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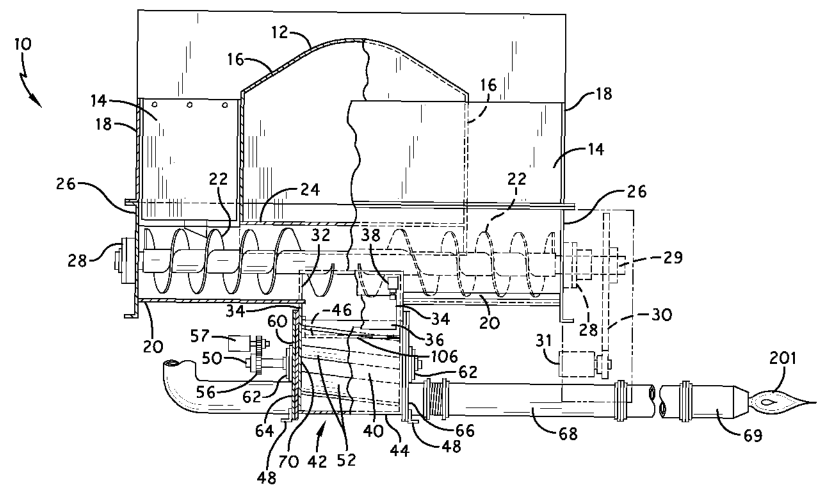
(54) **Title**: METHOD AND APPARATUS TO DELIVER SOLID FUEL TO A COMBUSTION ZONE



FIG−1

(57) **Abstract**: An apparatus and method for consistently delivering solid fuel to the combustion zone of a furnace is disclosed. The method includes feeding the solid fuel into the material inlet of a rotating rotary air lock valve which may have slanted vanes and moving the fuel from the material inlet of the rotating rotary air lock valve to the material outlet of the rotating rotary air lock valve, and conveying the fuel and gas through a discharge conduit to a fuel feed receiver of a furnace burner having a combustion zone.

WO 2009/143402 A2

METHOD AND APPARATUS TO DELIVER SOLID FUEL TO A COMBUSTION ZONE

Priorities and Cross References

This application claims priority from United States Provisional Application 61/055829 filed on May 23, 2008, the embodiments, examples, and claims of which are incorporated by reference.

Field of Invention

This invention relates to a method and apparatus for delivering solid fuel to a combustion zone.

Background

Many energy intensive industries need to consume fuel in many forms. The alternative fuels to coal, natural gas and oil are often provided in solid form. For example, in the manufacture of cement, limestone, sand, clay, and iron ore are blended, ground, and heated to 1400°C – 1550°C in a rotating kiln. The resulting material, called clinker, is cooled, pulverized, and mixed with gypsum to create what is known as cement, a hydraulic material primarily made up of calcium silicates. The nature of clinker and the enormous heat requirements of its manufacture require the cement industry to consume a wide variety of waste raw materials and fuels.

Fuels that have been used for primary firing of kilns include coal and other fossil fuels. High carbon fuels such as coal are preferred for kiln firing, because they yield a luminous flame. The clinker is brought to its peak temperature mainly by radiant heat transfer, and a consistent bright and hot flame is essential for this.

In addition to these primary fuels, various alternative fuel materials have been fed to kilns. These alternative fuels can often reduce manufacturing costs and at the same time benefit the environment. For example, waste that would otherwise have to be disposed in a landfill or other long term containment, or incinerated as a means of destroying the materials can be used. Landfill disposal typically is more expensive and less desirable than disposal by recovering the useful energy value of the waste. The environment also benefits from use of waste as fuel, because cement kilns have efficient destructive capacity for various wastes as fuel and resultant fuel combustion products, due to high burning zone temperatures and long retention times of materials in the high temperature zone. Valuable landfill space is conserved, fossil fuels are conserved, and wastes that might have contaminated land or water are efficiently destroyed.

Resultant cements differ from plant to plant due to changes in raw material properties due to such things as kiln temperatures. These changes can significantly affect concrete properties when different cements are used in concrete. Perhaps because of the high heat requirements in manufacturing cement, the choice of fuel and the fuel delivery system play a key role in the material properties and product quality of the cement. As an example, solid fuels are not easily blended and they present significant engineering challenges for their safe handling and delivery into rotary kilns. Further, the burning of combustible solids in the firing chamber, in particular the hot end (1300-2000°C) of a kiln faces other practical problems. Non-hazardous waste solids are not easily dispersed into the flame of the burning primary fuel. If waste solids are charged into the primary combustion zone, they will necessarily come into contact with the mineral bed at a very critical time in the clinker-forming process. It is important for the formation of quality clinker, both in terms of color and performance, that oxidizing conditions be maintained in the clinker-forming zone of the kiln. Charging combustible solids onto the forming clinker at temperatures in excess of 1300°C can create reducing conditions in the forming clinker and adversely affect cement quality.

The cement making process is very sensitive to variations in the heat, so the combustion of the fuel generally needs to be consistent in the amount of heat released per unit time and even the actual shape of the burning flame(s). Variations from variable energy value of the fuel or combustion rates of the fuel usually adversely affect the final cement product and emissions, particularly carbon monoxide.

These needs merge into an over-arching goal of improving the manner in which solid fuel is conveyed such as in the production of cement. Previous methods and apparatuses for conveying bulk solids are subject to jamming or bridging due to the build-up of waste material which tends to clump together and move as a large mass, instead of being easily shearable and moving as individual particles. These defects create problems ranging from inconsistent feed, feed surges and even no flow. Additionally, other methods and apparatuses have taken a more expensive and complex approach in an attempt to provide consistent feed to a combustion zone.

According to US Pat. Pub. No. 2007/0144791, one approach outlined in WO 99/13302 outlines a system for continuous gravimetric conveyance and/or dosing of bulk materials, with a dosing rotor weighfeeder preferably being used. The dosing apparatus following a supply of bulk material is arranged in an enclosed pneumatic conveying section and is supported on load cells. For performing a respective regulation of the desired conveyed quantity per unit of time (conveying strength), a computer-controlled central dosing control system is used, with the weighing signal of weighing cells being used as an input signal and the speed of the dosing rotor and, optionally, the feeder sluice being regulated for the supply of the bulk material.

In this feedback control system, the mass of bulk material acting momentarily in the rotor weighing section is detected in the dosing rotor weighfeeder, with the mass throughput of the bulk material being obtained by multiplication with the angular speed of the dosing rotor. The electronic system of the weighfeeder delays the delivery of the respective weight value of the bulk mass (charge) situated momentarily on the rotor weighing section (measuring section) until a specific pre-control point, so that the angular speed or rotary speed can be varied according to the predetermined setpoint conveying strength shortly before the delivery of the bulk material to the pneumatic conveying line, meaning that the dosing rotor is accelerated or delayed.

In another approach, using a rotorweighfeed system, secondary fuels are fed by a prefeeding system via diverter flap to a pre-hopper. The calibration pre-hopper above the rotorweighfeeder works additionally as material buffer. A helical stirrer keeps the fuel in motion. The material load inside the hopper is measured by load cells underneath the frame. The inner part of the rotor weighfeeder consists of a lower seal plate with discharge opening, rotor wheel including bars and inner ring as well as outer ring. The bulk material transported by the horizontal rotor wheel from the inlet to the outlet falls down at the discharge opening by gravity, while pneumatic nozzles support the material discharge. The body of the rotorweighfeeder is suspended via two weighing bearings. The weighing axis goes through the weighing bearings centred to the in- and outlet area. A third suspension point is connected with a load cell, which measure the content gravimetrically inside the rotor. The measured value (momentary load) and the related rotor position are stored in the weighing electronics at any time. A calculation of the needed rotor speed is made according to the required feed inverse to the material load. The rotor speed multipled with the load gives the actual feed rate controlled by the weight. The rotary valve feeds the material into the pneumatic transport system. Clean transport air from the blower is blown through the blowing shoe. Part of the transport air is used for cleaning the chambers of rotary valve. The air loaded with fuel is transported directly into the burner flame. During online calibration, the material supply into the pre-hopper is stopped. The static load cells underneath the rotorweigh feeder frame measure the loss in weight during the calibration period. This value is compared with the weighing data of the rotor weighfeeder. If necessary, an online taring can be executed.

The above rotor weighfeeder and rotary feeder systems have the following observed problems: besides being complex, the system suffers from a poor turndown ratio. Because the rotor weighfeeder and rotary feeder push the fuel feed, the feed is compacted creating a variable feed. At extremely low rates, the feed has been observed to stop until the vane of the rotary feeder has accumulated enough material to push it into the next step. This on again, off again feed created high variations in the final emitted carbon monoxide content. Therefore, there exists a need for a more useful conveying and discharging apparatus and method that reduces the incidence of blockage such as bridging for solid fuels and at the same time is less complex, less expensive for the user, and delivers a constant feed.

Summary of the Invention

It remained for the present inventors to recognize that an apparatus and method could be devised with particular embodiments to enable steady delivery of solid fuel to a combustion zone. This specification discloses such a method for delivering solid fuel to a combustion zone, wherein the method comprises a selection step which comprises selecting a solid fuel; an introduction step which comprises introducing the solid fuel into the material inlet of a rotating rotary air lock valve wherein the rotating rotary air lock valve has a material inlet, a central shaft and an axis of rotation of the shaft with multiple vanes defining pockets between the vanes, and a material outlet; a rotating step, wherein the rotating rotary air lock valve moves the solid fuel from the material inlet of the rotating rotary air lock valve to the material outlet of the rotating rotary air lock valve, wherein the solid fuel is optionally placed into a receiving chamber; a locomotive step, which comprises contacting the solid fuel with a moving gas, wherein the gas contacts the solid fuel at a location selected from the group consisting of the pocket between the vanes, the material outlet and the receiving chamber to move the solid fuel into a discharge conduit; and a conveying step, wherein the solid fuel is conveyed by the moving gas through the discharge conduit to a fuel feed receiver of a furnace burner having a combustion zone, wherein the solid fuel is transported from the fuel feed receiver to the combustion zone.

This specification also discloses a method of delivering solid fuel to a combustion zone wherein the introduction of the solid fuel into the material inlet of the rotating rotary air lock valve is made substantially perpendicular to the axis of rotation of the shaft.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein the introduction of the fuel into the material inlet of the rotating rotary air lock valve is kept substantially constant in terms of Btu/hour, by regulating the height of the fuel above the rotary air lock valve. This regulation would be within certain height parameters which could include regulating to a constant height.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein the amount solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve receives a plurality of doses over a period of time and at least some of the doses of the plurality are not weighed before entering the pocket.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein the moving gas contains at least one combustion enhancing gas in addition to the oxygen found in atmospheric air.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein the fuel is selected on the basis of high heating value of BTU/lb and a moisture content of percent moisture of the total weight. The moisture content may be less than 40% by weight and the high heating value may be greater than 5000 BTU/lb, and the fuel is not coal.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein a plurality of the vanes are not mounted parallel to the axis of rotation of the shaft.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein the vanes are not mounted parallel to the axis of rotation of the shaft and the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve receives a plurality of doses over a period of time and at least some of the doses of the plurality are not weighed before entering the pocket.

Further disclosed in the specification is a method of delivering solid fuel to a combustion zone wherein the vanes are not mounted parallel to the axis of rotation of the shaft and wherein the introduction of the solid fuel into the material inlet of the rotating rotary air lock valve is made substantially perpendicular to the axis of rotation of the shaft.

Further disclosed in the specification is an apparatus for delivering solid fuel to a combustion zone, comprising a feed receiver; a transition area located beneath the feed receiver; a rotary air lock valve located beneath the transition area and adjacent to feed receiver; a means for driving the rotary air lock valve; the rotary air lock valve having a cylindrical housing with a material inlet, a central shaft with multiple vanes defining a pocket between two adjacent vanes; a pressurized moving gas inlet; a pressurized moving gas outlet; a means for supplying pressurized moving gas to the pressurized moving gas inlet; a means for conveying the solid fuel from the pressurized moving gas outlet of the rotary air lock valve; a discharge conduit having a first end and a second end, the first end is attached to the pressurized moving gas outlet; and the second end is attached to a fuel feed receiver.

Other features disclosed include an apparatus for delivering solid fuel to a combustion zone, wherein the pressurized moving gas inlet and the pressurized moving gas outlet are part of the rotary air lock valve, the outlet offset from the inlet by the angle of the vane so that pressurized moving gas fed through the inlet is channeled through the pocket to the outlet.

Still another feature involves an apparatus for delivering solid fuel to a combustion zone, wherein the apparatus further comprises a receiving chamber located beneath the rotary air lock valve and the pressurized moving gas inlet is located on a first end of the receiving chamber and the pressurized moving gas outlet is located on a second end of the receiving chamber and the first and second end are opposite of each other.

Still another feature involves an apparatus for conveying delivering solid fuel to a combustion zone, wherein the feed receiver does not have a screw conveyer.

Still another feature involves an apparatus for conveying delivering solid fuel to a combustion zone, wherein the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve is not connected to a control device which weighs a dose of the solid fuel before entering a pocket.

Still another feature involves an apparatus for conveying delivering solid fuel to a combustion zone, wherein the solid fuel enters the material inlet of the rotary air lock valve substantially perpendicular to the axis of rotation of the central shaft.

Still another feature involves an apparatus for conveying delivering solid fuel to a combustion zone, wherein a plurality of the vanes are not mounted parallel to the axis of the shaft.

Still another feature involves an apparatus for conveying delivering solid fuel to a combustion zone, wherein a plurality of the vanes are not mounted parallel to the axis of the shaft and wherein the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve is not connected to a control device which weighs a dose of the solid fuel before entering a pocket.

Still another feature involves an apparatus for conveying delivering solid fuel to a combustion zone, wherein a plurality of the vanes are not mounted parallel to the axis of the shaft and wherein the soid fuel enters the material inlet of the rotary air lock valve substantially perpendicular to the axis of rotation of the central shaft.

Brief Description of the Drawings

FIG. 1 is a plan view, partly in section, showing the apparatus for delivering solid fuel to the combustion zone of the present invention;

FIG. 2 is a plan view of the rotary air lock assembly of the present invention;

FIG. 3 is a side elevation view showing the rotary air lock assembly of the present invention;

FIG. 4 is a plan view, partly in section, showing an alternative embodiment including a receiving chamber and the configuration for moving pressurized gas to the fuel feed receiver and the combustion zone;

FIG. 5 is a plan view, partly in section, showing another alternative configuration for movement of pressurized gas to the fuel feed receiver and the combustion zone;

FIG. 6 is a side elevation view showing a stationary bulk feed bin assembly;

FIG. 7 depicts a side elevational view, partly in section, showing an embodiment of the solid fuel delivery apparatus attached to the back of a truck;

FIG. 8 also depicts a side elevational view, partly in section, showing the fuel delivery process taking place within the solid fuel delivery apparatus attached to the back of a truck;

FIG. 9 is a rear elevational view of the back of the truck;

FIG. 10 is a rear elevational view, partly in section, of the back of the truck;

FIG. 11 is a rear elevational view of the hydraulic power source;

FIG. 12 is a side elevational view, partly in section, showing the solid fuel delivery apparatus from the opposite side of truck;

FIG. 13 depicts an alternative emodiment using bulk feed bins in conjunction with a bulk solids tank;

FIG. 14 depicts the lead up to the combustion zone;

FIG. 15 depicts a cross sectional view of the tip of the fuel feed receiver;

FIG. 16 depicts another embodiment of the present invention involving a multiple burner tube setup.

Detailed Description Including Drawings.

The details of the embodiments are best understood by reading the specification with reference to the drawings. Care has been taken to keep the numerical designation consistant from drawing to drawing and referenced by text and numerical designation throughout the specification.

The device depicted in Figure 1 of the present invention may comprise a hopper assembly (10) of basically rectangular cross section in length and square cross section in width with an open top and bottom. Placed midway across the length of the hopper (10) is a diverter (12) typically wedge-shaped that divides the hopper openings into two halves (14). The diverter (12) is positioned at or near the center of the hopper length. The sides (16) of the diverter (12) are usually positioned off parallel and sloping in such manner that feed material is encouraged towards the end wall (18) of the hopper (10) and downwards to the screw conveyor (22) without bridging. The rectangular section forming the hopper front may be hinged at the bottom to allow it to fold down for easy loading access.

The fuel is transported to the rotary air lock valve through a number of options. The option depicted in Figure 1, which is not a preferred embodiment, is a conveyor screw (22). It is mounted directly onto and generally below the hopper assembly is a flared trough (20) with a concave, semi-circular bottom containing a converging screw conveyor (22). The longitudinal axes of the trough (20), the screw (22), and the hopper assembly (10) are all parallel. The conveyor trough (20) is open on the top toward the ends with the openings being the ends of the hopper (18) and the sloped sides (16) of the diverter (12). Under the diverter (12) is a shroud (24) which transforms the open trough (20) into a conduit of essentially circular shape.

The screw (22), located concentrically in the concave arc of the trough (20), is supported and rotates on bearings (28) mounted on trough endplates (26) which coincide with the hopper ends (18) and is driven by a motor (31) connected to the screw conveyor shaft

(29) by a drive (30). The screw flighting is divided in half or nearly in half across the axis of rotation, with one side being right hand and the other being left hand. Thus when rotated in the proper direction, material is conveyed toward the center of the conveyor screw (22).

The pitch length of the right and left hand screw (22) is substantially the same, and is typically one half the outside diameter of the screw flighting. This pitch is uniform until the flighting extends approximately one pitch length underneath the trough shroud (24). At this point, the pitch length of the flighting abruptly changes to approximately equal the outside diameter of the screw. This screw pitch is maintained until the flighting ends at or near the conveyor midpoint.

Another way to feed the rotary air lock valve is to move the material to the discharge opening (32) via a walking floor on the bottom of the hopper or a moving belt (see Figure 7). However the material is conveyed to the discharge opening, it should remain uncompacted and freely flow, preferably by gravity, from the discharge opening into the material inlet of the rotary air lock valve. Compacting or forcing the material will cause variable densities which will result in a pulsating and variable feed to the combustion zone.

In one embodiment, located at the conveyor midpoint is a discharge opening (32) in the bottom of the conveyor trough (20). The opening (32) is approximately the same width as the outside diameter of the screw flights and is of sufficient length so approximately one half of the final pitch length of both the right and left hand screws is exposed to the opening.

Located generally beneath the opening (32) is an optional transition area (34) leading to the material inlet (46) of a rotary air lock valve (42). This optional transition area (34) is equipped with access doors (36) for inspection of the air valve/transition area (42/34), and to allow maintenance of the rotary air lock valve (42) without its removal. The doors (36) are often equipped with safety interlock devices (38) which will stop the rotary air lock valve (42) and the screw conveyor (22) rotation any time either of these doors (36) is opened.

The rotary air lock valve (42) consists of a cylindrical, tubular housing (44) having a section of the cylinder wall of the housing (44) removed to serve as a material inlet (46). The material inlet (46) receives bulk material and is approximately the same size as the discharge outlet (32) in the bottom of the conveyor trough (20). In general, the material inlet (46) is oriented so that it is located above the axial center-line of the cylindrical housing (44). Figure 2 shows that bordering along each of the two longitudinal sides of the material inlet (46), and parallel to the air valve rotor shaft (50), is a mounting shelf (114) containing an adjustable cutting knife (106) of approximately the same length as the material inlet (46). The knives (106) are oriented on the shelves (114) so the honed cutting edges (110), in general, oppose each other and face the material inlet (46) opening in the housing (44) (See Figure 1), extending into the opening (46) so the honed cutting edge (110) can be adjusted by the screws (112) on the shelf (114) to a minute distance within the inside diameter of the housing (44) (See Figure 1). The knives (106) can be held in place by clamping bolts (113) threaded into the shelf (114).

Concentric with the axial center-line of the housing (44) depicted in Figure 3, is a rotor (40) comprised of a central shaft (50) with multiple vanes (52) forming a multiple of pockets (54), with each vane (52) extending outward from the shaft (50) center-line to within close proximity of the inside diameter of the cylindrical housing (44). When viewed from a radial direction, all vanes (52) are mounted at, but not limited to, a preferred common angle which may vary between five and ten degrees as compared to the axial center-line of the shaft (50). While the preferred common angle is five to ten degrees, the vane at a minimum is not parallel to the axial center line of the shaft. The rotor (40) is powered by a motor (57) and drive (56) (see Figure 1 for a depiction of motor and drive assembly). As the shaft (50) rotates, the vanes (52) move circumferentially below the material inlet (46) area, and in general toward the cutting edge (110) of one cutting knife (106) and away from the other cutting knife (106). As the outside edge of a vane (52) passes the cutting edge (110) of the knife (106) it is moving toward, a cutting force is created on any material trapped between the two. The cutting action is enhanced by the close proximity of the honed cutting edge (110) of the knife (106) to the edge of the rotor vanes (52). Furthermore, with the vanes (52) canted at an angle, the cutting action occurs gradually as the edge of each vane (52) passes the cutting edge (110) of the knife (106) in an incremental manner along their respective lengths. Having a knife (106) on both sides of the material inlet (46) allows this cutting action to occur whether the rotor (40) is turning in either a clockwise or counter-clockwise direction.

In one embodiment of the current invention, the motor driving the rotor could have different configurations including, but not limited to, variable speeds.

End plates (60) cover each end of the cylindrical housing (44) and contain bearings (62) on which the rotor (40) is supported and rotates.

In the following embodiments depicted in Figure 4, the discharge conduit (68) is connected with a fuel feed receiver (69). The fuel feed receiver is connected to the combustion zone (201). The connection with the fuel feed receiver should be substantially void of sharp turns and angles, especially 90 degree T's. Further, the connection should be void of butterfly valves. The walls from the discharge conduit to the fuel feed receiver should be sufficiently smooth to avoid compaction, buildup or other restrictions of the solid fuel. The connection may be of any length, diameter or as many bends or curves as can be supported by the amount of pressurized gas relative to the rate of material being conveyed. In the event of curves, they should be of a gradated angle variety. Pressurized gas is used to move the material into the discharge conduit (68). The amount of gas is the minimum amount of cubic feet per minute that will not affect the air flow of the primary fuel, yet is enough to move the solid fuel through the discharge conduit (68) to the fuel feed receiver (69). When starting to feed the rotary air lock valve, one should start at a low solid fuel feed rate and slowly increase the rate to the desired rate.

In one embodiment, each end plate (60) contains one opening to act as an air inlet (64) or an air outlet (66), depending on the direction of air flow. While this description refers to air, it can also be described as a pressurized moving gas. These openings (64, 66) are located on the plates (60) radially between the inside diameter of the rotor vanes (52) and the inside diameter of the cylindrical housing (44). The air inlet (64) and outlet (66) openings, in general, are positioned below the axial center-line of the cylindrical housing (44), and in an offset manner defined by the vane (52) angle. Thus, as the vanes (52) rotate past the air inlet (64) and outlet (66), they do so in a simultaneous manner, that is, as the edge of a vane (52) end reaches the side of the air inlet (64) opening, it also reaches the same side of the air outlet (66) opening.

In one embodiment depicted in Figure 4, a receiving chamber (200) is located beneath the rotary air lock valve and the pressurized moving gas inlet (64) is located on a first end of the receiving chamber (200) and the pressurized moving gas outlet (66) is located on a second end of the receiving chamber and the first and second end are opposite of each other.

In another embodiment depicted in Figure 5, pressurized moving gas enters the housing (44) through the inlet (64) not parallel to the central shaft. Further, the pressurized moving gas exits the housing (44) through the outlet (66) not parallel to the central shaft.

Escape to the atmosphere of the pressurized air/gas through the material inlet (46) is minimized by the close proximity of the outside diameter of the rotor vanes (52) to the inside diameter of the cylindrical housing (44). Thus, the high pressure air is channeled through each pocket (54) as the vanes (52) rotate past the air inlet (64) and outlet (66). To diminish air leakage which occurs between the end plates (60) and the ends of the rotor vanes (52), a seal plate (70) of anti-friction material is placed at each end of the rotor (40). The seal plates (70) have roughly the same outside diameter as the inside diameter of the cylindrical housing (44). The seal plates (70) are also equipped with openings through the center of sufficient size to allow the rotor shaft (50) to extend through and openings of roughly the same shape, size, and location as the air inlet (64) and outlet

(66). The seal plates (70) are held stationary with respect to the end plates (60) and the cylindrical housing (44), with the rotor (40) ends turning in contact with the inside surface of the seal plates (70). As the seal plates (70) wear, shims (72) (see Figure 2 for a depiction of the seal plates and shims) between the rotor end plates (60) and the rotor housing (44) can be removed to bring the seal plates (70) back into contact with the rotor (40).

Bulk material, such as solid fuel, is fed into the hopper (10) by means of, but not limited to a loader, a conveyor, or a live bottom or dump truck. Material either falls directly through the hopper (10) into the screw conveyor trough (20), or comes in contact with the diverter (12) and is influenced downwards to the trough (20) openings at the ends of the screw conveyor (22). As the material fills the trough (20), the screw (22) acts upon it, moving it from the outside ends of the trough (20) toward the converging point of the conveyor (22). If sufficient material is fed to the trough (20) openings to cover the screw flighting, the screw conveyor (22) will run full. The screw conveyor (22) ends run full until the material reaches the pitch length change under the shroud (24). With the increased volume between the flights, the material level drops to less than full on each side. The material from one end is conveyed until it is thrust upon material being conveyed from the other end. The reduced capacity of the full pitch converging screw flighting (22) and any open area between the converging screw flights allows enough area for the two converging masses to interact and induce forces upon each other to break one another apart. This is particularly advantageous when the feed material is fibrous and tends to move as large mass instead of moving as individual particles such as solid fuel.

The loose material falls through the trough discharge opening (32) by the aforementioned converging action. The material falls through the transition area (34) into the material inlet (46).

As material falls into the rotary air lock valve (42), the rotating pockets (54) (See Figure 3) fill with material, usually in a random uneven fashion. With fibrous materials such as solid fuel, large pieces of material protruding out of a pocket (54) (See Figure 3) have a tendency to get jammed between the rotor housing (44) and the trailing vane (52) of that pocket as that vane (52) starts to pass from the material inlet (46) into the housing (44). The cutting knives (106) greatly reduce jamming by cutting any fibrous material extending beyond the outside diameter of the vanes (52), while the angled vane (52) reduces the cutting area so only a small portion of the knife (106) is cutting at any moment. The angled vane (52) also helps to more evenly distribute the material in the pockets (54) between the vanes (52) by allowing potential overage to spill to the next pocket (54), or axially down the pocket (54). Through this motion, the rotary air lock valve continuously meters the fuel. If a large piece of material does jam the air lock valve (42), the rotation of the air valve rotor (40) automatically reverses allowing the material causing the jam to fall into the pocket (54) or to be cut by the other knife (106). To maintain continuous metering of the solid fuel, several variables are coordinated. These variables include, but are not limited to, floor speed, fuel feed rate, rotary air lock valve rate and operating gas speed.

As depicted in Figure 6, material contained in the area defined by the pockets (54) and the housing (44) (See Figure 5) rotates around with the rotor (40) until the vane (52) ends come into communication with the air inlet (64) and outlet (66) ducts simultaneously. High pressure air is fed by a fan or blower (120) through the air inlet (64). High pressure air from a blower (120) is passed into the pocket (54) where the pressurized air picks up the bulk material and conveys it out of the air valve (42) and into the discharge conduit (68) seen previously in Figure 4.

Figure 7 depicts a side elevational view, partly in section, showing the solid fuel delivery apparatus attached to the back of a truck. In this embodiment, the rotary air lock valve (42) is positioned below and at the end of a walking floor (86). This figure also depicts a non-compressive auger (88) and an anticavitation device (90). The auger keeps the material moving from left to right across the top of the auger (88). At the same time, the slow augering motion of the non-compressive auger (88) also keeps the material fluffed. The word fluffed in the present embodiment is taken to mean non-clumped. The walking floor (86) situated underneath the non-compressive auger (88), moves the material from right to left towards the rotary air lock valve apparatus (42). As the material makes its way towards the rotary air lock valve, it passes under a gate (92) and makes contact with the blades (94) of an anticaviation device (90). The blades (94) break up the material and keep the material fluffed. The anticavitation device (90) is surrounded by an enclosure (98). As the fuel material continues past the walking floor (86), it falls via gravity through the material inlet (46) within a housing (44). Inside the housing (44) is a rotary air lock valve (42). The rotary air lock valve (42) has vanes (52) and knives (106) (See Figure 5). The slanted nature of the blades (52) allows the vanes to make contact with the fuel material at one spot (110).

Figure 8 also depicts the solid fuel delivery apparatus attached to the back of a truck. In the present embodiment, the rotary air lock valve (42) is positioned below and at the end of a walking floor (86). This figure also depicts a non-compressive auger (88) and an anticavitation device (90). The auger keeps the material moving from left to right across the top of the auger (88). At the same time, the slow augering motion of the non-compressive auger (88) also keeps the material fluffed. The word fluffed in the present embodiment is taken to mean non-clumping. The walking floor (86) situated underneath the non-compressive auger (88), moves the material from right to left towards the rotary air lock valve apparatus (42). As the material makes its way towards the rotary air lock valve, it passes a gate (92) (See Figure 7) and makes contact with the blades (94) of an anticaviation device (90). The blades (94) break up the material and keep the material fluffed. The anticavitation device (90) is surrounded by an enclosure (98) (See Figure 7). As the fuel material continues past the walking floor (86), it falls via gravity through the material inlet (46) within a housing (44). Inside the housing (44) is a rotary air lock valve (42). The rotary air lock valve (42) has vanes (52) and knives (106) (See Figure 5). The slanted nature of the blades (52) allows the vanes to make contact with the fuel material at one spot (110). In the present embodiment, fuel feed material exits from a material outlet (66) where it enters a discharge conduit (68). The discharge conduit (68) exits from the outlet opening (66) where the fuel makes its way to the furnace. In the present embodiment, regulating the height of fuel is important in providing a consistent delivery of solid fuel to a combustions zone. Three controls can regulate this height: floor speed (which notably on a walking floor or other system can move material without pushing), regulation of the height of the gate (this height may be constant but can be varied and not the same from one point in time to the other), and the speed of the rotary air lock valve. Fuel height in the present embodiment is taken to be the measured distance from the outside circumference described by the rotation of the vanes of the rotary air lock valve to the highest point of the fuel above the rotary air lock valve. The fuel height may vary on the surface to be higher to the left and right of the anticavitation device. Note that this embodiment does not include the addition of a dosing rotor weighfeeder or rotor weighfeeder which measures a dose. Therefore, this apparatus and the method can be said to done without measuring the dose or using a dose measuring device, without passing through a dosing rotor weighfeeder or a rotor weighfeeder. Because the dose weight is often calculated based upon the tare weight of the equipment, it can be said that the method be conducted without using the tare weight of the equipment and the apparatus be void of equipment to measure, record, store or otherwise use the tare weight in the operation of the process.

This invention replaces the rotary metering device or rotary feeder used today (See for example, Figure 3, US 7,479,606). A rotary feeder or rotary metering device has vanes or paddles or bent arms extending radially from a rotating from a central shaft that sweep the feed across a plate into a hole. These vanes rotate in a plane substantially perpendicular to gravity. Additionally, the central shaft is substantially parallel to the force of gravity. The method and apparatus described herein can be done without using, or in the absense of, a rotary feeder. While a rotary feeder may operate continously, it does not provide feed continuously. On the other hand, the current method and appartus provide a consisent continous feed, especially at low turn down rates.

Figure 9 is a rear elevational view of the back of the truck. A hydraulic piston (130) powers the open and shut mechanism of the gate/door (92). The gate/door (92) is adjustable. As a working embodiment, the vertical position of the gate/door (92) plays a role in ensuring contact is made between the fuel feed material and the anticavitation device (90), and no compaction of the material takes place. Further depicted in this view is the air/gas inlet (64) and air/gas outlet (66). As previously described, pressurized gas enters through the air/gas inlet (64) and exits through the outlet (66) and is used to move the material into the discharge conduit (68) (see Figure 8) on its way to the furnace.

Figure 10 is a rear elevational view, partly in section, of the back of the truck. A hydraulic piston (130) powers the open and shut mechanism of the gate/door (92). The gate/door (92) is adjustable. As a working embodiment, the vertical position of the gate/door (92) plays a role in ensuring contact is made between the fuel feed material and the anticavitation device (90), and no compaction of the material takes place. Further depicted in this view is the air/gas inlet (64) and air/gas outlet (66). As previously described, pressurized gas enters through the air/gas inlet (64) and exits through the outlet (66) and is used to move the material into the discharge conduit (68) on its way to the furnace. Also depicted are rear views of the rotary air lock valve (42) positioned below and at the end of a walking floor (86). This figure also depicts a non-compressive auger (88) and an anticavitation device (90). The slow augering motion of the non-compressive auger (88) keeps the material fluffed. The word fluffed in the present embodiment is taken to mean non-clumping. The walking floor (86) situated underneath the non-compressive auger (88), moves the material towards the rotary air lock valve apparatus (42). As the material makes its way towards the rotary air lock valve, it passes a gate (92) and makes contact with the blades (94) of an anticaviation device (90). The blades (94) break up the material and keep the material fluffed. As the fuel material continues past the walking floor (86), it falls via gravity through the material inlet (46) within a housing (44). Inside the housing (44) is a rotary air lock valve (42). The rotary air lock valve (42) has vanes (52) and knives (106) (See Figure 5). The slanted nature of the blades (52) allows the vanes to make contact with the fuel material at one spot (110).

Figure 11 is a rear elevational view of the hydraulic power source (136) located in this instance towards the front of the truck. Although the present embodiment utilizes a hydraulic power source, other power sources are contemplated, including, but not limited to, electrical, gas and air power sources.

Figure 12 depicts the position of the power source (136) towards the front of the truck. Although the current embodiment utilizes diesel, different configurations are envisioned, including, but not limited to electric, gas and air.

Figure 13 depicts an alternative embodiment utilizing bulk feed bins (142) in conjunction with a bulk solids tank (148). The stationary bulk feed bins (142) could be set up in place of the truck in previous embodiments. In such an arrangement, anticavitation devices (90) are positioned beneath the bulk feed bins (142). As material falls via gravitational forces, first through the material inlet (46), then into the rotary air lock housing (44), it comes in contact with the rotary air lock blades (52) and knives (106) (See Figure 5), until it finally exits the material outlet (66) and enters the discharge conduit (68). The discharge conduit (68) connects with the fuel feed receiver (69) and eventually ends with a flame (201) at the furnace.

Figure 14 depicts the lead up to the combustion zone. A discharge conduit (68) exits from the air outlet opening (66) and feeds into a fuel feed receiver (69). The fuel feed receiver (69) enters into a the walls of a kiln (76). A primary feed tube (74) containing coal or other primary fuel, also feeds into the fuel feed receiver (69). A layer of insulation (78) is incorporated into the fuel feed receiver (69). At the end of the fuel feed receiver (69) is a luminous flame (201). A valve shut off (82) may be used as a safety feature to shut off the delivery of the primary fuel (coal or other fuel) and secondary fuel (solid fuel such as that provided by Vexor Technology®, Inc.) sources. Such a shut off may occur if there are delivery issues such as when plugging occurs or if there are kiln issues such as when a coal mill goes down. Figure 15 depicts a cross sectional view of the fuel feed receiver.

Figure 16 depicts another embodiment of the present invention involving a multiple burner tube setup. In this embodiment, each multiple tube could be adapted for use inside the fuel feed receiver (69) (See Figure 13). The tube containing coal or other primary fuel could be concentric within a tube containing solid waste fuel or other secondary fuel source, which could be concentric within a tube containing air or other gas.

U.S. Pat. No. 5,299,888, describes using a screw conveyor to introduce the fuel into the material inlet of the rotating rotary air lock valve. Experience to date has shown that a screw conveyor does not keep the feed rate constant, but it is conceivable if properly designed. Therefore, in one embodiment, the introduction to the material inlet (46) (See Figure 1) of the rotating rotary air lock valve is done without a screw conveyor whose shaft is essentially parallel to the central shaft of the rotating rotary air lock valve. Instead, the feed is introduced to the material inlet of the rotating rotary air lock valve by systems including, but not limited to, conveyor belt and walking floor type systems.

In another embodiment of the current invention, a constant feed of solid fuel is achieved by regulating the height of the fuel above the rotary air lock valve within certain parameters which could be a constant height.

In another embodiment of the current invention, a constant feed of solid fuel is achieved without the use of a rotorweighfeeding system. In a rotor weighfeed system, a rotorweighfeed system, secondary fuels are fed by a prefeeding system via diverter flap to a pre-hopper. The calibration pre-hopper above the rotorweighfeeder works additionally as material buffer. A helical stirrer keeps the fuel in motion and ensures a constant fuel flow to the rotorweighfeeder. The material load inside the hopper is measured by load cells underneath the frame. The inner part of the rotor weighfeeder consists of a lower seal plate with discharge opening, rotor wheel including bars and inner ring as well as outer ring. The very slow rotating wheel guarantees an almost maintenance free system. The bulk material transported by the horizontal rotor wheel from the inlet to the outlet falls down at the discharge opening by gravity, while pneumatic nozzles support the material discharge. The body of the rotorweighfeeder is suspended via two weighing bearings. The weighing axis goes through the weighing bearings centred to the in- and outlet area. A third suspension point is connected with a load cell, which measure the content gravimetrically inside the rotor. The measured value (momentary load) and the related rotor position are stored in the weighing electronics at any time. A calculation of the needed rotor speed is made according to the required feed invese to the material load. The rotor speed multipled with the load gives the actual feed rate controlled by the weight. The result of the calibration and calculations is thought to provide a high constant material flow at the discharge point. The rotary valve feeds the material into the pneumatic transport system. Clean transport air from the blower is blown through the blowing shoe. Part of the transport air is used for cleaning the chambers of rotary valve. The air loaded with fuel is transported directly into the burner flame. During online calibration, the material supply into the pre-hopper is stopped. The static load cells underneath the rotorweigh feeder frame measure the loss in weight during the calibration period. This value is compared with the weighing data of the rotor weighfeeder. If necessary, an online taring can be executed. The present embodiment of the current invention, the rotor weighfeeder is eliminated, thereby reducing complexity, expensive and inconsistent delivery profile of fuel to a combustion zone.

The term solid fuel in the current embodiment includes, but is not limited to, solid fuels that have been used as fuel or that have been recycled or processed in a variety of high temperature situations, including, but not limited to cement kilns. Examples of fuels which have been converted into solids include, but are not limited to waste tires, either whole or when reduced in size by some means (U.S. Pat. No. 5,473,998); hazardous waste liquids, or solids or both (U.S. Pat. No. 5,454,333); agricultural waste, for example rice hulls; paper mill sludge (U.S. Pat. No. 5,392,721); soil, sludge, sand, rock or water contaminated with organic solvents and/or toxic metals (U.S. Pat. No. 4,921,538); sewage sludge (U.S. Pat. No. 5,217,624); petroleum refinery sludge (U.S. Pat. No. 5,141,526); various hazardous combustible wastes (see U.S. Pat. No. 5,454,333 or U.S. Pat. No. 4,984,983) and non-hazardous low-grade fuel wastes such as wood, paper and chemical waste (U.S. Pat. No. 5,336,317). Another example of a solid fuel is the engineered fuel produced by Vexor Technology®, Inc of Medina, Ohio.

In one embodiment of the current invention, the solid fuel is considered a secondary fuel source, with coal considered the primary fuel source. Other embodiments, include, but are not limited to, situations where the solid fuel acts as the primary, or even only, fuel source. Similarly, other embodiments of the current invention include other primary fuel sources, including, but not limited to, petroleum coke, natural gas, fuel oil and other fossil fuels.

In one embodiment of the current invention, the solid fuel selection may also be based upon such variables as high heat value (BTU/lb), moisture content, bulk density and particle size. Examples of acceptable ranges include, but are not limited to, fuels with a high heat value of greater than 5000 BTU/lb, a moisture content less than 40% by weight.

The term discharge conduit in the current embodiment includes, but is not limited to, a pipe. The pipe could be circular, oval, square or other configuration suitable for transporting the particles of solid fuel from the discharge of the rotating rotary air lock valve to the entrance of the fuel feed or the combustion zone. The wall of the discharge conduit could be flexible or rigid.

The term combustion zone in the current embodiment includes, but is not limited to, the location where chemical energy locked up within fuel is transformed into heat through oxidation of the fuel, which is preferrably the hot end. The actual combustion process is an incredibly complex series of chemical reactions that generally with fuel, air, and an ignition source. In fact, there are actually more than one thousand separate reactions involved from the transition of fuel into the final combustion products of carbon dioxide and water. The combustion process continues provided there is enough fuel and air supplied. The temperature of the combustion zone is typically in the order of

This method contemplates the addition of combustion enhancing gases. While one of ordinary skill would select air as the first choice for a motivating gas, knowing that the air has a variable oxygen content which is determined by the air at the particular elevation. This method would add at least one combustion gas in addition to the oxygen found in the atmospheric air. Nitrous oxide or oxygen are examples of a combustion enhancing gas. The combustion enhancing gas would be added after the helical rotary air lock valve or after the blower moving the conveying gas but prior to the rotary air lock valve, but in all cases the combustion enhancing gas is added prior to the flame base.

The current embodiment contemplates the use of this method of delivering solid fuels to combustion zones in high heat requiring, energy intensive systems including, but not limited to, cement kilns, lime kilns, furnaces, steam and power generators, and turbines.

The current embodiment contemplates the use of this apparatus to deliver solid fuel to a combustion zone in arrangements including, but not limited to, permanent fixtures or setups, hoppers, silos, mounted on trucks, for example trucks to blow mulch, seed or hay.

It thus will be appreciated that those skilled in the art will be able to devise numerous alternative arrangements that, while not shown or described herein, embody the principles of the invention and thus are within its spirit and scope. This application is not limited to the cement kilns, solid fuels, fuel feed receivers, blowers, rotary air lock valves, receiving chambers, discharge conduits, fuel feed receivers, furnace burners or combustion zones as described, but also to their equivalents.

Experimental Results

In tests conducted to date, the apparatus and method described herein has led to the consistent delivery of solid fuel to a combustion zone. This is due in large part to controlling several variables, as can be seen in the following chart.

Variables	Outcome
1100 CFM motivating gas 4" ID discharge conduit 40 lb/ft^3 bulk density Less than ¾" particle size	

Start at 1 tons per hour move to 3.5 tons per hour with +/- 0.1 ton/hour control	Failure due to 90 degree angle in pipe Failure due to butterfly valve in pipe
Change away from 90 degree angle and butterfly valve	Success

Additionally, some of these tests involved a comparison of the delivery profile of solid fuel to the combustion zone using the the apparatus and method described herein with a rotor weighfeeder apparatus and method. In this comparison, similar fuel material was used. In the rotary feeder apparatus and method, the feed rate varied and the resultant emitted amount of carbon monoxide varied as well, whereas in the present apparatus and method, a consistent continuous fuel feed was maintained and the resultant amount of emitted carbon monoxide was constant as well.

We claim:

1. Method for delivering solid fuel to a combustion zone wherein the method comprises:

A selection step which comprises selecting a solid fuel;

An introduction step which comprises introducing the solid fuel into a material inlet of a rotating rotary air lock valve,

wherein the rotating rotary air lock valve has a central shaft and an axis of rotation of said shaft with multiple vanes defining pockets between said vanes, and a material outlet;

A rotating step, wherein the rotating rotary air lock valve moves the solid fuel from the material inlet of the rotating rotary air lock valve to the material outlet of the rotating rotary air lock valve,

wherein the solid fuel is optionally placed into a receiving chamber;

A locomotive step, which comprises contacting the solid fuel with a moving gas, wherein the gas contacts the solid fuel at a location selected from the group consisting of the pocket between the vanes, the material outlet and the receiving chamber to move the solid fuel into a discharge conduit; and

A conveying step, wherein the solid fuel is conveyed by the moving gas through said discharge conduit to a solid fuel feed receiver of a furnace burner having a combustion zone, wherein the solid fuel is transported from the solid fuel feed receiver to the combustion zone.

2. The method of claim 1, wherein the introduction of the solid fuel into the material inlet of the rotating rotary air lock valve is made substantially perpendicular to the axis of rotation of said shaft.

3. The method of claim 1, wherein the introduction of the solid fuel into the material outlet of the rotating rotary air lock valve is kept substantially constant in terms of Btu/hour, by regulating the height of the fuel above the rotary air lock valve.

4. The method of claim 1, wherein the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve receives a plurality of doses over a period of time and at least some of the doses of the plurality are not weighed before entering the pocket.

5. The method of claim 1, wherein the moving gas contains at least one combustion enhancing gas in addition to the oxygen found in atmospheric air.

6. The method of claim 1, wherein the solid fuel has a heat value content greater than 5000 BTU/lb and a moisture content.

7. The method of claim 1, wherein a plurality said vanes are not mounted parallel to the axis of rotation said shaft.

8. The method of claim 7, wherein the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve receives a plurality of doses over a period of time and at least some of the doses of the plurality are not weighed before entering the pocket.

9. The method of claim 7, wherein the introduction of the solid fuel into the material inlet of the rotating rotary air lock valve is made substantially perpendicular to the axis of rotation of said shaft.

10. An apparatus for delivering solid fuel to a combustion zone, comprising:

a feed receiver;

a transition area located beneath said feed receiver;
a rotary air lock valve located beneath said transition area and adjacent to the feed receiver;
said rotary air lock valve having a cylindrical housing with a material inlet, a central shaft with multiple vanes defining a pocket between two adjacent vanes;
a moving gas inlet;
a moving gas outlet;
a discharge conduit having a first end and a second end, said first end is attached to said moving gas outlet and said second end is attached to a fuel feed receiver.

11. The apparatus of claim 10, wherein the moving gas inlet and the moving gas outlet are part of the rotary air lock valve, said outlet offset from said inlet by the angle of said vane so that moving gas fed through said inlet is channeled through said pocket to said outlet.

12. The apparatus of claim 10, wherein the apparatus further comprises a receiving chamber located beneath the rotary air lock valve and the moving gas inlet is located on a first end of the receiving chamber and the moving gas outlet is located on a second end of the receiving chamber and the first and second end are opposite of each other.

13. The apparatus of claim 10, wherein the feed receiver does not have a screw conveyer.

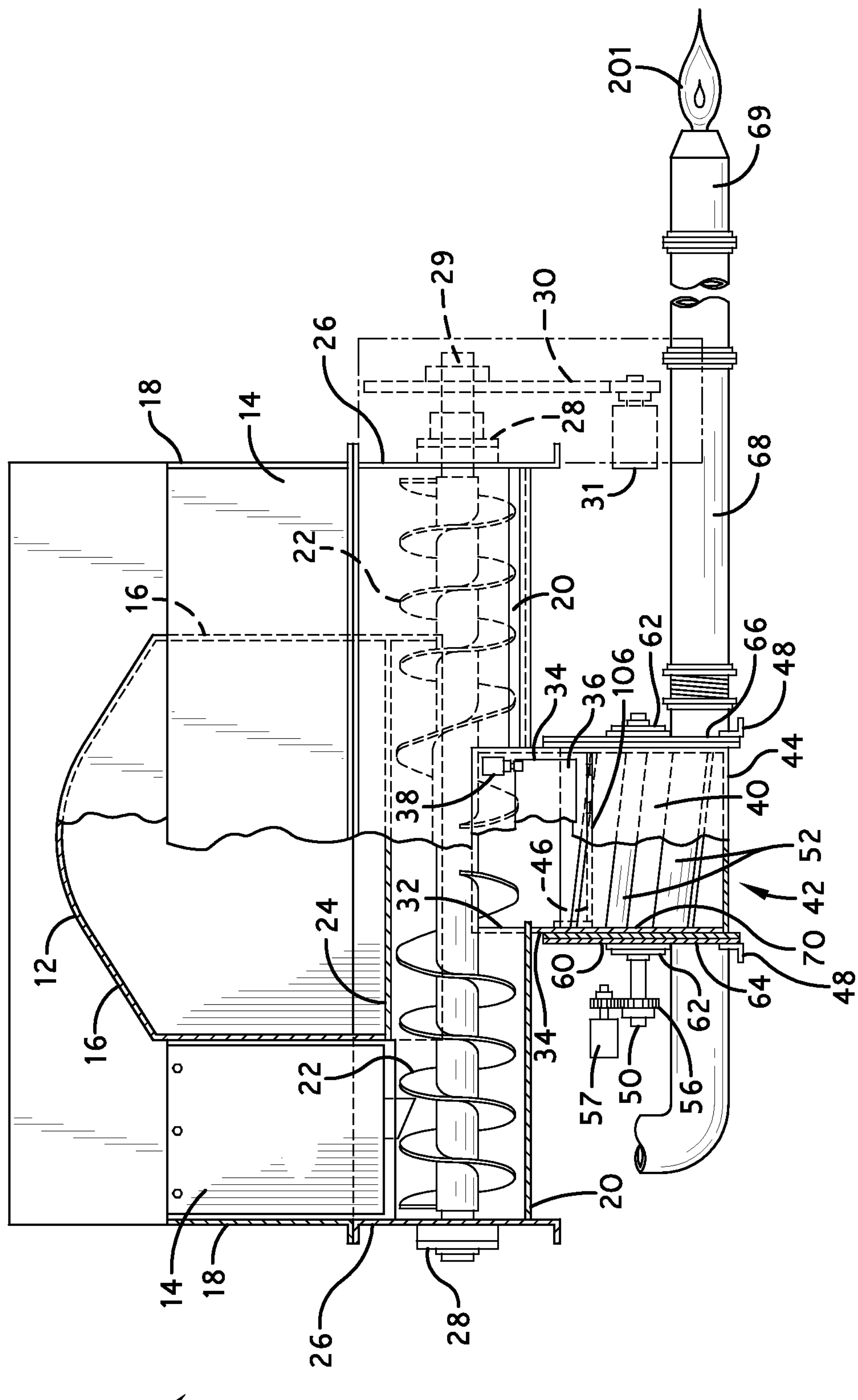
14. The apparatus of claim 10, wherein the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve is not connected to a control device which weighs a dose of the solid fuel before entering a pocket.

15. The apparatus of claim 10, wherein the solid fuel enters the material inlet of the rotary air lock valve perpendicular to the axis of rotation of the central shaft.

16. The apparatus of claim 10, wherein a plurality of said vanes are not mounted parallel to the axis of said shaft.

17. The apparatus of claim 16, wherein the amount of solid fuel occupying a pocket of the rotary air lock valve is known as a dose and wherein the rotary air lock valve is not connected to a control device which weighs a dose of the solid fuel before entering a pocket.

18. The apparatus of claim 16, wherein the solid fuel enters the material inlet of the rotary air lock valve perpendicular to the axis of rotation of the central shaft.



FIG—1

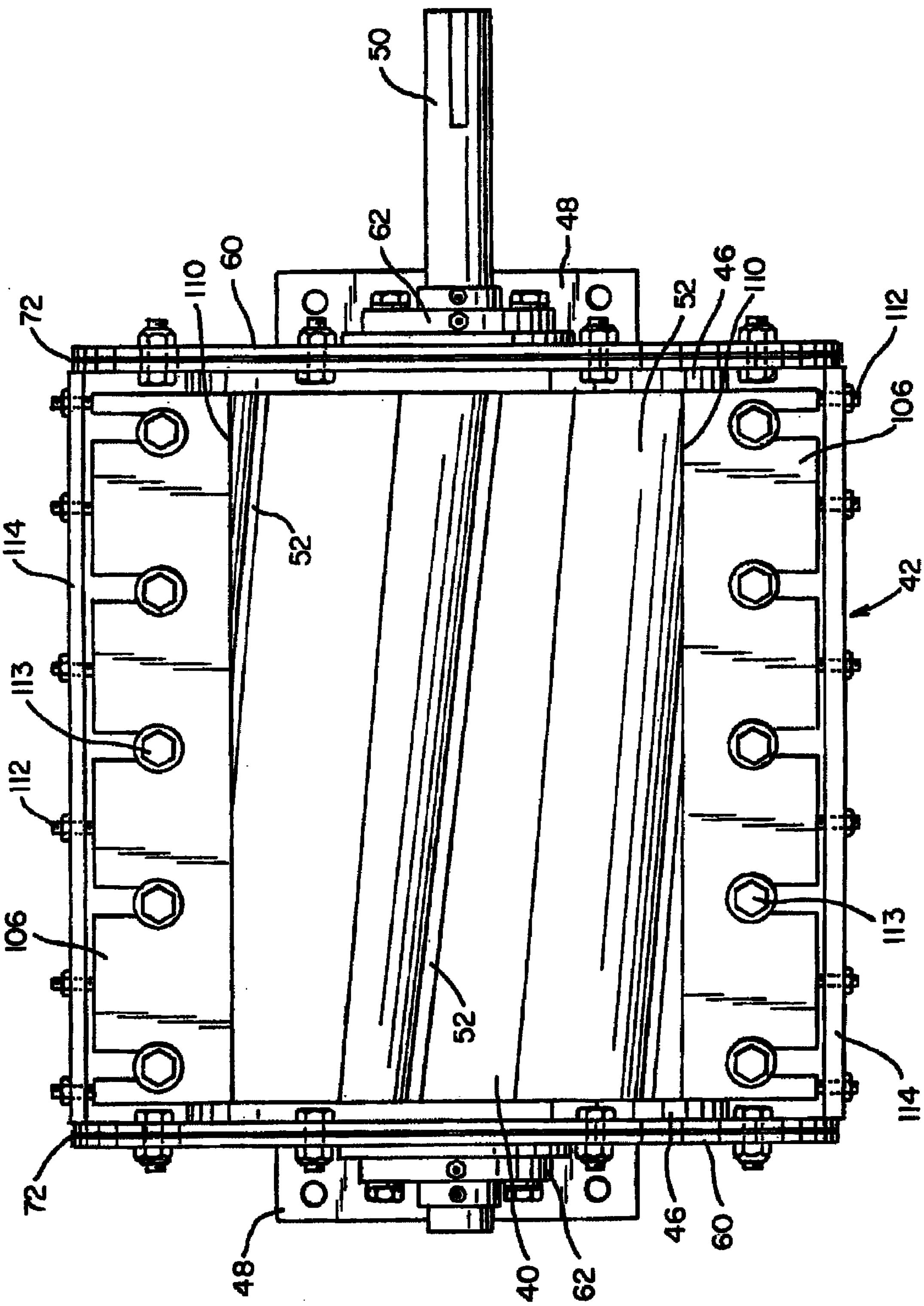

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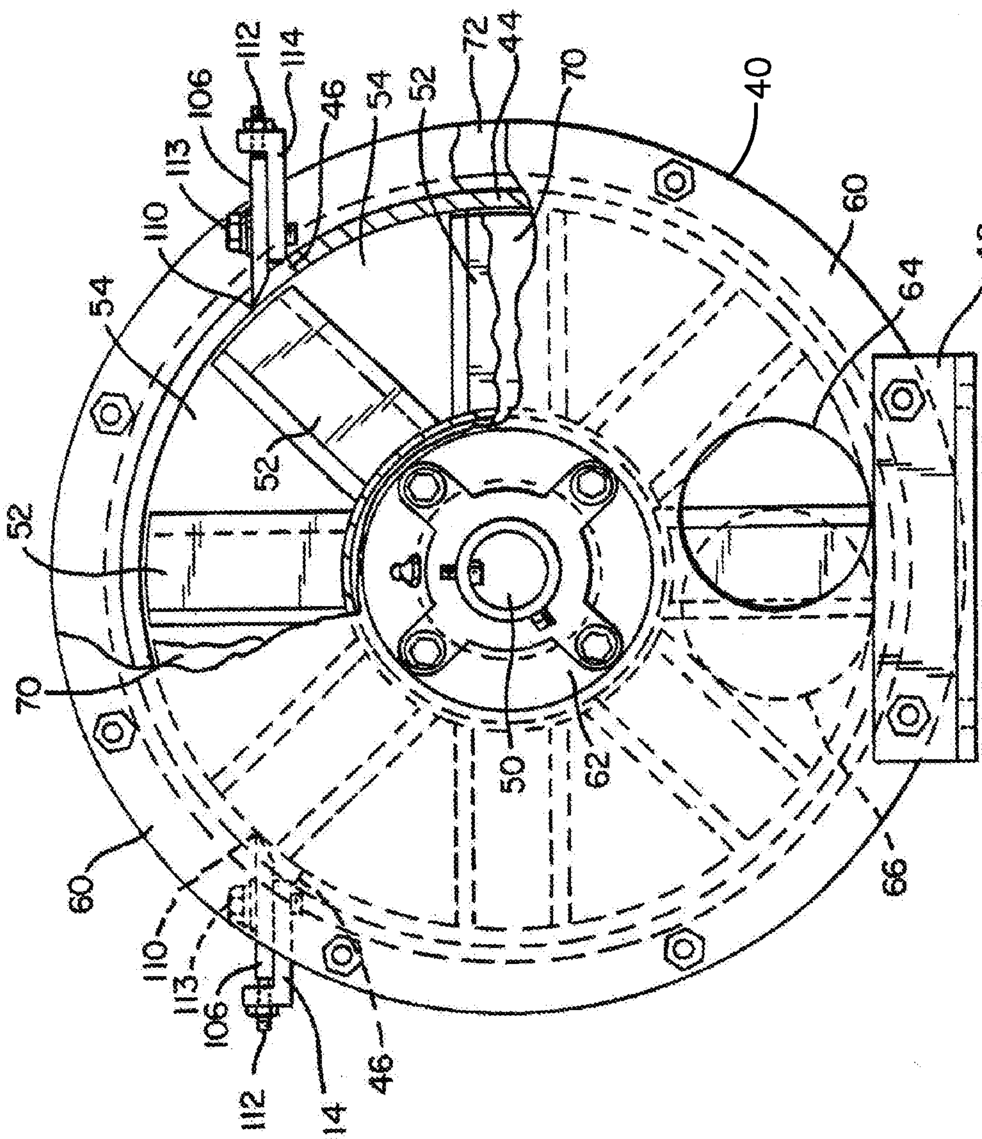
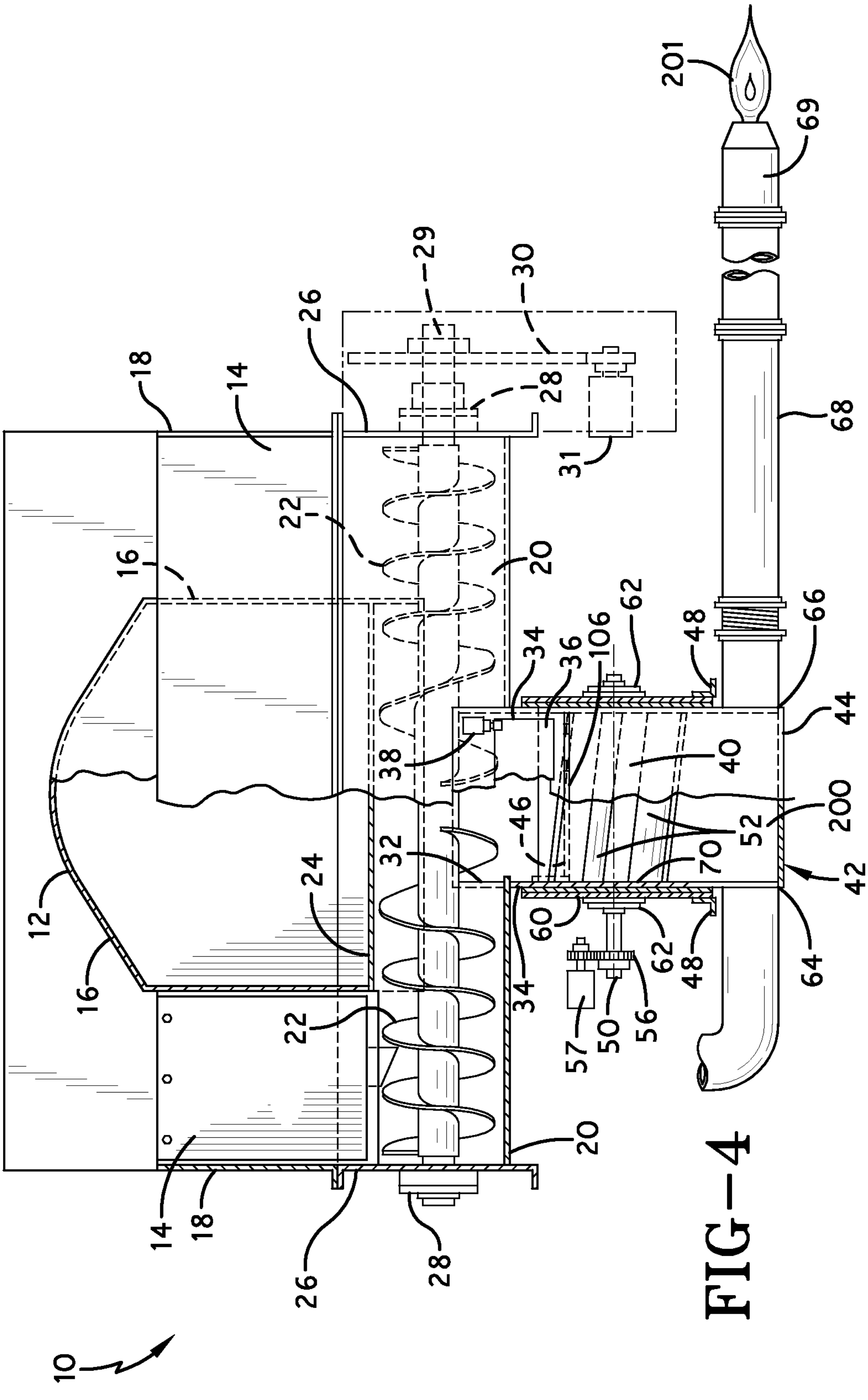
FIG-2



FIG—3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106
200
201

FIG-4

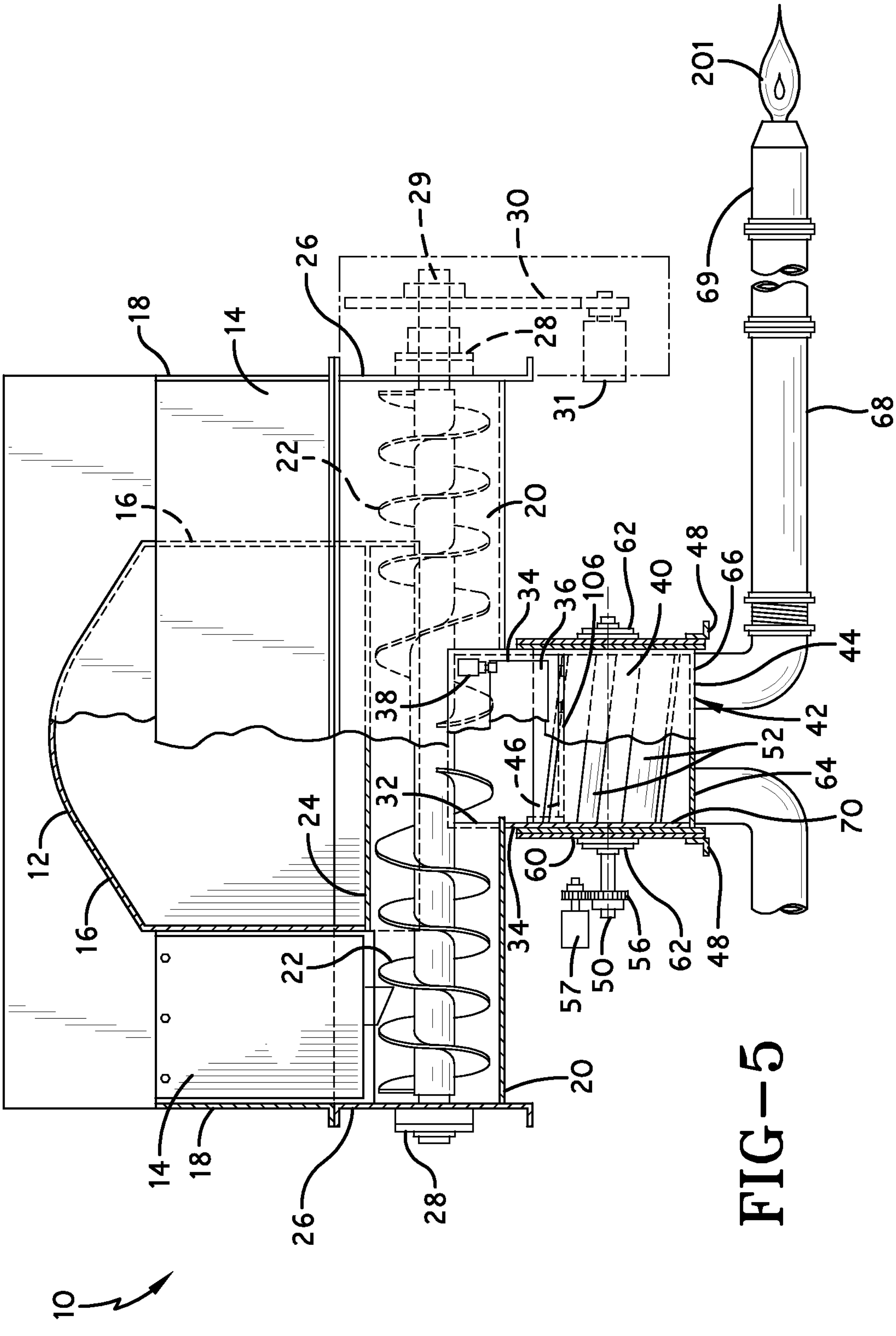


FIG-5

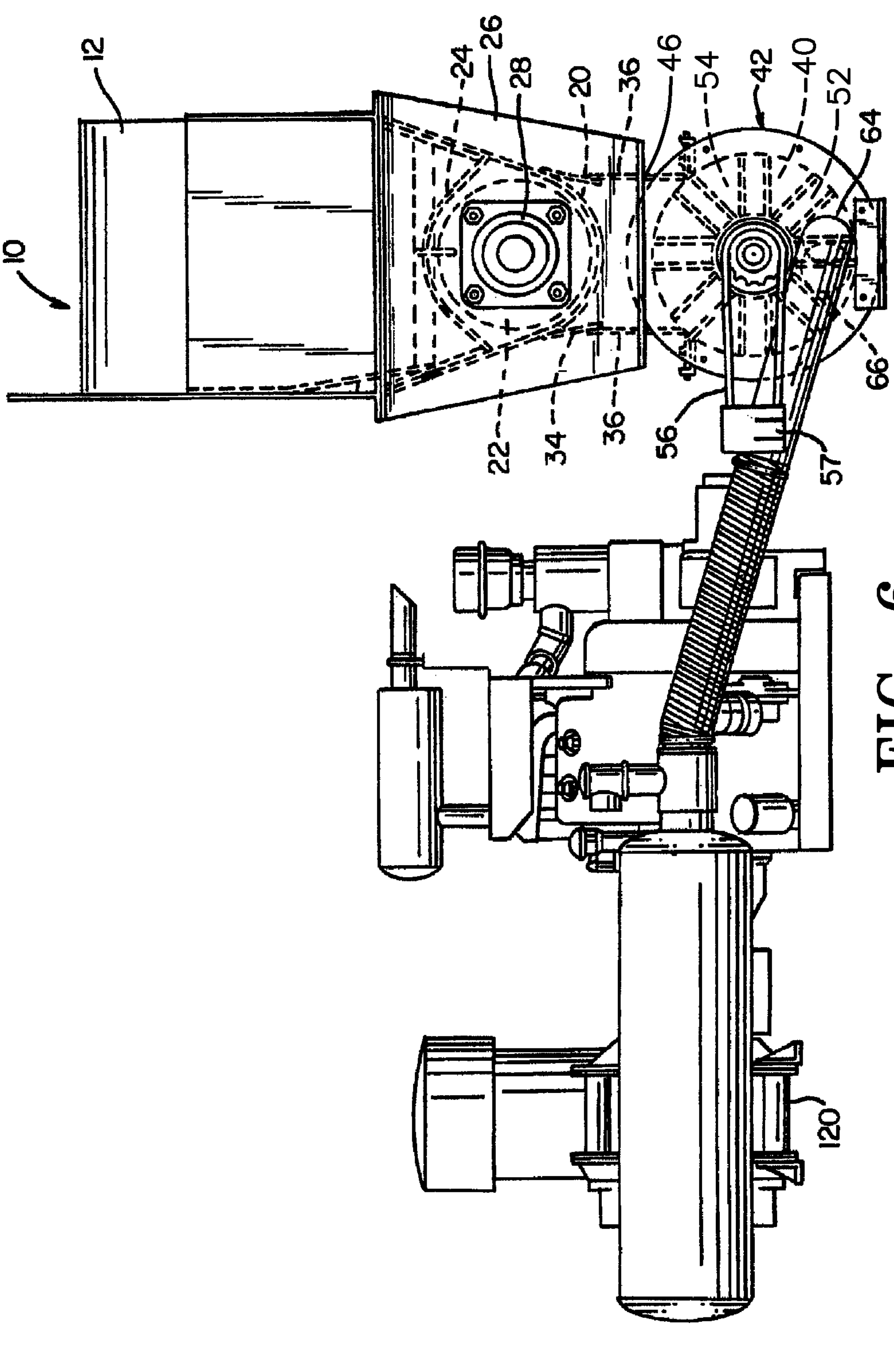


FIG-6

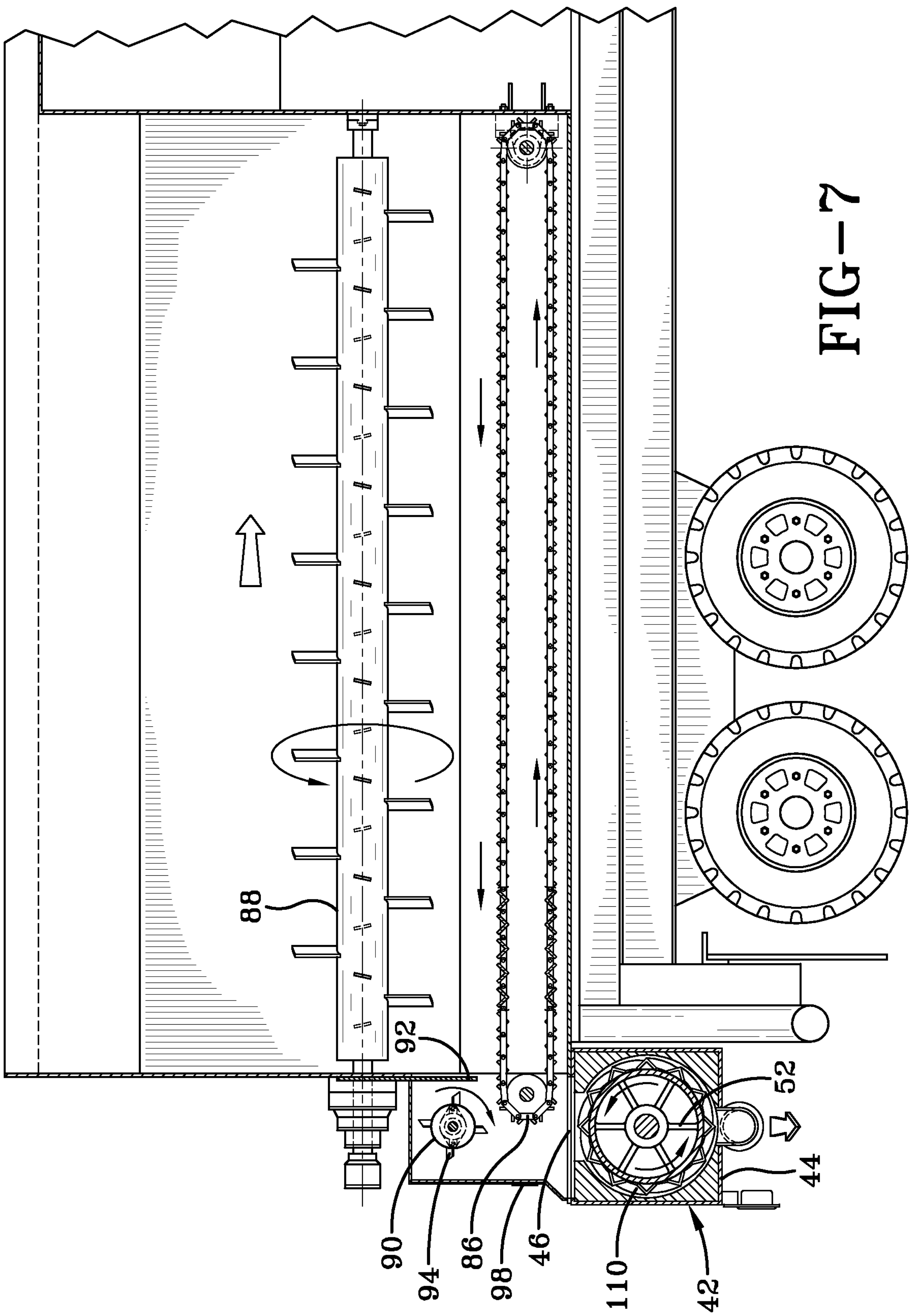


FIG-7

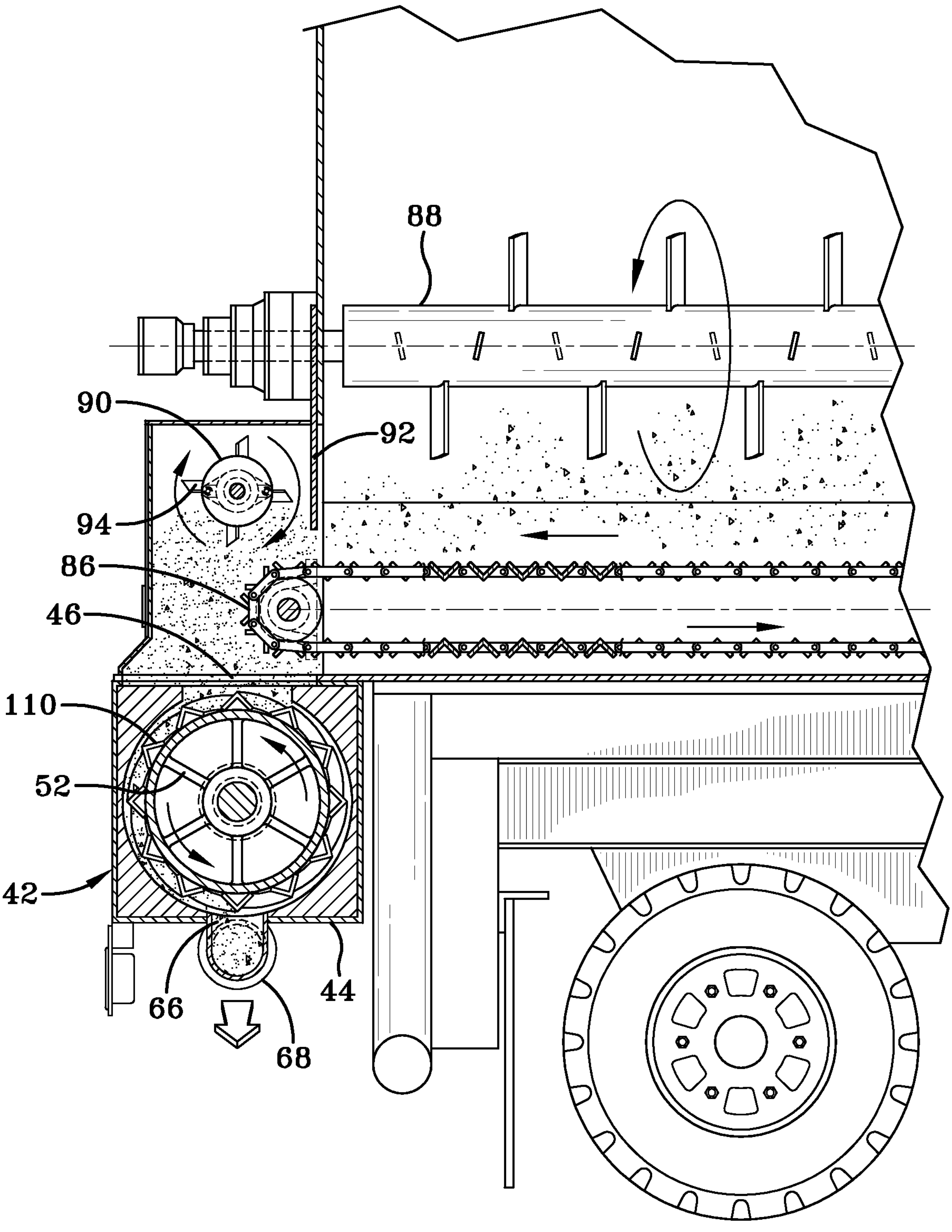


FIG-8

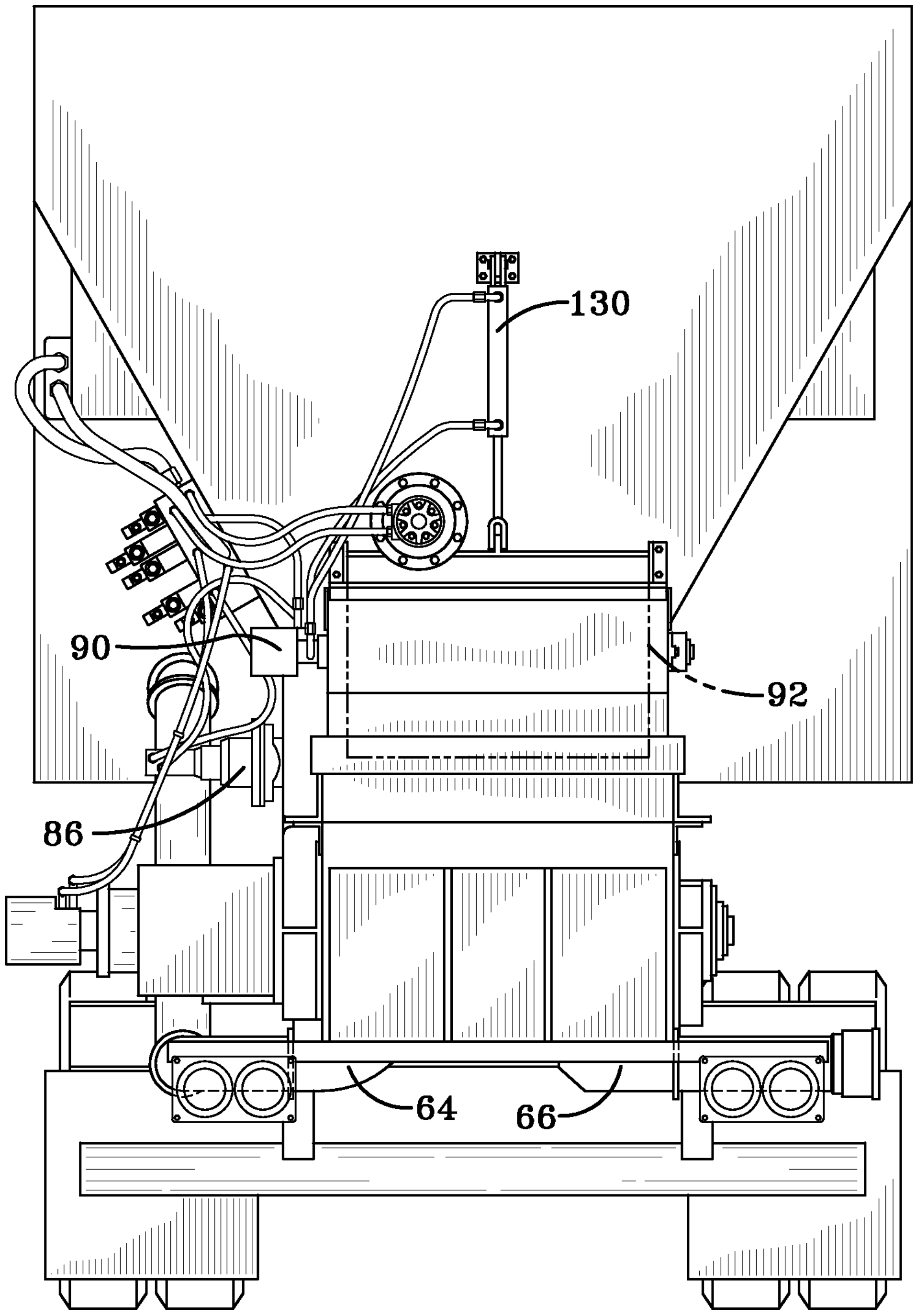
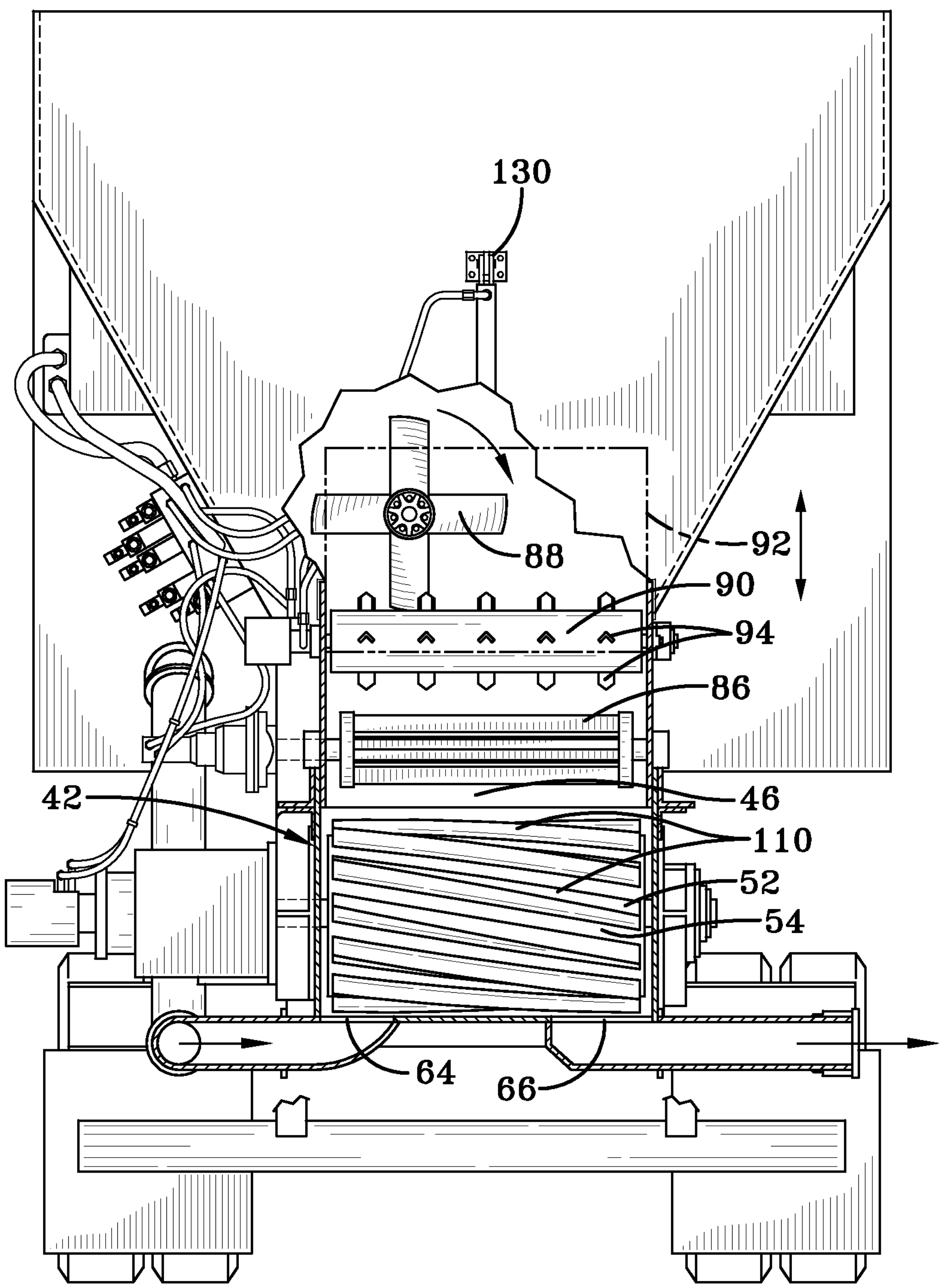


FIG-9



FIG−10

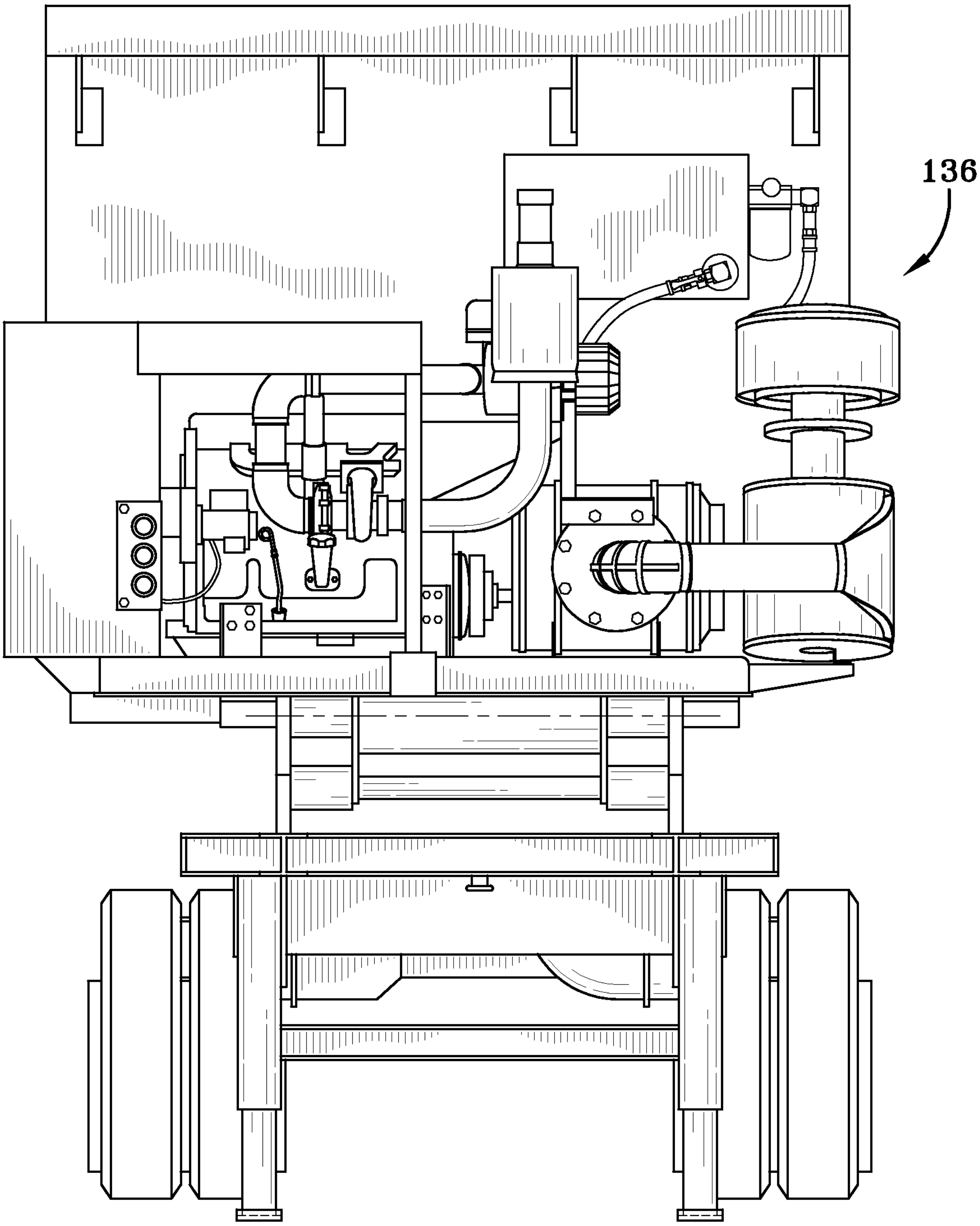


FIG-11

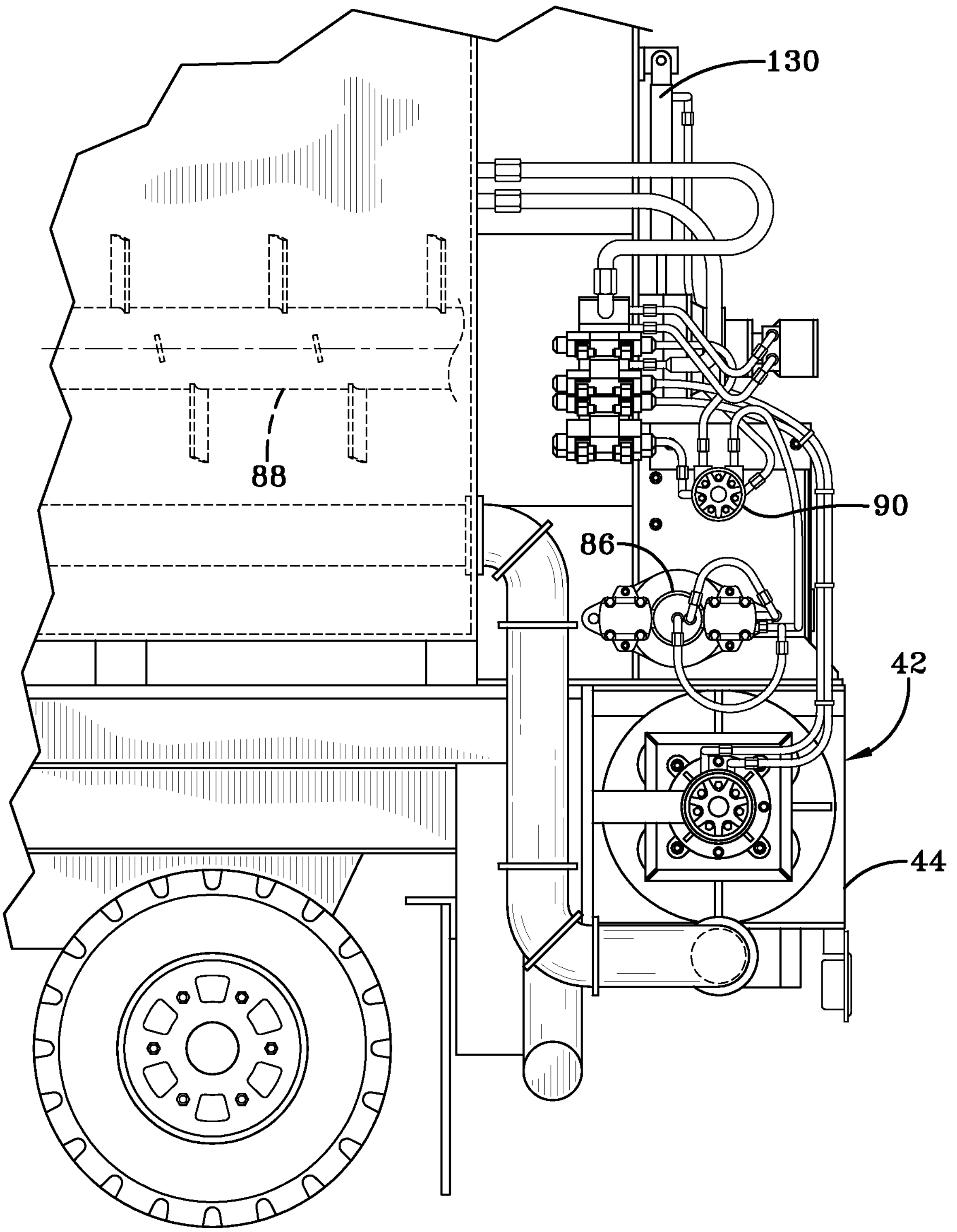


FIG-12

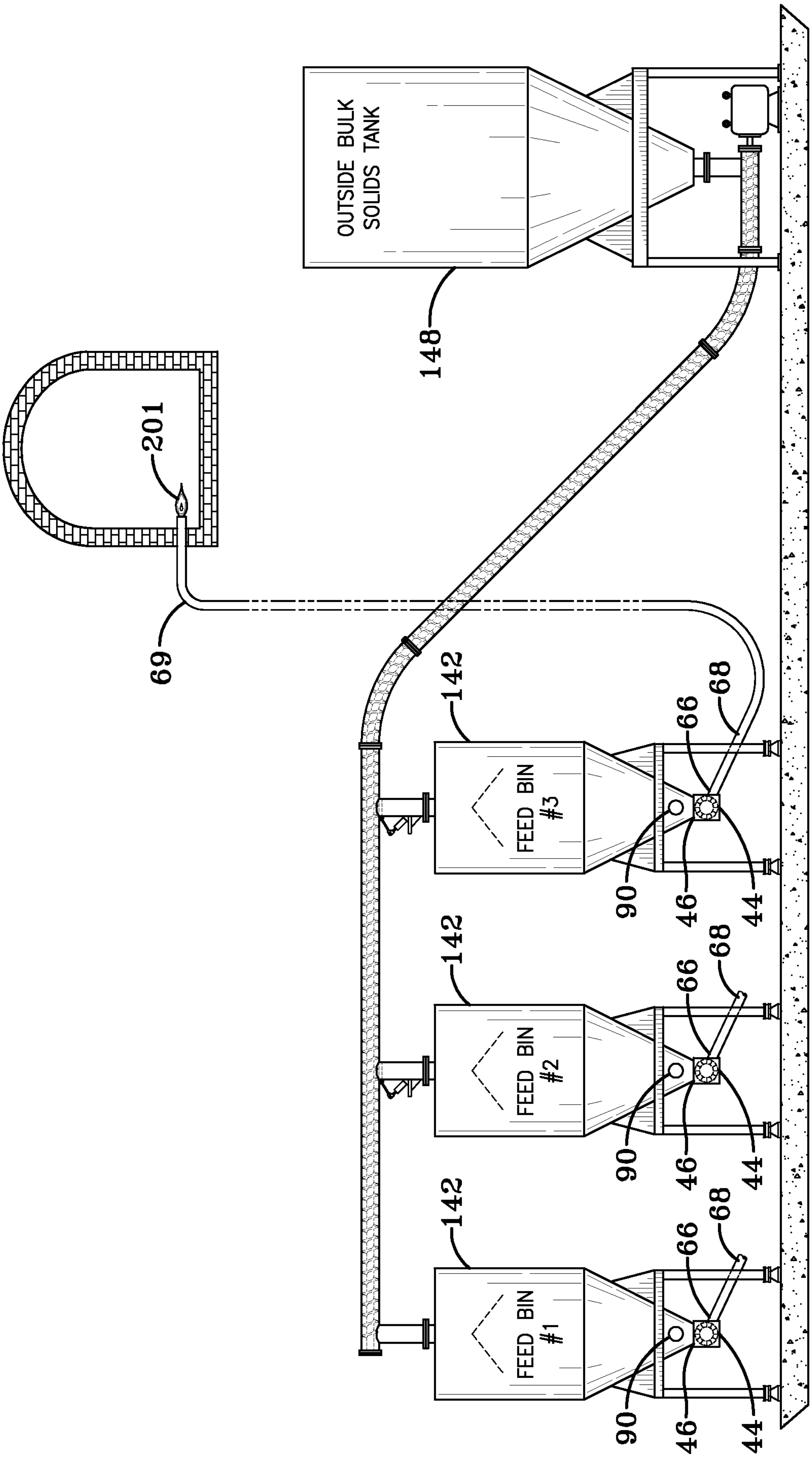

OUTSIDE BULK SOLIDS TANK
148
201
69
142
142
142
FEED BIN #3
FEED BIN #2
FEED BIN #1
66
68
90
46
44

FIG-13

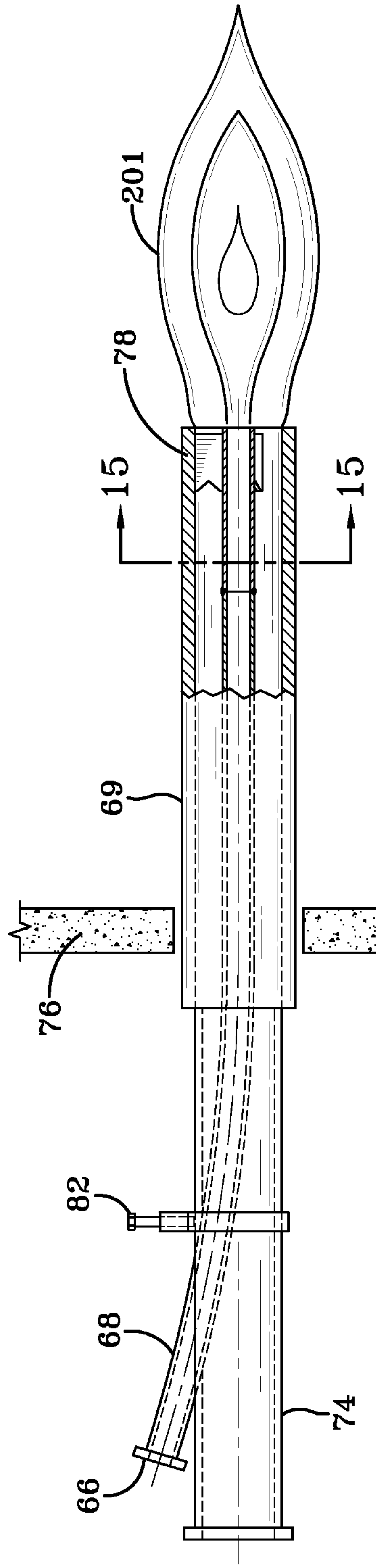


FIG-14

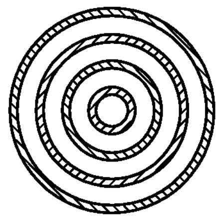


FIG-16

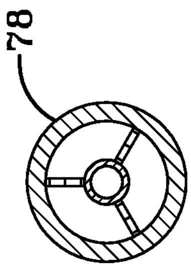


FIG-15