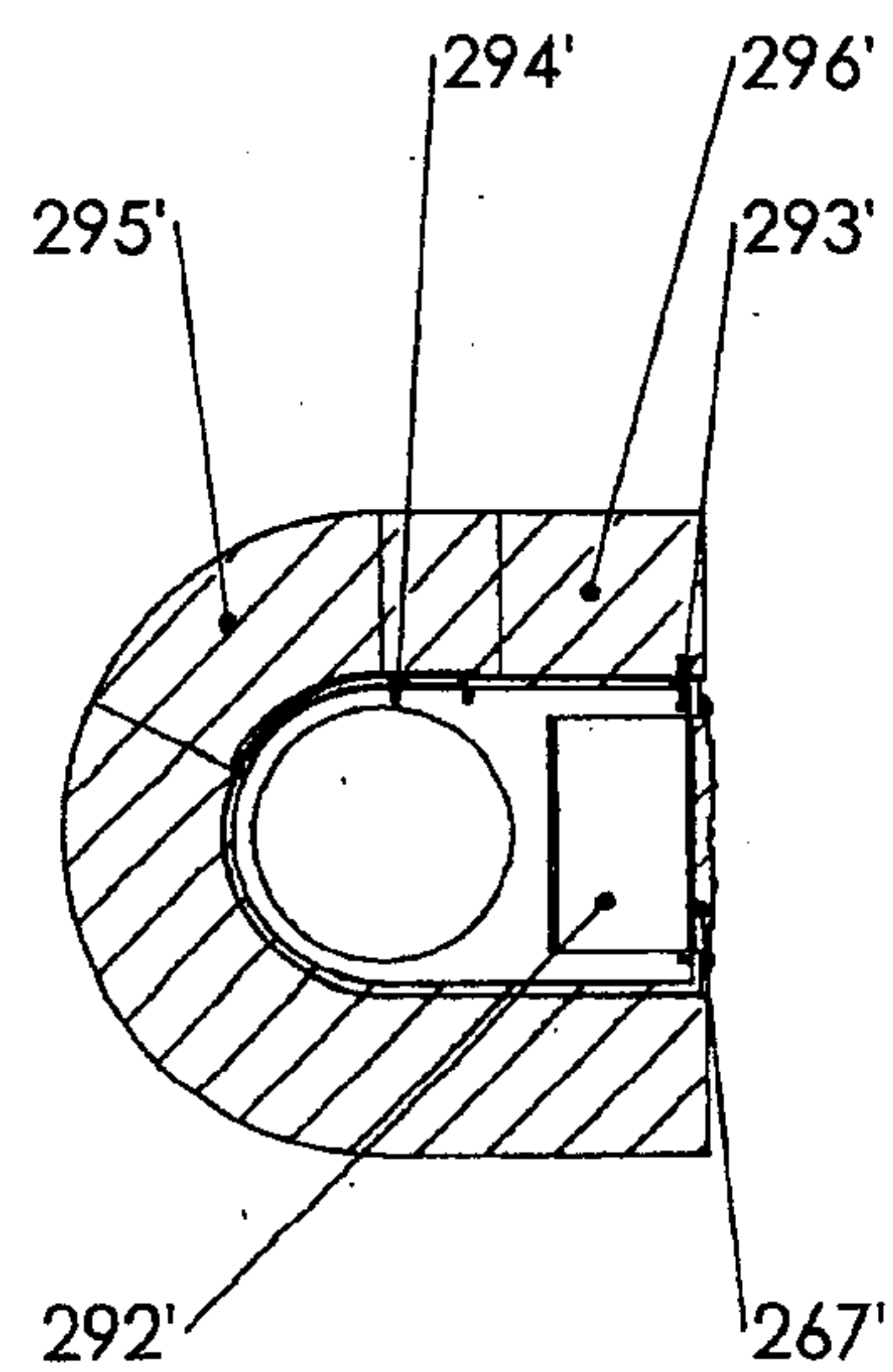
22/56

FIGURE 12C



DETAIL C

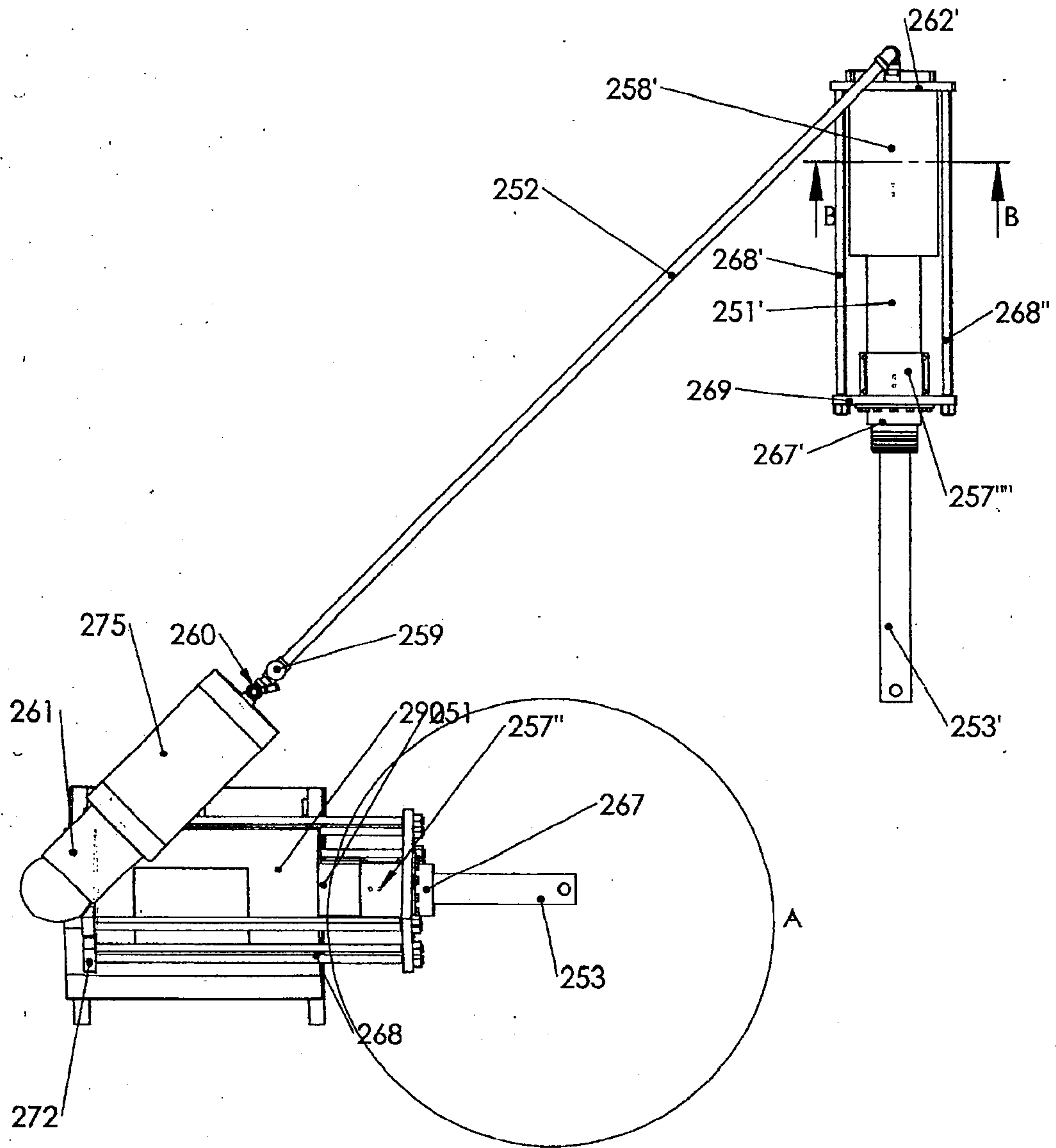
FIGURE 12D



SECTION B-B

23/56

FIGURE 13A



24/56

FIGURE 13B

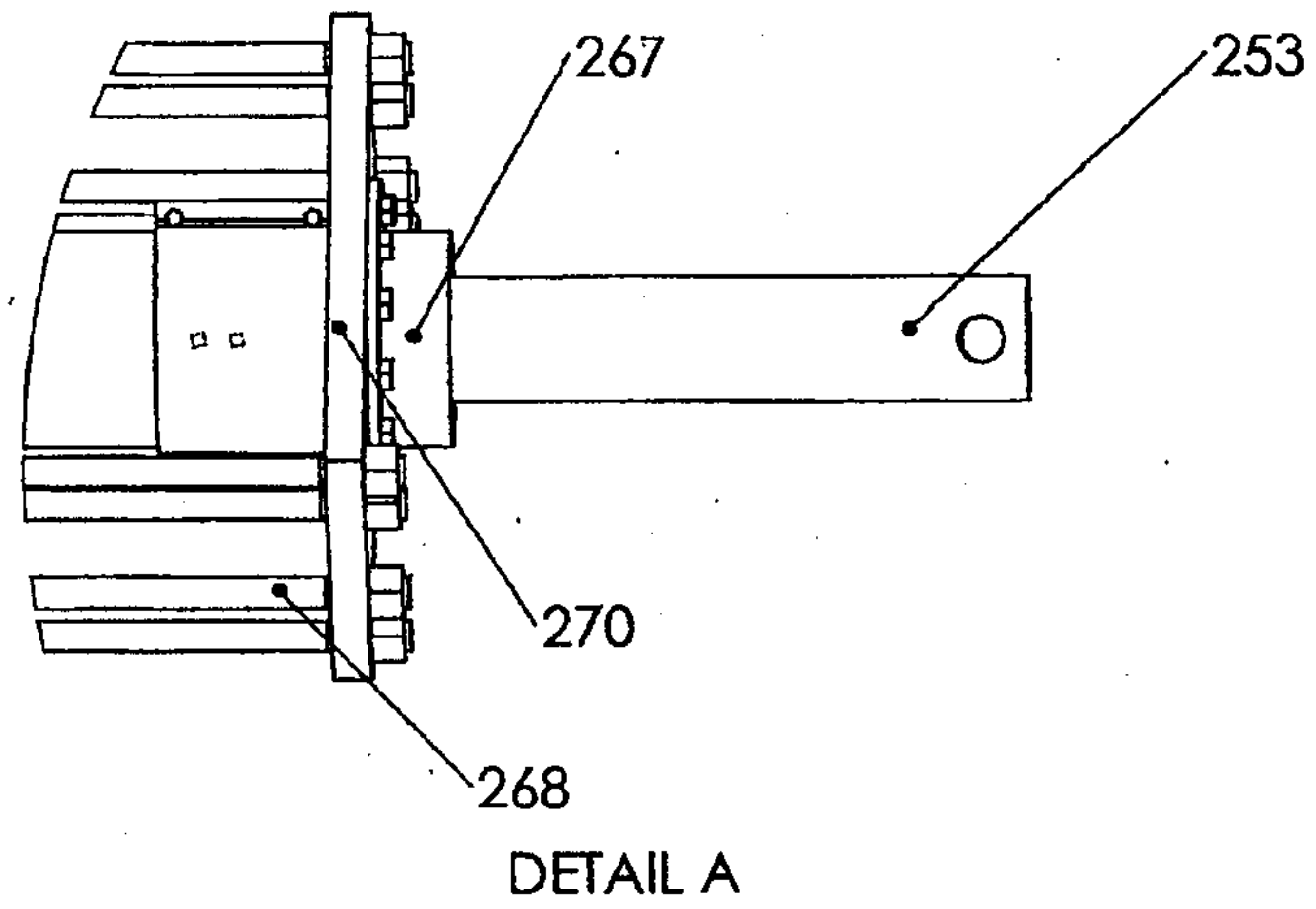
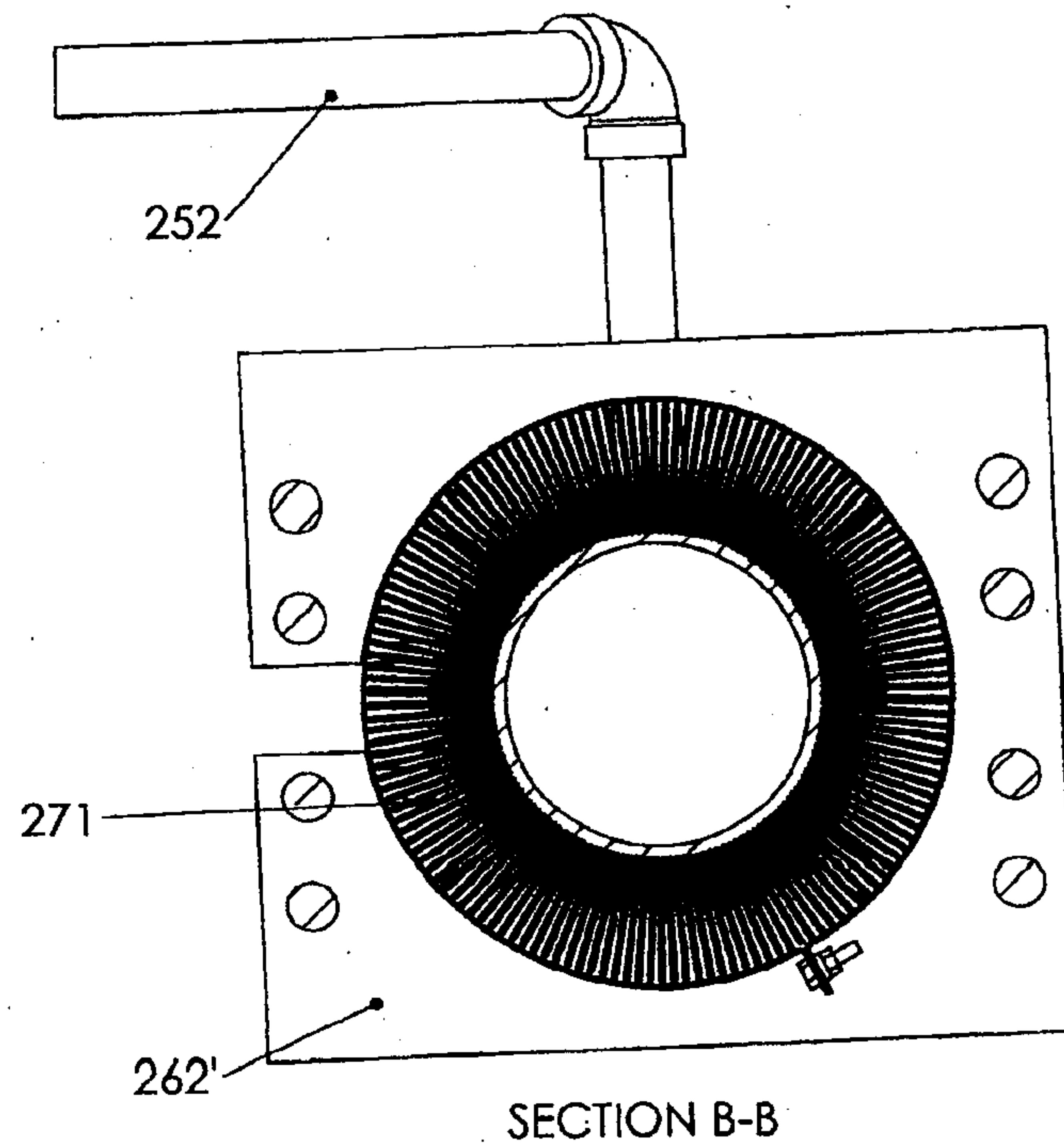
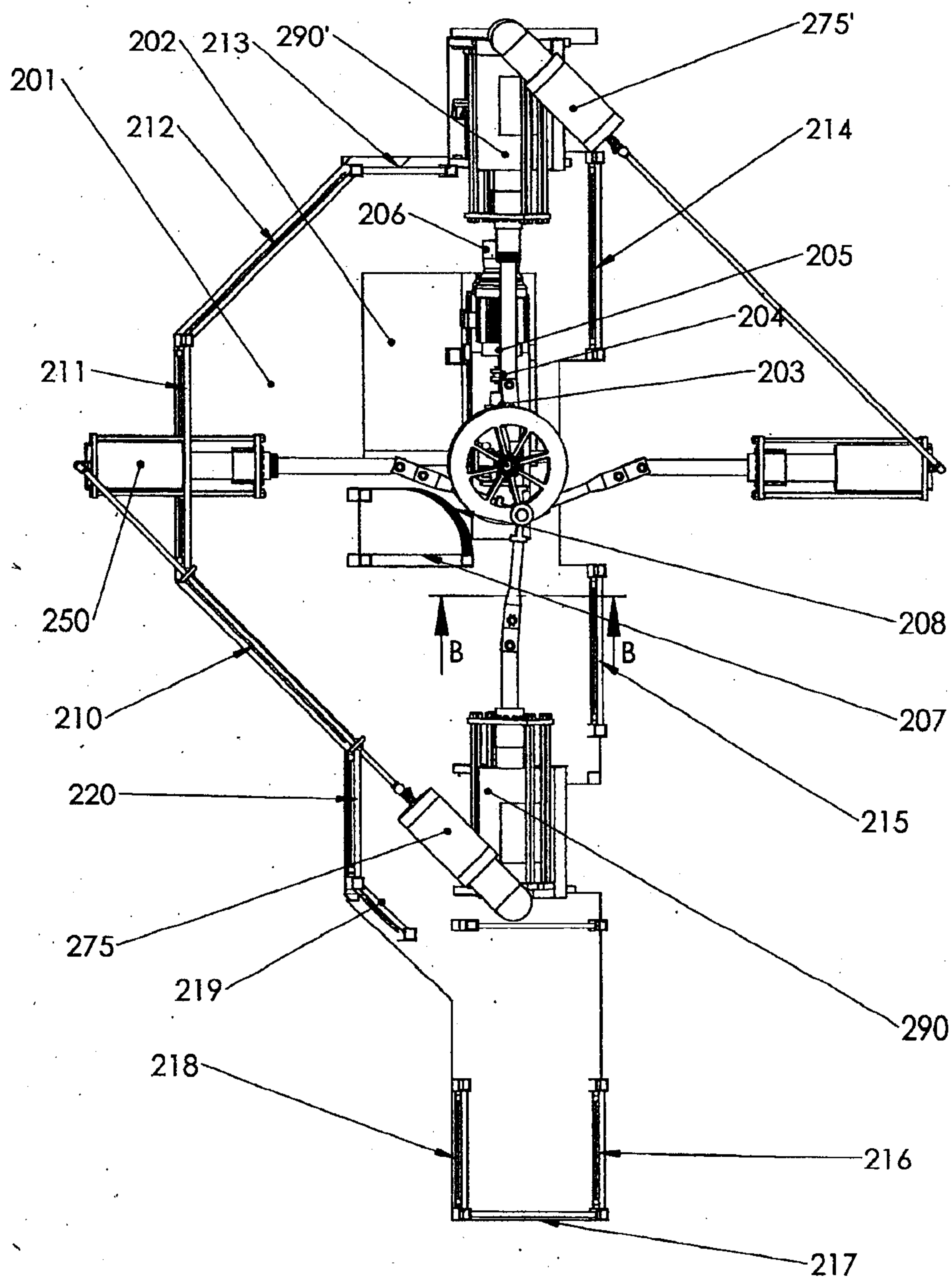


FIGURE 13C



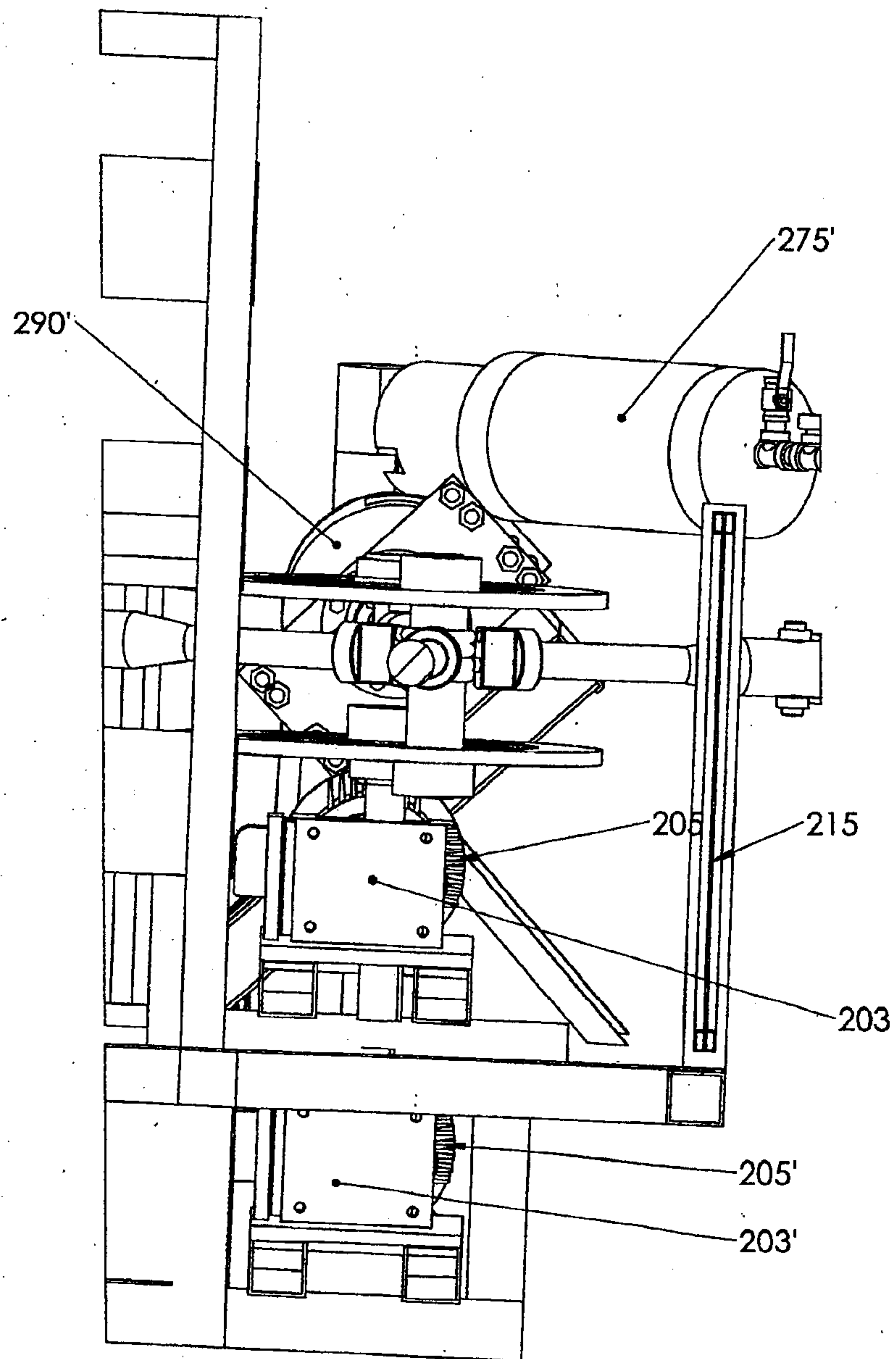
25/56

FIGURE 14A



26/56

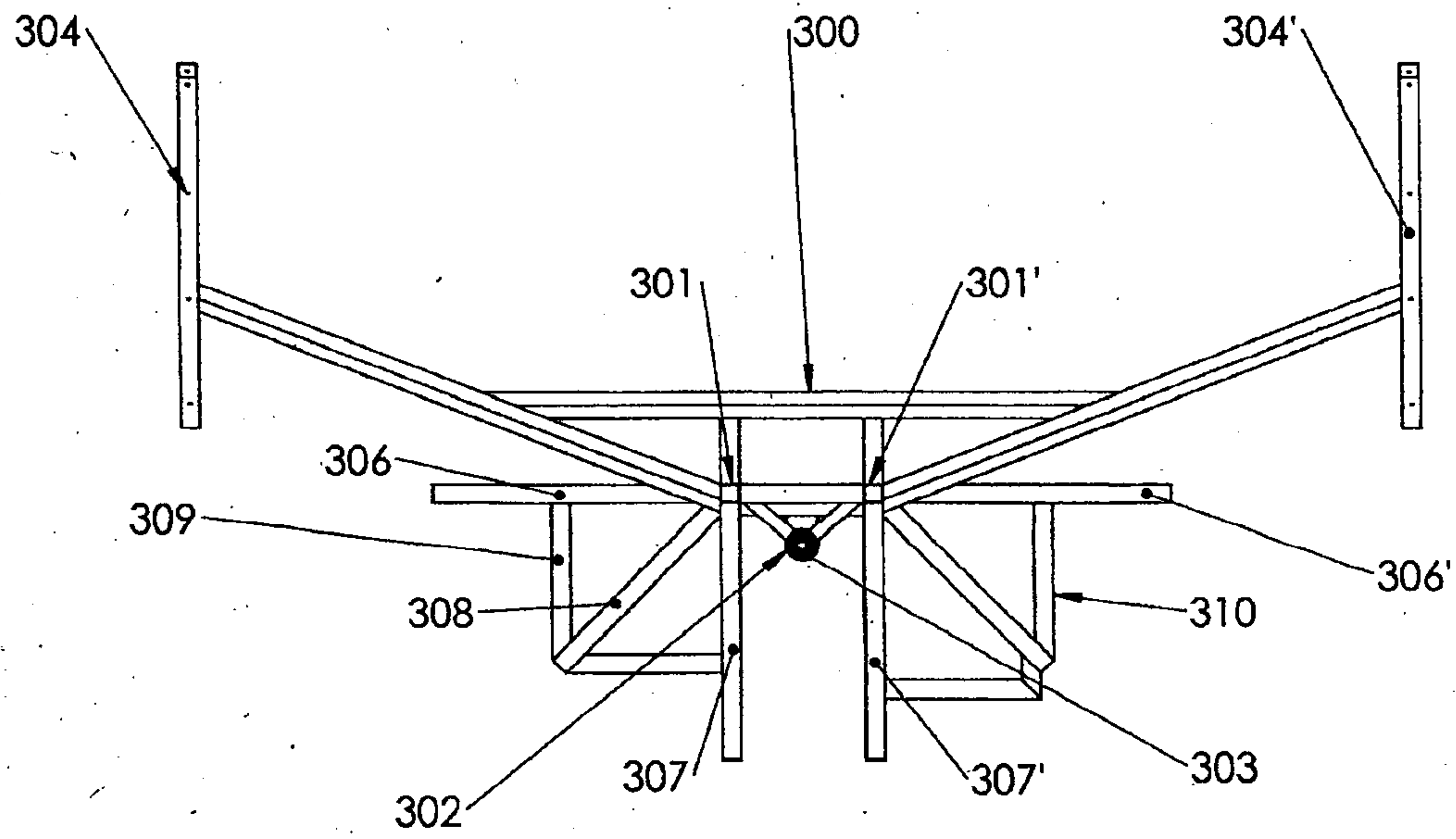
FIGURE 14B



SECTION B-B

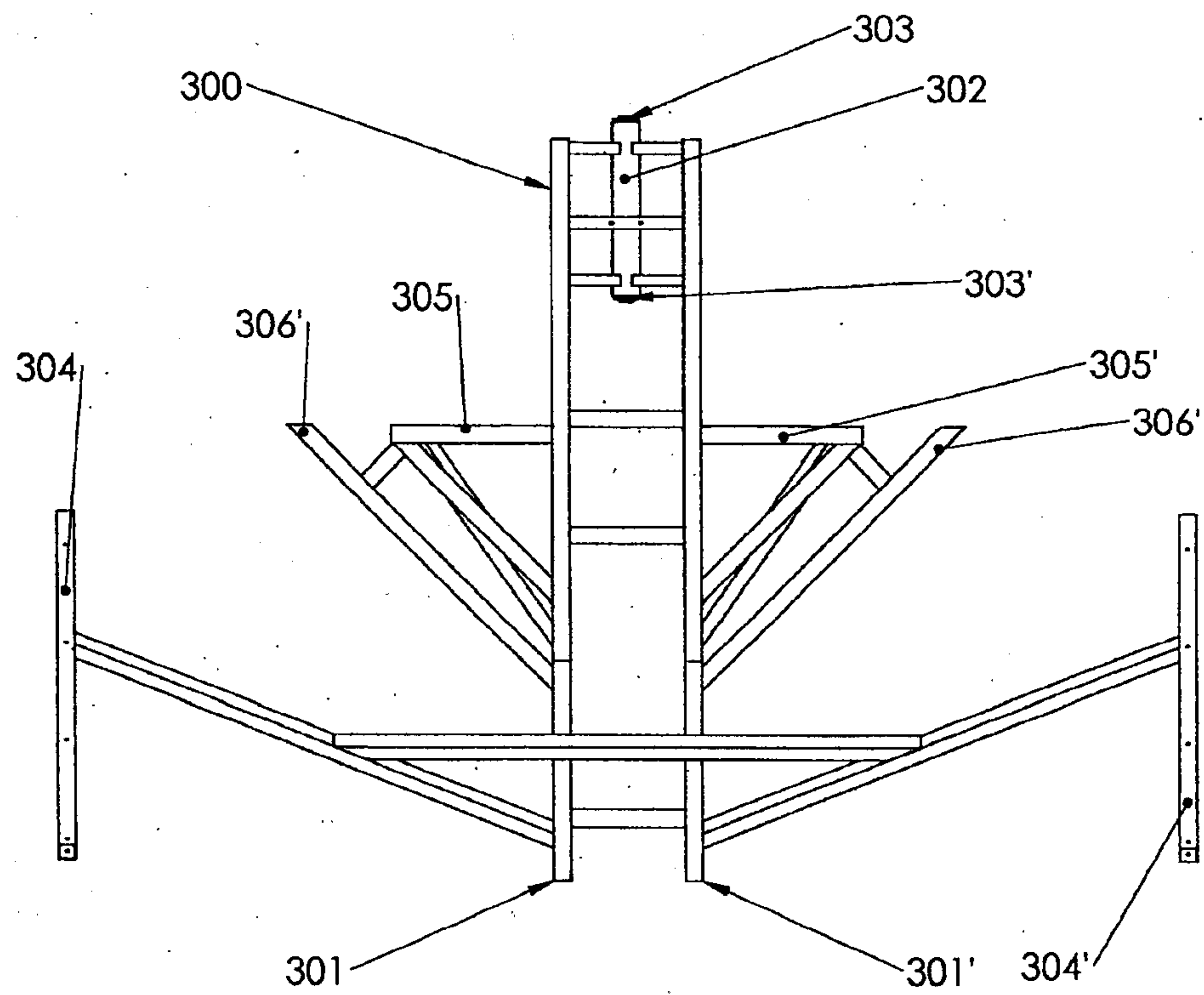
27/56

FIGURE 15A



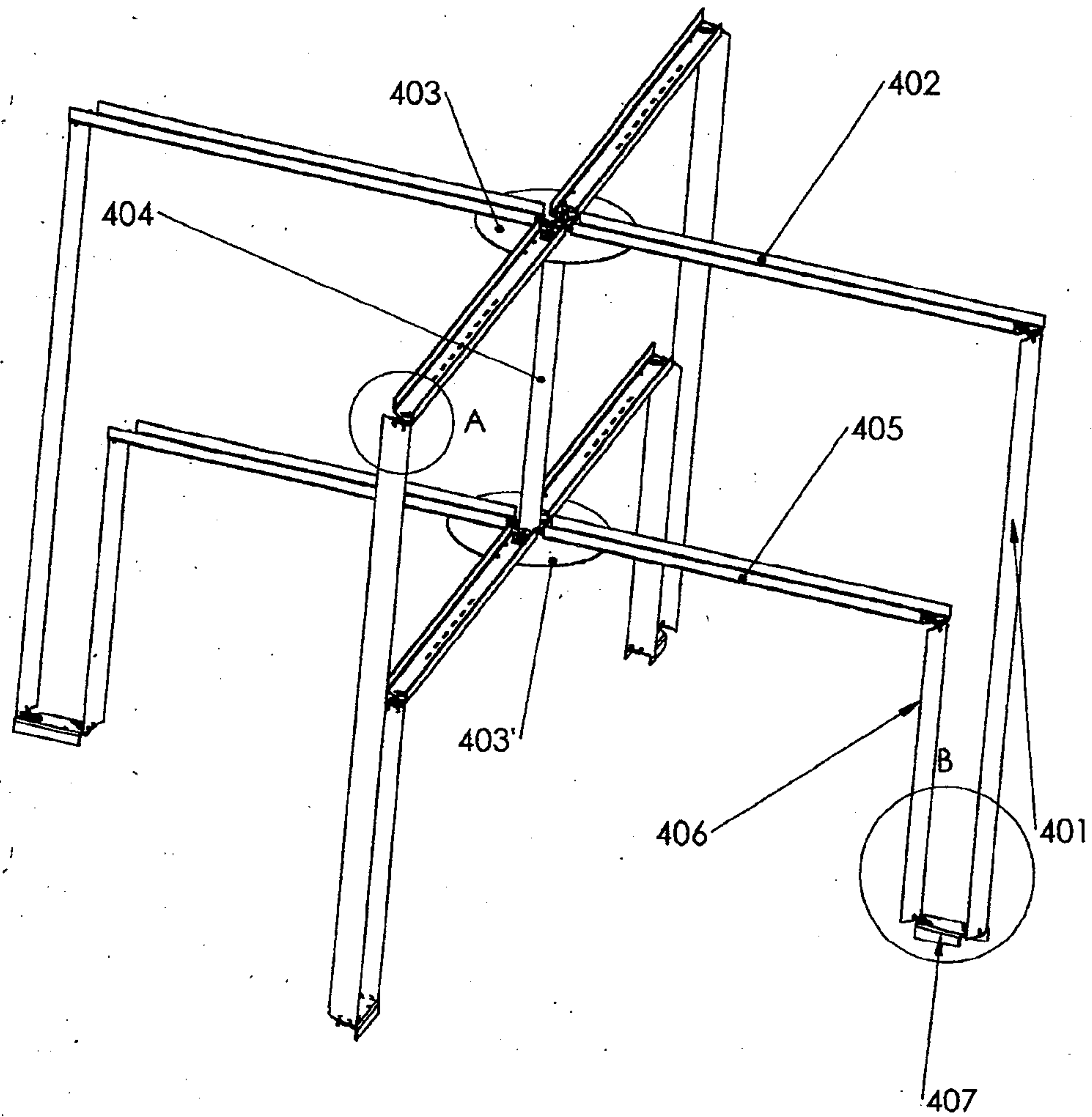
28/56

FIGURE 15B



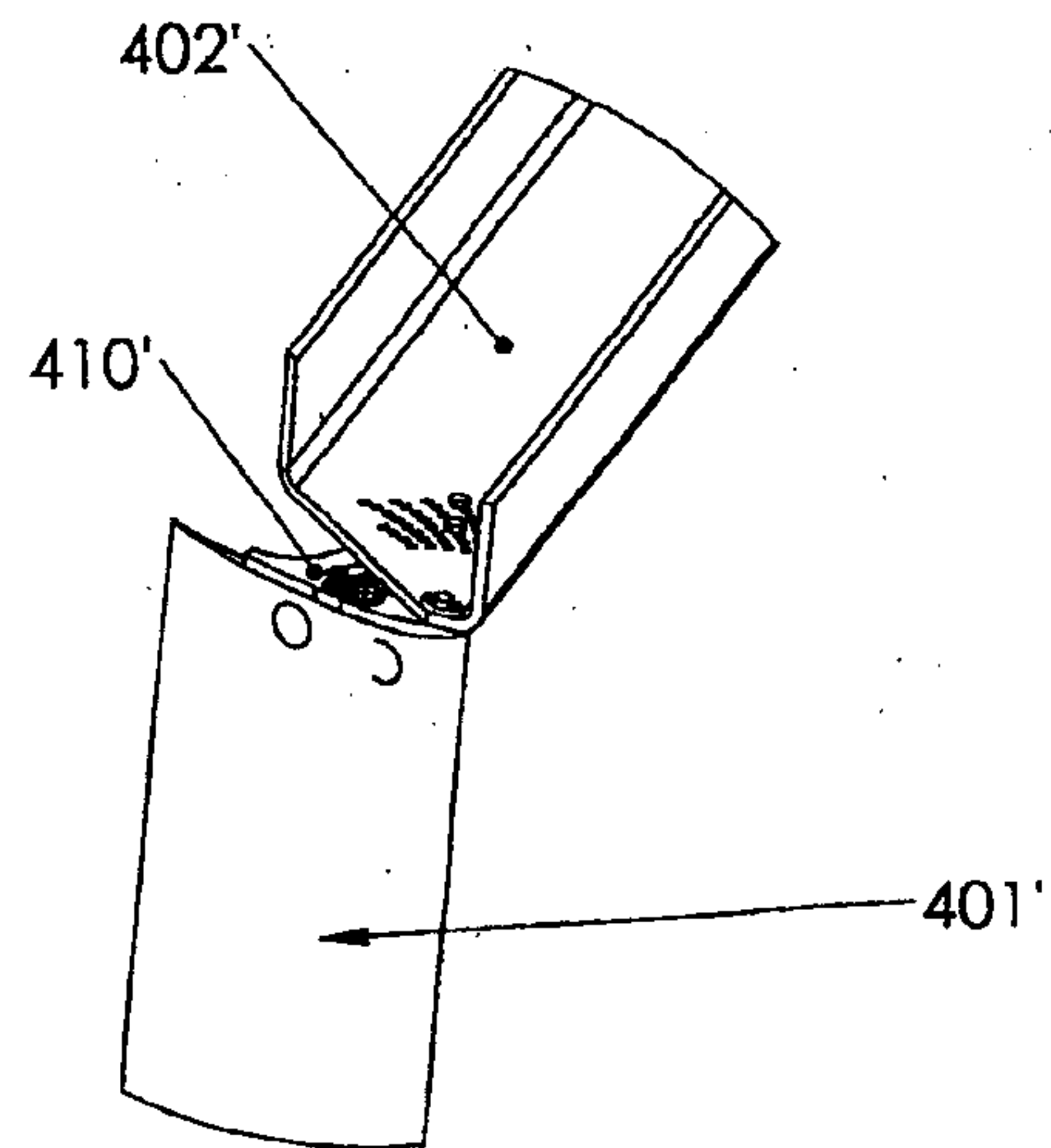
29/56

FIGURE 16A



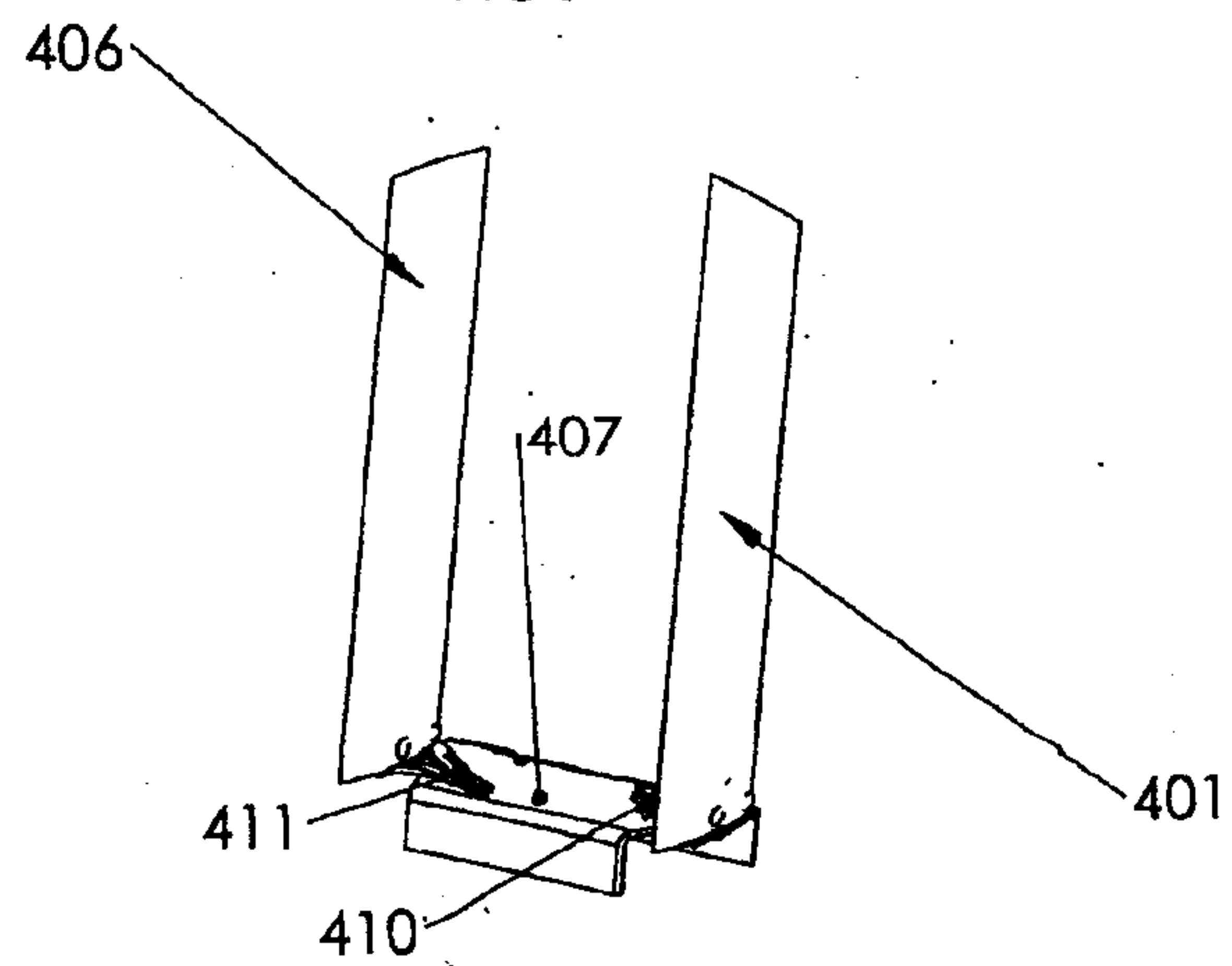
30/56

FIGURE 16B



DETAIL A

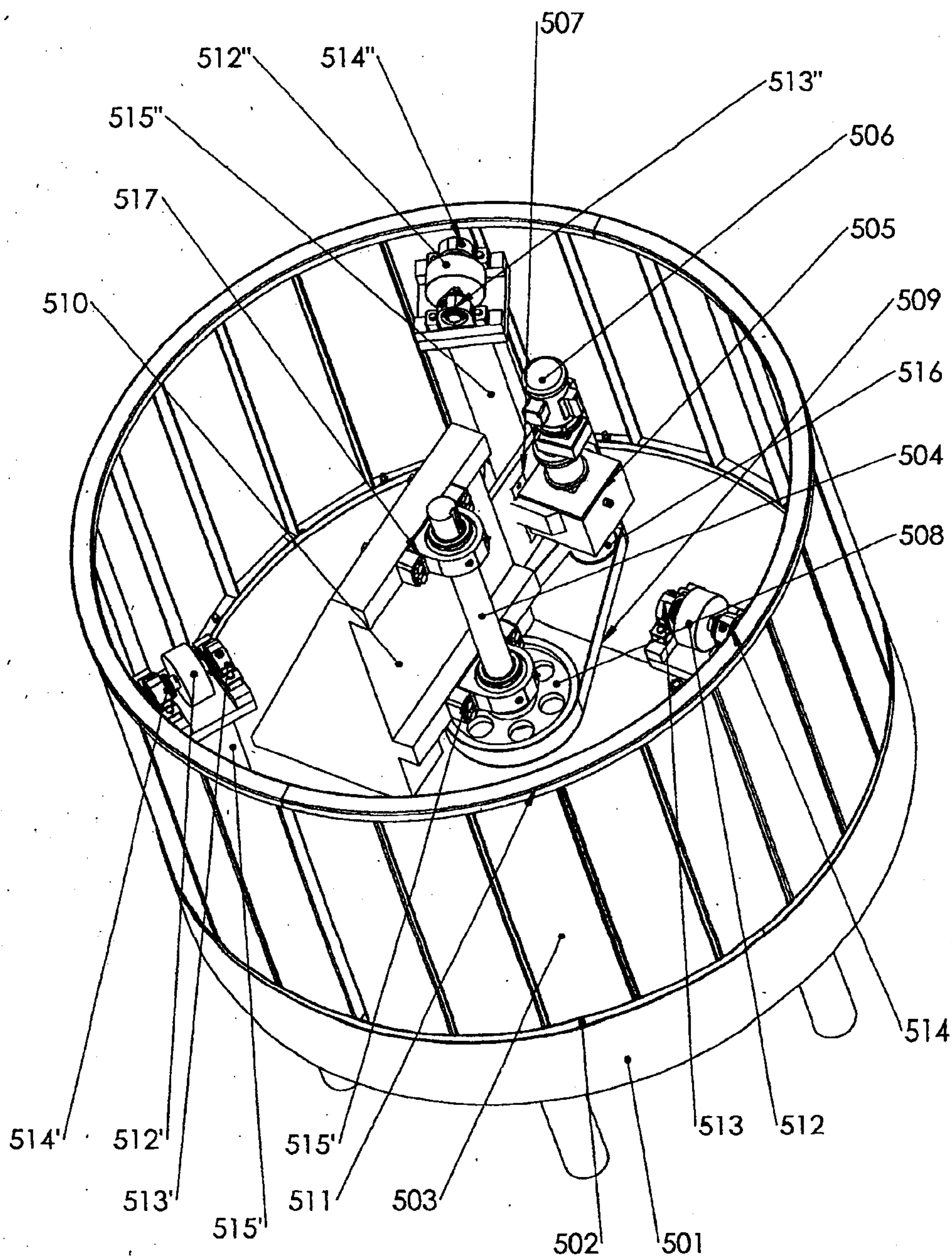
FIGURE 16C



DETAIL B

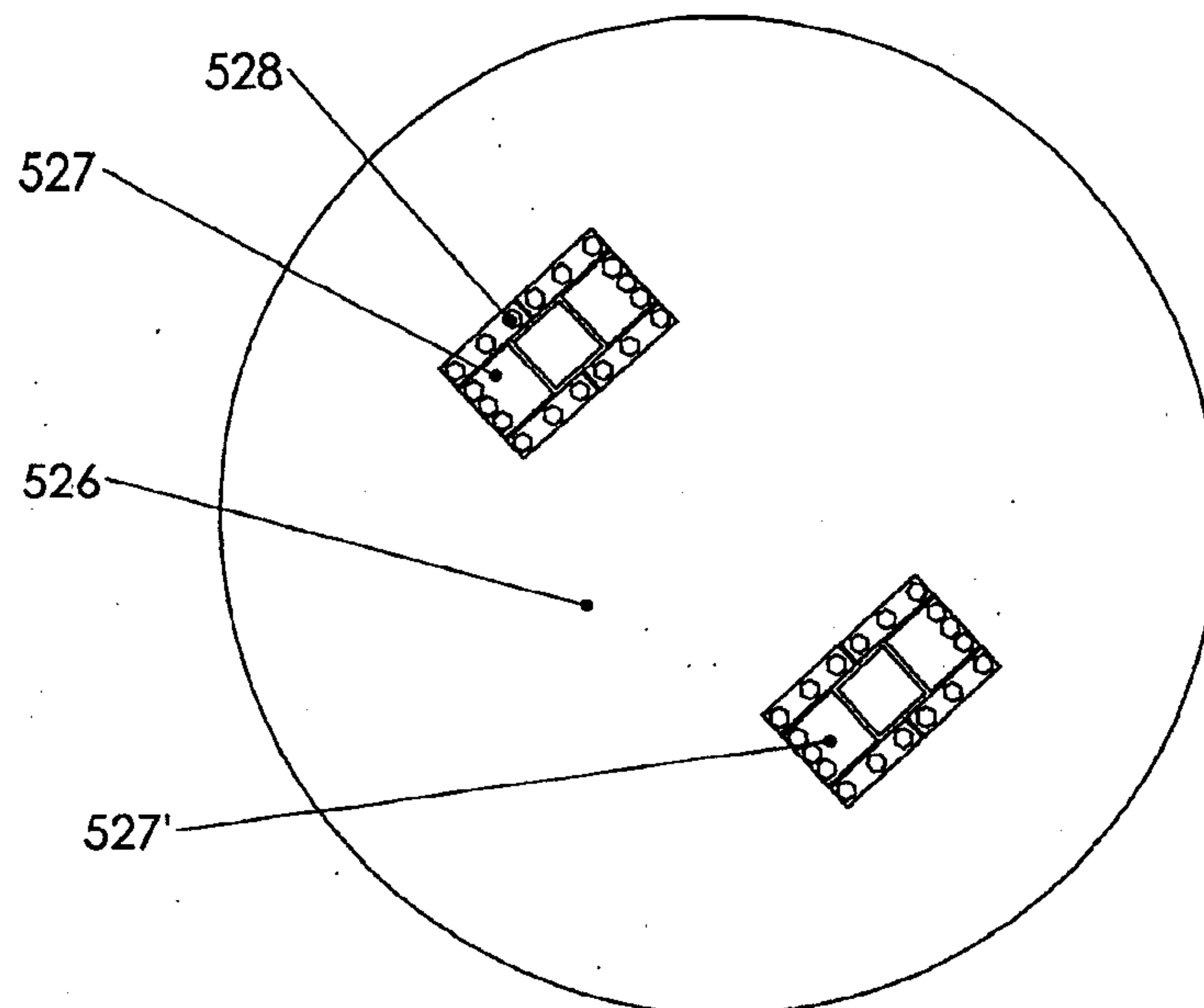
31/56

FIGURE 17



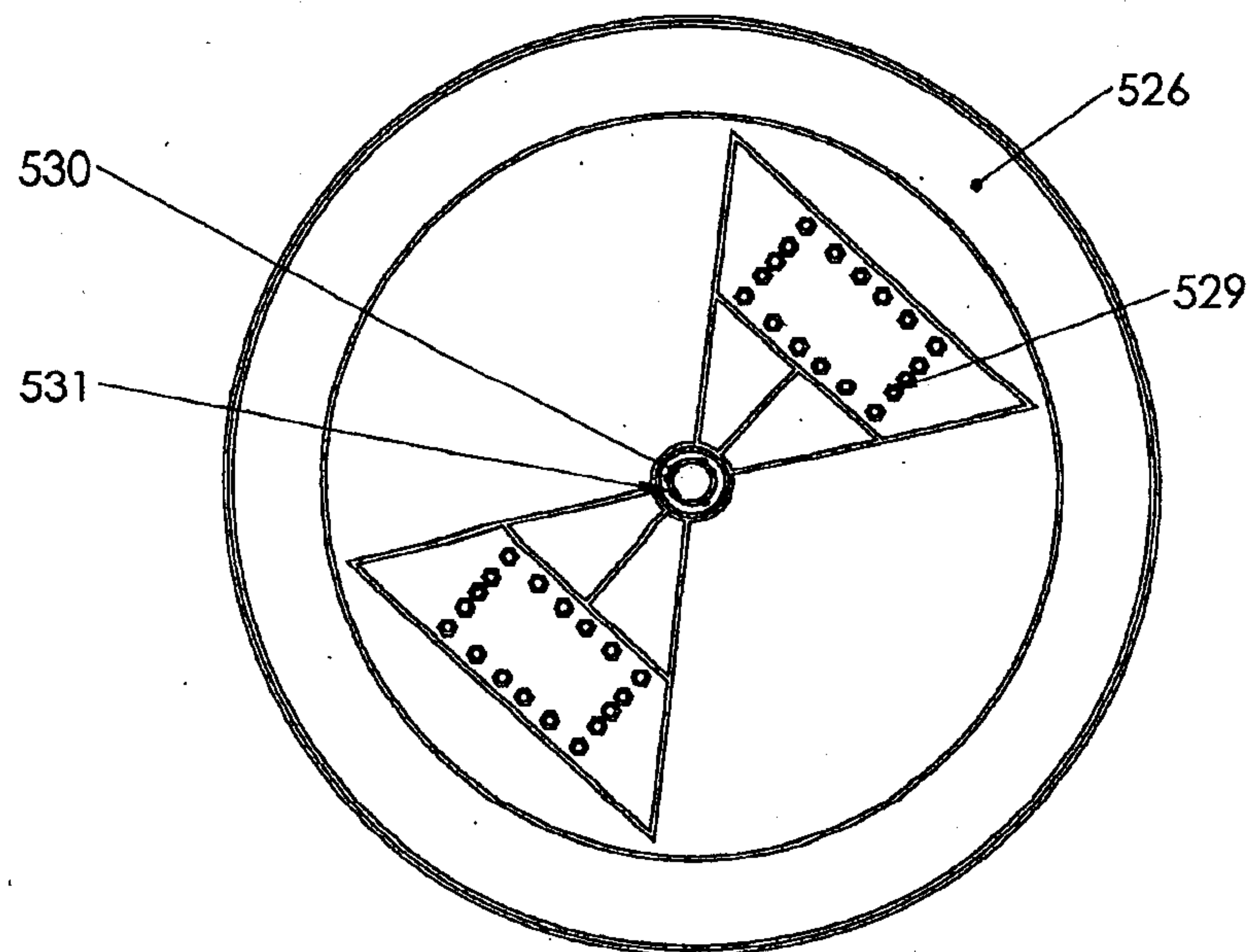
32/56

FIGURE 18A



TOP VIEW

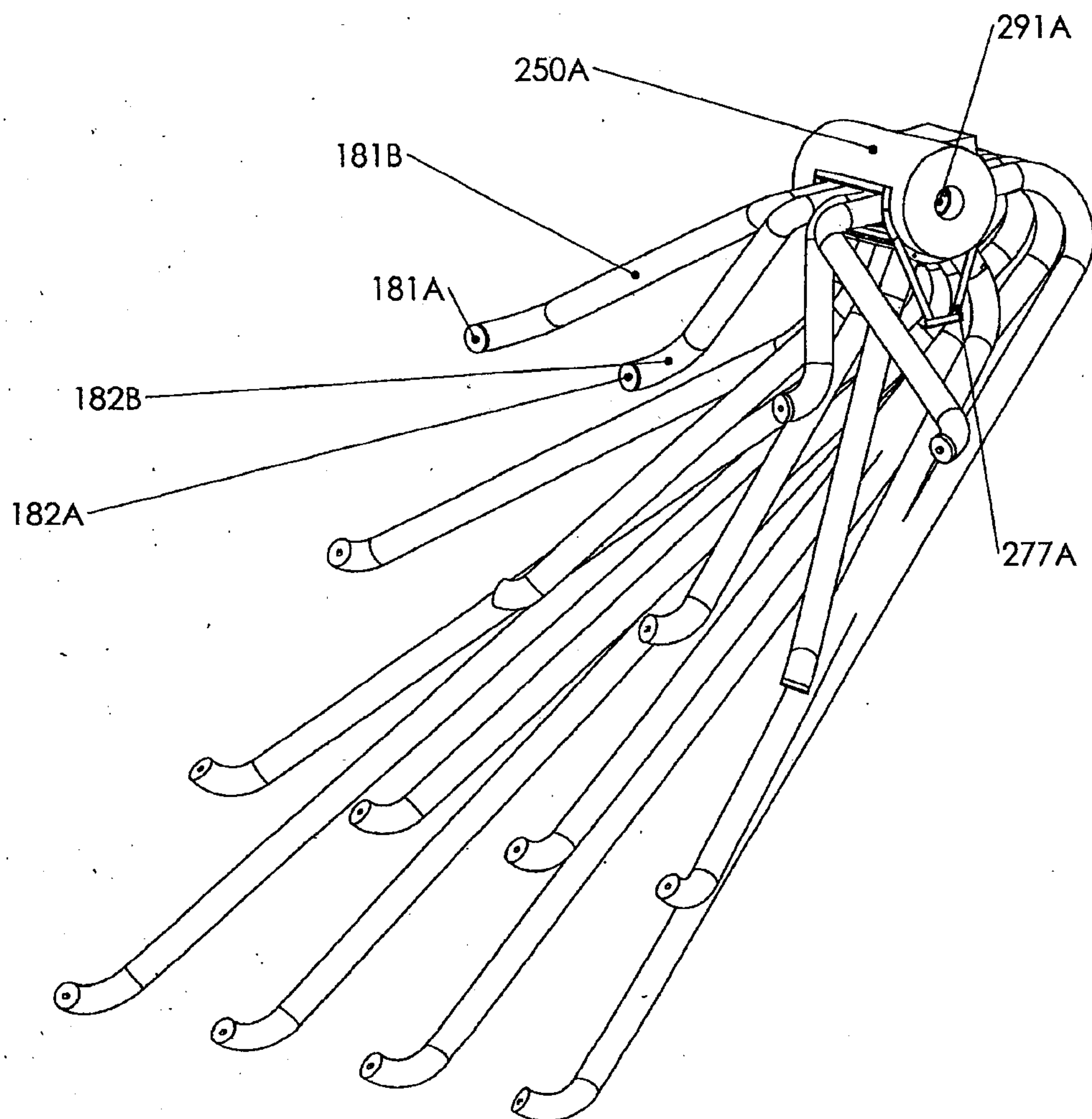
FIGURE 18B



BOTTOM VIEW

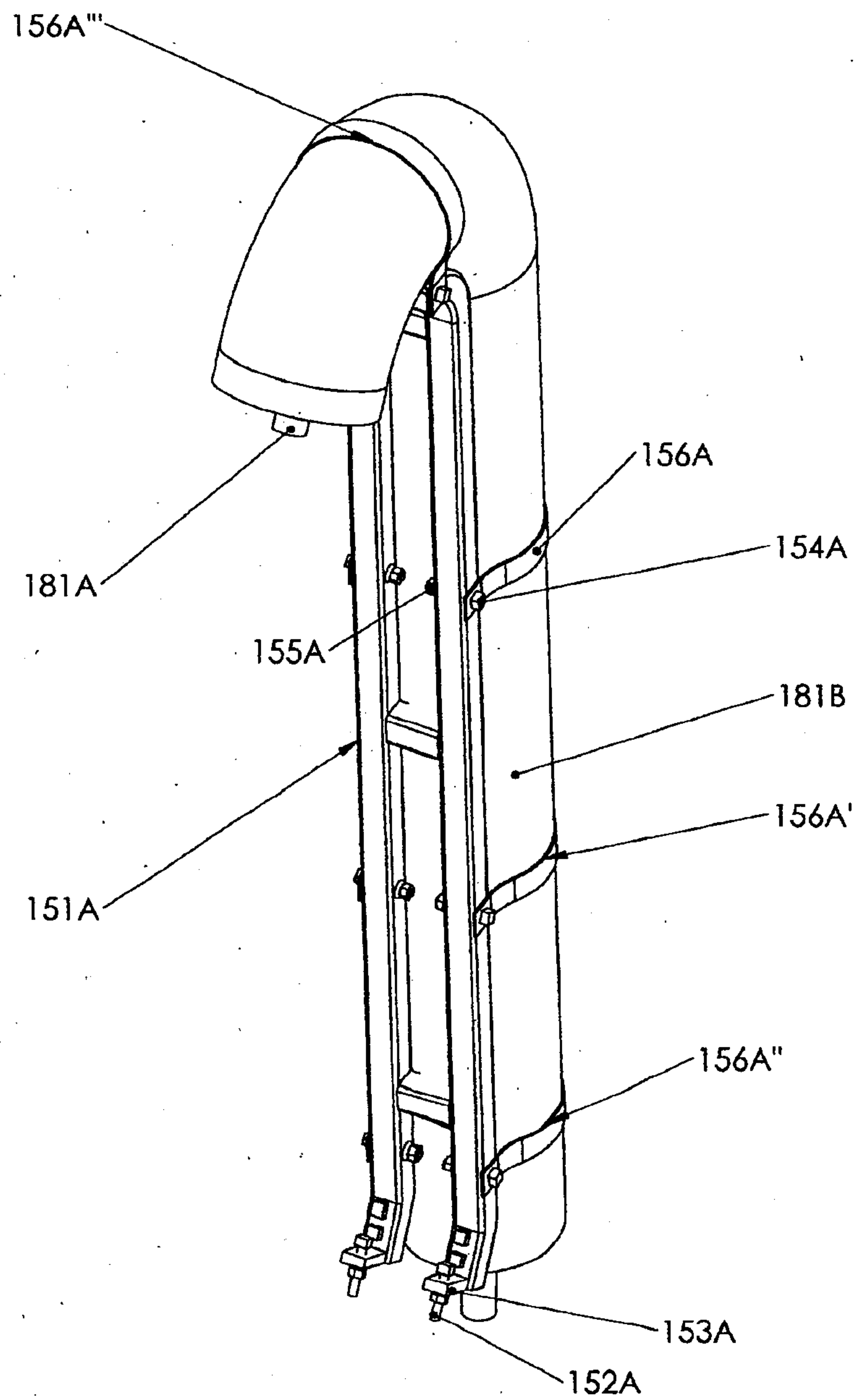
33/56

FIGURE 19



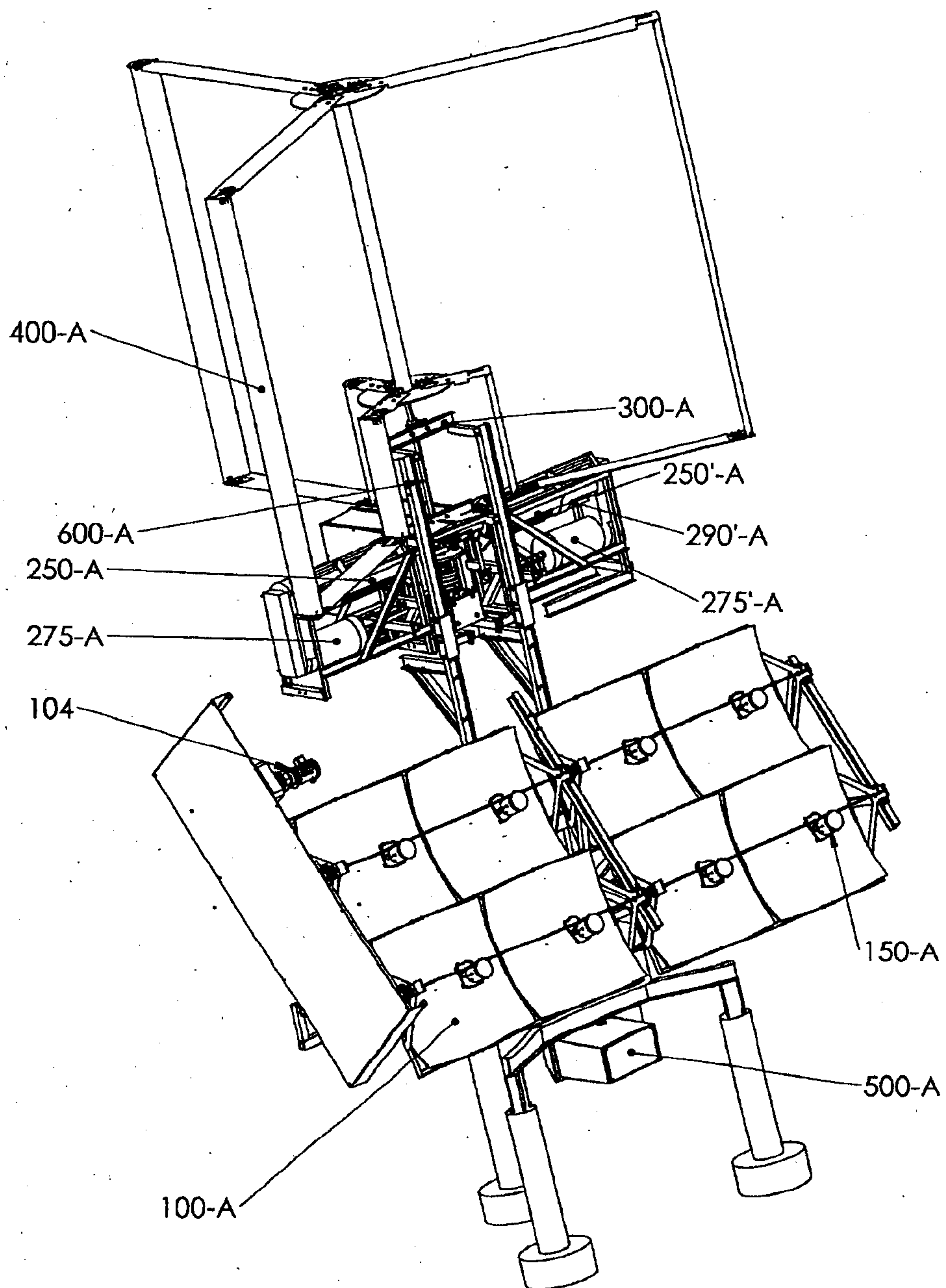
34/56

FIGURE 20



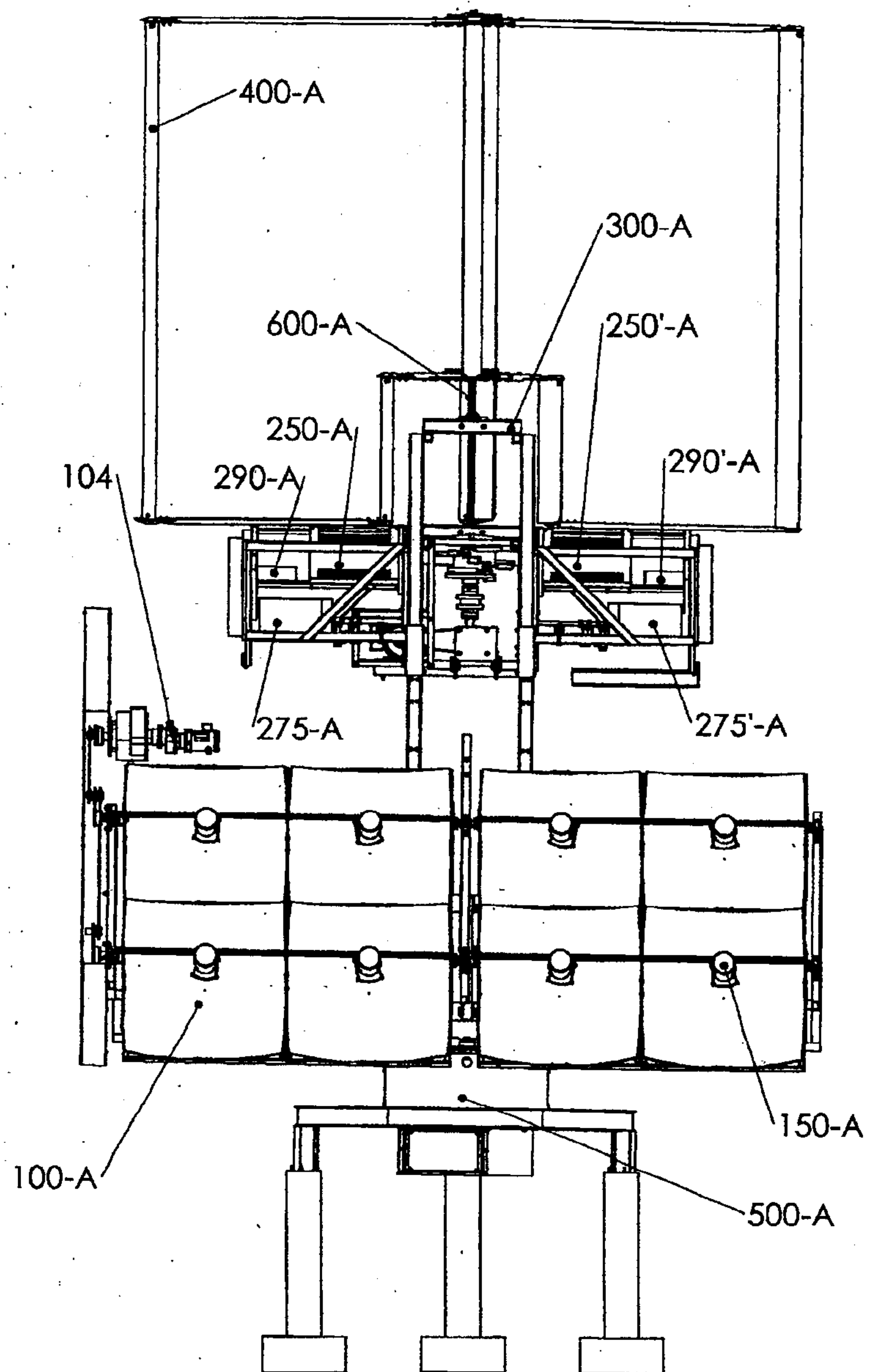
35/56

FIGURE 21



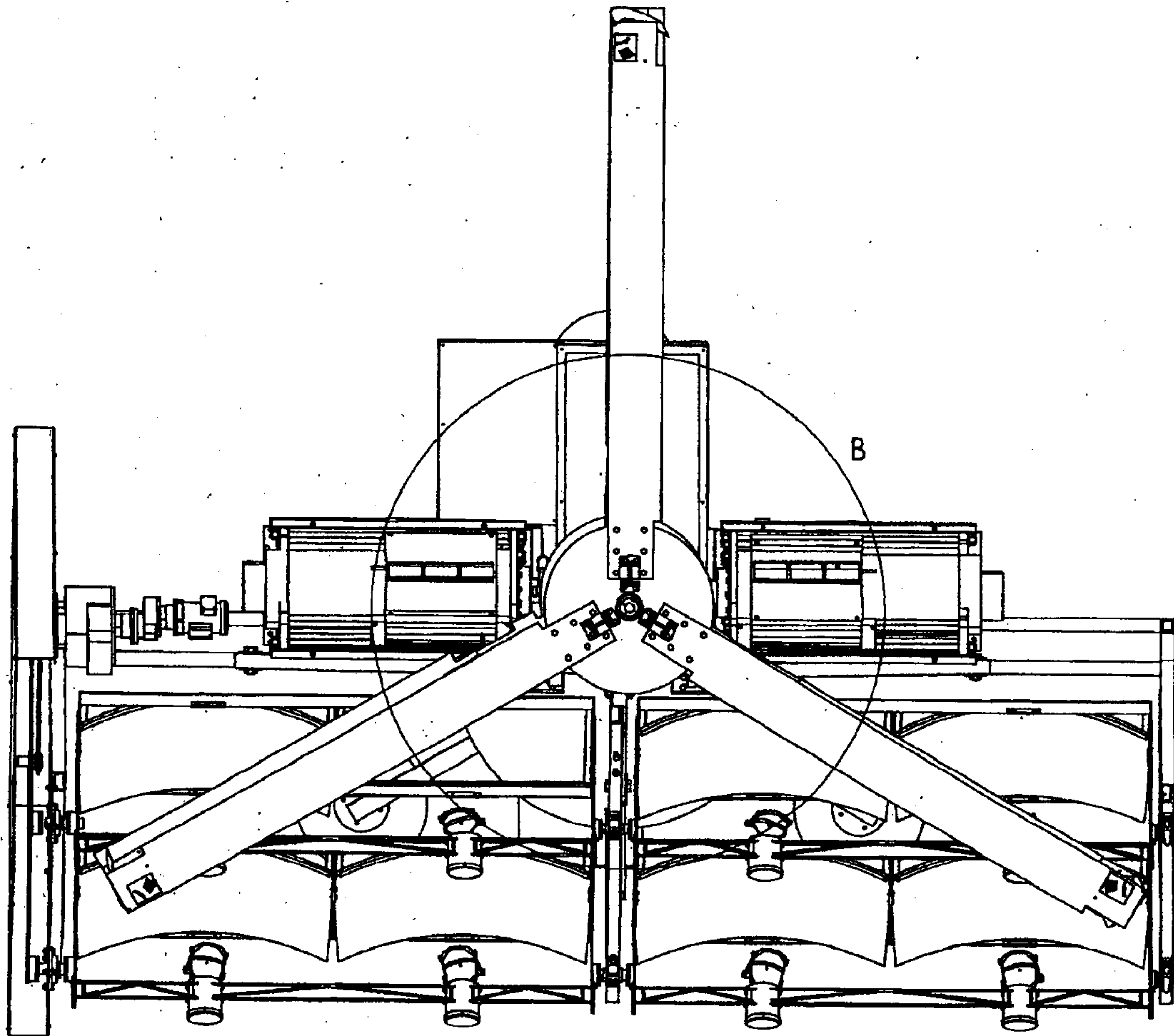
36/56

FIGURE 22



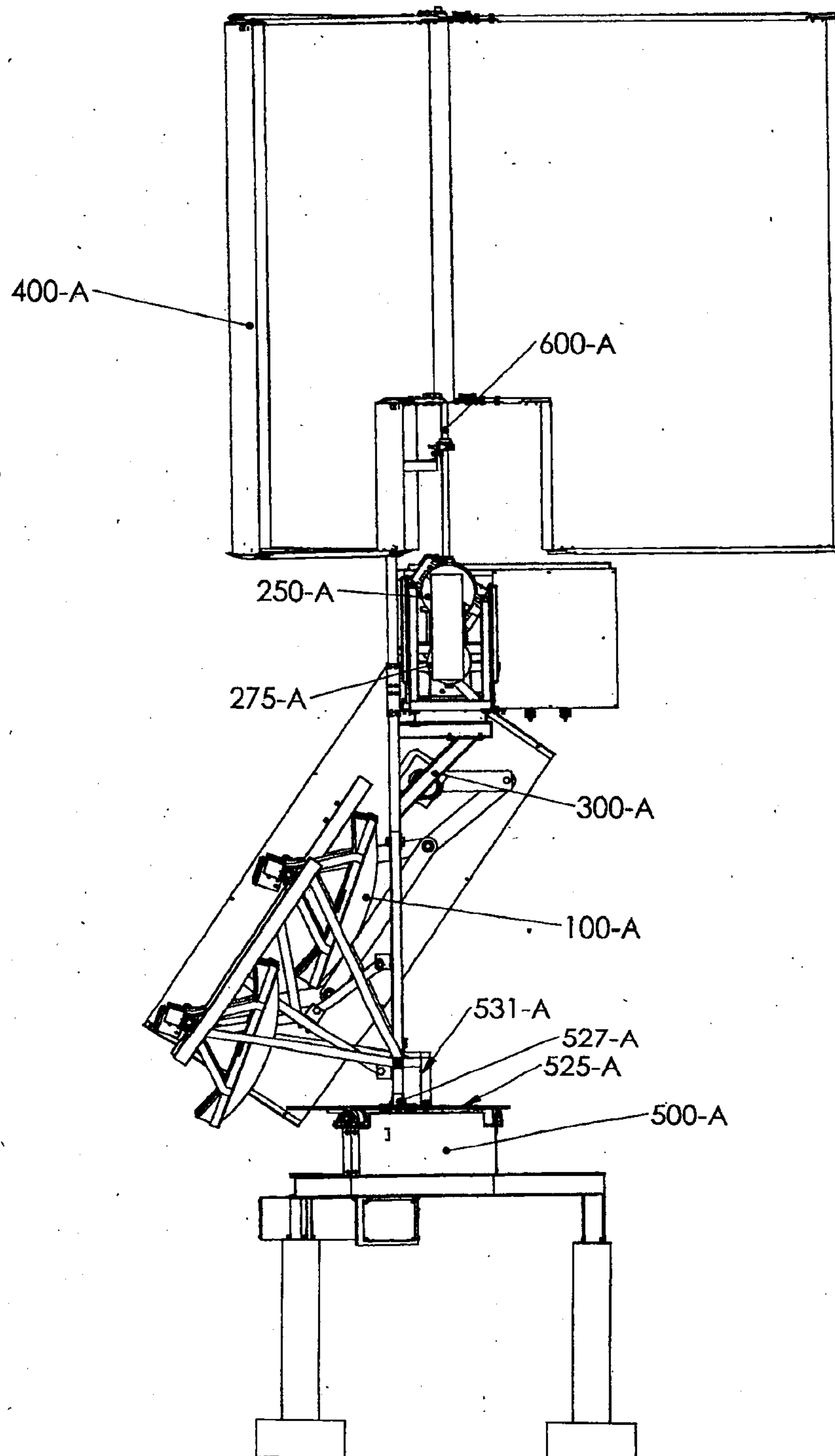
37/56

FIGURE 23



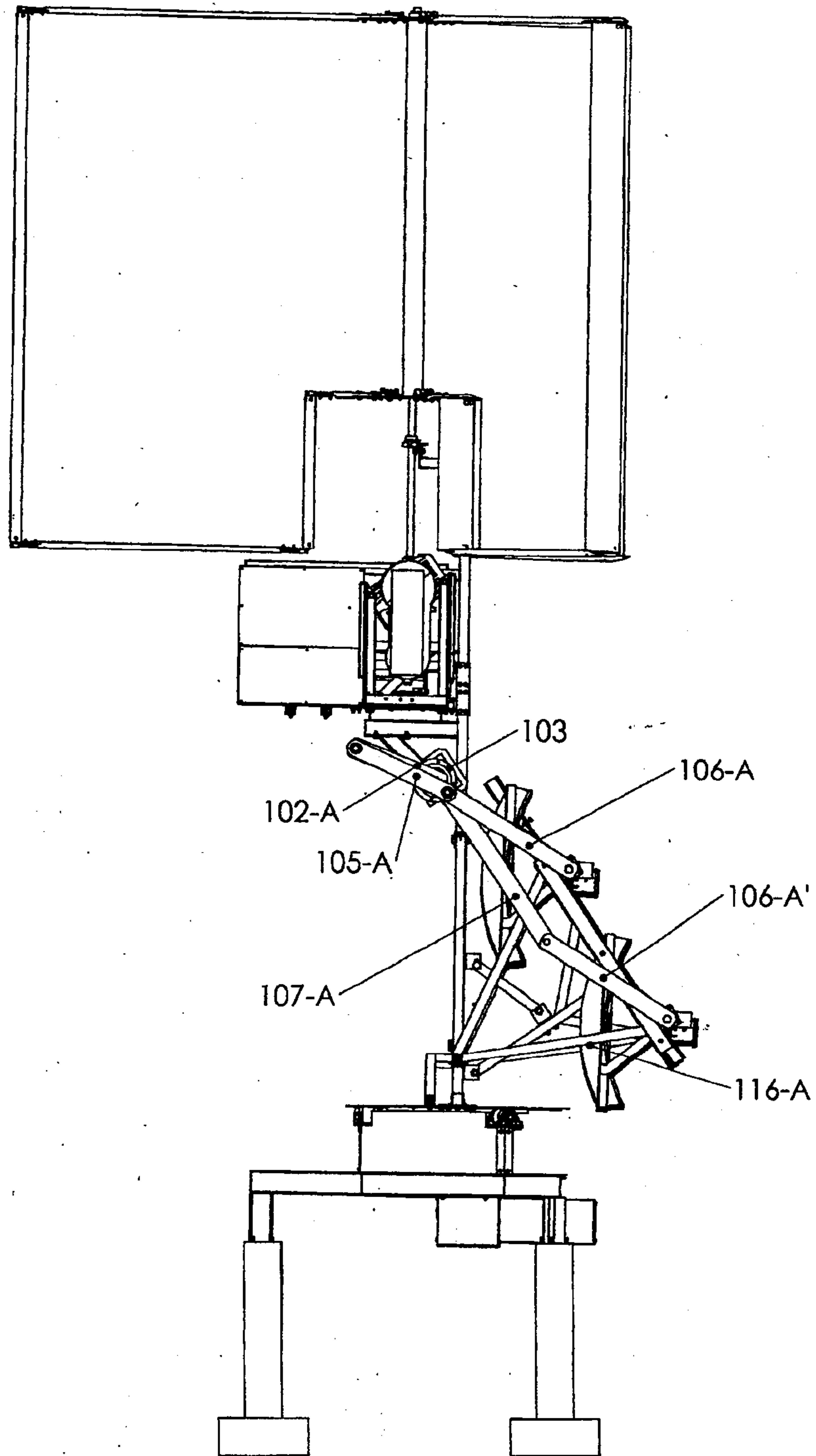
38/56

FIGURE 24A



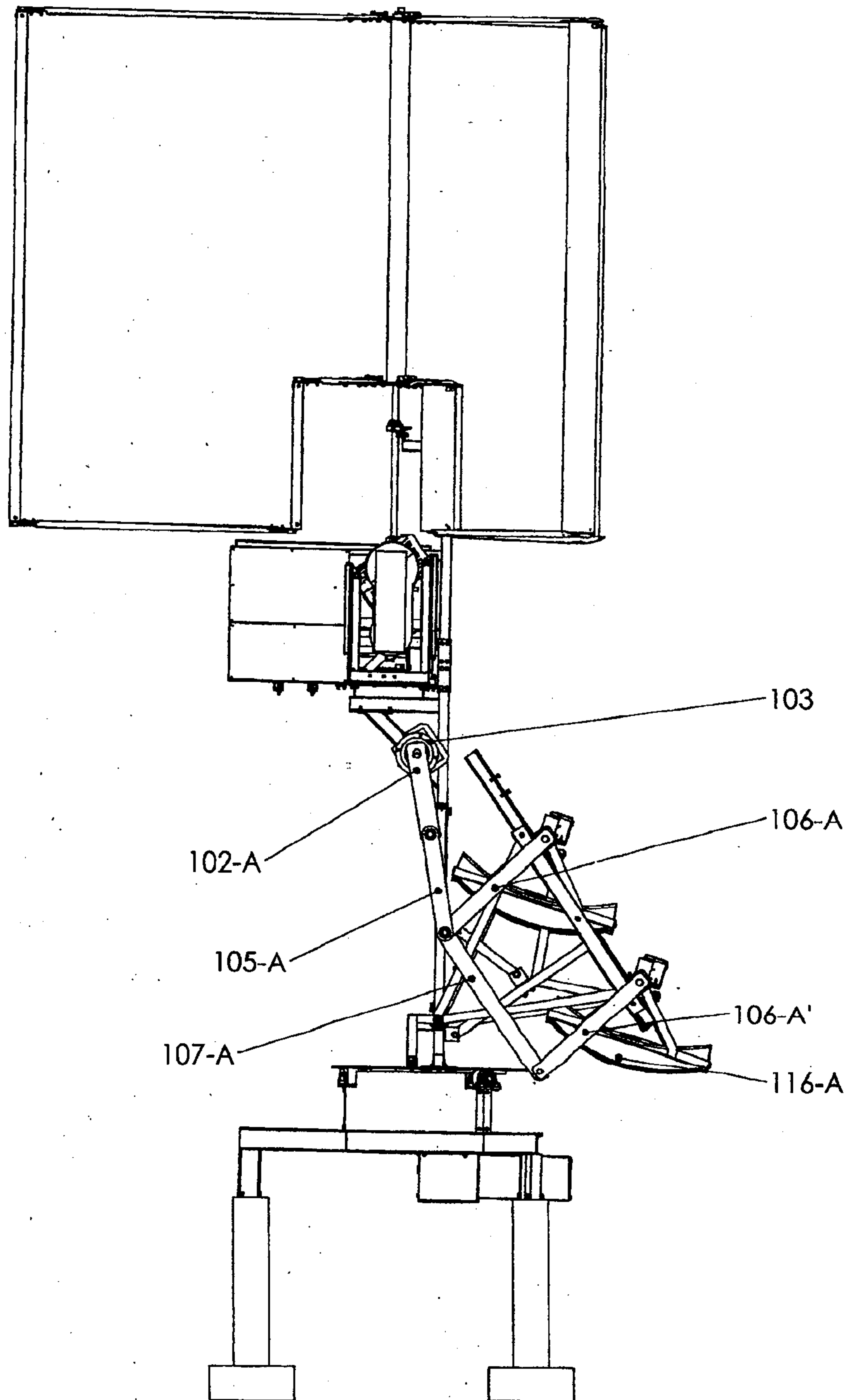
39/56

FIGURE 24B



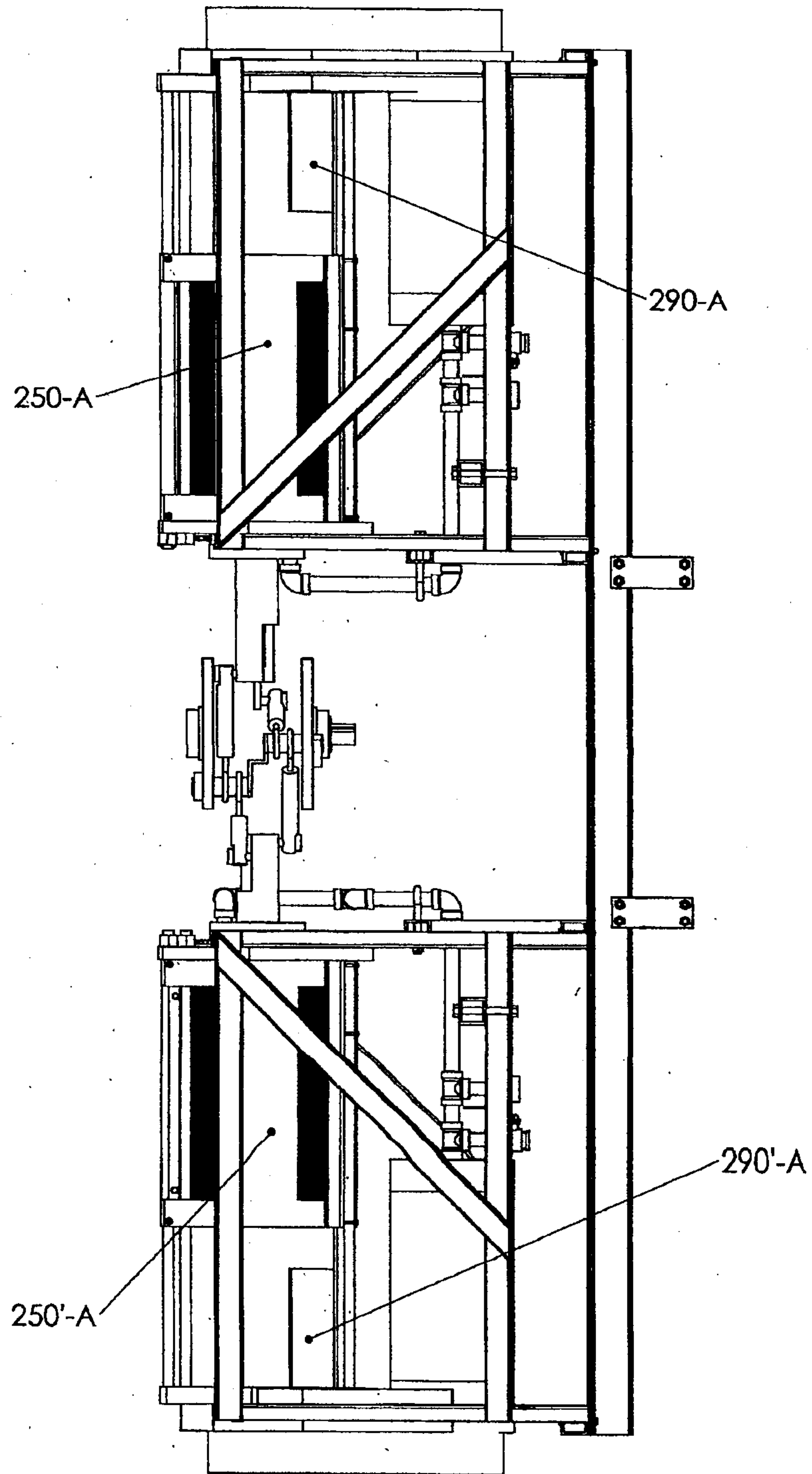
40/56

FIGURE 24C



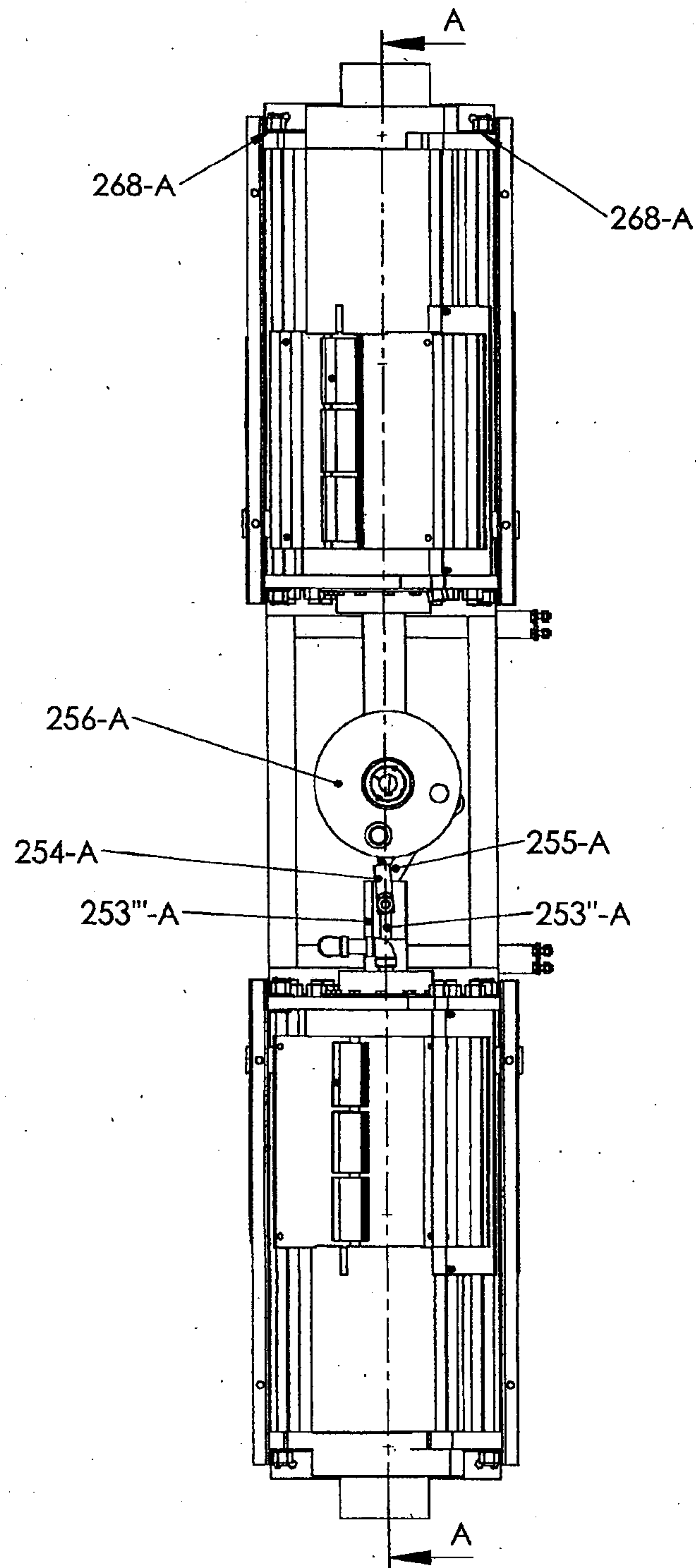
41/56

FIGURE 25A



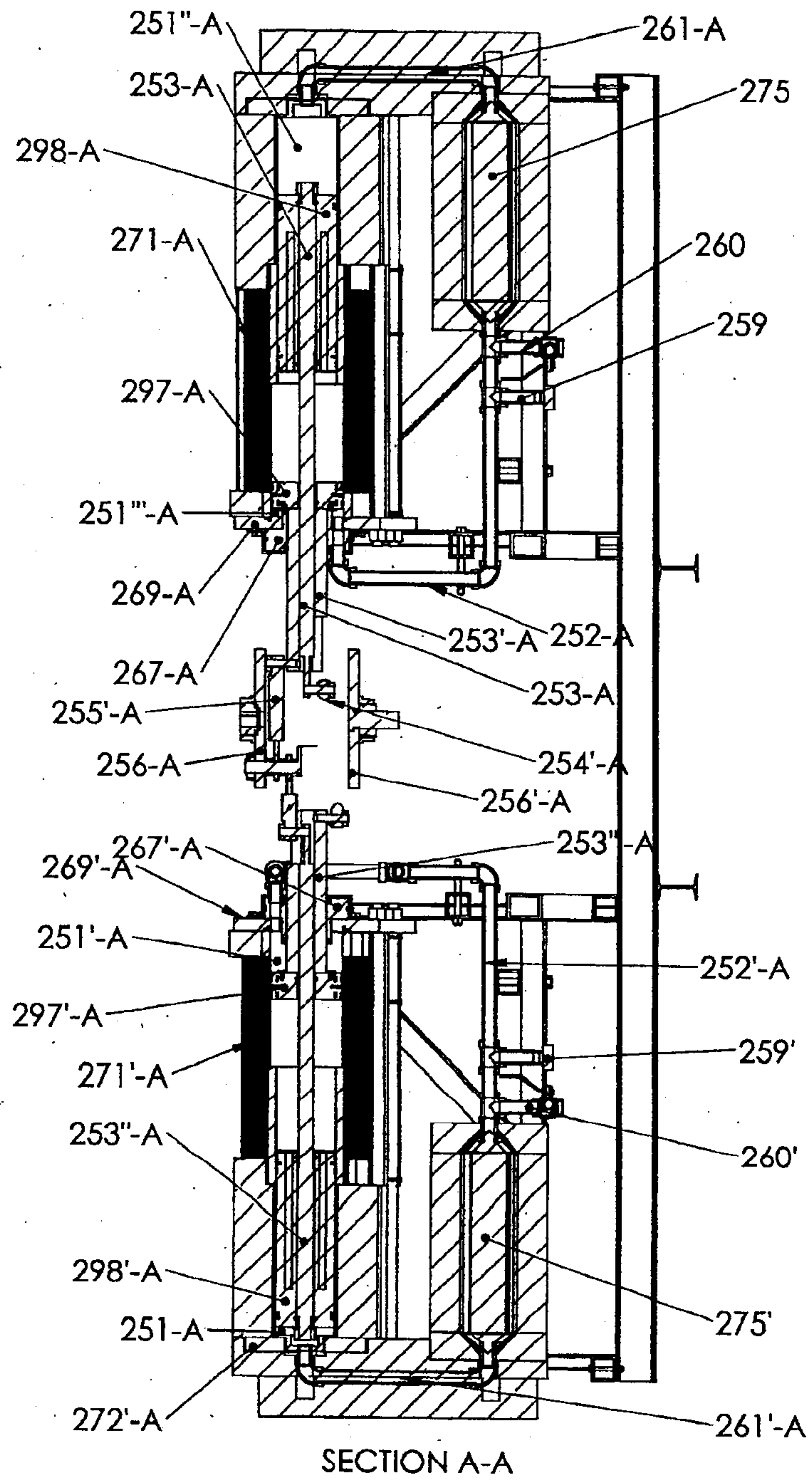
42/56

FIGURE 25B



43/56

FIGURE 25C



44/56

FIGURE 26A

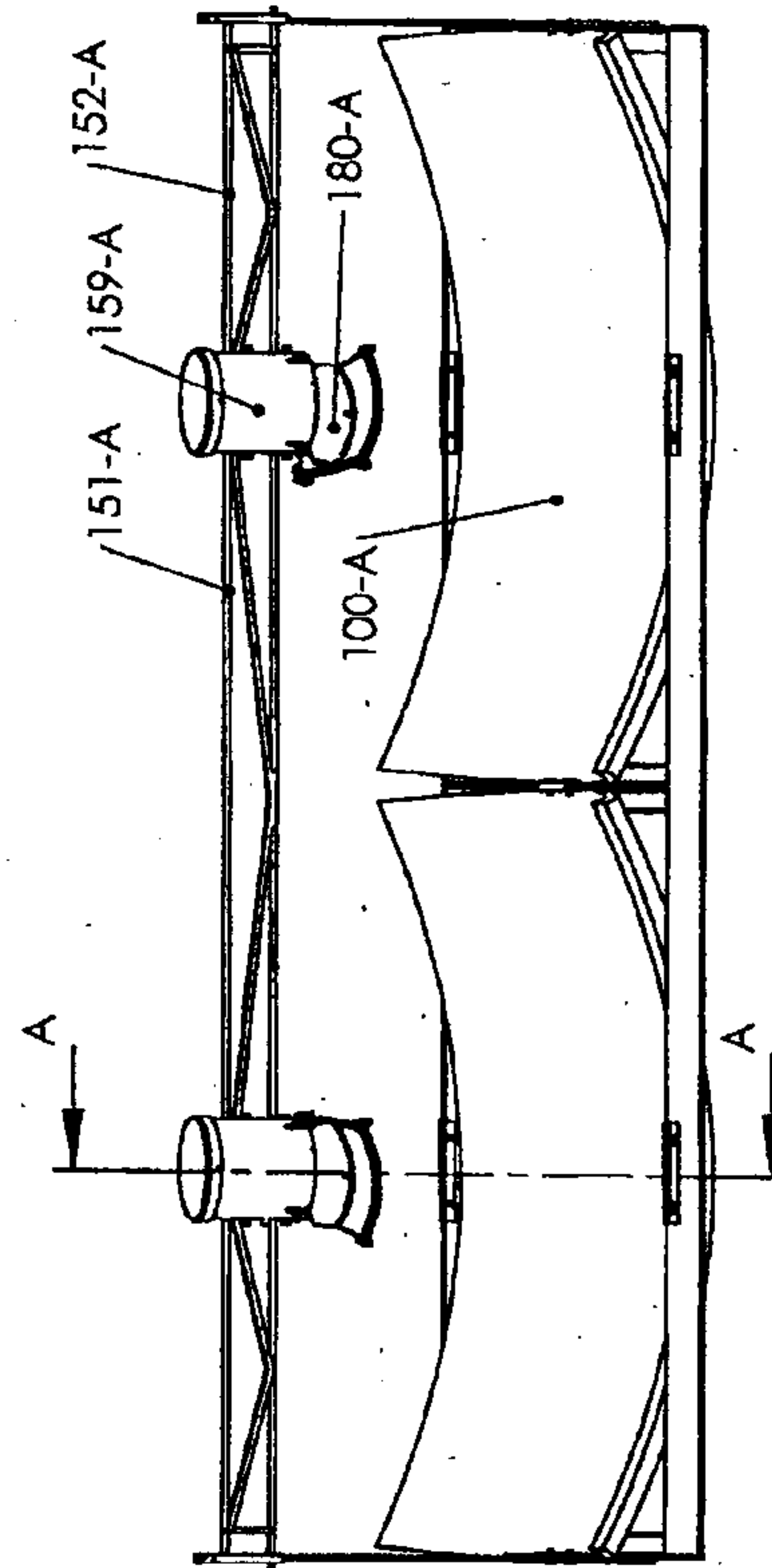
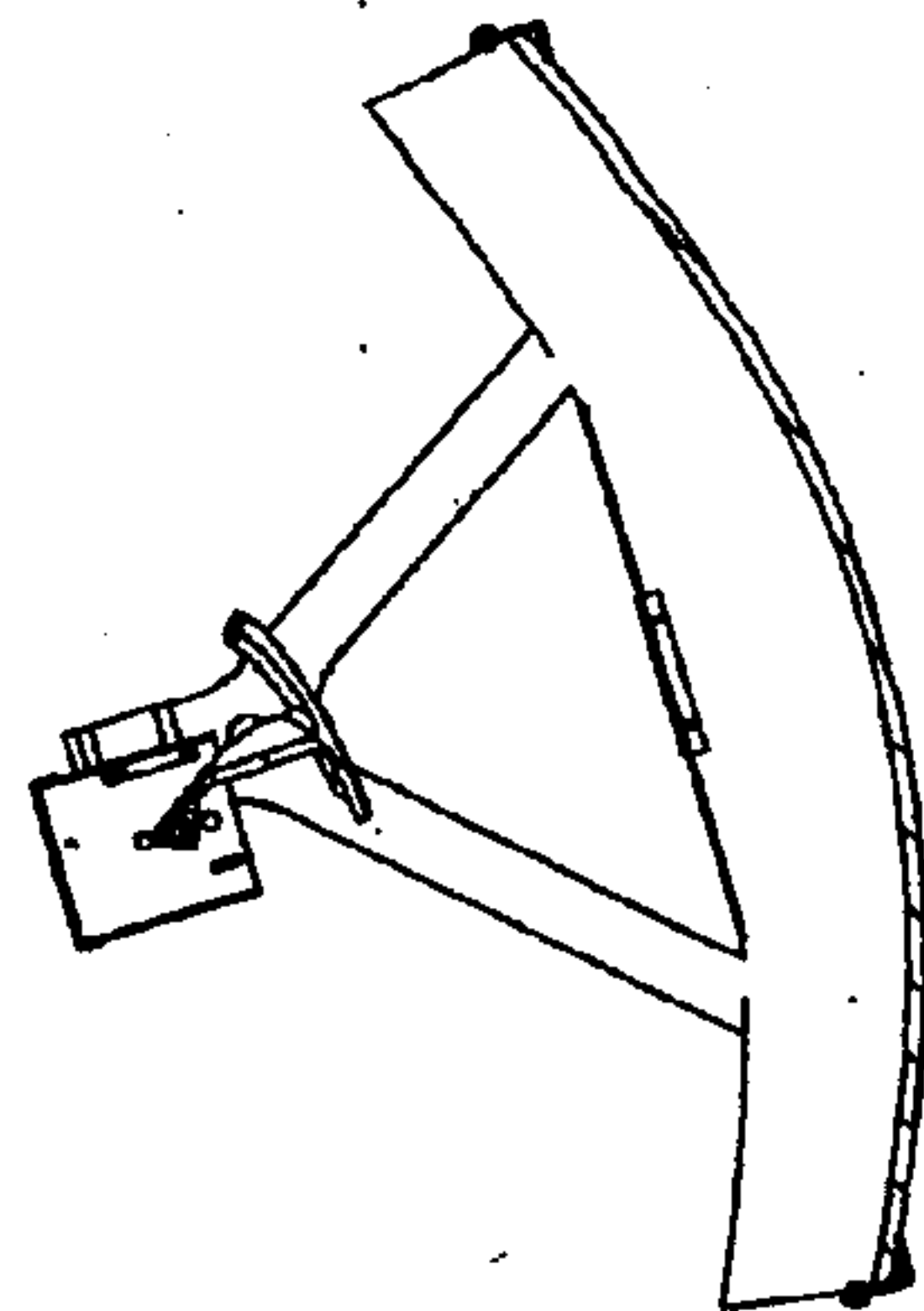


FIGURE 26B



SECTION A-A

45/56

FIGURE 26C

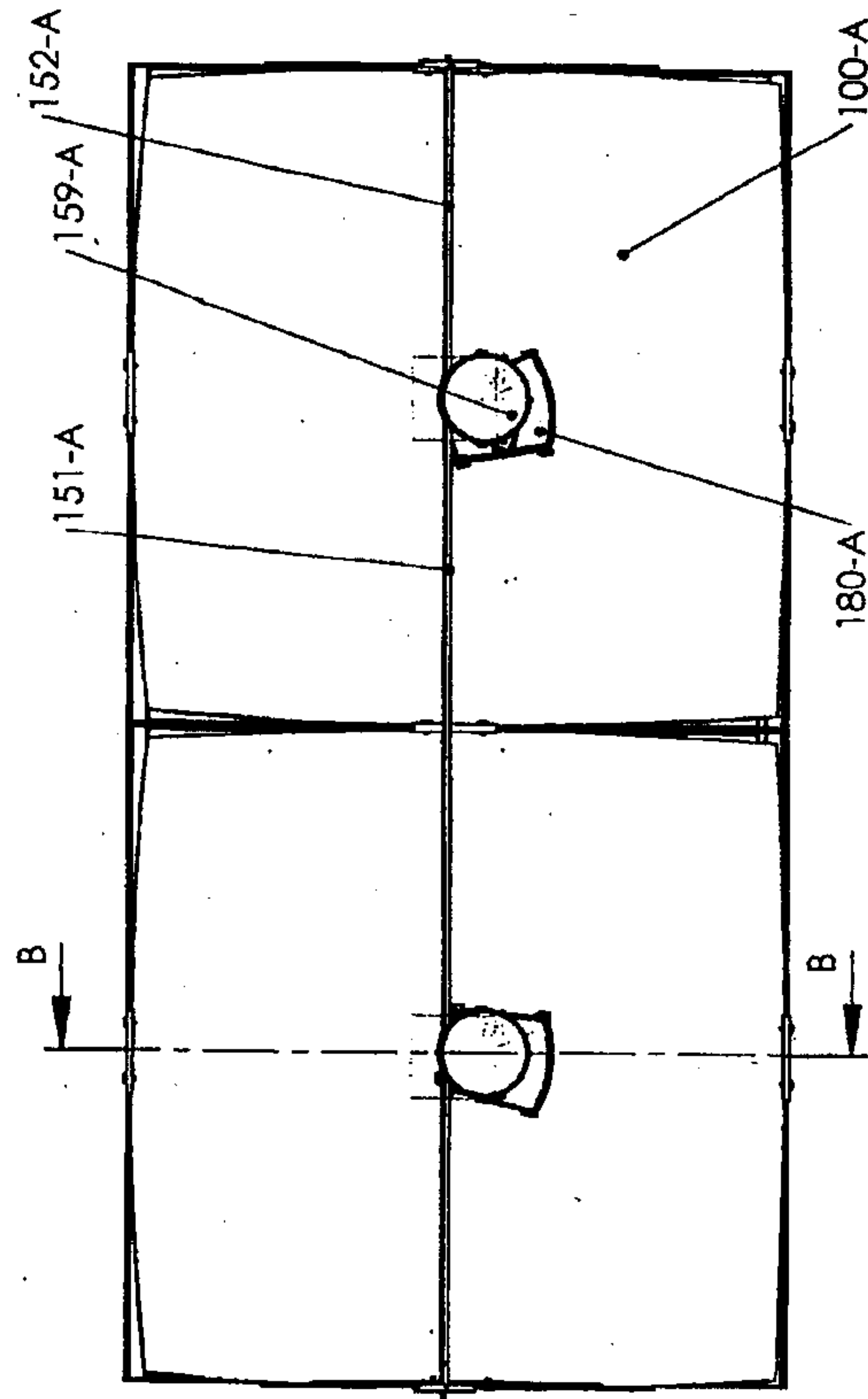
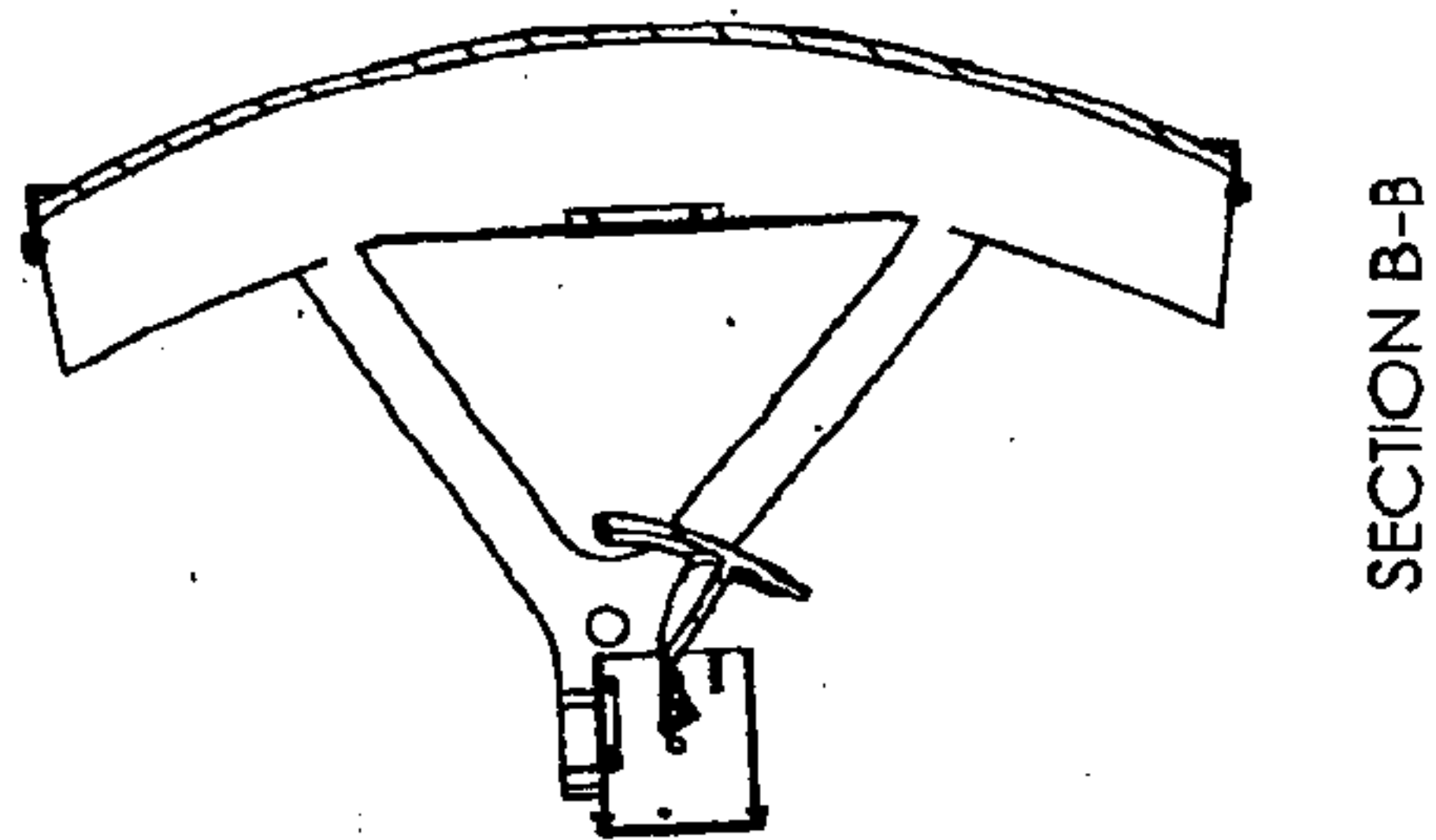
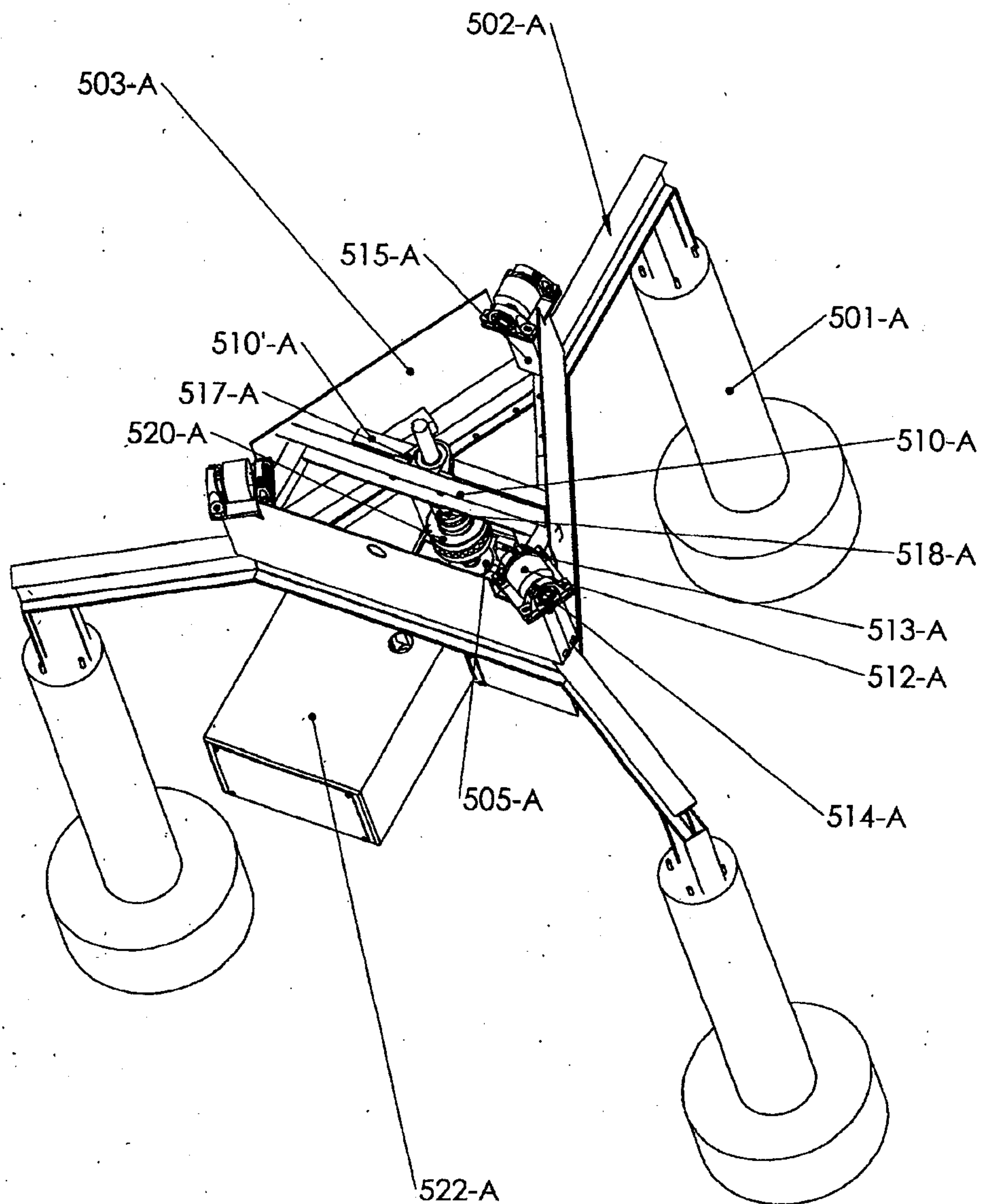


FIGURE 26D



46/56

FIGURE 27



47/56

FIGURE 28A

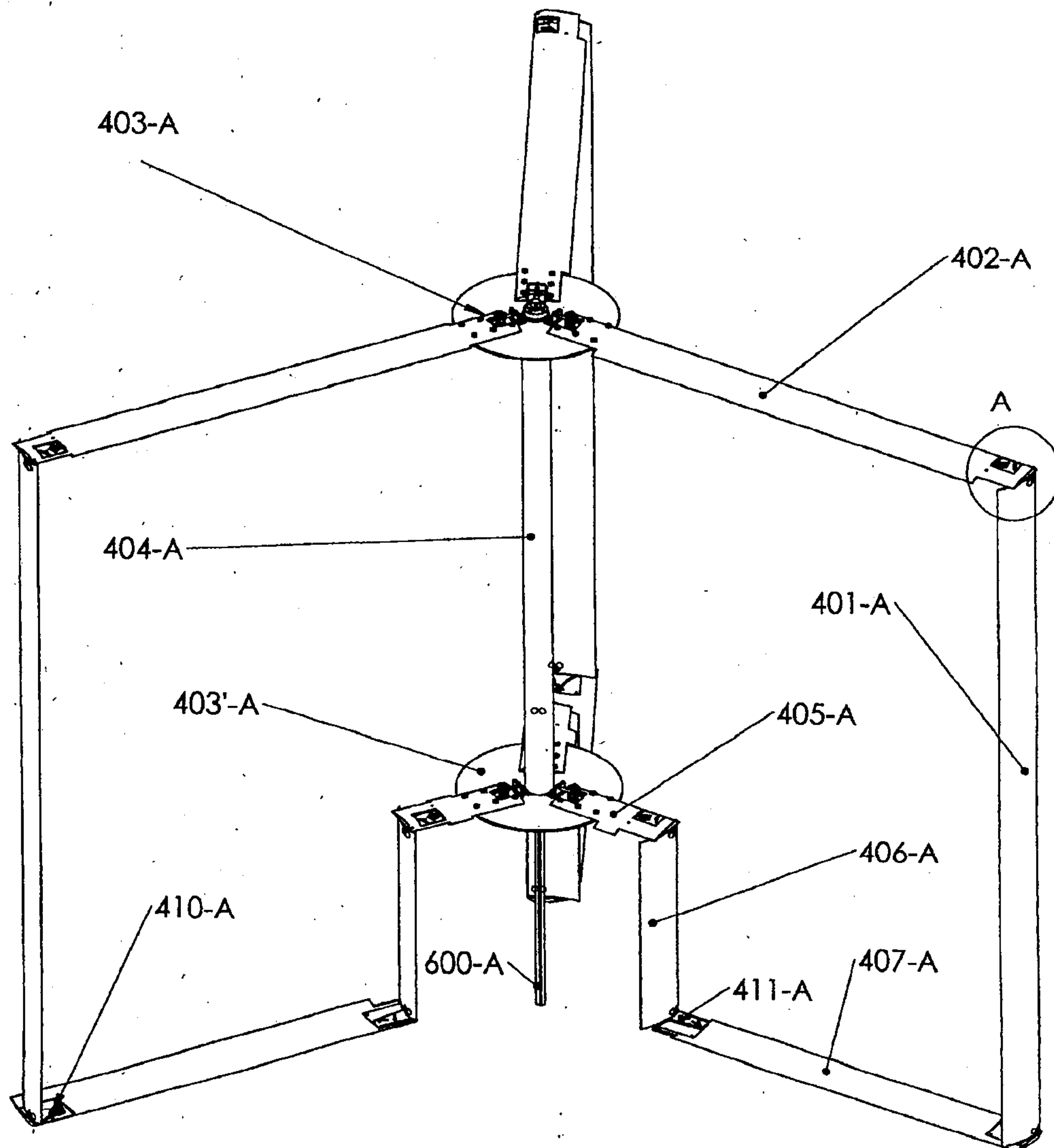
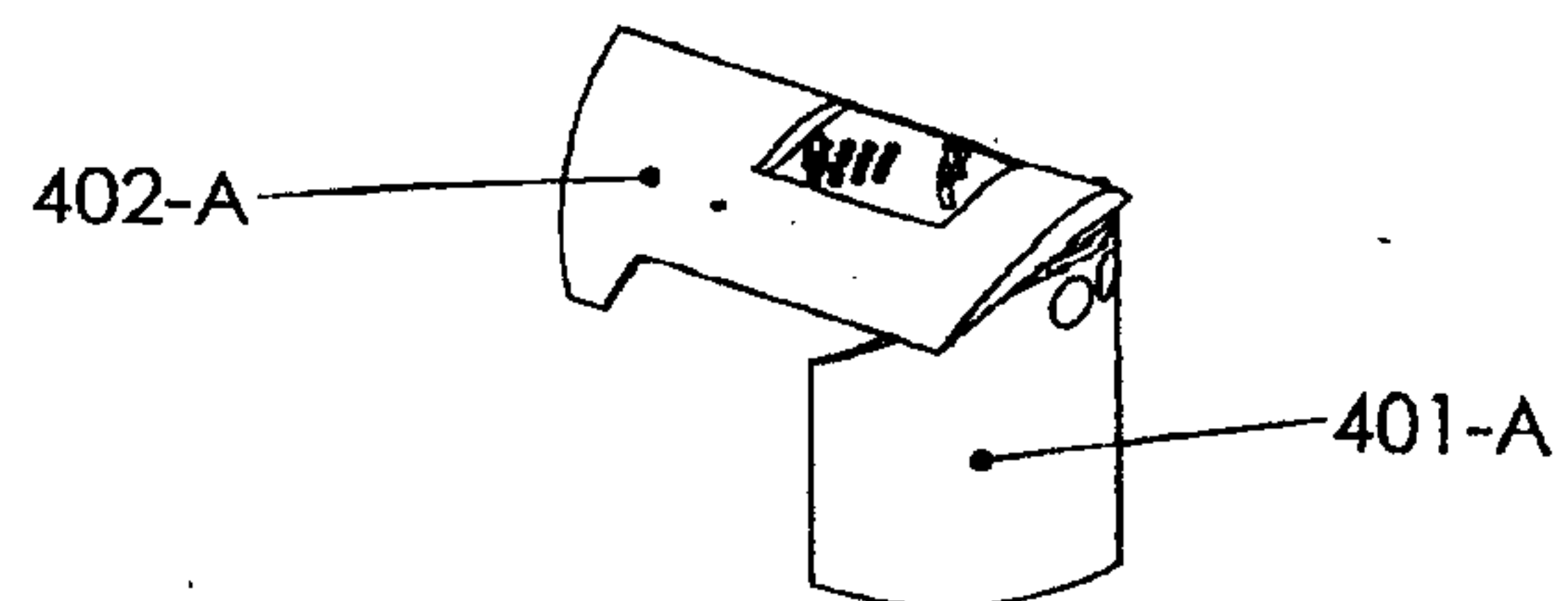


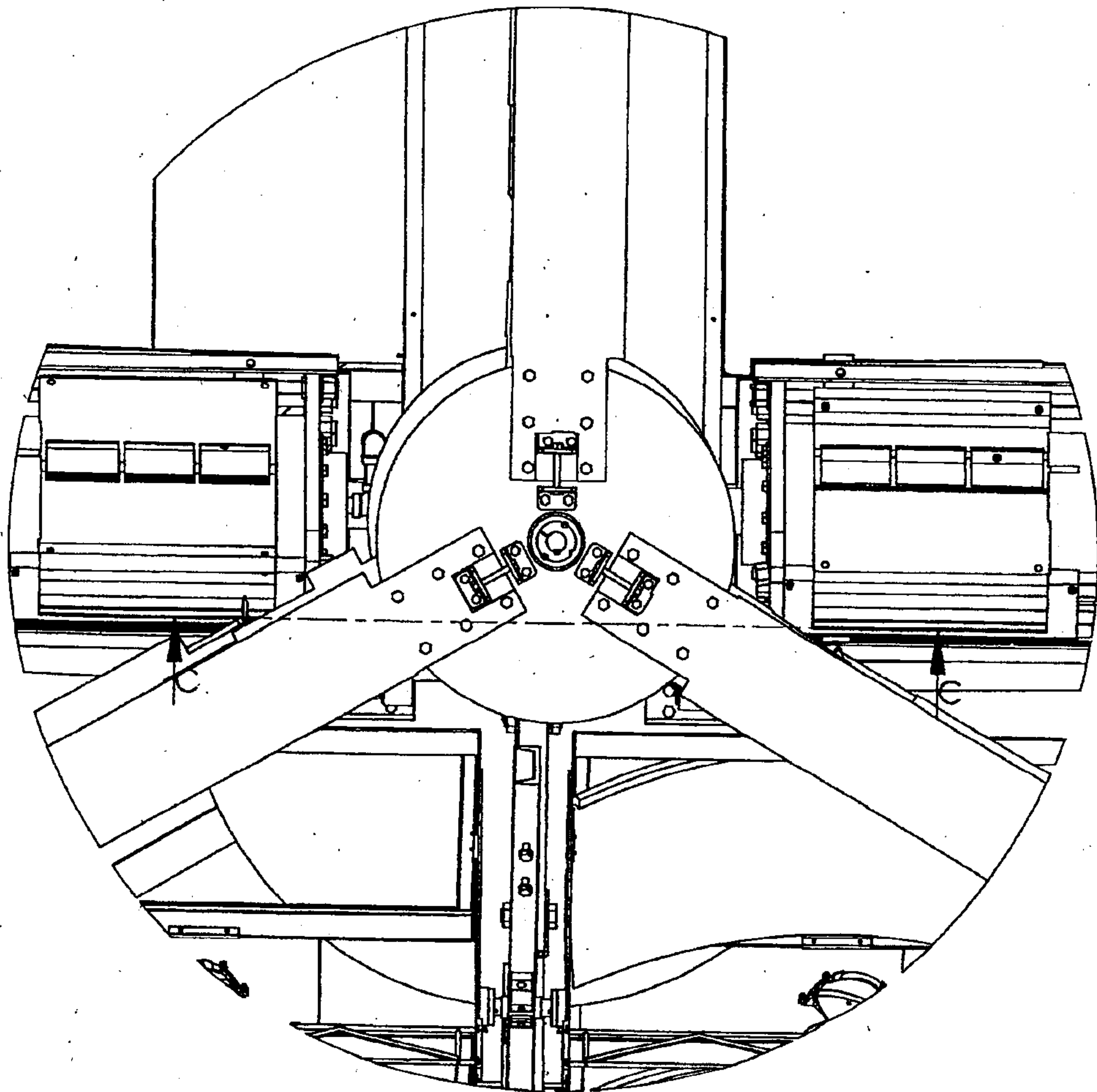
FIGURE 28B



DETAIL A

48/56

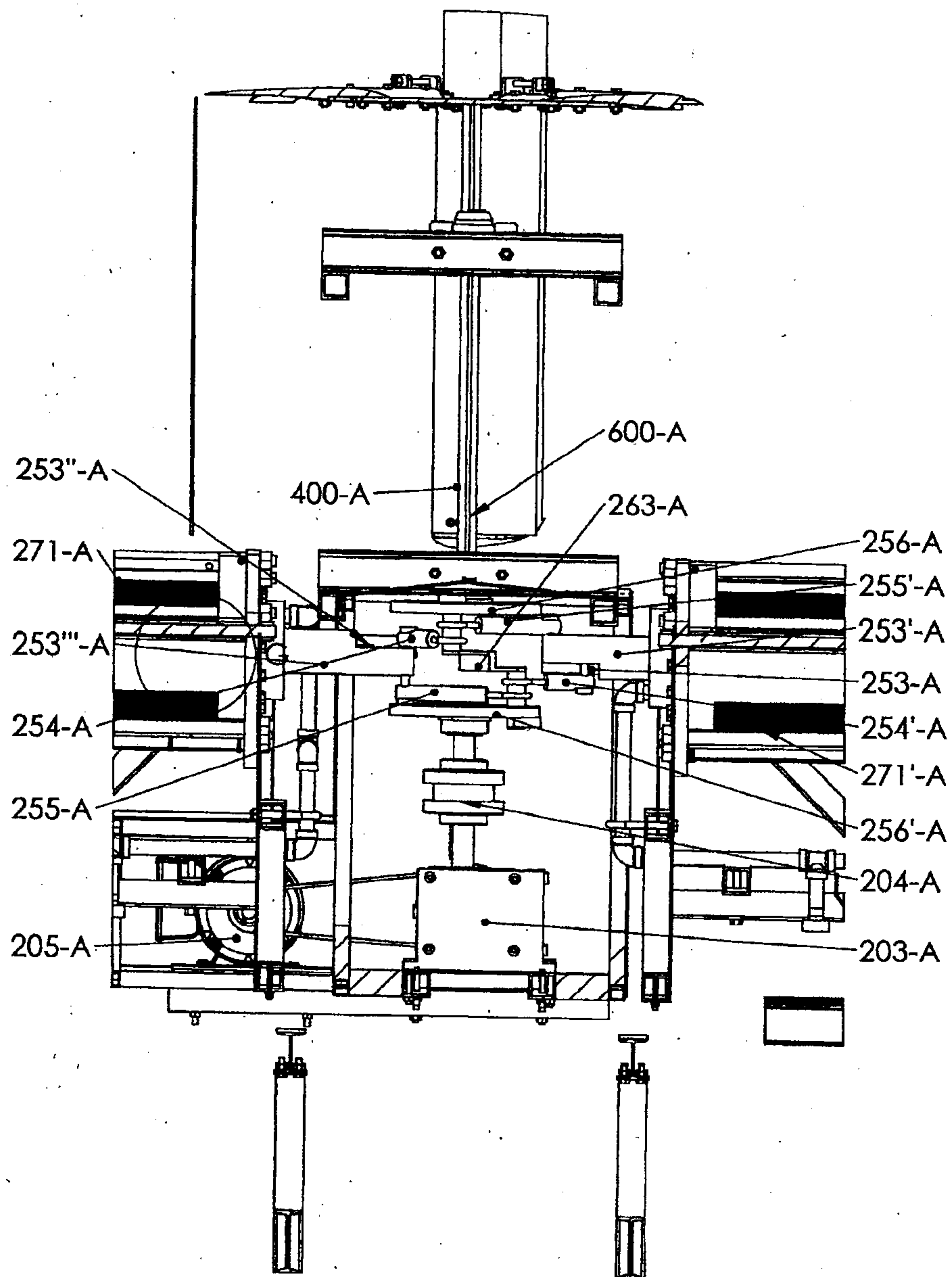
FIGURE 29A



DETAIL B

49/56

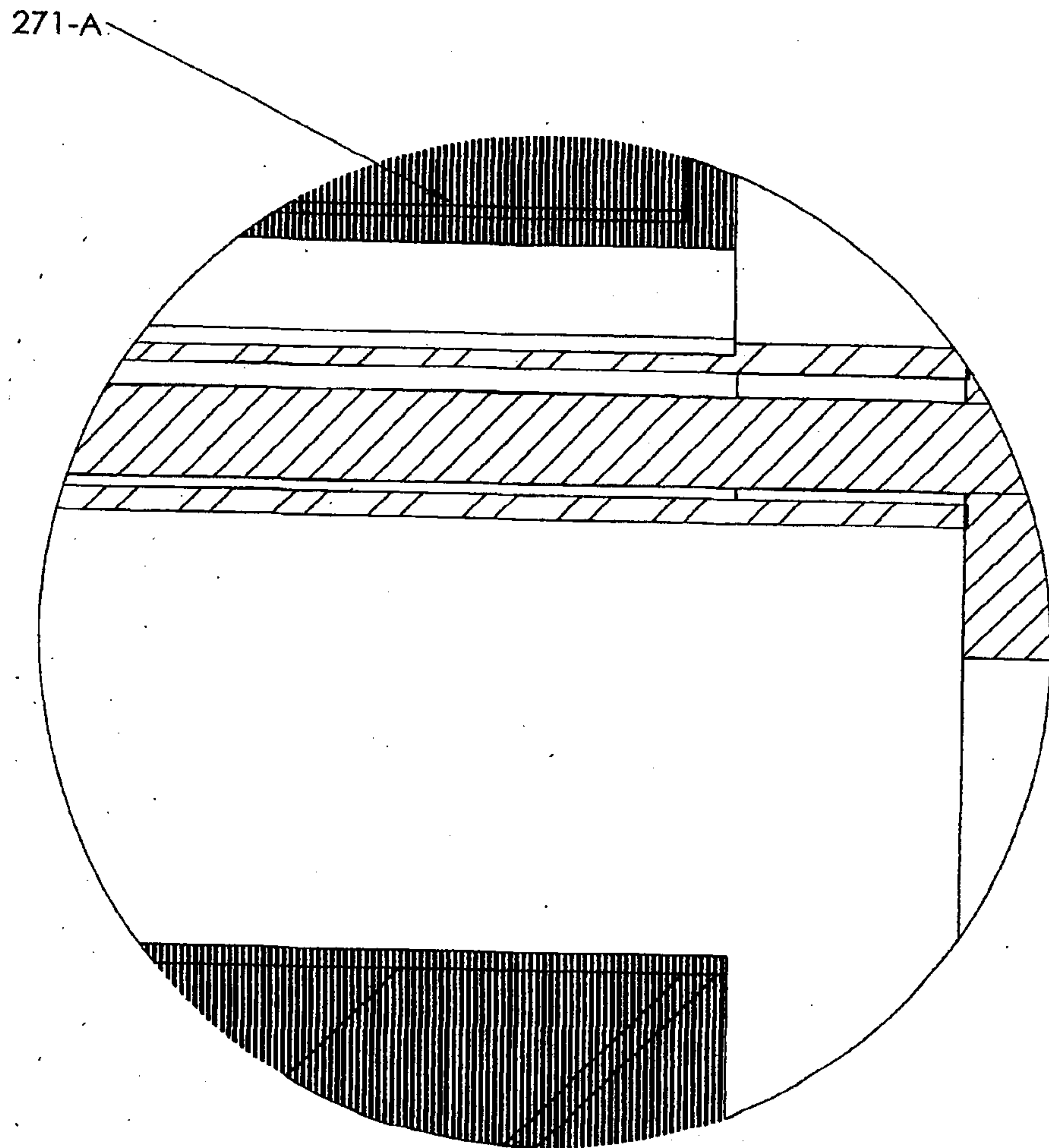
FIGURE 29B



SECTION C-C

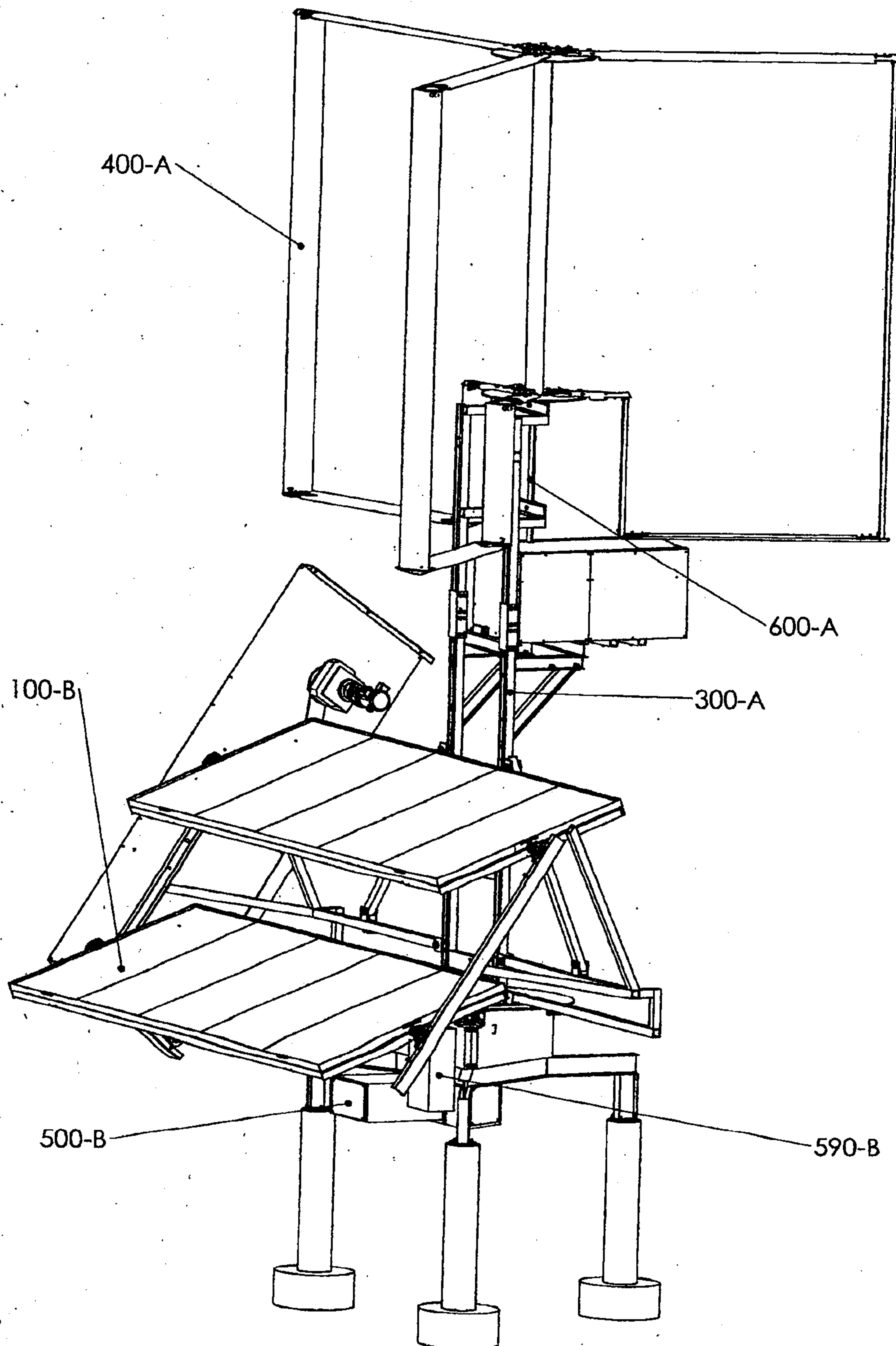
50/56

FIGURE 29C



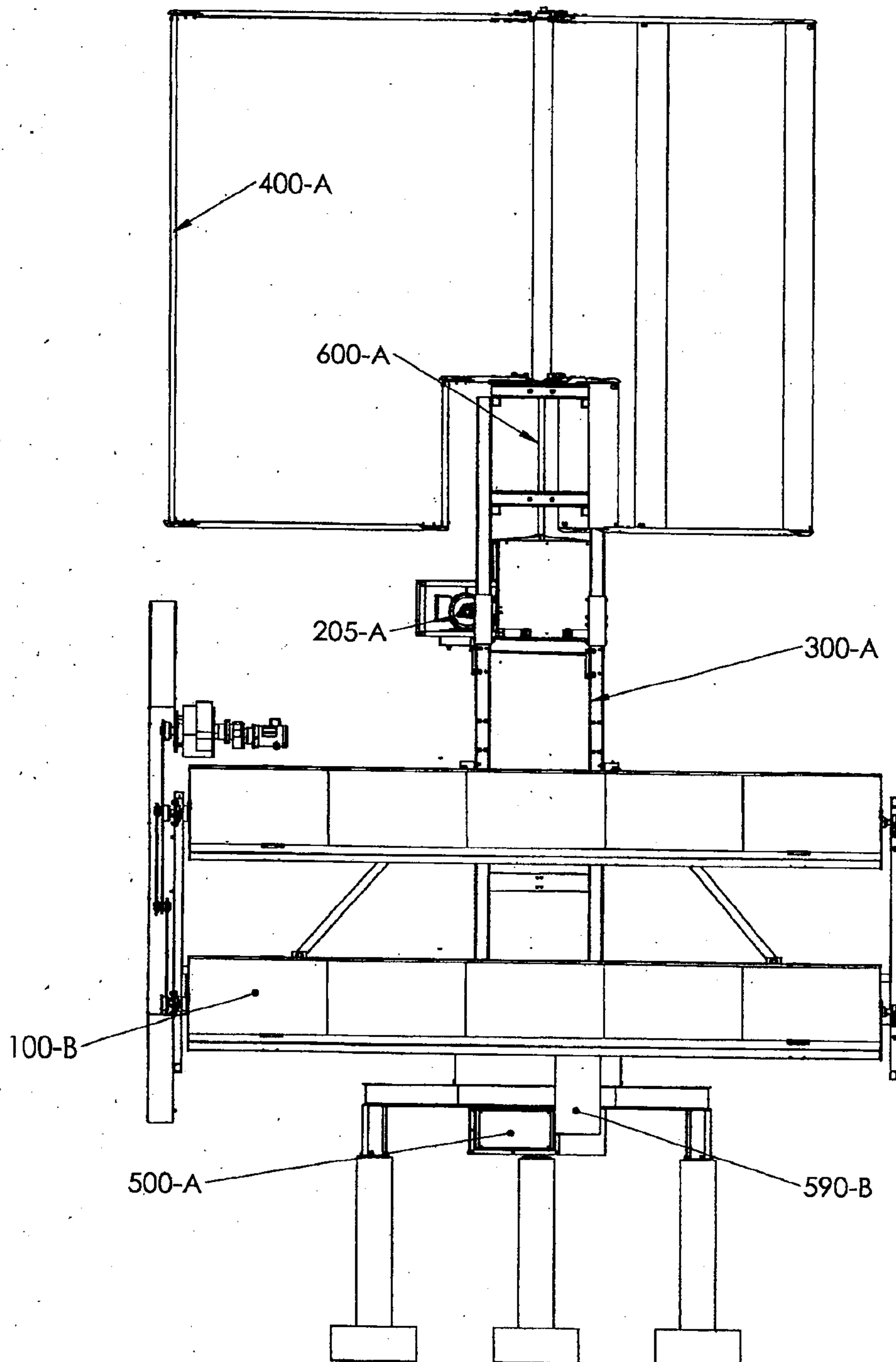
51/56

FIGURE 30



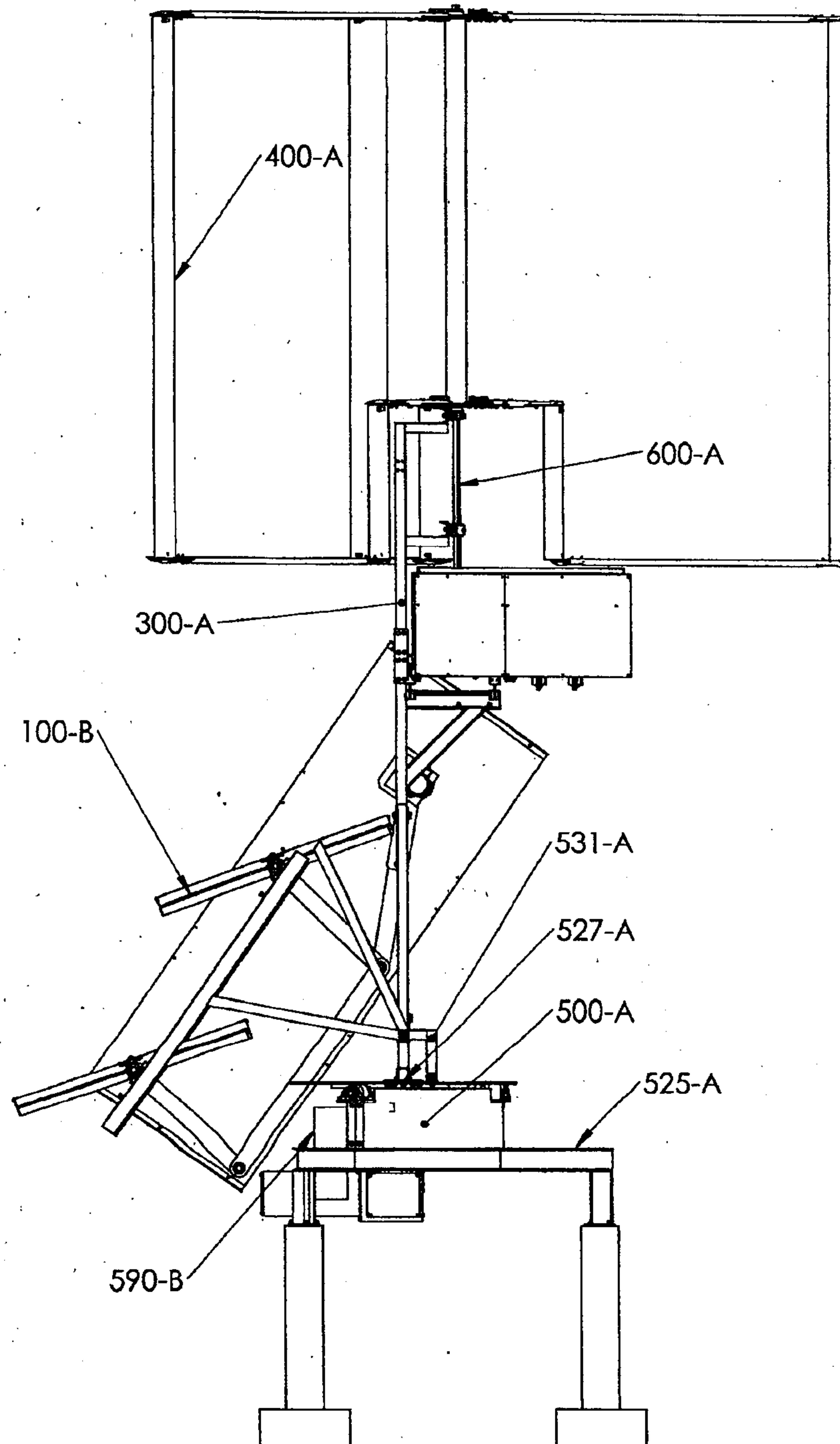
52/56

FIGURE 31



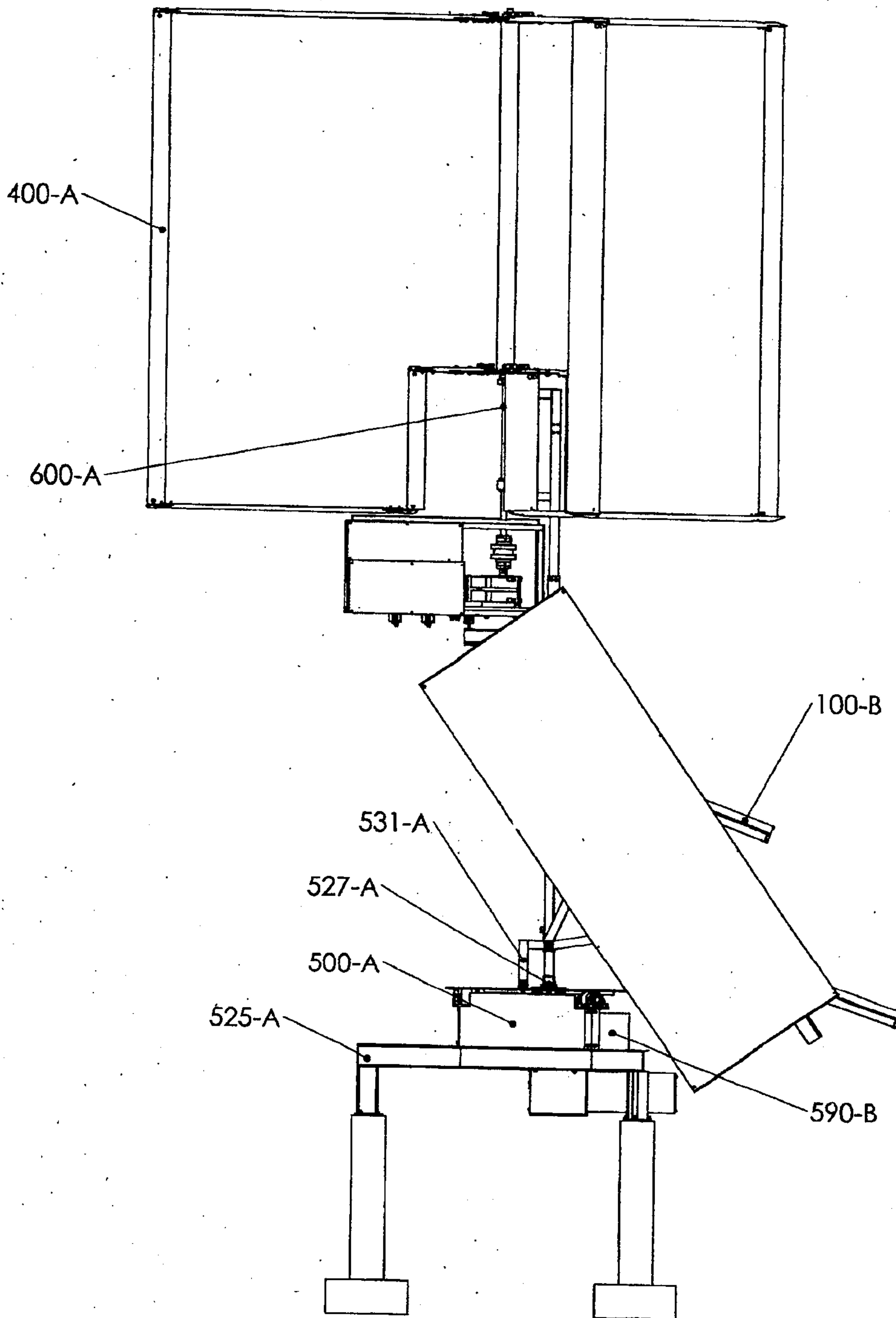
53/56

FIGURE 32



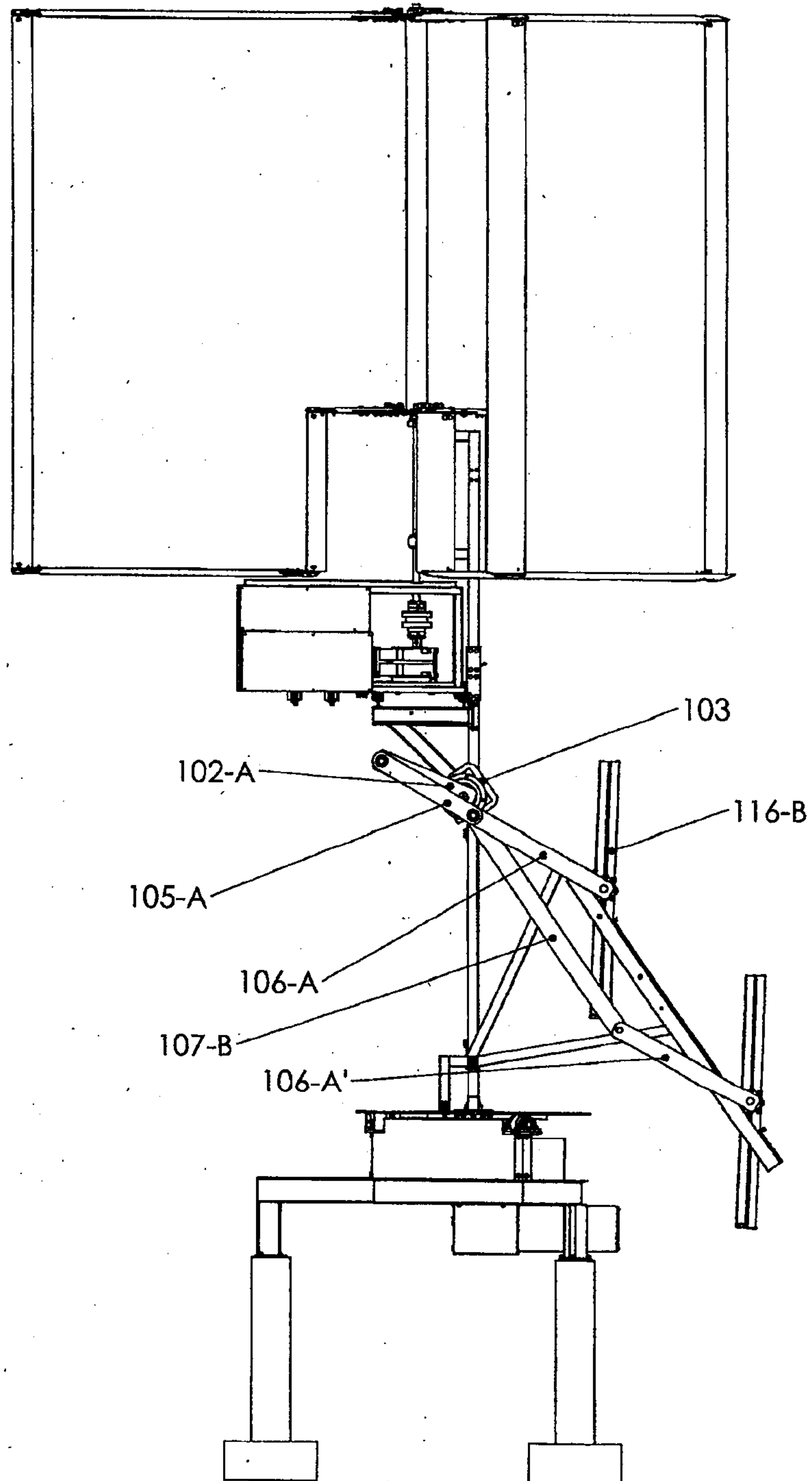
54/56

FIGURE 33A



55/56

FIGURE 33B



56/56

FIGURE 33C

