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Szendroi

[11] **3,901,419**

[45] **Aug. 26, 1975**

[54] **FLOW PROMOTING DEVICE FOR BATCH HOPPERS**

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[73] Assignee: **Bethlehem Steel Corporation,** Bethlehem, Pa.

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[21] Appl. No.: **476,006**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 237,316, March 23, 1972, Pat. No. 3,817,432.

[52] **U.S. Cl.** **222/506;** 222/564; 105/282; 105/247; 302/52

[51] **Int. Cl.** **B65g 65/70**

[58] **Field of Search** 222/564, 410, 233, 506, 222/508, 503, 545, 70, 476, 166, 462; 259/45; 302/52, 56

[56] **References Cited**

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Primary Examiner—Stanley H. Tollberg
Attorney, Agent, or Firm—Joseph O'Keefe; Michael J. Delaney; John J. Selko

[57] **ABSTRACT**

An apparatus for minimizing arching of granular material within a gravity operated, batch-type hopper. A plate rotatable about a horizontal shaft is mounted within the hopper above a bottom discharge opening. Prior to charging, the plate is rotated to a horizontally extending position and during discharging to a vertically extending position. The plate is power actuated to cause rotation in a predetermined time interval after the opening of the hopper.

7 Claims, 8 Drawing Figures

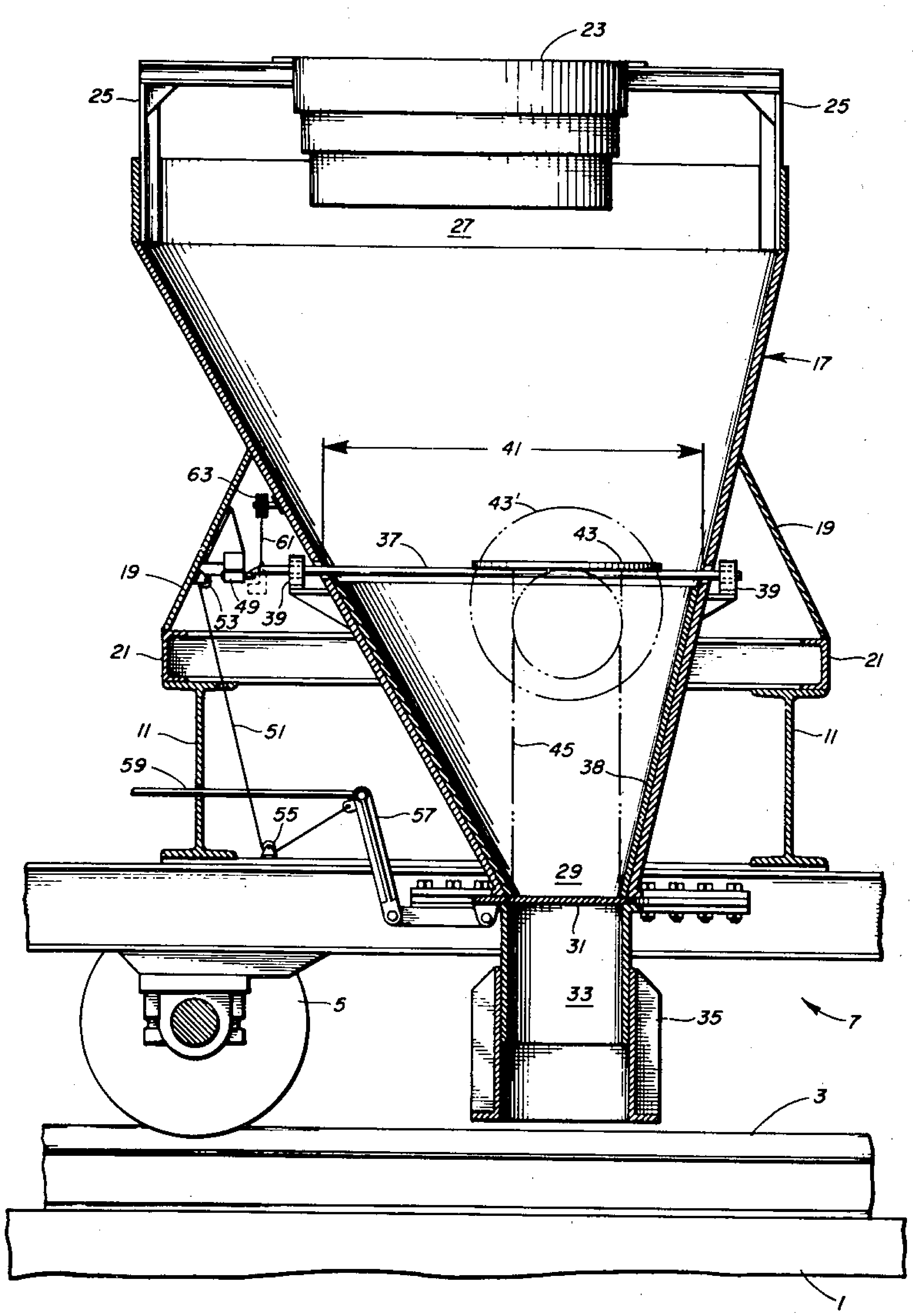
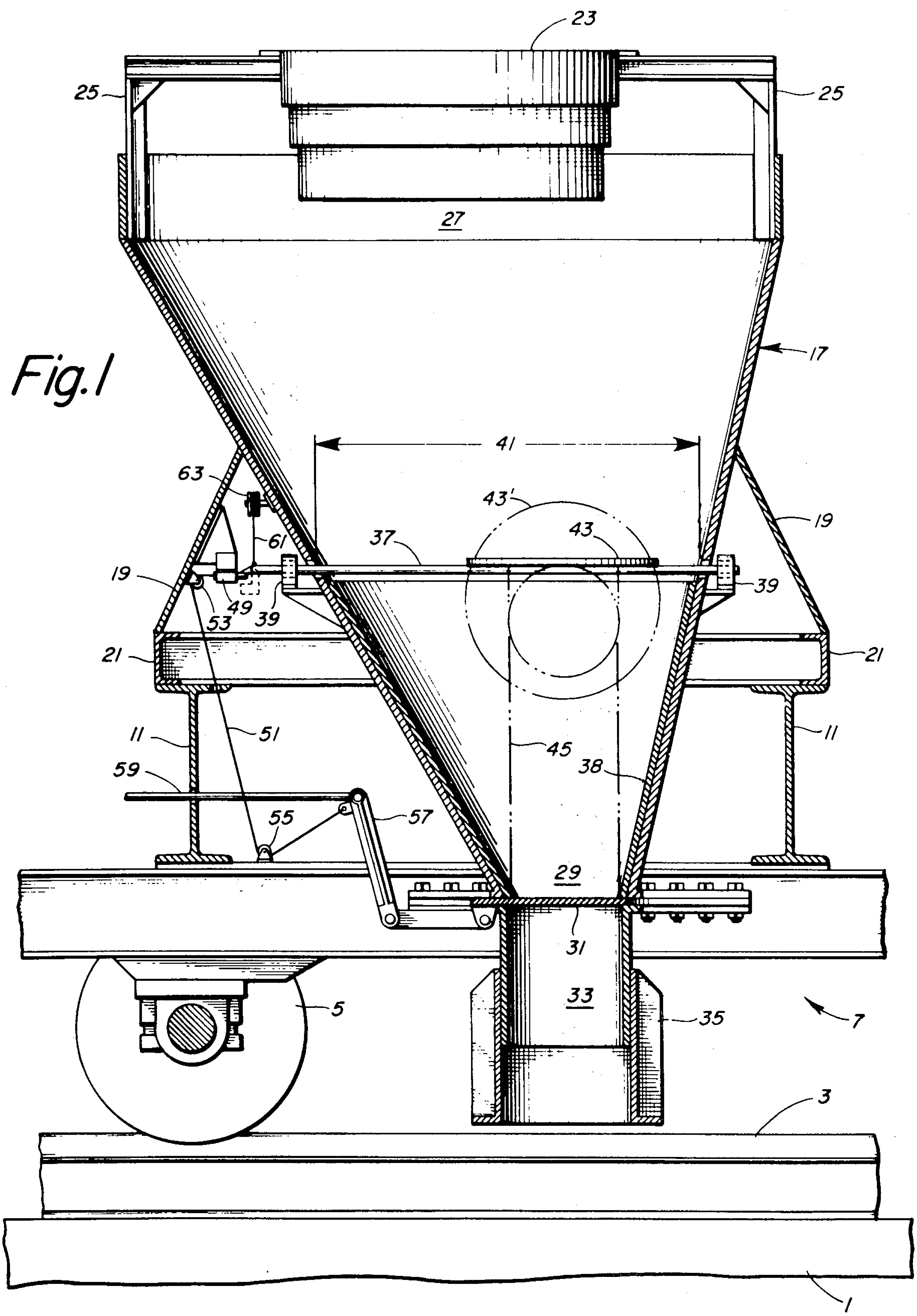


Fig. 1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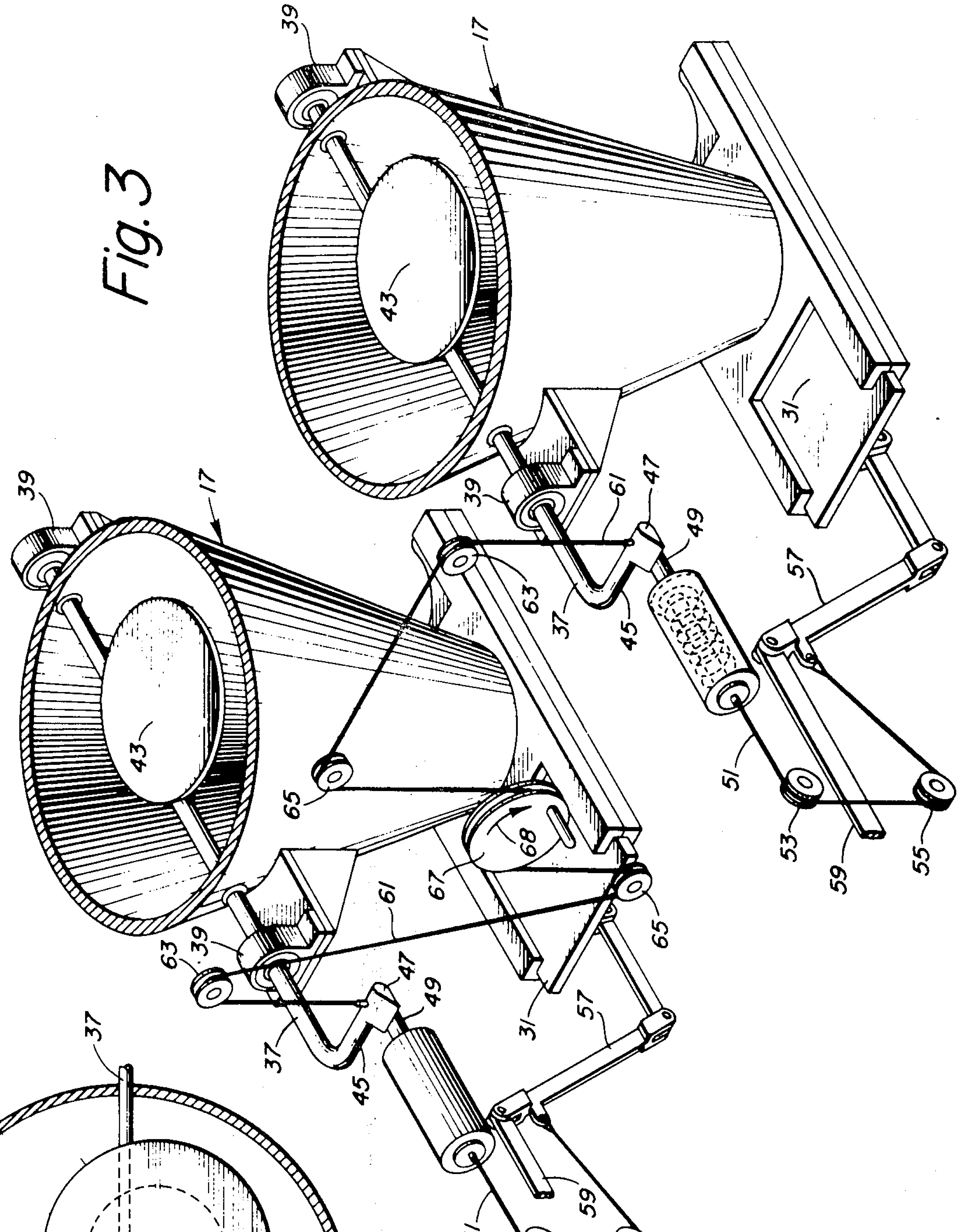
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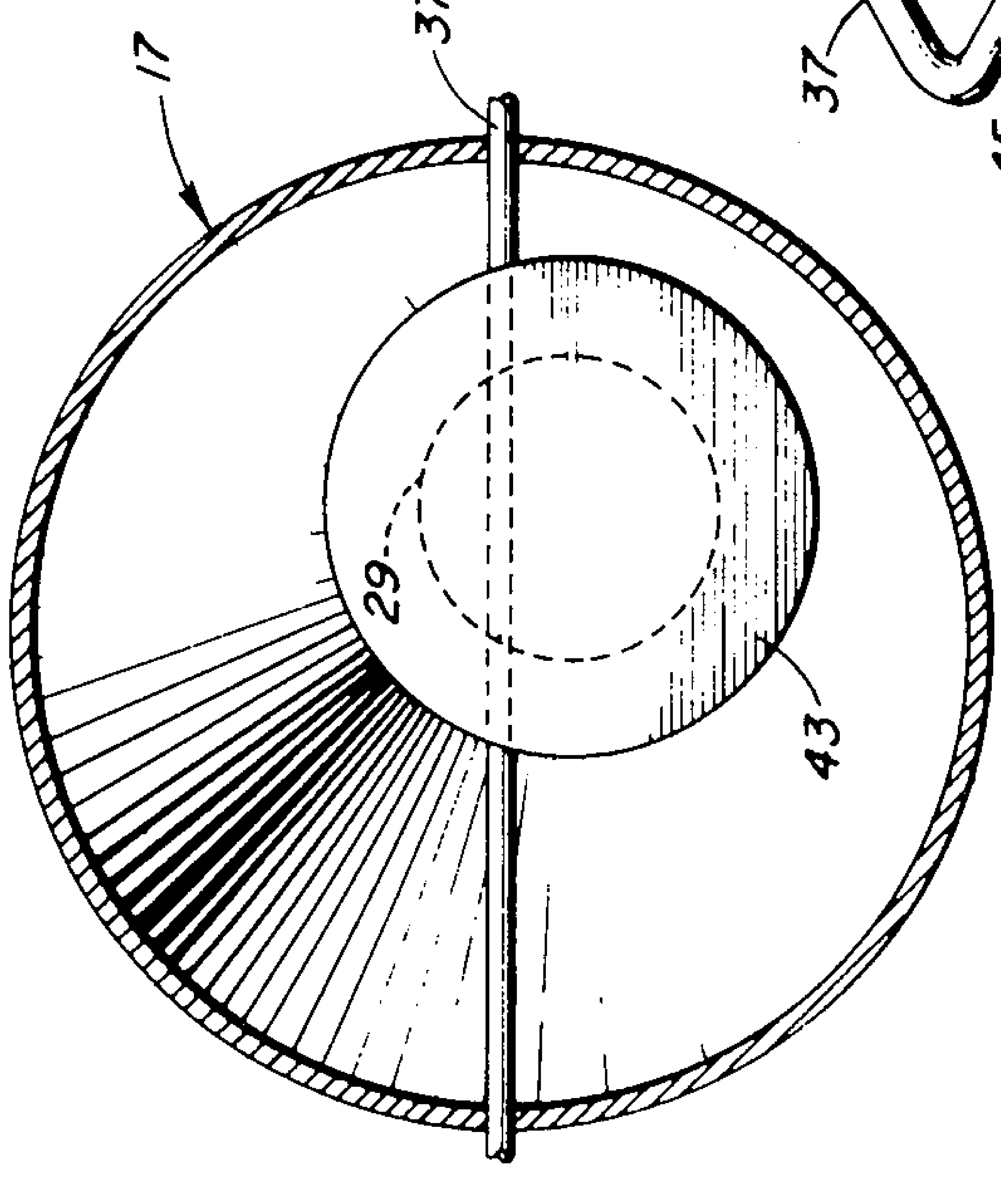
Fig. 3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43

Fig. 2

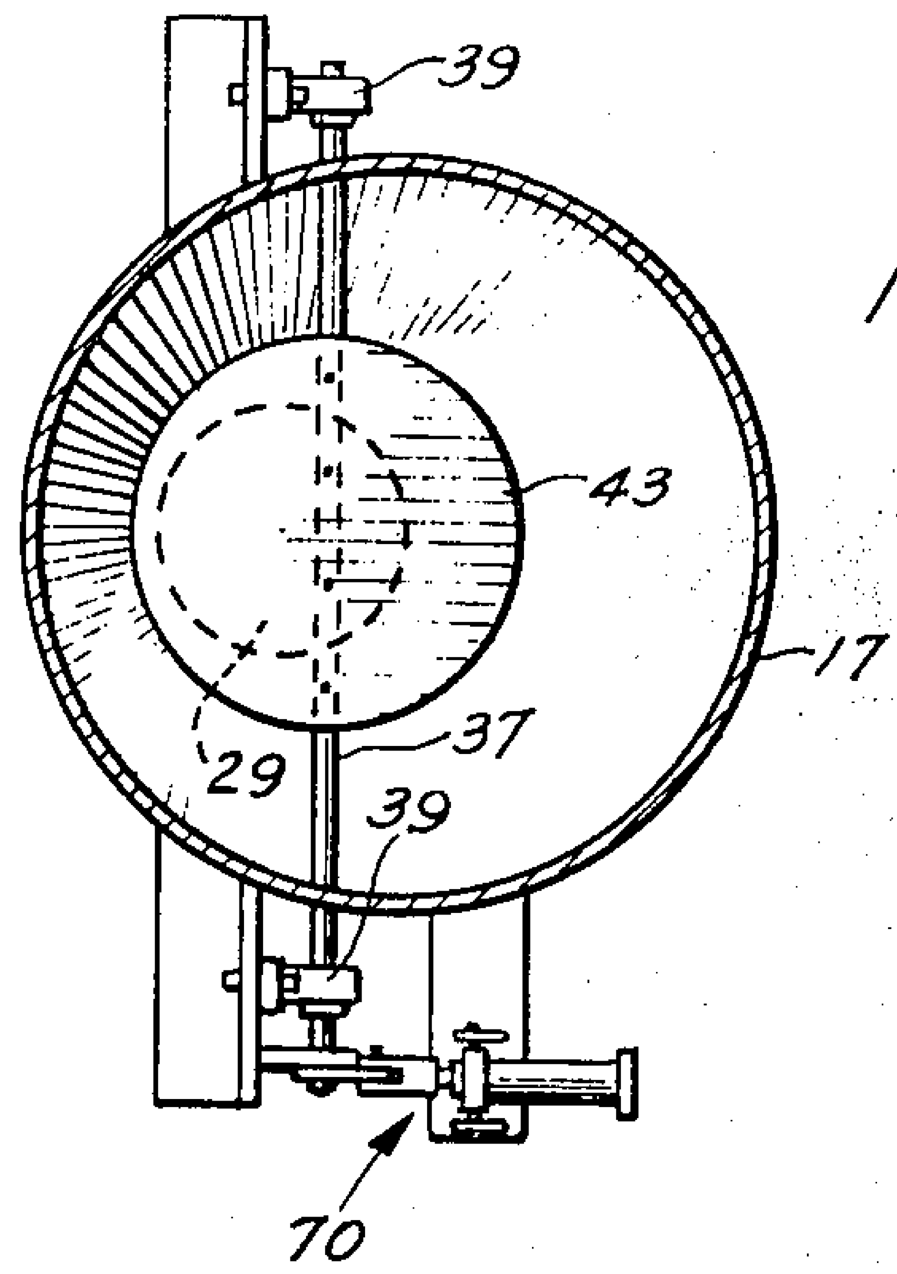

FIG. 5

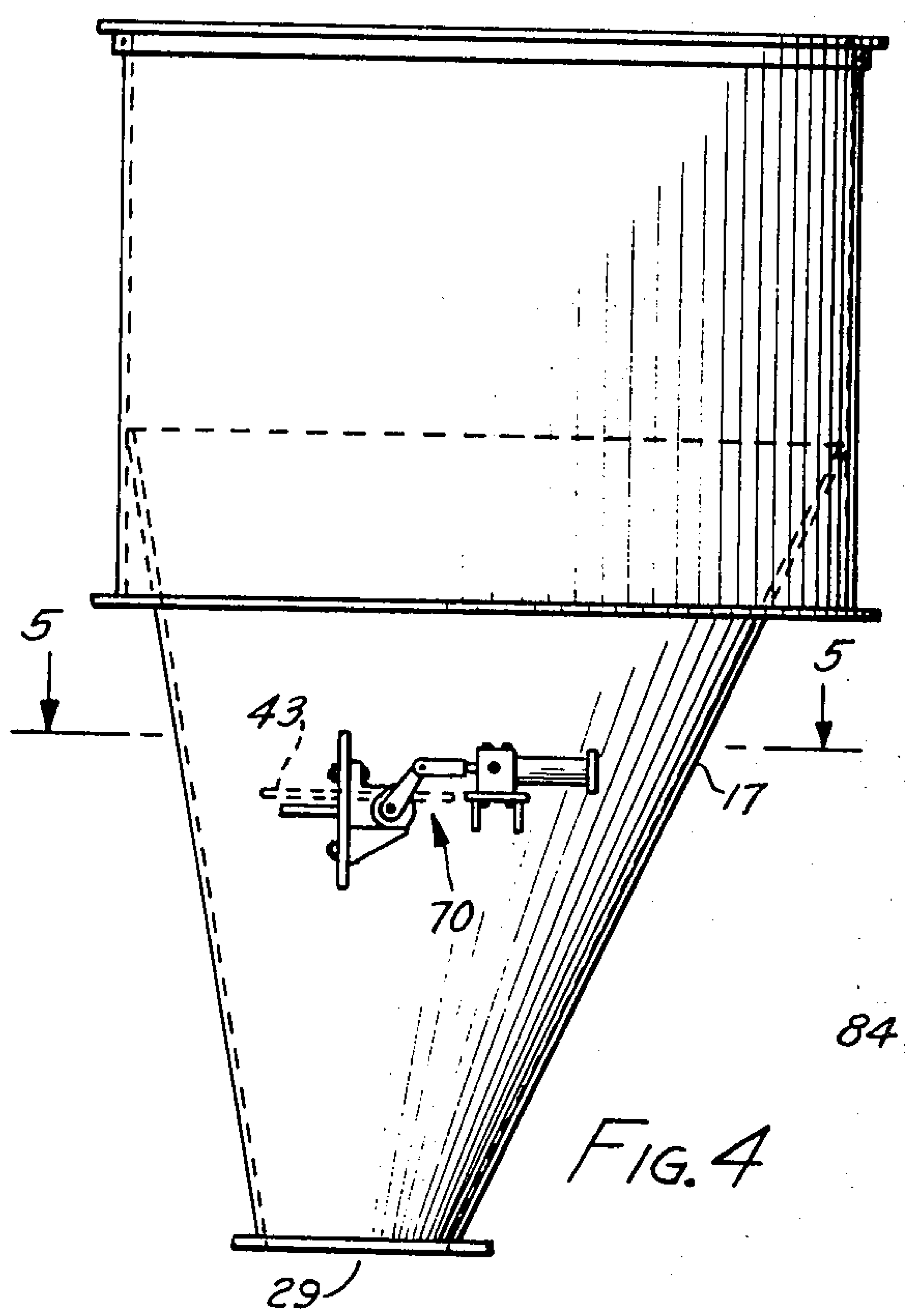

FIG. 4

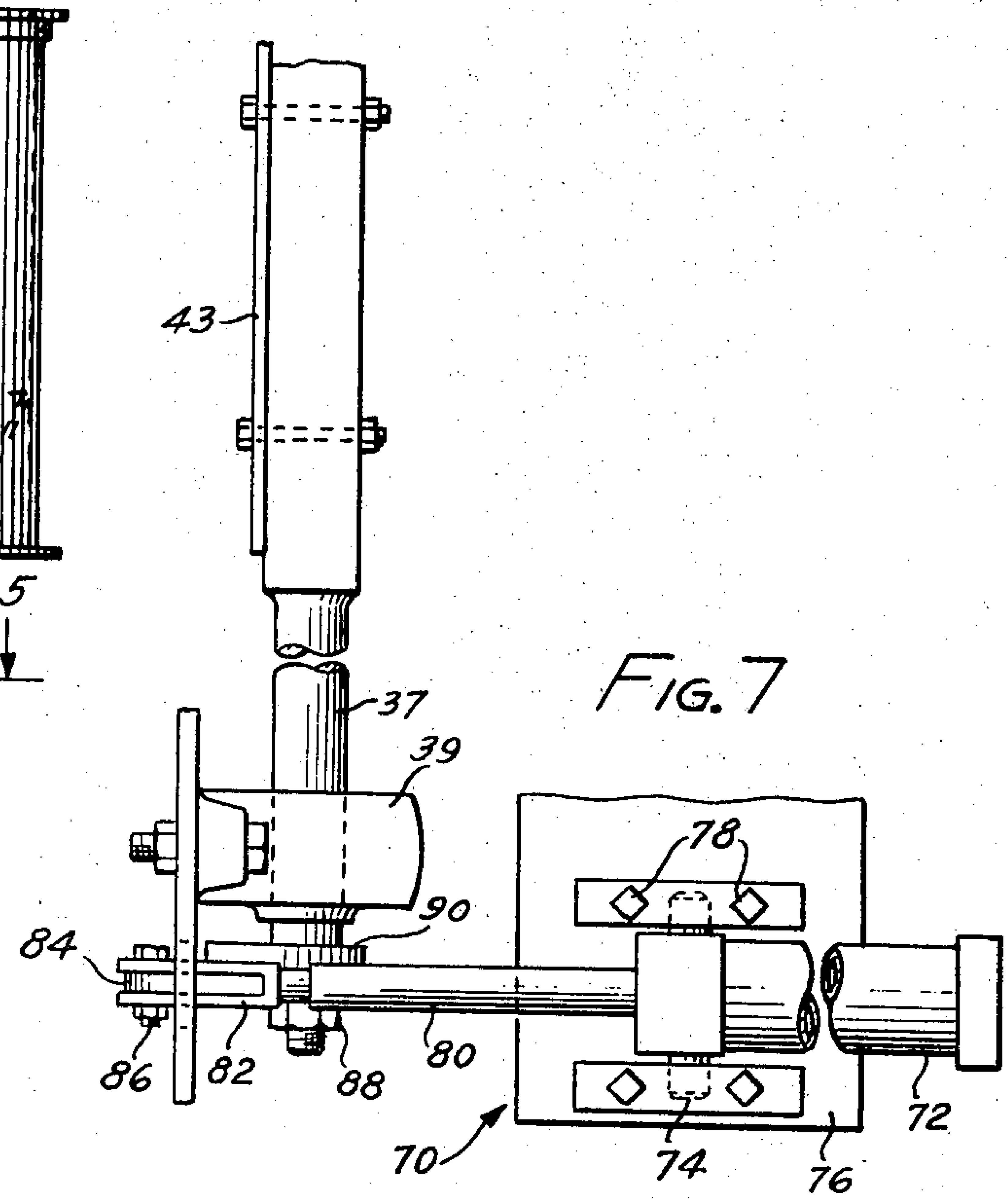

FIG. 7

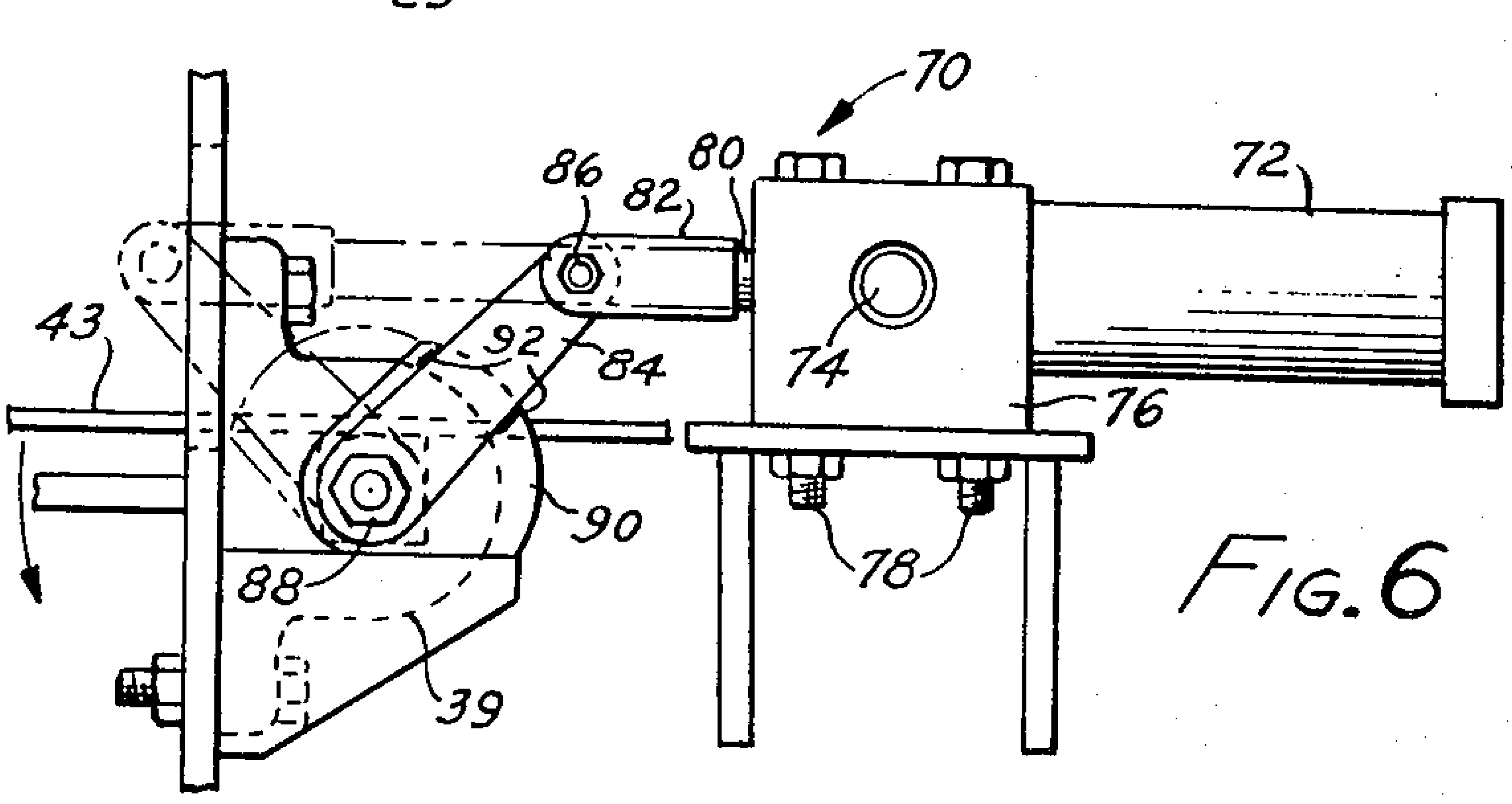

FIG. 6

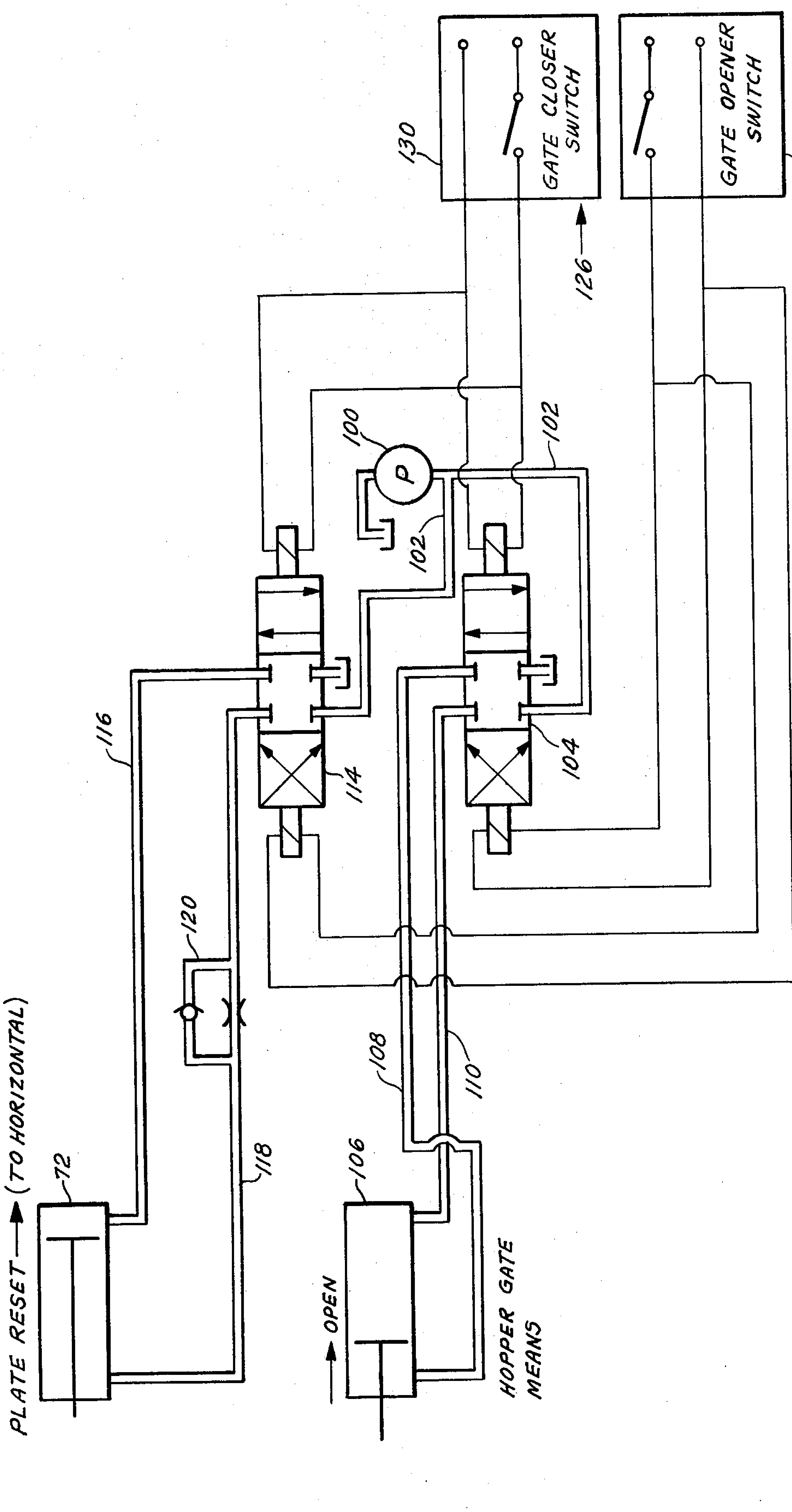
GATE CLOSER SWITCH
GATE OPENER SWITCH
130
128
126
100
P
102
102
102
114
104
116
120
118
108
110
106
72
PLATE RESET
(TO HORIZONTAL)
OPEN
HOPPER GATE MEANS

FIG. 8

FLOW PROMOTING DEVICE FOR BATCH HOPPERS

CROSS-REFERENCES TO RELATED APPLICATION

This application is a continuation-in-part of my application Ser. No. **237,316**, filed Mar. **23, 1972**, entitled "Flow Promoting Device for Batch Hoppers" now U.S. Pat. No. **3,817,432.**

BACKGROUND OF THE INVENTION

This invention relates to hoppers, and more particularly to flow promoting devices, which are positioned inside gravity operated batch-type hoppers such as are used to handle bulk materials, e.g. hoppers used to charge coke ovens.

Hoppers which are charged with batch quantities of material are known as batch-type hoppers. If the hopper depends upon gravity to help material to discharge through an opening in its lower portion, it is referred to as gravity-operated. Such devices are commonly employed to handle bulk materials. As is well known in the art, bulk materials are granular solids of various particle sizes, as for example, crushed coal, ore, cement, flour, clay and soil.

During the discharge of gravity operated hoppers, a serious problem referred to as arching or bridging can occur. Arching occurs when a portion of the material in the hopper becomes consolidated and forms a stable arch which extends between the walls of the hopper and prevents or retards the discharge of the remaining material from the hopper. Consolidation is used in reference to the action of such material. Consolidation is influenced by many factors including moisture, the action caused by the weight of the material and compaction of the material during charging and moving of a hopper. Compaction refers to the condition which results from successive layers of material being charged layer upon layer into a hopper.

Many approaches have been tried in order to eliminate arching. For example, selection of hopper construction material to minimize friction, design of hoppers to include steep walls, and use of vibrators. Each of these approaches has disadvantages.

Also, the size of the discharging opening can be carefully selected to take into consideration flow characteristics of the particular material to be handled. It is well known in the art that flow characteristics of each particular granular material can be measured and used to predict the minimum size of the bottom discharge opening which will prevent formation of a stable arch. This minimum size is also equal to the critical arching dimension. If the opening is larger than this critical arching dimension, a stable arch will not form in the hopper above it. On the other hand, if the opening is smaller than the critical arching dimension, a stable arch can form. The disadvantage of this approach is that, frequently, the size of the discharge opening is smaller than the critical arching dimension and is fixed by external factors such as the size of a charging opening with which the hopper opening must correspond or the dimensions of a receptacle which is to be charged from the hopper.

Various types of internally mounted, static flow promoting devices have been tried. These devices have taken the form of flat plates, cones, and cylinders, to name a few, and are generally mounted inside the hop-

per, above the discharge opening. Such static devices help prevent arching by minimizing consolidation of material during and after charging. Material falling into an empty hopper arrives at the bottom after being slowed down by striking the device. Thereafter, the device continues to absorb part of the kinetic energy of the falling material, as well as support part of the material after charging is completed.

While these static devices help prevent arching, they also cause problems. Arching of material tends to occur in the area between such devices and the hopper wall. Thus, the static device, while preventing arching in one area of the hopper, actually creates the structure which can lead to arching in another location. Also, the static devices affect the downward flow of material directly above the device. This effect can have the result of slowing the speed of discharge of the hopper as a whole. In operations which require rapid emptying of the hopper, anything which retards the emptying is a disadvantage.

Since, as is well known in the art, gravity-operated batch-type hoppers form a part of the charging machine used to charge coke ovens, the arching problems associated with these hoppers are not only present but are aggravated by conditions found in coke oven operations.

For instance, arching can result from compaction due to charging of crushed coal from the storage bin into the hopper carried on a larry car charging machine. In addition, increased consolidation takes place due to vibration when the larry car moves from the charging bin to a charging hole in the coke oven furnace. As an increasing amount of moisture is present in the coal, the danger of arching increases considerably.

Also, larry cars commonly contain four hoppers which simultaneously charge into four coke oven openings. The hoppers can only be closed simultaneously, and should one or more hoppers require a prolonged discharging time, the remaining already empty hoppers are exposed to escaping furnace gases laden with volatiles which can condense on the hopper interior. Such condensation can increase friction between the hopper wall and coal in the next charge, thereby increasing the risk of arching.

In addition, arching can cause insufficient material to be charged into the coke oven, resulting in loss of production and less uniform coke quality.

Finally, prolonged hopper discharge time, due to arching, can result in increased amounts of pollutant gases escaping from the furnace interior.

OBJECTS

It is therefore an object of this invention to provide an improved gravity-operated batch-type hopper which minimizes arching of material over the discharge opening, by minimizing compaction of material during charging of the hopper.

It is a further object of this invention to provide an improved gravity-operated batch-type hopper which prevents arching between the hopper walls and a flow promoting device.

It is also an object of this invention to provide an improved gravity-operated batch-type hopper containing a flow promoting device which avoids retarding material flow during discharge of the hopper.

It is also an object of this invention to provide an improved gravity-operated batch-type hopper containing a power-actuated flow promoting device which operates in a predetermined time interval after the opening of the hopper.

It is also an object of this invention to provide an improved coke oven larry car which greatly minimizes arching of crushed coal above the discharge opening by minimizing consolidation of coal during charging and movement of the larry car.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial cross sectional view of a hopper containing the non-power actuated device mounted on a coke oven larry car.

FIG. 2 is a cross sectional plan view of the hopper of FIG. 1.

FIG. 3 is an isometric schematic view of a locking means used on a plurality of hoppers containing the non-power actuated device.

FIG. 4 is an elevation showing the power actuated device in a hopper with parts removed.

FIG. 5 is a section along lines 5—5 of FIG. 4.

FIG. 6 is an enlarged elevational view of the power actuating means.

FIG. 7 is an enlarged plan view, with some parts removed of the power actuating means.

FIG. 8 is a combined schematic of an electrical and hydraulic circuit for operating the rotating means for controlling the rotation of the plate and opening of the hopper.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring more particularly to the drawings, FIG. 1 shows a coke oven roof 1 which is provided with a rail structure 3 for supporting wheels 5 of a coke oven larry car shown generally as 7. The wheels 5 are driven by any suitable drive means, not shown, and depend from charging car 7.

One of the conical batch type coal hoppers 17 is mounted on larry car 7, by means of support member 19 which is fastened to channels 21 which are fastened to support member 11. A volume regulating device 23 supported by brackets 25 defines a top charging opening 27. A bottom discharging opening 29 is closed by any suitable gate means, which in this case is a sliding plate 31. Beneath sliding plate 31 and bottom opening 29 is an extension 33 which carries a sliding sleeve 35. In the charging of a coke oven, lower extension 33 and sliding sleeve 35 are positioned over a coke oven charging hole (now shown) before sliding plate 31 is retracted, permitting coal to pass through the bottom discharge opening 29.

Extending through the interior of hopper 17, and above the discharge opening 29 and sliding plate 31, is horizontal shaft 37. The shaft is retained in position by bearings 39 which also permit the shaft to rotate. For best results, the shaft is located at or above an elevation at which the minimum horizontal distance between opposing hopper walls is equal to the critical arching dimension of the material being processed, in this case crushed coal. The critical arching dimension of the material can be calculated from the theory and information reported by Andrew Jenike, in "Storage and Flow of Solids," Bulletin No. 123 of the Utah Engineering Experiment Station, Vol. 53, No. 26, November 1964. In FIG. 1, 41 represents the critical arching dimension for the coal processed in hopper 17. Shaft 37 is shown

located at an elevation wherein the interior hopper clearance is not less than the critical arching dimension 41 of the coal. Preferably shaft 37 is positioned at or just above the elevation wherein the distance between opposing wall portions of the hopper is equal to the critical arching dimension so that secondary consolidation of the coal does not occur when coal particles fall from the horizontally extending plate 43 to the bottom of hopper 17 during charging.

Below the shaft 37, and conforming to the interior wall of the hopper 17 is a stainless steel liner 38 which functions to minimize friction between the coal and hopper 17, thereby enhancing flow of coal during discharge of hopper 17.

Securely mounted on the shaft 37, as by welding, and directly above the bottom opening 29 and sliding plate 31 is flat plate 43 which turns with shaft 37 when it rotates. During charging, plate 43 is placed in a horizontal position as shown in the FIGURE. During discharge of hopper 17, plate 43 gradually rotates as material is discharged from the hopper and eventually plate 43 is in the vertically extending position 43' shown in phantom in FIG. 1. The plate 43 is mounted eccentrically on the shaft 37 so that the weight or coal acting on the plate 43 in the horizontally extending position exerts a torque on it causing the plate 43 to rotate to a vertically extending position upon discharge of the hopper. It should be understood that the eccentrically mounted plate comprises subject matter in the above mentioned application Ser. No. 237,316. In FIG. 1, in the horizontal position, plate 43 intersects and substantially overlaps the vertical projection 45 of the discharge opening 29. This overlapping is better shown in phantom wherein the plate is in the vertically extending position 43' in FIG. 1 and with this plate in the horizontal position in FIG. 2.

Referring to FIG. 2, the plate 43 is shown to overlap the discharge opening 29, and the cross sectional area of the plate 43 is not less than the horizontal cross sectional area of the discharge opening 29. The shape of the plate 43 can vary, and preferably it should intercept the entire width of the column of falling coal when the plate is horizontal. In the preferred embodiment the hopper 17 is circular in cross section and the flat plate 43 is circular in shape. For best results, the dimensions of the plate 43 are not less than the corresponding dimension of the bottom opening 29 measured on a horizontal plane through the opening 29. However, it should be understood that the plate size should be small enough so that it does not come into contact with the hopper 17 when the plate 43 is horizontal but large enough to completely shield the bottom opening 29 from direct impact of falling coal thereby providing unconsolidated coal beneath plate 43 after hopper 17 is charged.

Referring to FIG. 3, outside the hopper 17, one end of shaft 37 forms a 90° angle making a handle portion 45. Attached to the end of the handle 45 is a wedge shaped block 47, which is supported below by a spring mounted pin 49. The pin 49 prevents the wedge shaped block 47 from moving downward, thereby preventing rotation of shaft 37, and locking plate 43 into a horizontally extending position suitable for the charging of the hopper 17.

Attached to the outward end of the pin 49 is a cable 51 which passes over pulleys 53 and 55 and attaches to linkage arm 57 which is pivotably connected at one end to sliding plate 31. Pivotably connected to the other end of linkage arm 57 is a horizontal shaft 59 which connects with a driving means (not shown) to open and close sliding plate 31. Where necessary, the driving means can open and close a plurality of hoppers simultaneously. Opening of sliding plate 31 to discharge the hopper 17 is accompanied by movement of linkage arm 57 which pulls on cable 51, which retracts spring mounted pin 49 from beneath wedge shaped block 47, automatically unlocking the shaft 37 and plate 43, permitting rotation of the shaft 37 and plate 43 to take place simultaneously with the opening of the closure 31, of bottom opening 29.

It should be understood that this is but one embodiment of the locking and unlocking means and that other arrangements can be used depending upon the type of mechanism used to open and close the hopper.

Connected to handle 45 is cable 61 which passes over pulleys 63 and 65 and is fastened to rotatable wheel 67. Rotation of wheel 67 in the direction indicated by the arrow 68 pulls on cable 61 which pulls handle 45 upward causing shaft 37 and plate 43 to rotate from a vertically extending discharging position to a horizontally extending charging position. As wedge shaped block 47 presses upwardly against spring mounted pin 49, the wedge 47 forces the pin 49 inwardly until the wedge 47 passes the pin 49. Immediately, the spring mounted pin extends outwardly under the wedge shaped block 47 and locks it into place until the closure device sliding plate 31 is again moved to an open position.

In hoppers in which the charging opening 27 is not directly aligned over the discharge opening 29, a deflector chute can be positioned between the charging opening 27 and the plate 43 to assure that all incoming coal will fall against the plate 43.

FIG. 4 shows the invention of this application in which the plate 43 is power actuated for rotation between a horizontally extending charging position and a vertically extending discharging position. Plate 43 is positioned within hopper 17 in relation to bottom opening 29 as described above. Plate 43 is shown mounted symmetrically on shaft 37. Because plate 43 is power actuated, the need for eccentric mounting of plate 43 on shaft 37 is no longer present. However, plate 43 can be eccentrically mounted as in FIGS. 1 through 3 if so desired.

The power actuated rotation of plate 43 in a predetermined time interval which is substantially simultaneous with the discharge of unconsolidated material below plate 43 and while substantially all of the coal is still in hopper 17 above plate 43 has been found to be effective in breaking up any arching which might occur between the plate 43 and hopper 17 in the unusual situation where an extremely high flow rate of coal and high drop height exists between the coal supply bunker (not shown) and plate 43 in hopper 17. Such a high flow rate and drop height can result in coal striking plate 43 with such force that some coal temporarily "welds" itself to plate 43 causing an arch between the plate 43 and hopper 17, thereby preventing plate 43 from being rotated merely by the weight of coal in hopper 17 pressing downward on plate 43.

The power actuated turning of plate 43 to a vertically extending position in a predetermined time interval while substantially all of the coal is still in the hopper above plate 43 causes the weight of coal in hopper 17 to press down upon any arch which might be present, and together with the rotation of plate 43 helps break the arch, enhancing coal flow.

Power actuated moving means, shown generally in FIGS. 4 through 7 as 70, includes hydraulic cylinder 72 pivotably mounted at 74 on bracket 76 by means of bolts and nuts 78. Bracket 76 is attached as by welding to the side of hopper 17. Piston rod 80 is movable within cylinder 72.

Attached to one end of piston rod 80 is clevis 82. The other end of clevis 82 is pivotably attached to arm 84 by means of clevis pin 86. Arm 84 is held onto shaft 37 by nut 88. Keyed into shaft is lifter cam 90 as is well known. Arm 84 and lifter cam 90 are joined together as by welding at 92.

With this arrangement it is understood that plate 43 which is mounted on shaft 37 can be rotated between a horizontally and vertically extending position in response to the extension and retraction of piston rod 80. The shaft 37 and moving means 70 are connected so that the plate 43 is horizontally extending when the piston rod 80 is retracted and vertically extending when the piston rod 80 is extended. It should be understood that with plate 43 being power actuated the locking and unlocking means described in FIG. 3 are not necessary.

FIG. 8 shows a preferred combined electrical and hydraulic schematic diagram for automatically rotating plate 43 from a horizontally extending charging position to a vertically extending discharging position in a predetermined time interval after the opening of gate means 31.

Pump 100 supplies hydraulic fluid via line 102 to a four way solenoid operated valve 104 under control to supply fluid under pressure to cylinder 106 via line 108 and eventually a sump (not shown) via line 110, as is well known, to cause sliding plate gate means 31 to open in response to the urging of cylinder 106. During closing of gate means 31 solenoid valve 104 is reversed and cylinder 106 operates in the reverse direction, as is well known.

Simultaneously with the operation of gate means 31, pump 100 supplies hydraulic fluid via line 102 to a four way solenoid operated valve 114 under control to supply fluid under pressure to cylinder 72 via line 116 and eventually to a sump (not shown) via line 118 to cause piston rod 80 to extend, as is well known. Located in line 118 is a conventional flow control valve 120. Valve 120 is adjusted so that the rate of forward extension of piston rod 80 is slowed down and takes place over a predetermined time interval which is substantially simultaneous with the discharge of unconsolidated material below plate 43 when hopper 17 is opened. I have determined that a predetermined time interval of about 6 seconds is sufficient. Changing the time interval required for the forward extension of piston rod 80 can be achieved by adjustment of valve 120. During the resetting of plate 43, solenoid valve 114 is reversed and cylinder 72 operated in the reverse direction, as is well known. Solenoid valve 114 is the type which has a neutral postion in which all ports are blocked so that if the opening circuit is deenergized, the plate stops its rotation and stays locked in its current position.

Solenoid valves 104 and 114 are energized from a power source (not shown) which power source is under control of switches 128 and 130 as hereinafter described.

The electrical schematic shows a preferred control means 126 for actuating the power actuated moving means 70 after the gate means 31 is opened. The gate opener switch 128 activates both the gate means 31 and plate 43, and the plate 43 rotates in its predetermined time interval while the gate means 31 opens immediately.

Gate closing switch 130 automatically simultaneously closes gate means 31 and resets plate 43. Switches 128 and 130 can be manually operated or can be combined with a sensing device which senses when the hopper is empty and automatically closes the gate and resets the plate.

Thus, it can be understood that, together, power actuated moving means 70 and control means 126 form rotating means for rotating plate 43 from a horizontally extending charging position to a vertically extending discharging position in a predetermined time interval after the opening of gate means 31.

Operation

The empty larry car 7 is charged with crushed coal through the top charging opening 27. The plate 43, locked into a horizontally extending charging position, above the bottom discharging opening 28, is struck by the falling coal. The plate 43 substantially slows the falling coal which then gently flows off the plate 43 and settles into the bottom of the hopper 17 which is closed by sliding plate 31. By absorbing the impact of the falling coal, the plate 43 provides unconsolidated coal in the hopper 17 below the plate 43 thereby minimizing the possibility of arching below the plate 43.

Because the size of the plate 43 exceeds the corresponding size of the bottom discharge opening 29 as measured on a horizontal plane through the opening 29, the plate 43 prevents coal from falling uninterrupted into the bottom of hopper 17.

When the hopper 17 is fully charged, the plate 43 supports the weight of the overlying coal, lessening consolidation of the coal below plate 43. Also, as the loaded larry car 7, moves along the rails 3 on the coke oven roof 1, the plate 43 minimizes additional consolidation of the coal below the plate which consolidation arises due to movement and vibration of the hopper 17.

As the hopper 17 is discharged, sliding plate 31 retracts to open the discharge opening 29. Simultaneously and automatically, the shaft 37 and plate 43 are free to rotate. The coal below the plate 43 flows without arching because coal consolidation has been previously minimized by the horizontally extending plate 43, and coal flow is enhanced by stainless steel liner.

In response to the urging of piston rod 80 and cylinder 72, the power actuated plate 43 rotates in a predetermined time interval from a horizontally extending position to a vertically extending position substantially simultaneously with the discharge of coal below plate 43. The rotation of plate 43 plus the weight of the coal in the substantially full hopper 17 prevent arching from occurring between the plate 43 and the hopper 17. With the flat plate 43 in the vertically extending discharge position blockage to coal flow is minimal and the hopper 17 is emptied rapidly.

After discharge of hopper 17, the plate 43 is reset into a horizontally extending charging position.

In actual practice, a larry car frame carrying four hoppers as described was put into service charging crushed coal having a critical arching dimension of 44 inches as calculated in accordance within the aforementioned report by Andrew Jenike. The diameter of the hopper at which the shaft was located, was 51 inches. The total time required for complete discharge of the four hoppers on the larry car averaged 50 seconds as compared to a normal range of 180 to 300 seconds, with extreme cases due to arching up to 900 seconds.

I claim:

1. In combination with a hopper adapted to receive through a top charging opening batch quantities of granular material and to discharge said material through a bottom discharge opening, the improvement comprising:

a. gate means associated with said bottom discharge opening and adapted to be closed when said hopper is being charged and opened when said hopper is being discharged,

b. a plate mounted on a rotatable shaft and locked in a horizontally extending position within said hopper above said bottom discharge opening to absorb the impact of said material during charging to provide unconsolidated material below said plate; and

c. rotating means for rotating said plate from a horizontally extending charging position to a vertically extending discharging position in a predetermined time interval after the opening of said gate means.

2. Apparatus according to claim 1 in which said plate in a horizontally extending position intersects and substantially overlaps a vertical projection of said discharge opening.

3. Apparatus according to claim 2 in which said rotating means rotates said plate from a horizontally extending to a vertically extending position substantially simultaneously with the discharge of said unconsolidated material.

4. Apparatus according to claim 3 in which said hopper comprises opposite wall portions and in which said shaft is located at an elevation wherein the minimum horizontal dimension between said wall portions is not less than the critical arching dimension of said granular material.

5. Apparatus according to claim 4 in which said rotating means includes:

a. power actuated moving means connected to said rotatable shaft for rotating said plate between a horizontally extending position and a vertically extending position; and

b. control means for actuating said power actuated moving means after said gate means is opened.

6. Apparatus according to claim 5 in which said power actuated moving means includes:

a. a hydraulic cylinder pivotably mounted on said hopper;

b. a piston rod movable within said hydraulic cylinder; and

c. means for connecting said rotatable shaft to said piston rod to rotate said plate between a horizontally extending position and a vertically extending position when said piston rod is extended and retracted.

7. The invention of claim 1 in which said time interval is approximately 6 seconds.

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