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(54) **Air drilling system and method for containing and separating cuttings**

(57) Cuttings are removed from air drilling fluid used in an air drilling system by delivering the cuttings and air drilling fluid into an air-tight enclosure (22), decreasing the flow rate of the air through the enclosure (22) to allow the cuttings to settle and separate from the airflow and be contained within the enclosure (22). The air, substan-

tially devoid of the cuttings, is discharged. The enclosure (22) is positioned at an angle to facilitate the discharge of the contained cuttings. Preferably, the enclosure (22) is of a size which will allow it to be transported on public highways without special movement permits, and the exhilarating equipment used may be contained within the enclosure (22) during transportation.

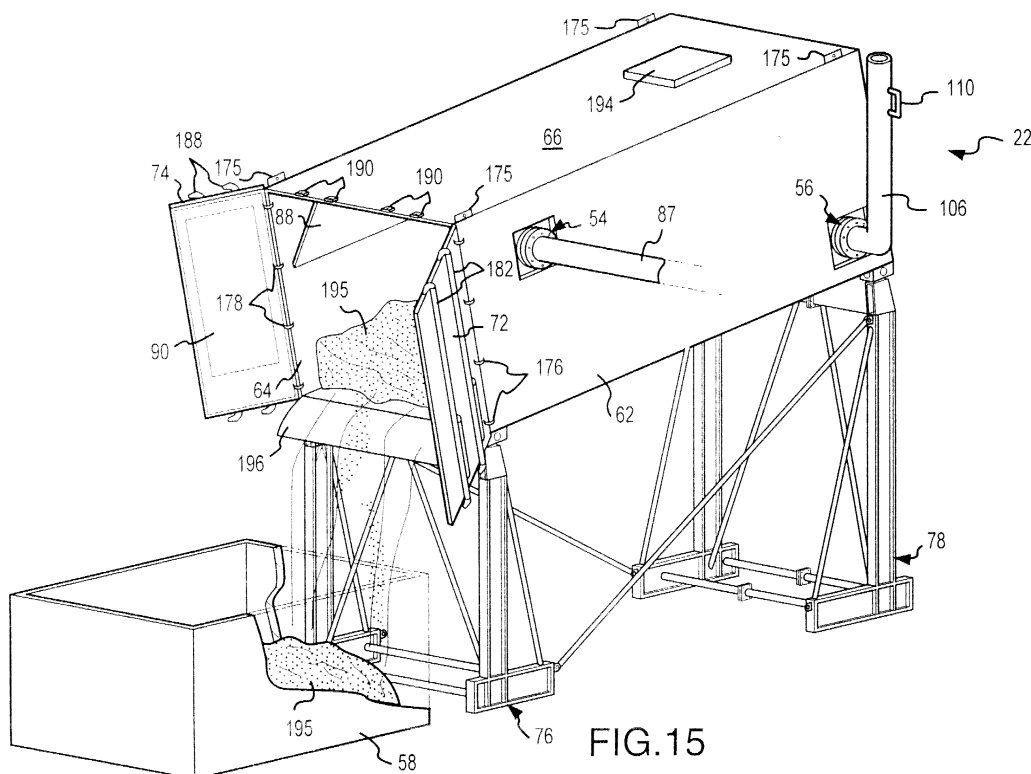


FIG. 15

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Description

[0001] This invention relates to a system and method for drilling well bores in which gas or air is used as a drilling fluid for removing earth cuttings from the well bore. More particularly, the present invention relates to a new and improved air drilling system and method which utilizes a container-separator for containing and separating the cuttings from the drilling air discharged from the well bore, to thereby prevent the uncontrolled release of the cuttings into the ambient environment.

Background of the Invention

[0002] Air drilling is a well drilling technique in which air or gas is used as the drilling fluid to remove the earth-en particles called cuttings which are cut, broken, ground, eroded and otherwise separated from an earth formation by a drill bit as the drill bit cuts the well bore into the earth formation. Air is pressurized on the surface of the earth, forced down the center of a drill string of connected drilling pipes and discharged from the drill bit connected at the bottom end of the drill string. The drill bit cuts a circular opening which is slightly larger than the outside diameter of the drill string, thereby leaving a cylindrical space, called an annulus, between the outside of the drill string and the wall of the well bore. The cuttings which are separated from the earth formation are picked up and carried up the annulus by the flow of air discharged from the drill bit. Once at the surface, the cuttings are discharged into the ambient environment along with the air drilling fluid which carried the cuttings. The air drilling fluid continues to remove the cuttings from the bottom of the well bore, thereby maintaining the cutting efficiency of the drill bit in drilling through the earth formation.

[0003] In addition to air or gas, liquid called "mud" is also used as a drilling fluid. The flow path of mud drilling fluid is the same as that described for the air, except that the mud and the cuttings are usually separated at the earth's surface and the recovered mud is reused. The liquid drilling fluid is typically referred to as mud, because it contains a liquid such as water and/or petroleum products which are mixed with selected natural and synthetic components such as clay and polymers, resulting in a very thick and fluid substance which has the appearance of ordinary mud. Drilling muds are employed for a variety of particular reasons, and are generally used in deep wells where the added buoyancy of a thick liquid is necessary to lift the cuttings from a relatively deep depth to the earth surface.

[0004] In both air and mud drilling systems, it is essential to maintain circulation down the drill string, from the drill bit and up the annulus. A loss of circulation may result in a large part of the air or drilling mud discharging into cracks, fissures or other openings in the earth formation which are encountered as the well bore penetrates through various different earth formations. While

a loss of circulation into the surrounding earth formation may not necessarily be detrimental to the progress of the drilling, a large amount of mud flowing into the surrounding earth formation is relatively costly because the drilling mud is lost and cannot be reclaimed and reused. Furthermore, the substances used in the mud are expensive to replace. Moreover, the drilling mud substances are usually selected to form a sealing surface at the sidewall of the well bore in the earth formation, thereby sealing the annulus so that the drilling fluid does not escape.

[0005] In many cases, however, the size and extent of the cracks, fissures and other openings in the earth formation is so large or expansive that it is impossible, or extremely difficult and expensive to seal the side wall of the well bore in order to maintain circulation. In aggravated circumstances, it may be necessary to pull the entire drill string and drill bit from the well bore and place special tools down the well bore to cement or otherwise encase the well bore so that circulation can thereafter be maintained. In other cases, very expensive substances must be used in the drilling mud to seal the side walls of the well bore, thereby increasing the already sizeable expense of drilling the well.

[0006] Apart from the added expense and greater time requirements to drill the well, some circumstances simply do not permit the use of drilling mud. For example, environmental, preservation and scenic regulations may not permit the discharge of a substantial amount of drilling mud into the adjoining earth formations, if that discharge is likely to have a detrimental impact on water supplies within the earth formation or if the earth formation is adjacent to scenic and natural preserves which may be damaged by the influence of foreign substances penetrating into those formations.

[0007] Air drilling has advantages over mud drilling in those circumstances where the risk of circulation loss is present and where it is illegal or inappropriate to have quantities of drilling mud penetrate into the adjoining earth formations. By use of air drilling, the natural earth particles themselves, without any adverse influence from foreign substances, are forced into the adjoining earth formation if a lack of circulation is encountered. Since the particles themselves are natural particles, no environmental damage or adverse influence occurs to the adjoining scenic, environmentally-sensitive and preserved areas. To the extent that the earth formation is subject to cracks, fissures and other influences which could result in a loss of circulation, air drilling can be used to penetrate the well bore through those vertical depths. Once the well bore is through those vertical depths which are subject to a loss of circulation, that part of the well bore may be enclosed within a casing so that mud drilling may be used beyond that area to greater depths.

[0008] Although air drilling has advantages in avoiding the detrimental impacts from mud drilling in earth formations which are subject to loss of circulation, the dis-

advantage of air drilling is that the cuttings carried with the air to the surface of the earth are thereafter discharged into the ambient environment with the air. This discharge may itself create an adverse environmental impact, because the cuttings are free to drift in the natural wind currents throughout the area surrounding the drilling site. Unlike mud drilling where the cuttings are readily separated from the drilling mud and stored in pits, containment ponds or other containers, the cuttings in the air drilling fluid are not believed to have been previously contained or otherwise separated from the discharged air. In those environmental circumstances where the cuttings cannot be discharged into the ambient environment, air drilling is not believed to have been previously available for use.

[0009] It is with respect to these and other background factors and considerations that the present invention has resulted.

Summary of the Invention

[0010] An important aspect of the present invention is a technique of air drilling that achieves containment and separation of the cuttings carried by the drilling air, prior to discharging that drilling air into the ambient environment. As a result of the present invention, air drilling may be effectively used in circumstances where it could not previously have been used due to regulations which prevented the discharge of any cuttings into the environment in an uncontrolled manner. Furthermore, the present invention allows air drilling to be effectively used in those circumstances where previously only mud drilling could be used, due to the ability of the present invention to separate the cuttings from the discharged drilling air and confine them for proper disposal. Thus, the present invention provides an effective technique for controlling the discharge of cuttings into the ambient environment in those circumstances where only air drilling can be used effectively, due to down-hole considerations imposed by the earth formation.

[0011] To achieve these and other improvements, the present invention comprises an air drilling system using air as the drilling fluid for removing cuttings from a bore hole. The air drilling system comprises a drill bit to remove cuttings from the earth formation, a source of air drilling fluid, and a path for the air drilling fluid within the bore hole to carry and lift the cuttings to the surface. A container-separator is connected to receive the flow of cuttings and the air drilling fluid, and the container-separator comprises an enclosure having a substantially air-tight interior and an exterior. An inlet carries the air drilling fluid and cuttings the interior. An outlet carries the air from the interior to the exterior of the enclosure. An interior airflow path is defined between the inlet and outlet. The interior airflow path has a cross-sectional size to reduce the flow rate of the air to a rate which is insufficient to carry the cuttings within the interior flow path. The reduced flow rate allows gravity to settle the

cuttings out of the air before the air exits from the outlet and is discharged into the ambient environment.

[0012] Other preferable features of the container-separator include the following. The air drilling fluid and the cuttings are delivered into the enclosure in an initial trajectory, and a deflector plate is located in the initial trajectory and at an angle to deflect cuttings downward. An access door is located adjacent to the one end of the enclosure and the deflector plate deflects at least some of the cuttings into an accumulation adjacent to the access door, where the cuttings can be conveniently removed. Stilts or some other structure supports the enclosure at an angle relative to the horizontal with the access door located at a lower end of the enclosure. The angle and the elevation facilitate the discharge of the accumulated cuttings. A stand pipe is located within the interior of the enclosure and has an open upper end located near an upper end of the enclosure. The upper end of the stand pipe causes the air from the interior airflow path to leave the interior from a high location, thereby maximizing the opportunity for the cuttings to settle within the enclosure. A disconnectable discharge pipe is located on the exterior of the enclosure to facilitate the distribution of the air into the ambient environment.

[0013] Improvements of the present invention are also obtained in a method of separating cuttings from air drilling fluid when drilling a bore hole with a drill bit. The method includes the steps of conducting air drilling fluid into the bore hole, carrying and lifting the cuttings from the bore hole by the air drilling fluid flowing out of the bore hole, conducting the flow of cuttings and the air drilling fluid into a substantially airtight enclosure having an interior, and creating an interior airflow path within the enclosure having a cross-sectional size which is insufficient to carry the cuttings within the interior flow path, settling the cuttings out of the air in the interior airflow path, containing the cuttings within the enclosure, and exiting air without cuttings from the enclosure.

[0014] Other preferred aspects of the method include the following steps. The cuttings are deflected downward from the initial trajectory, preferably to a location adjacent to the access door. The enclosure is supported at an angle relative to the horizontal with the access door located at a lower end of the enclosure, and the accumulation of cuttings is removed through the access door. The enclosure supported above the earth surface by stilt structures located at opposite ends of the enclosure. The air from the interior airflow path exits from a generally uppermost location within the enclosure, but the discharged air is delivered into the ambient environment in a generally upward direction.

[0015] In addition to the advantages and improvements in drilling available from the present invention, another improvement relates to the relative ease and convenience of transporting the enclosure and its auxiliary equipment to the drilling site. These improvements are achieved as a result of the container-separator having

a sufficient size and relatively large access doors to allow all of the auxiliary equipment used in connection with the container-separator to be stored within its interior during transportation to the well drilling site. Because the container-separator can be a self-containing enclosure for transportation, all of the auxiliary equipment is conveniently available for immediate use and is not subject to being lost, misplaced, delayed or damaged during transportation.

[0016] In accordance with this improvement, the present invention also involves a method of transporting a container-separator used to separate cuttings from air drilling fluid at a drill site. The method comprises the steps of sizing an airtight enclosure to fit upon a trailer and to comply with standard dimensions for loads carried on public highways, forming an inlet into the enclosure through which air drilling fluid and particles carried by the air drilling fluid are delivered into an interior of the enclosure, forming an outlet from the enclosure through which air that has been separated from the particles exits from the interior of the enclosure, locating the inlet and the outlet not protrude substantially beyond the outer dimensions of the enclosure, adapting stilt structures to support the enclosure above the ground surface, placing the stilt structures into the interior of the enclosure through the access door, and moving the enclosure on the trailer on a public highway with the stilt structures within the interior of the enclosure.

[0017] A more complete appreciation of the present invention and its scope, and the manner in which it achieves the above noted improvements, can be obtained by reference to the following detailed description of presently preferred embodiments of the invention taken in connection with the accompanying drawings, which are briefly summarized below, and the appended claims.

Brief Description of the Drawings

[0018] Fig. 1 is a block diagram of an air drilling system which incorporates the present invention, and a schematic diagram of a well bore formed by using the air drilling system.

[0019] Fig. 2 is a perspective view of a container-separator and a partial perspective view of an adjacent collection bin of the air drilling system shown in Fig. 1.

[0020] Fig. 3 is a side elevational view of the container-separator and a part of the collection bin shown in Fig. 2.

[0021] Fig. 4 is a partial cross-sectional view of an enclosure and an inlet of the container-separator shown in Figs. 2 and 3, taken substantially in the plane of line 4-4 of Fig. 3.

[0022] Fig. 5 is a partial outside perspective view of the inlet shown in Fig. 4 of the container-separator shown in Figs. 2 and 3.

[0023] Fig. 6 is a partial cross-sectional view of an outlet of the container-separator, taken substantially in the

plane of line 6-6 of Fig. 3.

[0024] Fig. 7 is a partial outside perspective view of the outlet of the container-separator, which is also shown in Fig. 6.

[0025] Fig. 8 is a perspective view of a stilt structure which supports the container-separator at a lower end, as shown in Figs. 2 and 3.

[0026] Fig. 9 is a perspective view of a stilt structure which supports the container-separator at a higher end, as shown in Figs. 2 and 3.

[0027] Fig. 10 is a partial perspective view of one of a plurality of struts which extend as shown in Figs. 2 and 3 between the stilt structures shown in Figs. 8 and 9, with a portion broken out.

[0028] Fig. 11 is an exploded perspective view of a connecting mechanism operative between the upper ends of the stilt structures shown in Figs. 8 and 9 and the bottom of the enclosure of the container-separator shown in Figs. 2 and 3, with the perspective angle of the bottom portion of Fig. 11 taken looking downward and with the perspective angle of the upper portion of Fig. 11 taken looking upward. Fig. 11 also illustrates an unlocked position of the connecting mechanism.

[0029] Fig. 12 is a side elevational view through the connecting mechanism shown in Fig. 11, illustrating a different locked position of the connecting mechanism.

[0030] Fig. 13 is a partial perspective view of a door retaining mechanism for access doors of the enclosure of the container-separator shown in Figs. 2 and 3, with the solid portion illustrating an open condition and the phantom portion illustrating a closed position.

[0031] Fig. 14 is a top plan view of the enclosure of the container-separator shown in Figs. 2 and 3, illustrating an access hatch to the enclosure.

[0032] Fig. 15 is a perspective view of the container-separator shown in Figs. 2 and 3, with the access doors thereof opened to reveal well bore cuttings contained and separated within the container-separator and discharged into the collection bin.

[0033] Fig. 16 is a perspective view of the enclosure of the container-separator shown in Figs. 2 and 3 resting on a truck-drawn flat-bed trailer during transportation, with the external auxiliary components of the container-separator stored within the interior of the enclosure.

Detailed Description

[0034] A system for drilling a well bore using air as a drilling and circulating fluid is shown in Fig. 1. The air drilling system, which is generally referenced 20 in Fig. 1, includes a container-separator 22 which results in a significantly improved air drilling system. An improved method of drilling well bores by using air as the circulating fluid and using the functionality of the container-separator 22 to separate and contain cuttings from the circulating air is also similarly disclosed in Fig. 1.

[0035] The air drilling system 20 is used to cut a well bore 24 into an earth formation 26, from the surface or

ground level 28 of the earth formation 26. A drill bit 30 cuts the bore hole 24 into the earth formation 26. Usually, the drill bit 30 works as a result of rotation of a drill string 32. The drill string is formed by segments of conventional drill pipe which are threaded together and extend from the ground level 28 to the bottom of the bore hole 24. The connected-together segments of drill pipe are rotated by a conventional turntable or other rotating mechanism (not shown) associated with a drilling rig (also not shown). Alternatively, a down-hole drill motor (not shown) is connected to the drill bit, and the drill motor rotates the drill bit 30 with respect to a stationary drill string 32. In any case, the drill bit 30 cuts the bore hole 24 at a diameter which is greater than the outside diameter of the drill string 32, thereby leaving a concentric space called an annulus 34 between a sidewall 36 of the bore hole 24 and the outside surface of the drill string 32.

[0036] Air drilling fluid is used by the system 20 and is obtained from the ambient air at an inlet 40 to an air compressor 42. The air compressor 42 compresses the ambient air and delivers the compressed air through an outlet 44. The outlet 44 is connected to an interior opening within the drill string 32, and the interior opening conducts the compressed air down the drill string to the drill bit 30. Water or other liquid from a tank 46 is supplied by a mist-water pump 48 into the compressed air flow delivered down the interior opening of the drill string. In addition to the air, the water serves as a lubricating and cooling fluid for the drill bit 30.

[0037] As the drill bit rotates, it continually erodes and separates pieces and fine dust-like particles from the earth formation 26, called "cuttings." The cuttings are caught up in a discharge of the compressed air from the drill bit 30. The water mist in the air drilling fluid entraps and agglomerates the fine particles and dust of the cuttings, and thereby assures that these fine particles and dust may be handled as effectively as the larger cuttings.

[0038] The discharged air from the drill bit 30 lifts the cuttings up the annulus 34 to the ground level 28 where the cuttings enter into a conductor pipe 50. The conductor pipe 50 surrounds the drill string 32 and is seated into the earth formation 26 around the upper end of the bore hole 24, to assure that the air drilling fluid and the cuttings carried by the air enter into the interior of the conductor pipe 50 rather than flow to the outside of the conductor pipe 50. An upper end of the conductor pipe 50 is sealed in a conventional manner around the drill string 32 to prevent the escape of the air from within the interior of the conductor pipe 50 around the drill string 32. An outlet 52 is connected to the conductor pipe 50, and the outlet 52 discharges the air and water-mist drilling fluid which contains the cuttings into an inlet 54 of the container-separator 22.

[0039] The container-separator 22 contains the cuttings introduced into it by the air flow entering through the inlet 54. The container-separator 22 also separates

the cuttings from the air. In general, separation is achieved as a result of gravity. The relatively large interior volume of the container-separator, compared to the size of the discharge outlet 52 and inlet 54 greatly decreases the air flow rate through the interior of container-separator 22. The decreased air flow rate through the container-separator 22 allows the cuttings to settle by gravity to the bottom of the container-separator 22. The air, which is freed of the cuttings, is discharged from the container-separator through an outlet 56.

[0040] Because of the separation obtained within the container-separator, the air discharged from the outlet 56 is substantially cleaned of the cuttings. Therefore the discharge of the air from the outlet 56 does not adversely impact the environment and ambient surroundings at the well drilling site by spreading the cuttings that would otherwise be present in the air discharged. As far as is known, previous air drilling systems have not attempted to clean or separate the cuttings from the discharged air. Instead, the air containing the cuttings has been discharged directly into the environment.

[0041] Occasionally, at times when actual drilling is not in progress and air drilling fluid is not being circulated or injected down the drill string, the accumulated cuttings within the container-separator 22 are removed by opening access doors (72 and 74, shown in Fig. 2) and discharging the cuttings into a collection bin 58 for future disposal at an environmentally approved site. Although it may be advantageous to do so, the cuttings need not be removed when an additional joint of drill pipe is added to the drill string as a result of the continual deepening of the well hole 24 (an activity known as "making a connection"), or when the drill string is removed from the well bore 24 by disconnecting each joint of drill pipe at the top of the string (an activity referred to as "tripping"). Water within the air drilling fluid also accumulates in and is discharged from the container-separator 22 in the same manner.

[0042] More details concerning the container-separator 22 and its use in the otherwise conventional air drilling system 20, are described in conjunction with Figs. 2 and 3. The container-separator 22 is formed primarily by an enclosure 60. The enclosure 60 preferably takes the form of a conventional sea freight container. The enclosure 60 has steel or otherwise rigid sidewalls 62 and 64, a floor 66, a roof 68, one end wall 70, and a pair of access doors 72 and 74 located at the end of the enclosure 60 opposite of the end wall 70. The sidewalls 62 and 64, the floor 66, the roof 68 and the end wall 70 are all rigidly and permanently connected and sealed together. The access doors 72 and 74 are hinged to the sidewalls 62 and 64, respectively. When the access doors 72 and 74 are closed, an essentially airtight connection is established at the end of the enclosure 60 opposite of the end wall 70. Thus, when the doors 72 and 74 are closed, the enclosure is essentially airtight to permit only the air drilling fluid and cuttings to enter the inlet 54, and to allow the cleaned air to exit from the outlet 56.

[0043] The cuttings which separate from the air drilling fluid settle within the container-separator 22 are contained or confined within the container-separator 22 until the access doors 72 and 74 are opened. At that time, the collected cuttings and water are discharged from the open end of the enclosure 60 into the collection bin 58, as shown in Fig. 15. After the enclosure 60 has been cleaned of the accumulated cuttings, the doors 72 and 74 are again closed so that the container-separator 22 can be continued to be used to separate cuttings from the air drilling fluid before the air is discharged into the ambient environment.

[0044] To facilitate the discharge of the collected cuttings and water from the container-separator 22, the container-separator 22 is supported above the collection bin 58 by stilt structures 76 and 78 located at opposite ends of the enclosure 60. The stilt structure 76, which is located below the open end of the enclosure 60 at the access doors 72 and 74, has a lesser vertical height than the stilt structure 78 which is located below the opposite closed end of the enclosure 60. Consequently, the enclosure 60 is supported vertically above the collection bin 58 and at an angle which slopes toward the collection bin. The angle facilitates transferring the collected cuttings into the collection bin 58, because the angle permits gravity to assist in the movement of the collected and accumulated cuttings out of the open end of the enclosure and into the bin 58.

[0045] The inlet 54 into the enclosure 60 is formed by a length of inlet pipe 80 to which a flange 82 is connected at its outer end, as is shown in Figs. 4 and 5. A box-like recess 84 is formed from the sidewall 62 into the interior of the enclosure 60, and the inlet pipe 80 extends through and is connected to an inner wall 86 of the recess 84. The flange 82 of the inlet pipe 80 is located in a vertical plane which is parallel to the plane of the sidewall 62, as shown in Fig. 4. In this manner the flange 82 does not extend beyond the sidewall 62 or the outer width dimension of the enclosure 60. Positioning the inlet pipe 80 and its flange 82 in this manner facilitates the transportation of the container-separator 22, since none of its components extends beyond the width of the enclosure 60. Preferably, the width of the enclosure 60 is approximately that maximum allowable width which can be transported over public highways without incurring special transportation regulations, such as those applicable to "wide loads."

[0046] Piping 87 (Fig. 4) is connected to the flange 82 in a conventional manner. The piping extends from the inlet 54 of the container-separator to the discharge outlet 52 (Fig. 1) of the conductor pipe of the drilling system 20. The length and extent of the piping 87 between the discharge outlet 52 and the inlet 54 depends on the position orientation of the container-separator relative to the rest of the drilling rig. Therefore, this piping 87 is typically fabricated differently in each application.

[0047] The inlet pipe 80 extends generally horizontally into the interior of the enclosure 60 at location near

the roof 68 and the open end of the enclosure 60 near the access doors 72 and 74, as shown in Figs. 2, 3 and 4. A deflector plate 88 is attached to the opposite sidewall 64 and the roof 68 at a location in alignment with the inlet pipe 80. The cuttings are blown into the enclosure 60 into a trajectory or path which extends transversely across the interior of the enclosure in alignment with the inlet pipe 80. The cuttings impact the deflector plate 88. The deflector plate 88 angles from the roof 68 downward toward the sidewall 64. The deflector plate 88 also protects the sidewall 64 and roof 68 from the abrasive effects of the impacting cuttings.

[0048] Once the air and cuttings are discharged from the inner end of the inlet pipe 80 in the trajectory toward the deflector plate 88, the momentum of the cuttings carries them into contact with the deflector plate 88. The angle of the deflector plate 88 causes the cuttings to ricochet downward off of the deflector plate 88 toward the floor 66. However, the carrying effect of the high flow rate of the air is immediately lost at the interior end of the inlet pipe 80, because of the large volume of the enclosure 60. Thus, once the air leaves the inner end of the inlet pipe 80, there is insufficient force from the air flow to carry or support the cuttings. Gravity, aided by the downward deflection effect from the deflector plate 88, causes the particles to settle to the floor 66 of the enclosure. Because the location of the inlet pipe 80 is adjacent to the access doors 72 and 74, the majority of the cuttings accumulate at a location which facilitates their removal when the access doors 72 and 74 are opened (Fig. 15).

[0049] In addition to the deflection plate 88, a shielding plate 90 (also see Figs. 2 and 15) is attached to the access door 74 at a location adjacent to that location where the deflector plate 88 extends between the sidewall 64 and the roof 68, when the access door 74 is closed. The shielding plate 90 shields the access door 74 from the abrasive effects of the impacting cuttings. The abrasive effect is caused by the continual impact of the cuttings on the deflection plate 88, and some of those cuttings will naturally reflect in the direction of the access door 74. The plates 88 and 90 may need to be replaced periodically because of these abrasive effects. Replacing the worn plates 88 and 90 is considerably easier and less expensive than replacing sections of the sidewall 64, roof 68 and access door 74. Because of the relatively longer distance to the opposite closed end 70 of the enclosure 60, any particles which reflect from the deflector plate 88 in that direction will fall to the floor 66 before reaching the opposite closed end 70.

[0050] The outlet 56 from the container-separator 22 is formed by a stand pipe 92 located within the interior of the enclosure 60, as shown in Fig. 6. The stand pipe 92 extends substantially vertically, and an open end 94 thereof is located adjacent to the roof 68. A lower end of the stand pipe 92 is connected at a 90 degree elbow 96 which extends through a box-like recess 98 in the sidewall 62. A straight portion 102 of the elbow 96 is

connected to the inner wall 100 of the recess 98 to support the stand pipe 92 and the elbow 96. A flange 104 is connected to the outer end of the straight portion 102. The flange 104 is located in a vertical plane which is parallel to the plane of the sidewall 62. In this manner the flange 104 does not extend beyond the sidewall 62 or the outer width dimension of the enclosure 60, to facilitate the transportation of the container-separator 22.

[0051] A discharge pipe 106 is connected to the flange 104 when the container-separator 22 is used, as shown in Fig. 6 and 7. The discharge pipe 106 is preferably oriented in a vertical direction. A flange 108 is connected to the bottom end of the discharge pipe 106, and the flange 108 is connected to the flange 104 to hold the discharge pipe 106 in position. A handle 110 is connected to the discharge pipe 106 to facilitate its positioning when the flanges 108 and 104 are connected.

[0052] The open end 94 of the interior stand pipe 92 (figure 6) is located adjacent to the roof 66 to cause the air within the enclosure 60 to traverse vertically and along the length of the enclosure 60 in order to exit from the stand pipe 92, through the elbow 96, and out the discharge pipe 106. By causing the air within the interior of the enclosure 60 to flow this relatively lengthy horizontal distance, a greater opportunity exists for the separation and settling of the finer cuttings from the air. The vertical orientation of the discharge pipe 106 facilitates the delivery of the cleaned air into the natural wind currents at the drilling site, thereby facilitating the dispersal of any slight amount of remaining extremely fine cuttings that might pass through the container-separator 22. Furthermore, by supporting the enclosure 60 on the stilt structures 76 and 78, the upper end of the discharge pipe 106 is located at a higher location within the naturally occurring wind currents to further facilitate the distribution of the cleaned air and any remaining amounts of extremely fine cuttings. By making the discharge pipe 106 disconnectable at the flanges 104 and 106, the discharge pipe can be separated from the enclosure 60 and stored within the enclosure 60 when the container-separator 22 is transported to the drilling site.

[0053] The shorter-height stilt structure 76 and the taller-height stilt structure 78 are essentially similar in construction, as shown in Figs. 8 and 9. Both stilt structures 76 and 78 include a transverse beam 114 which extends between the upper ends of vertical beams 116 and 118. Horizontal support pieces 120 and 122 are connected to the lower end of the vertical beams 116 and 118, respectively. One end of the horizontal support pieces 120 and 122 is connected more closely to the lower end of the vertical beams 116 and 118, than the other end, thereby forming an L-shaped side structure of the vertical beam 116 and horizontal support piece 120 and another L-shaped side structure of the vertical beam 118 and horizontal piece 122. Braces 124 and 126 extend between ends of the horizontal support pieces 120 and 122, parallel to the transverse beam 114. The braces 124 and 126 prevent the vertical beams 116, 118

and horizontal support pieces 120, 122 from bending toward one another, thereby adding rigidity to the stilt structures 76 and 78 in a plane generally transverse to the enclosure 60 (Figs. 2 and 3) which those stilt structures support. Angle braces 128 and 130 extend from the more separated end of the horizontal support pieces 120, 122 to the upper ends of the vertical beams 116, 118, respectively. The angle braces 128 and 130 add rigidity to each of the L-shaped side structures in a direction parallel to the longitudinal dimension of the enclosure 60 (Figs. 2 and 3). Transverse angle braces 132 and 134 extend from the lower ends of the vertical beams 116 and 118 to about a midpoint location of the transverse beam 114. The transverse angle braces 132 and 134 create additional rigidity of the stilt structures 76 and 78 to withstand side forces in a direction transverse to the enclosure 60 (Figs. 2 and 3).

[0054] Each stilt structure 76 and 78 is separate from the other. To add structural strength between the stilt structures so that they would not inadvertently tilt in a direction generally parallel to the longitudinal dimension of the enclosure 60 (Figs. 1 and 2), tension struts 136 and 138 extend between the stilt structures 76 and 78, in a crossed pattern as shown in Figs. 2 and 3. For example, one strut 136 extends from the upper end of the vertical beam 116 of the stilt structure 78 to the lower end of the vertical beam 116 of the stilt structure 76. Similarly, the other strut 138 extends from the upper end of the vertical beam 118 of the stilt structure 76 to the lower end of the vertical beam 118 of the stilt structure 78, as shown in Figs. 2 and 3.

[0055] As shown in Fig. 10 each of the struts 136 and 138 comprises a cylindrical pipe 140, to which a connection tab 142 is welded or otherwise permanently affixed at one end. A threaded nut 144 is welded or otherwise permanently affixed to the other end of each cylindrical pipe 140. A threaded rod 146 is threaded into the nut 144. A tab 148 is welded onto the end of the threaded rod 146. By screwing the threaded rod 146 relative to the nut 144, the overall length of each strut 136 and 138 between the tabs 144 and 148 is adjusted. The tabs 142 and 148 are positioned between a pair of flanges 149 (Figs. 8 and 9) located at the upper and lower ends of each vertical beam 116 and 118 of the stilt structures 76 and 78. Bolts (not shown) extend through holes 147 in the tabs 142 and 148 and through holes in the flange pairs 149 to connect the ends of the struts to the stilt structures. The adjustment capability obtained by the threaded rod 146 accommodates differences in position and angle of the stilt structures 76 and 78 at each drilling site, according to the position and orientation of the container-separator 22 supported on the stilt structures.

[0056] Although the stilt structures 76 and 78 are similar in construction, the taller stilt structure 78 is preferably formed into two separable pieces, as shown in Fig. 9. The transverse beam 114 and the horizontal braces 124 and 126 are each severed, and flanges 151 are con-

nected to the ends at the severed location. Bolts (not shown) extend through the flanges 151 to rigidly connect together the transverse beam 116 and horizontal pieces 124 and 126. By disconnecting the separable pieces of the taller stilt structure 78, the two separated pieces may be easily loaded into and contained within the enclosure 60 (Figs. 2 and 3) when transporting the container-separator 22 and its auxiliary equipment to and from the drilling site.

[0057] The stilt structures 76 and 78 are also connected to the floor 66 of the enclosure 60 by a connecting mechanism 150, shown in Figs. 11 and 12. One connecting mechanism 150 is located at each corner of the enclosure 60, and two connecting mechanisms 150 are located at opposite ends of the transverse beam 114 of the stilt structures 76 and 78 (Figs. 8 and 9). The connecting mechanism 150 is preferably of the same type as is used to hold conventional sea freight containers in a fixed position on a ship and with respect to one another. Each connecting mechanism 150 rigidly connects the stilt structures 76 and 78 to the enclosure 60, thereby preventing the inadvertent vertical separation of the stilt structures and the enclosure. The connecting mechanisms 150 thereby establish a rigid connection of the enclosure through the stilt structures to the supporting earth formation 26 at the ground level 28 (Fig. 1). The connecting mechanisms 150 can also be used in the conventional manner to hold the enclosure 60 on a truck or trailer (Fig. 15) or transporting it and the auxiliary equipment used with the container-separator 22 to a drilling site.

[0058] Each connecting mechanism 150 includes a pyramid shaped structure 152 which rests on a square block 154, as shown in Figs. 11 and 12. A shaft 156 (Fig. 12) is rigidly connected to the pyramid structure 152 and extends through an opening in the block 154. A lower end of the shaft 156 is connected to a lever 158. The lever 158 extends out of a slot 160 formed by a support bracket 162 upon which the block 154 and pyramid structure 152 are supported. By pivoting the lever 158 within the slot 160, the pyramid structure 152 rotates relative to the block 154. When in the unlocked position shown in Fig. 11, the outside lateral edges of the pyramid structure 152 are aligned with the outside edges of the block 154.

[0059] A square connection opening 164 (Fig. 11) forms another part of the connecting mechanism 150. The connection opening is formed in supporting material 166 of the floor 66 of the enclosure 60. The connection opening 164 has dimensions slightly larger than the outside dimensions of the square block 154 and the outside edges of the pyramid structure 152. The supporting material 166 into which the connection opening 164 is formed, has a height dimension slightly less than the height dimension of the block 154 at the location where the lower flat surface of the pyramid structure 152 rests on the upper surface of the block 154.

[0060] When in the unlocked position shown in Fig.

11, the pyramid structure 152 serves as a guide to positioning the connection opening 164 into a position where it surrounds the block 154, as the enclosure 60 is lowered onto the stilt structures 76 and 78 (Fig. 2). Once in the proper position, a lower surface 168 of the supporting material 166 rests on an upper surface 170 of the support bracket 162. The block 154 extends through the connection opening 164. The pyramid structure 152 extends above an upper surface 172 of the support material 166. In this position, the connecting mechanism 150 can be locked.

[0061] Locking is achieved by rotating the lever 158 from the unlocked position shown in Fig. 11 to the locked position shown in Fig. 12. When the lever 158 is rotated in this manner, the pyramid structure 152 also rotates with the lever 158 and the shaft 156. Outer corners 174 of the pyramid structure 152 move out of alignment with the edges of the block 154 and over the upper surface 172 of the support material 166, as shown in Fig. 12. With the outer corners 174 of the pyramid structure 152 over the upper surface 172, the pyramid structure prevents the support structure 166 and the enclosure 60 from separating vertically with respect to the stilt structure 76 or 78 to which the connecting mechanism 150 is connected and upon which the enclosure rests. The enclosure 60 is readily separated from the stilt mechanisms 76 or 78 when the container-separator is no longer used at the drilling site, by simply rotating the levers 158 to the unlocked position.

[0062] To position the enclosure 60 on the stilt structures 76 and 78, a chain or cable is looped through rings 175 (Figs. 2, 3 and 15) located at each top corner of the enclosure 60. The chains or cables are thereafter lifted by a hoist or crane. The connection position of the chains and cables is preferably adjusted so that when the enclosure 60 is suspended, its closed end 70 will be higher than the open end to which the access doors 72 and 74 are connected. Thereafter, with the enclosure suspended, the stilt structures 76 and 78 are located below the ends of the enclosure 60. The enclosure is thereafter gently lowered and the pyramid structures 152 (Figs. 11 and 12) guide the stilt structures into the proper position as the connection openings 164 (Figs. 11 and 12) fit over the pyramid structures 152. Thereafter, the struts 136 and 138 (Figs. 2 and 3) are connected between the stilt structures 76 and 78.

[0063] The access doors 72 and 74 are pivotally connected to the sidewalls 62 and 64 by hinges 176 and 178, respectively, as shown in Fig. 15. The access doors 72 and 74 are held in the closed position by a door retaining mechanism 180, shown in Fig. 13 which is conventionally used on sea freight containers. The door retaining mechanism 180 includes a rotatable shaft 182 which extends vertically along the height of each access door. Straps 184 connect the shaft 182 to each access door 72 and 74 and allow the shaft 182 to rotate relative to the access door. A handle 186 is connected to the shaft 182 and is used to rotate the shaft. An eccentric

188 is connected to each end of the shafts 182. Each eccentric 188 extends slightly beyond the upper and lower edges of each access door. One receiver 190 is located on the edges of the floor 66 and roof 68 at the location where each eccentric 188 is positioned when the access doors are closed. The eccentric 188 fits within the receiver 190 when the access doors are closed. Rotating the shaft 182 by the handle 186 causes the eccentric 188 to rotate relative to a projection 192 of the receiver 190, causing a camming effect of the eccentric 188 against the projection 192. The camming effect pulls the access door tightly against the enclosure and also locks the access doors against the enclosure 60.

[0064] In addition to the access doors 72 and 74, the enclosure 60 also includes a hatch 194 formed in the roof 68, as shown in Fig. 14. The hatch 194 is of a conventional construction and provides another access route into the enclosure 60, if necessary, other than through the doors 72 and 74. Furthermore, if it is desired to wash the interior of the enclosure 60, hoses can be inserted through the open hatch 194. Of course when the container-separator 22 is in use, the hatch 194 is closed in an airtight manner.

[0065] To clean out the enclosure 60 of the container-separator 22, the access doors 72 and 74 are opened, as shown in Fig. 15. With the access doors 72 and 74 opened, the accumulated cuttings 195 and water are discharged from the open end of the enclosure 60 into the collection bin 58. The downward angle of the enclosure 60, toward the collection bin 58, assists in discharging the collected cuttings 195. A workman with the shovel can more easily move the accumulated cuttings out of the enclosure and into the bin because of the angle of the enclosure. A chute-like plate 196 may be connected to span any gap between the edge of the floor 66 and the cuttings-receiving opening of the collection bin 58. The chute-like plate 196 may be connected by any appropriate means to the edge of the floor 66 or to the transverse beam 114 (Figs. 8 and 9) of the stilt structures 76. The chute-like plate 196 may also be disassembled and placed in the interior of the enclosure 60 when the container-separator 22 is moved to and from the drilling site.

[0066] Transportation of the container-separator 22, and its associated equipment, is accomplished by placing the enclosure 60 on a flat bed trailer pulled by a truck or on the flat bed trailer of a truck itself, as shown in Fig. 16. In the same way that conventional sea freight containers are retained to a flat bed trailer or truck by the connecting mechanism 150, the connecting mechanism 150 retains the enclosure 60 to the flat bed truck or trailer. Because of the recesses 84 and 98 (Figs. 4 and 6) and the use of the flanges 82 and 104 (Figs. 4 and 6), all of the exterior auxiliary equipment associated with the container-separator 22 can be disconnected so nothing extends beyond the outer dimensions of the sidewalls 62 and 64. Furthermore, no auxiliary equipment extends above the roof 68. All of the auxiliary

equipment is contained within the standard-sized enclosure 60, which allows it to be transported on public highways without the need to invoke special regulations or obtain special permits. Furthermore, the enclosure 60 provides a convenient method of containing all of the equipment associated with the container-separator 22, thereby avoiding the necessity to ship and store separately the auxiliary equipment.

[0067] In addition to these advantages in transporting the container-separator 22, its capability to separate cuttings from air drilling fluid is a substantial improvement. Air drilling may be used in circumstances where it had previously been prohibited because of an inability to contain the discharge of the cuttings into the surrounding environment. Furthermore, air drilling may be used in circumstances where previously the more costly and time-consuming use of mud drilling was required. The cuttings are collected because of the separation capability of the container-separator 22, thereby eliminating essentially all of the cuttings from the air discharged into the environment. The accumulated cuttings are easily and quickly discharged from the enclosure into a collection bin because of the angular orientation of the enclosure. The elevated position of the enclosure also allows the collection bin to be effectively positioned to receive the collected cuttings without substantial risk of discharging the cuttings other than into the collection bin. Many other improvements and advantages will be apparent upon gaining a complete understanding of the present invention.

[0068] Presently preferred embodiments of the invention and its improvements have been described with a degree of particularity. This description has been made by way of preferred example. It should be understood that the scope of the present invention is defined by the following claims, and should not be unnecessarily limited by the detailed description of the preferred embodiment set forth above.

Claims

1. An air drilling system using air as a drilling fluid for removing cuttings from a bore hole formed into an earth formation from a surface of the earth formation, comprising:

a drill bit operative in the bore hole to remove cuttings from the earth formation;

a source of air drilling fluid;

a conduction path for the air drilling fluid into the bore hole to a position adjacent to the drill bit to cause the air drilling fluid to carry and lift the cuttings created by the drill bit to the surface of the earth formation; and

a container-separator connected to receive the flow of air drilling fluid and the cuttings carried thereby, the container-separator further com-

prising:

an enclosure defining a substantially airtight interior, the enclosure further having an exterior;

an inlet formed from the exterior into the interior of the enclosure and through which the air drilling fluid and cuttings are carried into the interior;

an outlet formed from the interior to the exterior of the enclosure and through which the air from the interior is carried to the exterior of the enclosure;

the inlet and the outlet occupying separated locations within the enclosure and defining an interior airflow path within the enclosure between the inlet and the outlet;

the interior airflow path within the enclosure having a larger cross-sectional size than the cross-sectional size of the inlet to reduce the flow rate of the air through the interior airflow path to an amount which is insufficient to carry the cuttings within the interior flow path; and

the reduced flow rate within the interior airflow path allowing gravity to settle the cuttings out of the air before the air exits from the outlet.

2. An air drilling system as defined in claim 1 wherein the inlet of the enclosure further comprises:

an inlet pipe extending into the interior of the enclosure through which the air drilling fluid and the cuttings are delivered into the interior in an initial trajectory in the interior airflow path; and a deflector plate located within the interior in the initial trajectory and at an angle to deflect cuttings from the initial trajectory downward.

3. An air drilling system as defined in claim 2 wherein: the inlet pipe is located adjacent to one end of the enclosure:

the enclosure further includes an access door located adjacent to the one end of the enclosure; and

the deflector plate is also located adjacent to the one end of the enclosure, the deflector plate deflecting at least some of the cuttings into an accumulation adjacent to the access door.

4. An air drilling system as defined in claim 3 further comprising:

a structure for supporting the enclosure at an angle relative to the horizontal with the access door located at a lower end of the enclosure.

5. An air drilling system as defined in claim 4 wherein the support structure comprises:

a stilt structure located at each opposite end of the enclosure, the stilt structures supporting the enclosure above the surface of the earth.

6. An air drilling system as defined in claim 3 wherein the enclosure further comprises:

a shielding plate connected to the access door adjacent to the deflecting plate, the shielding plate preventing the impact of cuttings on the access door deflected from the deflecting plate.

7. An air drilling system as defined in claim 2 wherein the outlet of the enclosure further includes:

a stand pipe located within the interior of the enclosure and which extends generally vertically within the interior, the stand pipe having an open upper end located near an upper end of the enclosure and a lower end which extends through the enclosure, the air from the interior airflow path flowing generally from the upper end of the enclosure downward through the stand pipe to exit from the enclosure.

8. An air drilling system as defined in claim 7 wherein the outlet of the enclosure further includes:

a discharge pipe located on the exterior of the enclosure and which generally extends vertically, the discharge pipe having an open upper end and a lower end which connects to the lower end of the stand pipe.

9. An air drilling system as defined in claim 8 wherein:

the discharge pipe is disconnectable at the exterior of the enclosure from the lower end of the stand pipe; and

the lower end of the stand pipe does not extend beyond an exterior surface of the enclosure.

10. An air drilling system as defined in claim 1 wherein:

the enclosure is generally rectangularly shaped and has parallel sidewalls;

the inlet and the outlet include connections by which exterior flow conducting components may be connected to the inlet and the outlet; and

the enclosure further includes recesses formed in the sidewalls at the inlet and the outlet within which the connections are located, the connections occupying positions within the recesses to extend no further outward than the exterior of the enclosure.

11. An air drilling system as defined in claim 10 wherein:

the enclosure is no greater than the size of a

standard sea freight container which may be transported on public highways without exceeding standard width dimensions for transportation on public highways.

12. An air drilling system as defined in claim 1 wherein:

the enclosure is generally rectangularly shaped and has parallel sidewalls, a floor, a roof, one closed end, an other end with an opening, and at least one access door which selectively opens and closes the opening of the other end, the access door allowing accumulated cuttings to be removed from the enclosure;

the inlet and the outlet are located at substantially opposite longitudinal ends of the enclosure;

the inlet is located adjacent to the other end having the opening which is opened and closed by the access door; and

the container-separator further comprising:

a pair of stilt structures supporting the enclosure above the surface of the earth at an angular orientation with the other end of the enclosure having the opening lower than the one closed end, one of the stilt structures located adjacent to the other end of the enclosure with the opening and the other of the stilt structures located at the one closed end of the enclosure.

13. An air drilling system as defined in claim 12 further comprising:

a connecting mechanism located on the stilt structures and the floor to selectively connect and disconnect each stilt structure to the floor of the enclosure.

14. An air drilling system as defined in claim 12 wherein:

at least one of the stilt structures is separable into two components, each component having a size which will pass through the opening which is opened and closed by the access door.

15. An air drilling system as defined in claim 14 wherein;

the outlet of the enclosure further includes a discharge pipe located on the exterior of the enclosure;

the discharge pipe being disconnectable at the exterior of the enclosure; and

the discharge pipe having a size which will pass through the opening which is opened and closed by the access door.

16. An air drilling system as defined in claim 15 further comprising:

a connecting mechanism located on the stilt structures and the floor to selectively connect and disconnect each stilt structure to the floor of the enclosure; and wherein:

the connecting mechanism further selectively connects and disconnects the floor of the enclosure to components of the connecting mechanism located on a trailer for transportation.

17. A method of separating cuttings from air drilling fluid when drilling a bore hole with a drill bit into an earth formation from a surface of the earth formation, comprising the steps of:

conducting air drilling fluid into the bore hole; carrying and lifting the cuttings from the bore hole by the air drilling fluid flowing out of the bore hole;

conducting the flow of cuttings and the air drilling fluid into a substantially airtight enclosure having an interior;

creating an interior airflow path within the enclosure having a cross-sectional size which is insufficient to carry the cuttings within the interior flow path;

settling the cuttings out of the air in the interior airflow path;

containing the cuttings within the enclosure; and

exiting air without cuttings from the enclosure.

18. A method as defined in claim 17 further comprising the steps of:

delivering the cuttings and air drilling fluid into the interior of the enclosure in an initial trajectory of the interior airflow path; and deflecting cuttings in the airflow path downward from the initial trajectory.

19. A method as defined in claim 18 wherein the enclosure includes an access door, and said method further comprises the step of:

deflecting the cuttings downward from the initial trajectory to a location adjacent to the access door.

20. A method as defined in claim 19 further comprising the step of:

supporting the enclosure at an angle relative to the horizontal with the access door located at a lower end of the enclosure.

21. A method as defined in claim 20 further comprising the step of:

removing an accumulation of cuttings from the interior of the enclosure through the access door.

22. A method as defined in claim 20 further comprising the step of:
 supporting the enclosure above the earth surface by stilt structures located at opposite ends of the enclosure. 5
23. A method as defined in claim 17 further comprising the step of:
 flowing air from the interior airflow path from a generally uppermost location within the enclosure generally downward as the air exits from the interior of the enclosure. 10
24. A method as defined in claim 23 further comprising the step of:
 discharging the air exiting from the enclosure into the ambient environment in a generally upward direction. 15
25. A method of transporting a container-separator used to separate cuttings from air drilling fluid at a drill site when drilling a bore hole with a drill bit into an earth formation from a surface of the earth formation, comprising the steps of: 20
 sizing an airtight enclosure to fit upon a trailer and to comply with standard dimensions for loads carried on public highways;
 forming an inlet into the enclosure through which air drilling fluid and particles carried by the air drilling fluid are delivered into an interior of the enclosure; 30
 forming an outlet from the enclosure through which air that has been separated from the particles exits from the interior of the enclosure; 35
 locating the inlet and the outlet in the enclosure to not protrude substantially beyond the outer dimensions of the enclosure;
 adapting stilt structures to support the enclosure above the ground surface; 40
 placing the stilt structures into the interior of the enclosure through the access door; and
 moving the enclosure on the trailer on a public highway with the stilt structures within the interior of the enclosure. 45
26. A method as defined in claim 25 further comprising the step of:
 connecting the enclosure to the trailer by a connecting mechanism which is also used to connect the enclosure to the stilt structures. 50
27. A method as defined in claim 25 wherein the enclosure is principally a conventional sea freight container. 55
28. A method as defined in claim 25 further comprising the steps of:

adapting the outlet to connect to a vertically oriented discharge pipe through which the air exits into the ambient environment;
 disconnecting the discharge pipe from the outlet;
 placing the discharge pipe into the interior of the enclosure through the access door; and
 moving the enclosure on the trailer on a public highway with the discharge pipe within the interior of the enclosure.

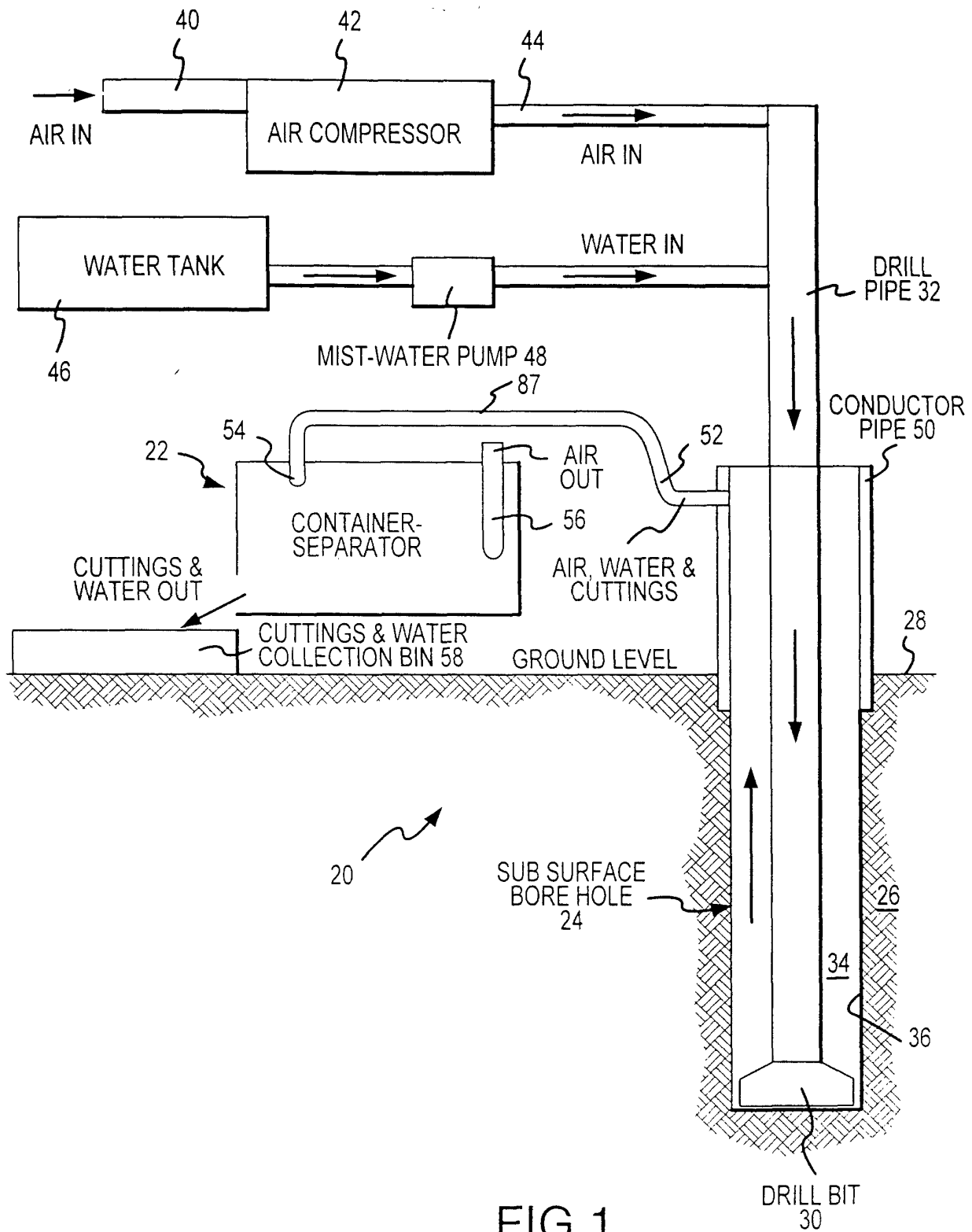


FIG.1

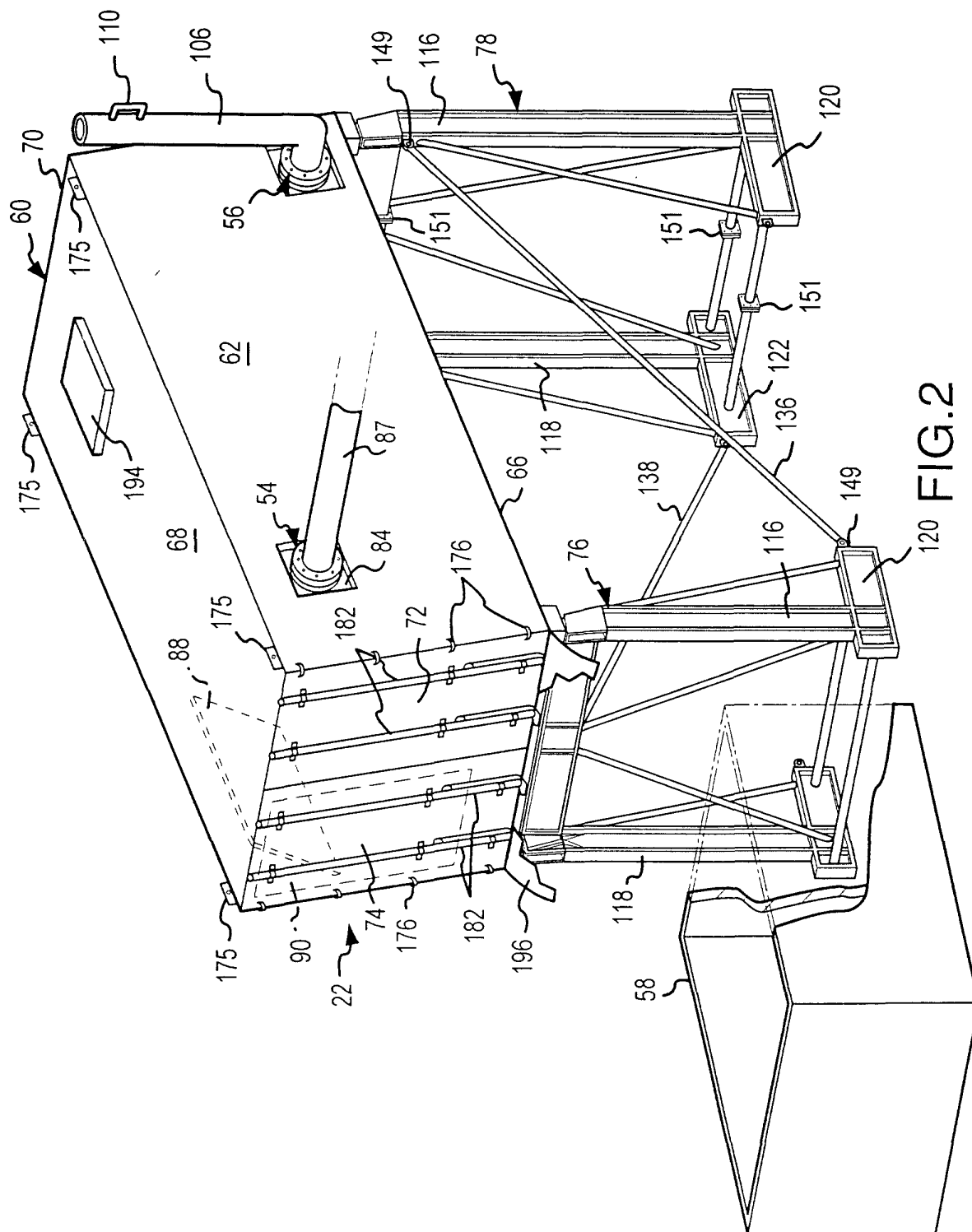


FIG. 2

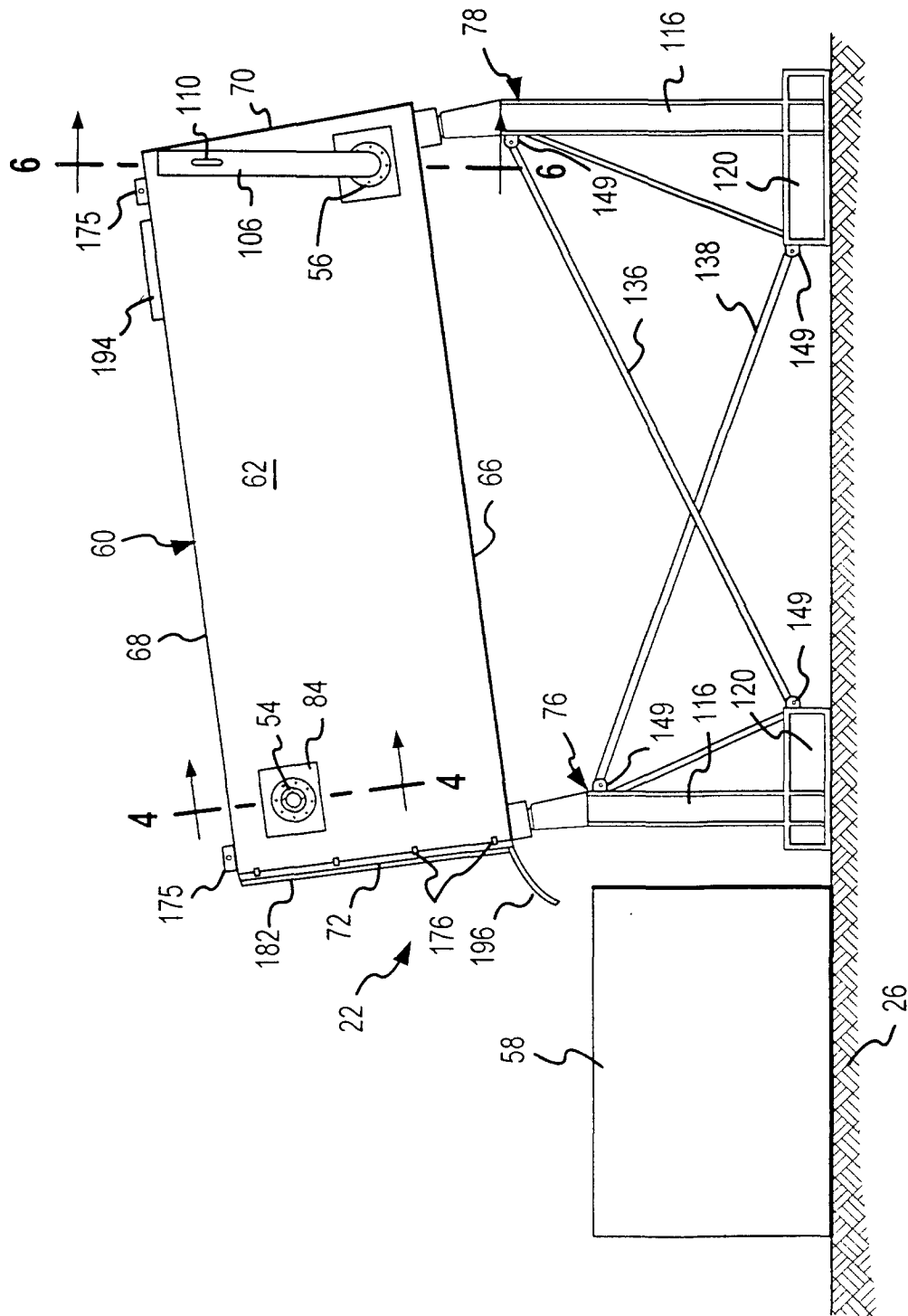


FIG. 3

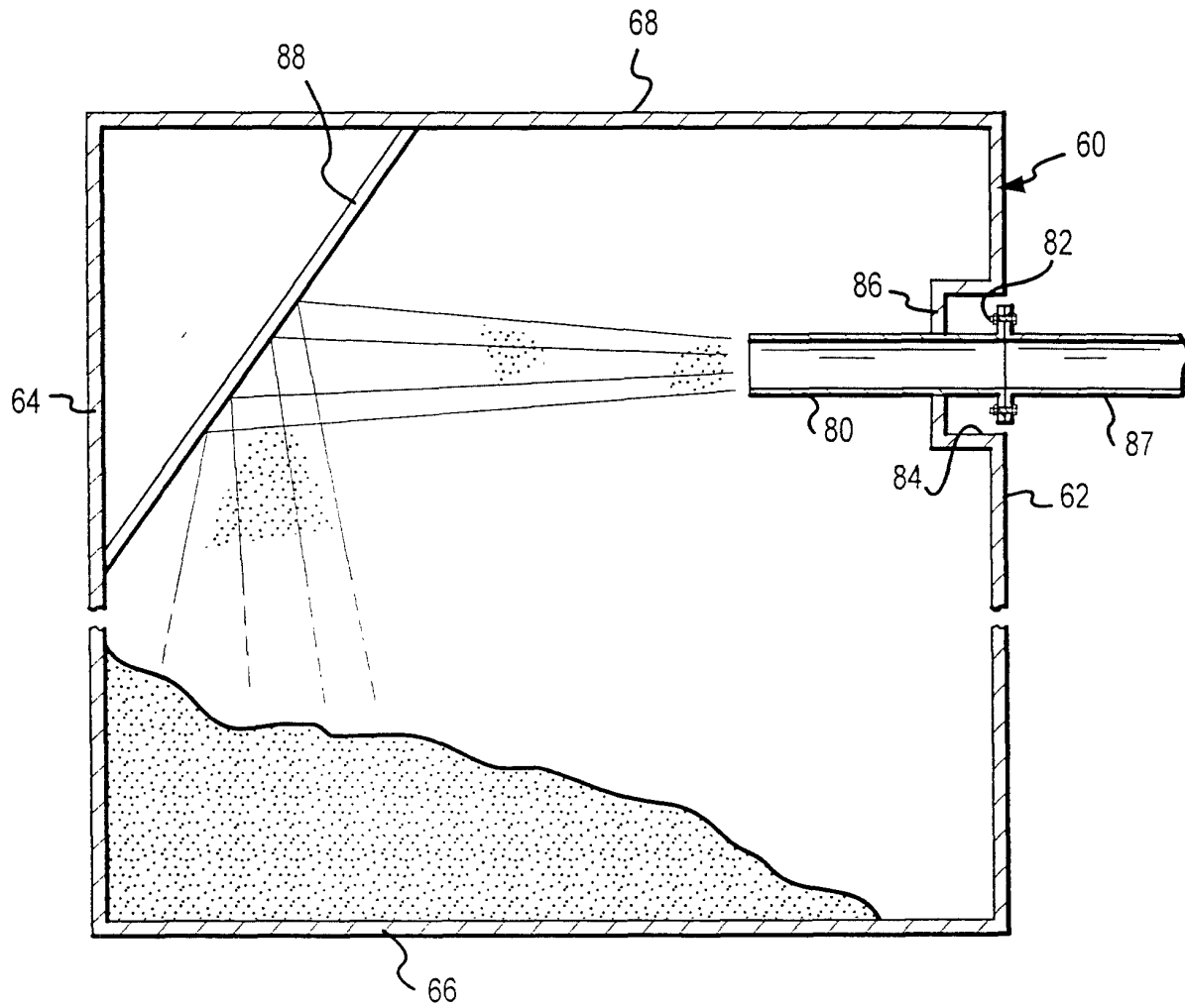


FIG. 4

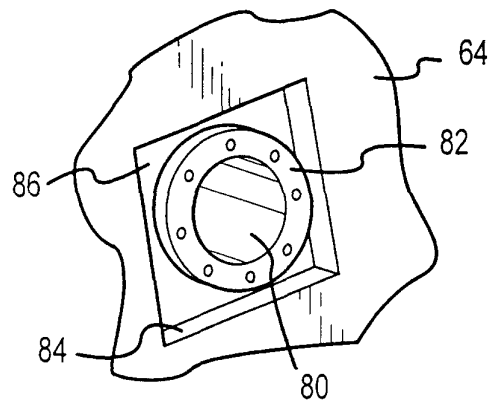


FIG. 5

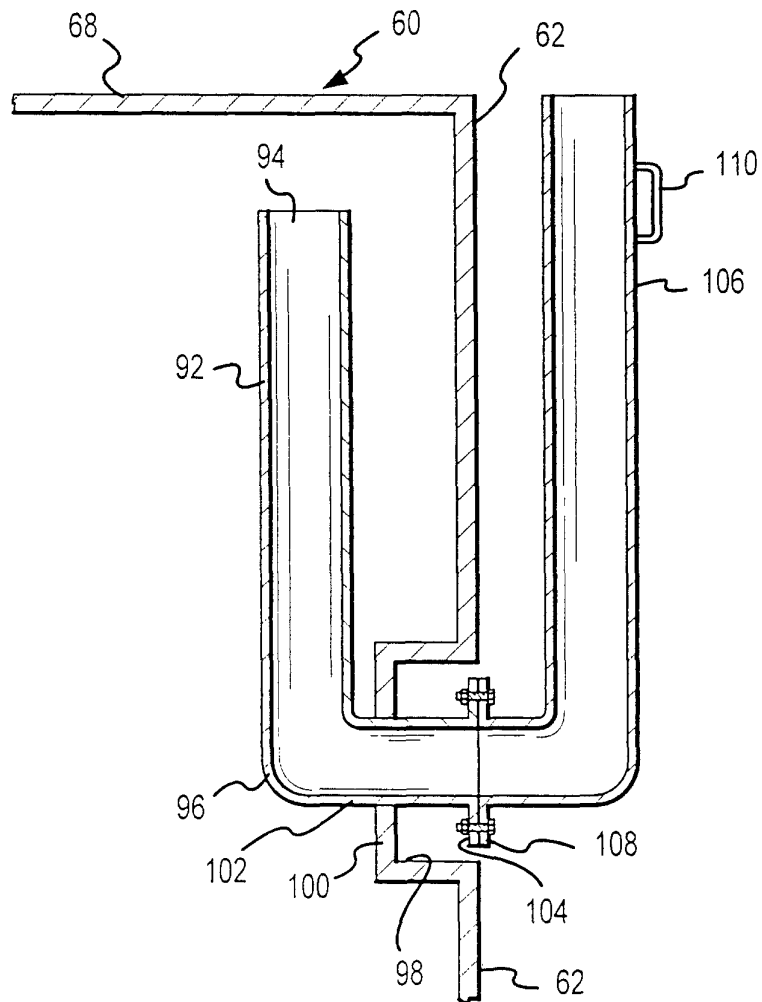


FIG. 6

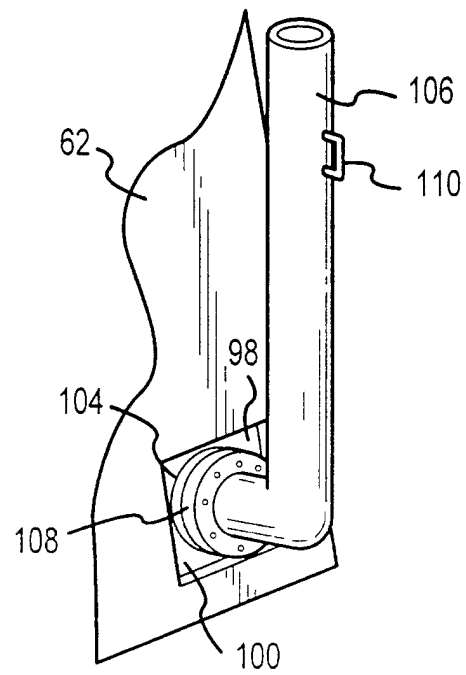


FIG.7

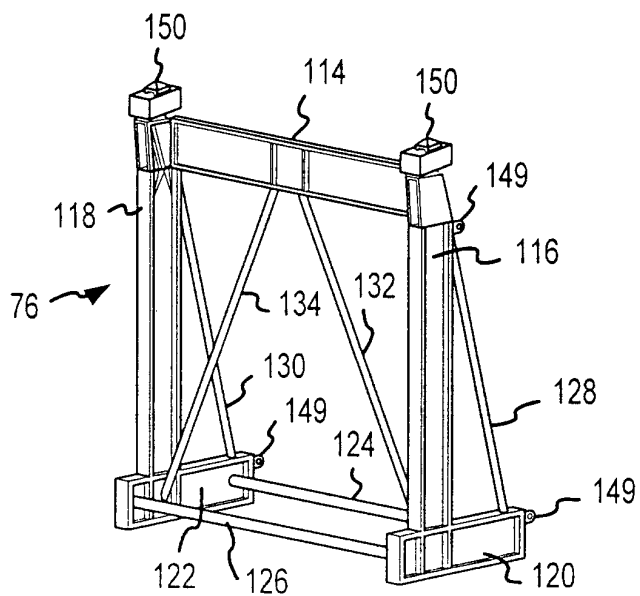


FIG. 8

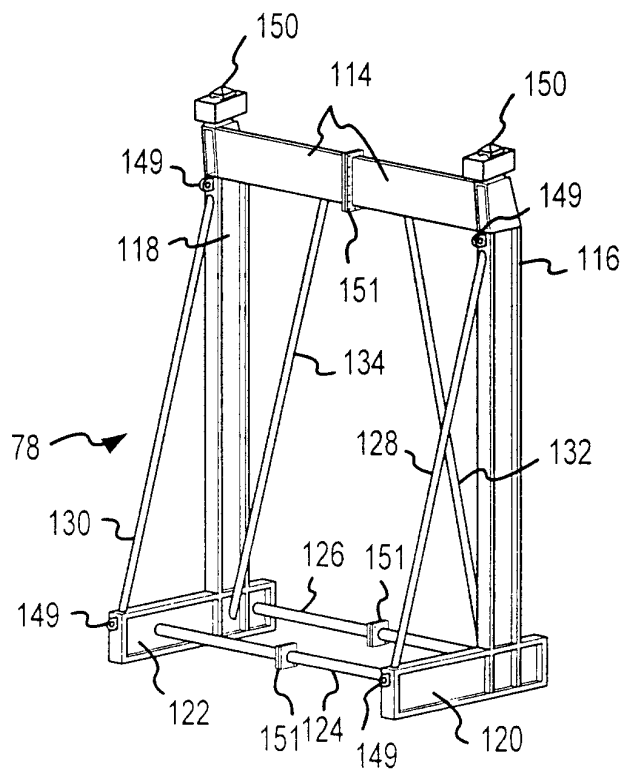


FIG. 9

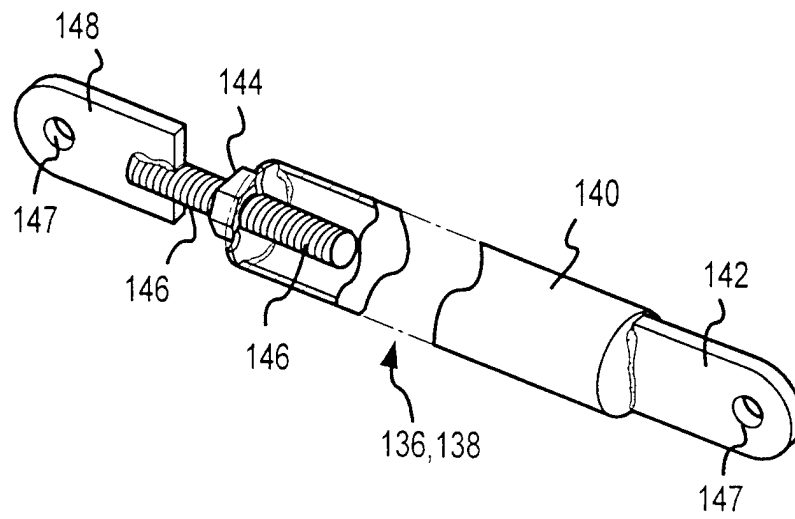


FIG.10

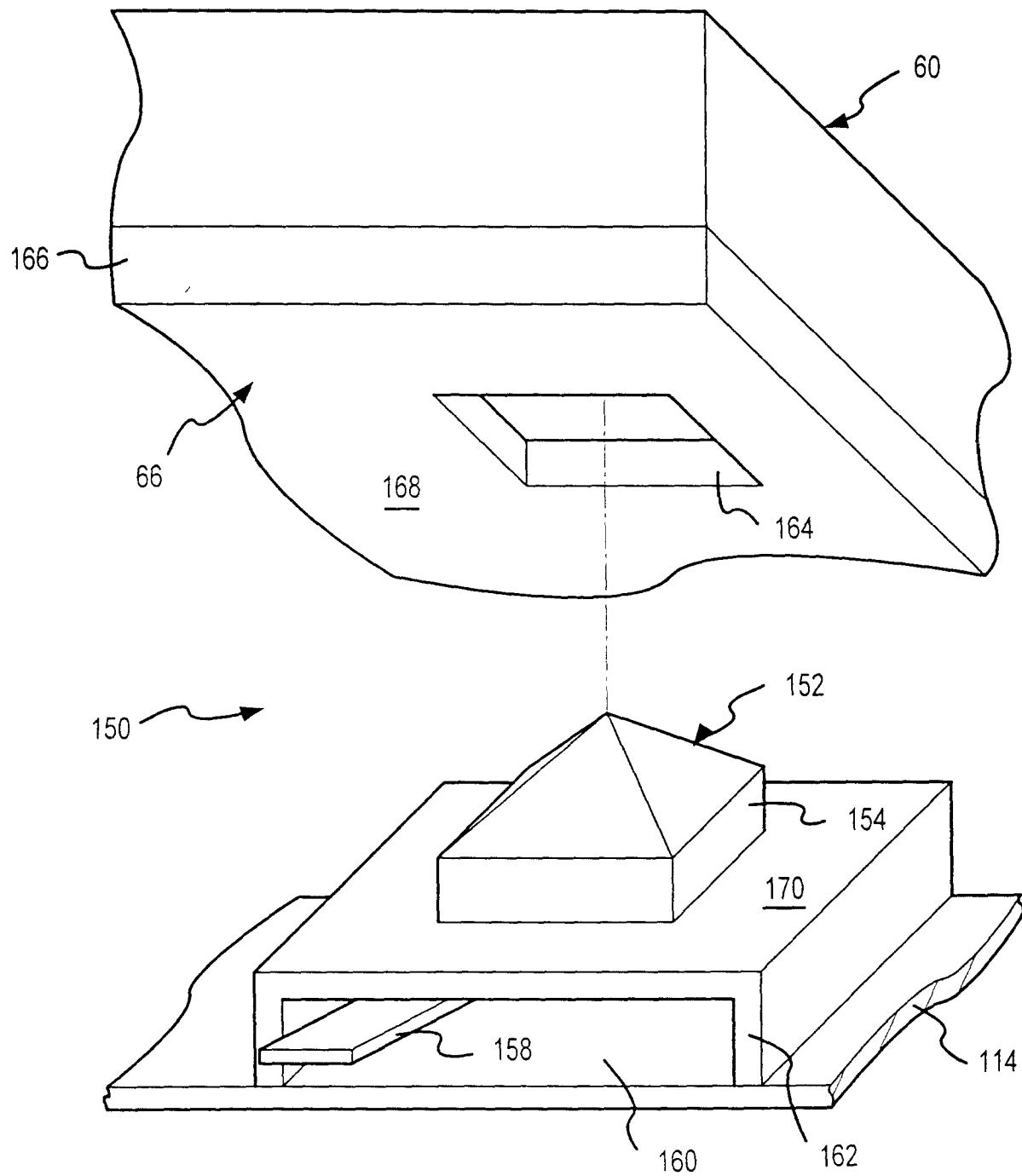


FIG. 11

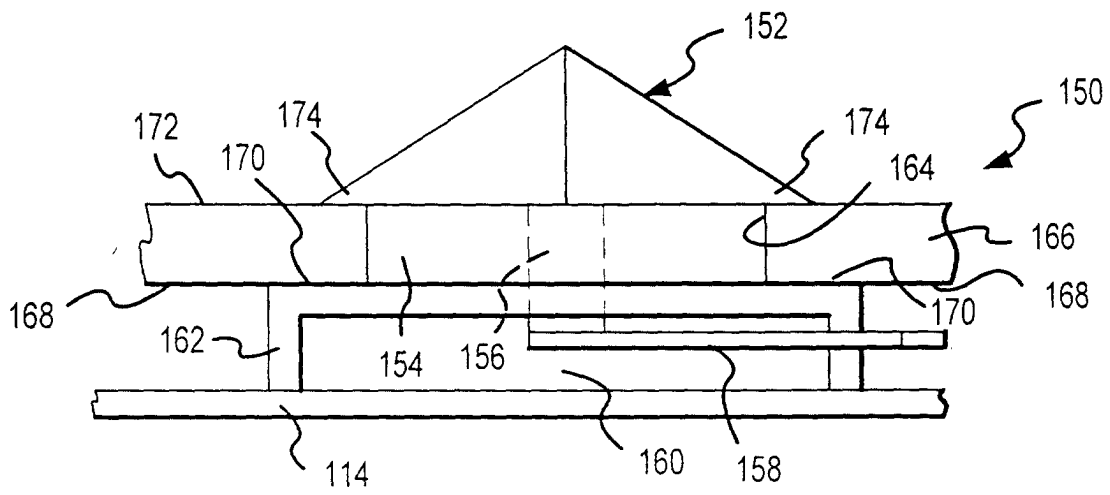


FIG.12

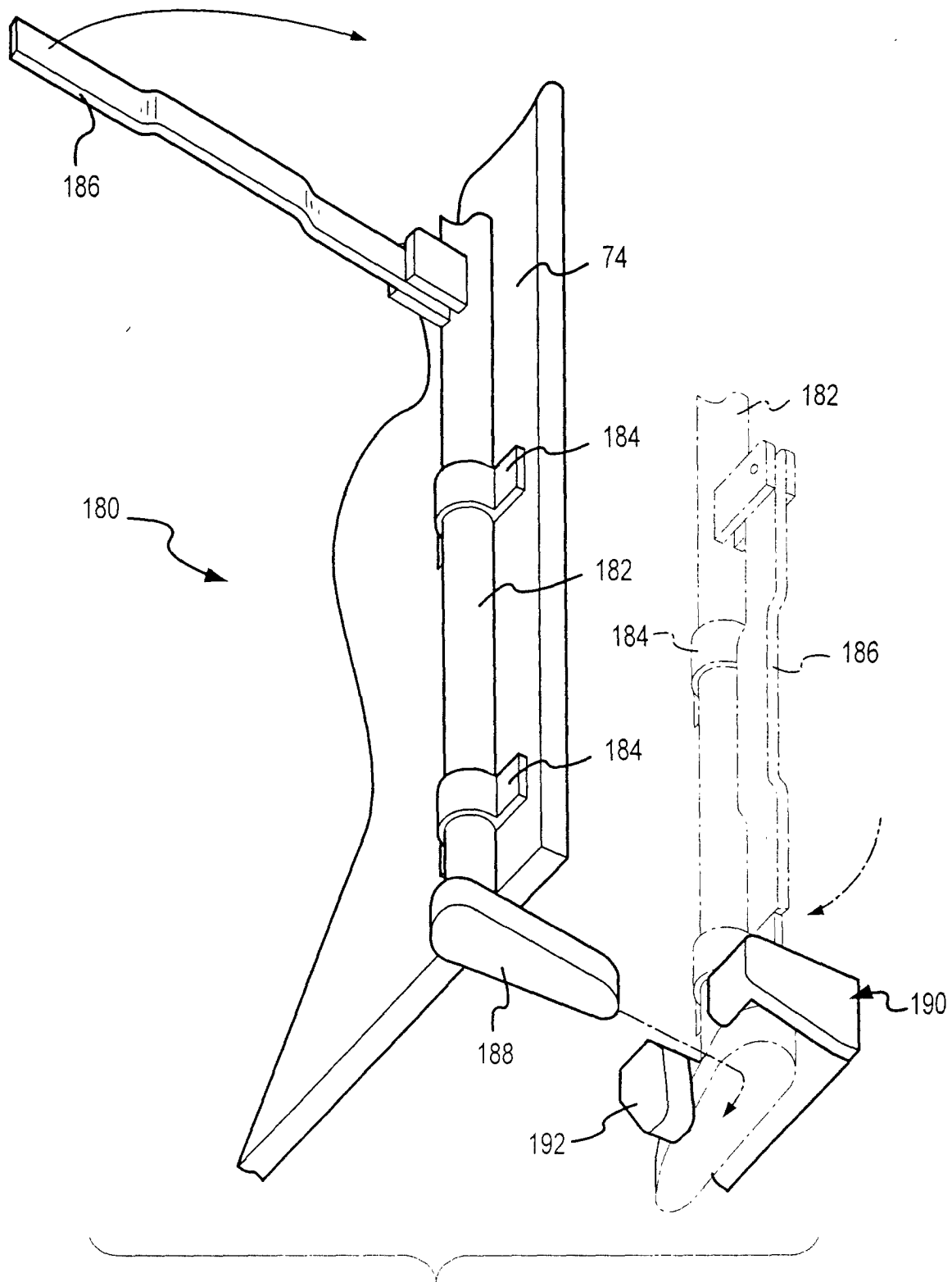


FIG.13

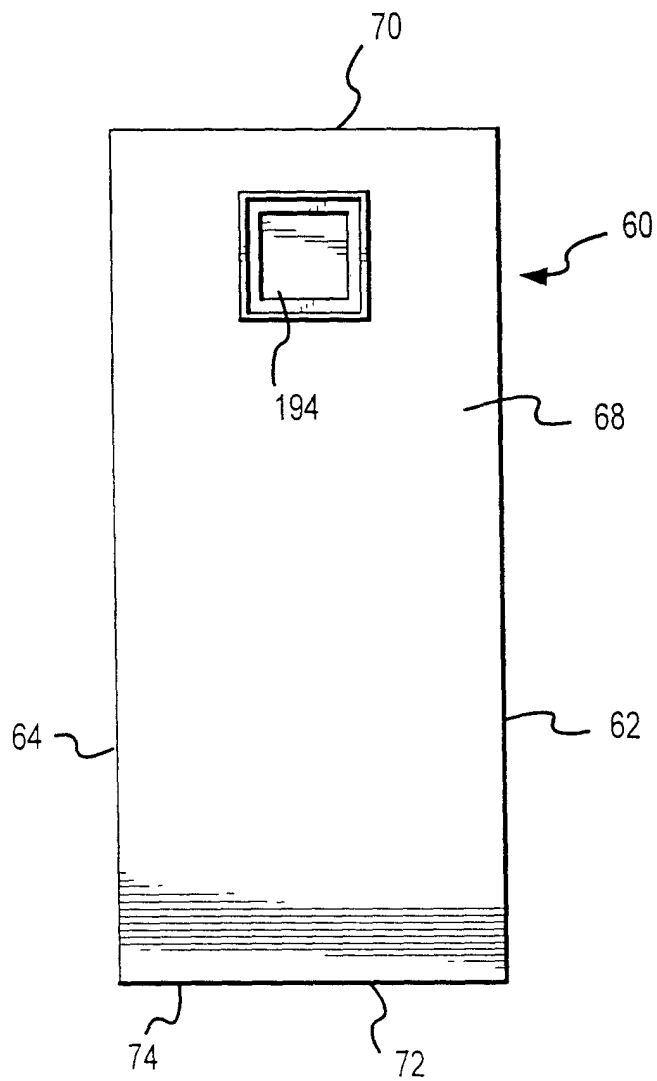
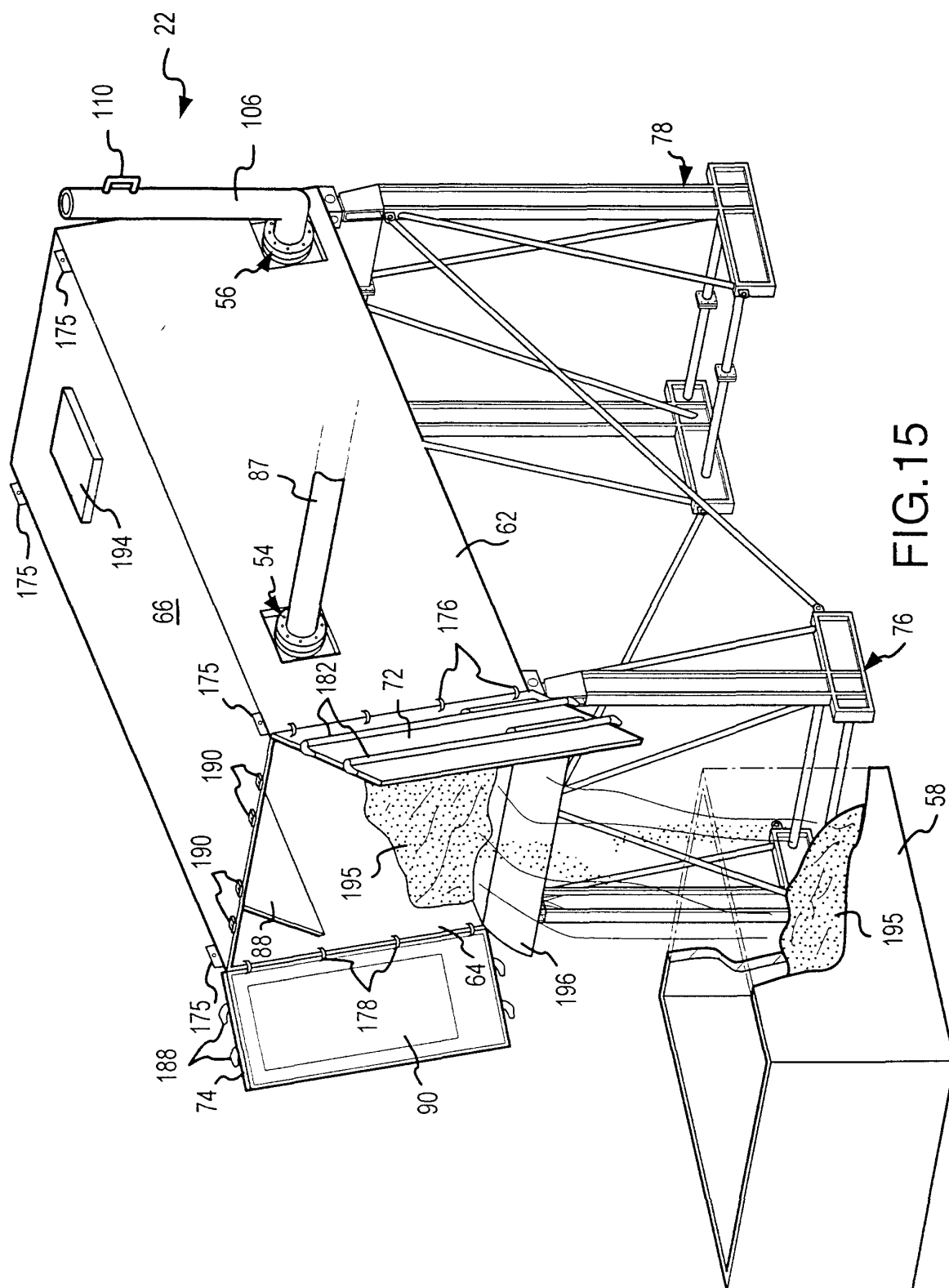


FIG.14



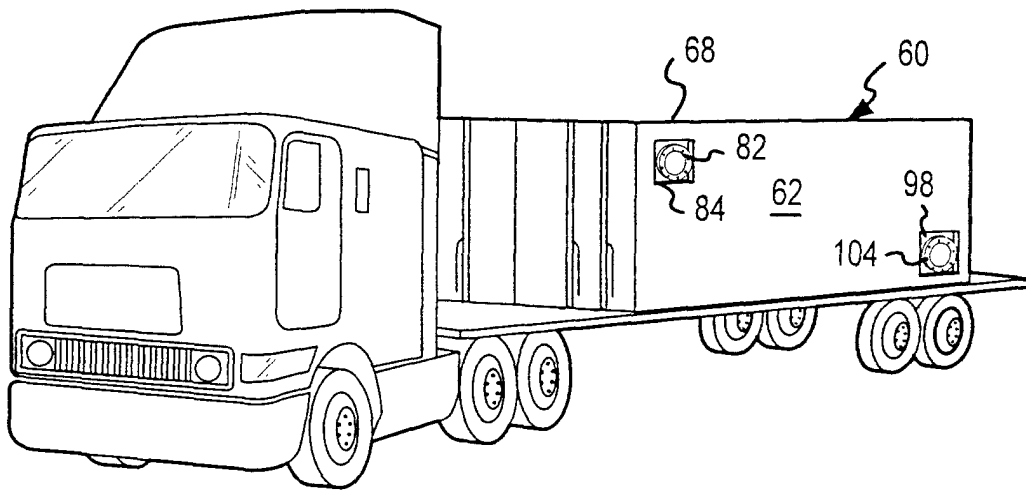


FIG.16