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(54) PERCUSSIVE/ROTATING DRILL WITH BLOW-OUT, BROKEN BIT, AND PRESSURE LOSS DETECTION SYSTEMS

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E21B 7/02 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 1/02*** (2013.01); ***E21B 7/022*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 1/02; E21B 7/022
See application file for complete search history.

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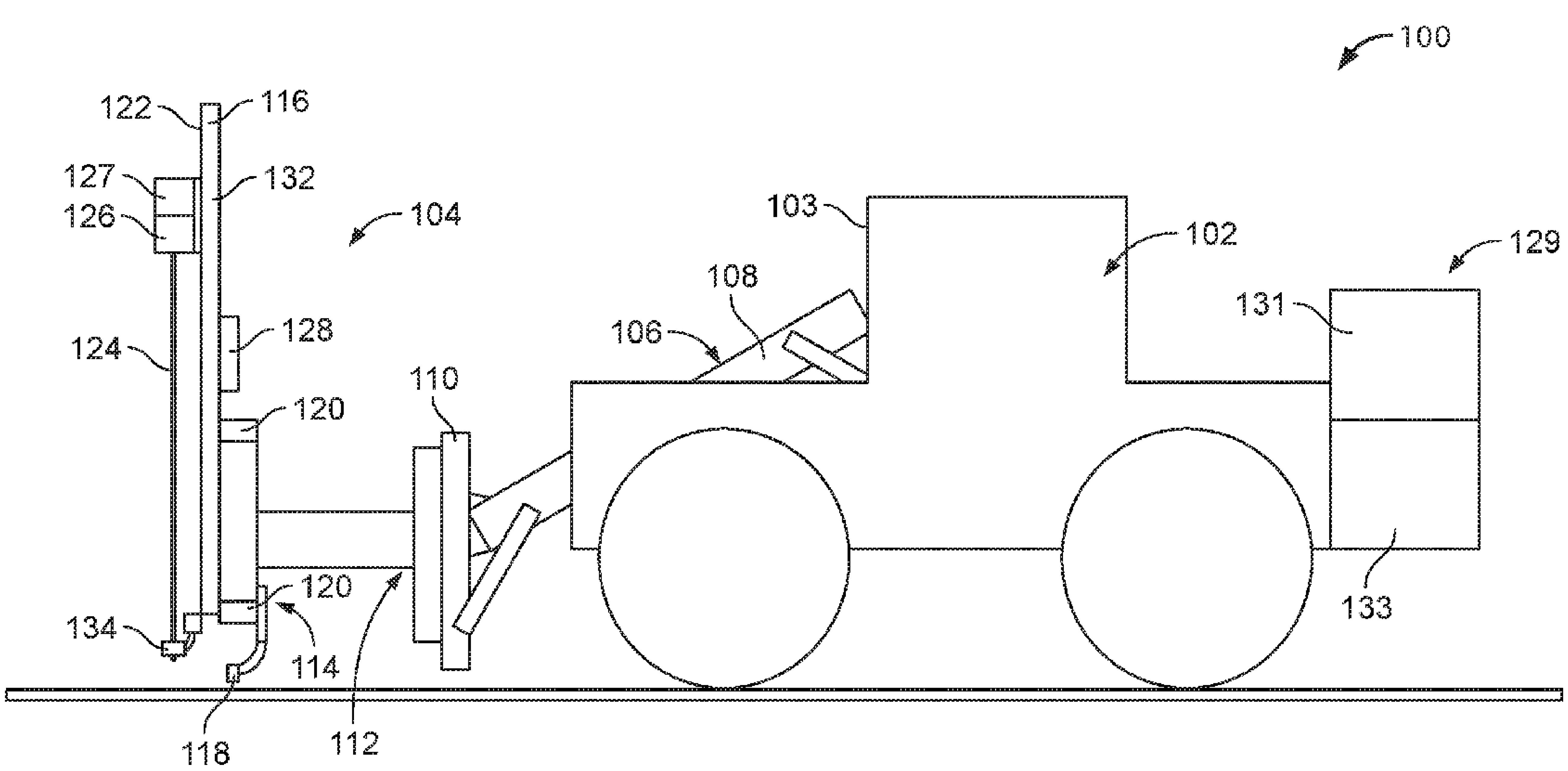
(57) **ABSTRACT**

A drilling system includes a control system that monitors operating parameters so as to protect the drilling machine from damage and increases drilling operation efficiency. A method of using a hydraulic system of a percussive drill as a sensing system includes sensing a drill bit blow-out event by measuring changes in the operating hydraulic fluid pressure in the hydraulic system used to operate the percussive drill.

9 Claims, 13 Drawing Sheets



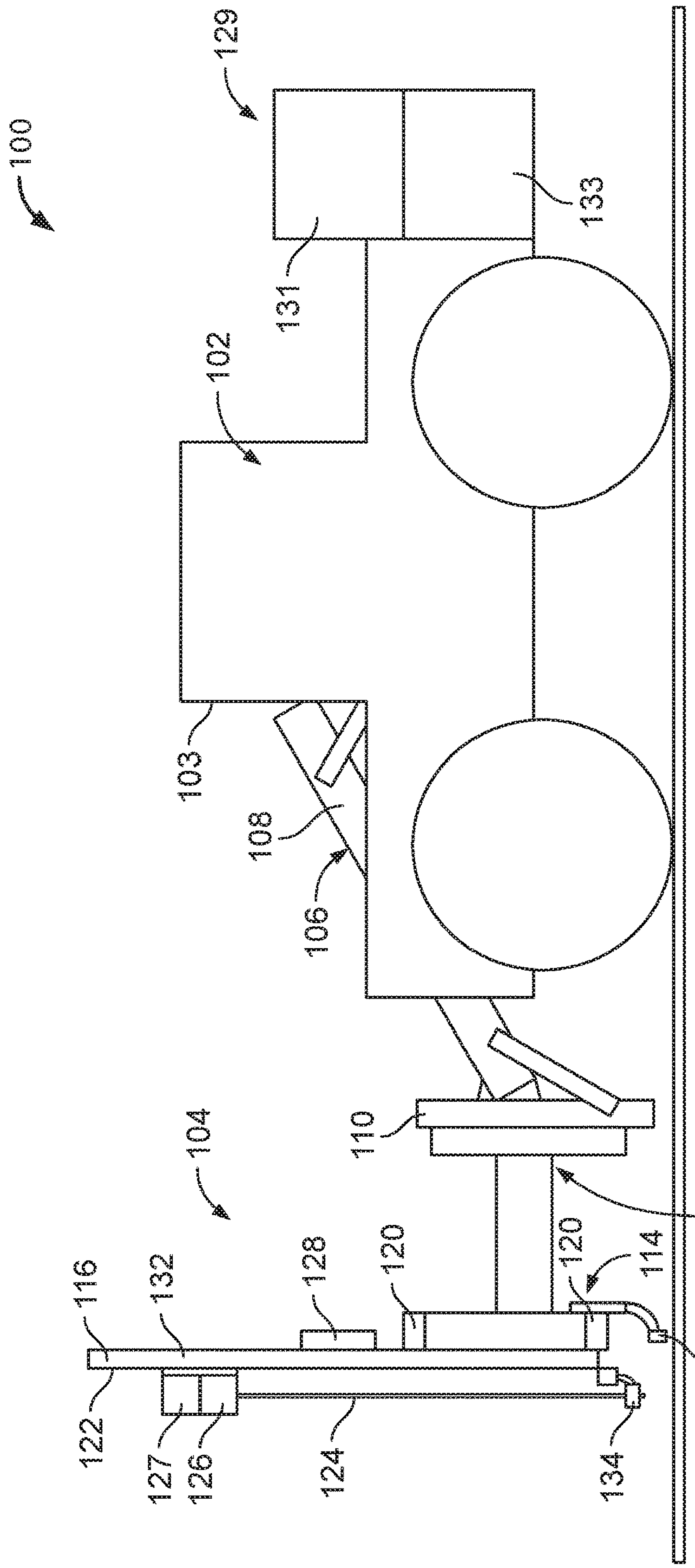

100
129
131
133
102
103
108
106
104
110
112
114
120
120
128
116
132
118
122
127
126
124
134

FIG. 1

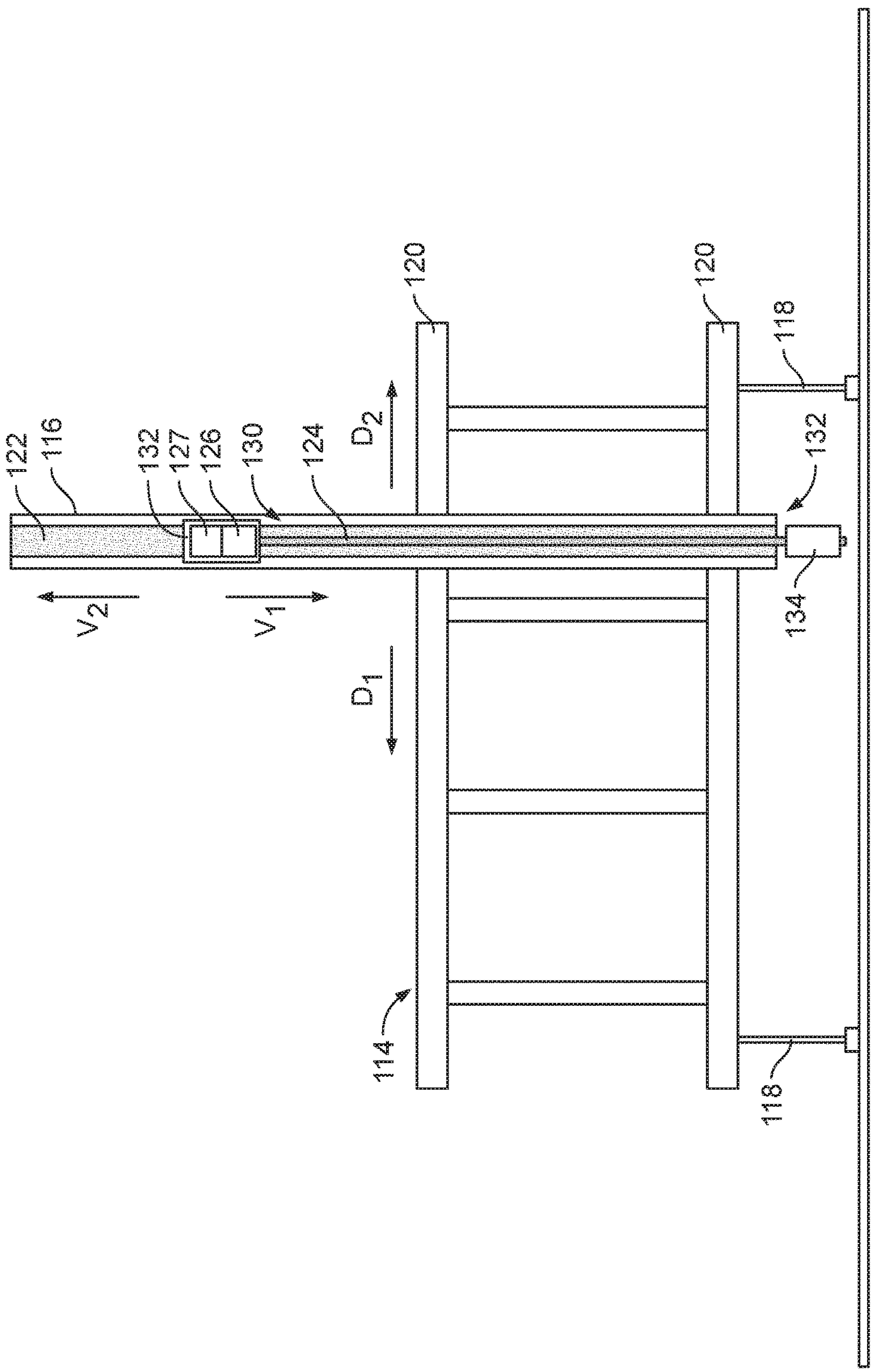

122
116
132
127
126
130
124
D_2
D_1
V_2
V_1
120
120
118
118
132
134
114

FIG. 2

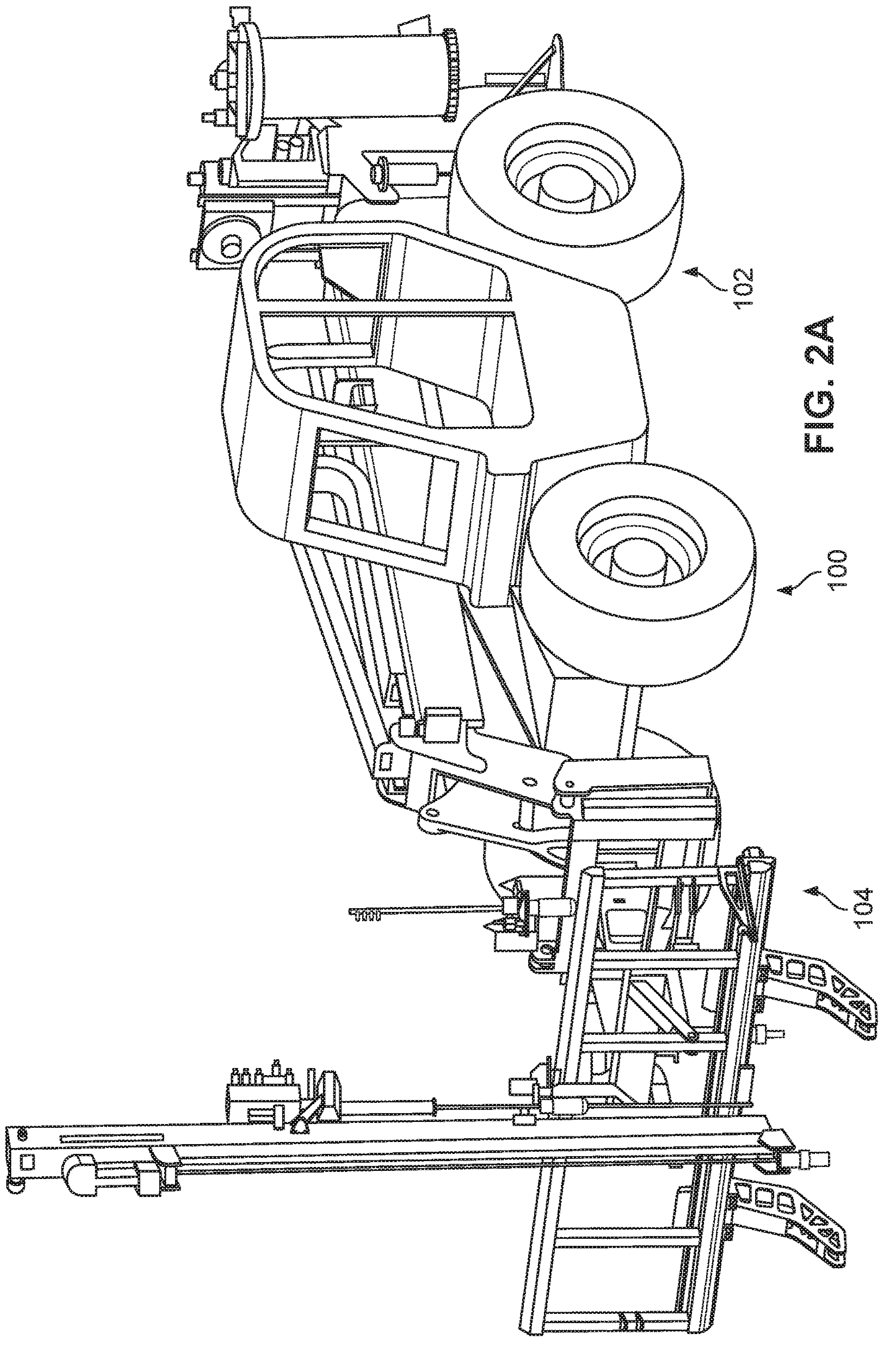


FIG. 2A

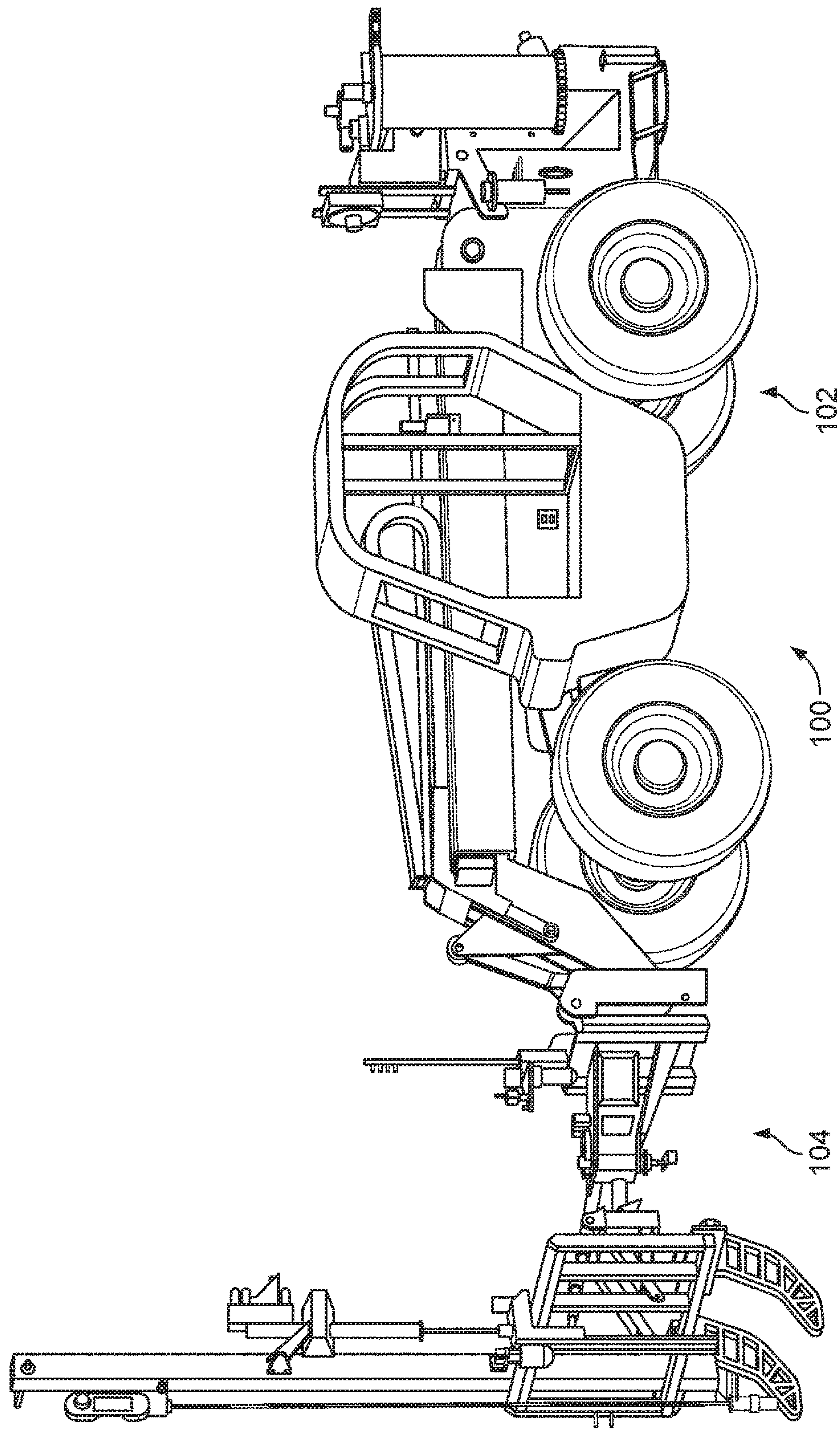


FIG. 2B

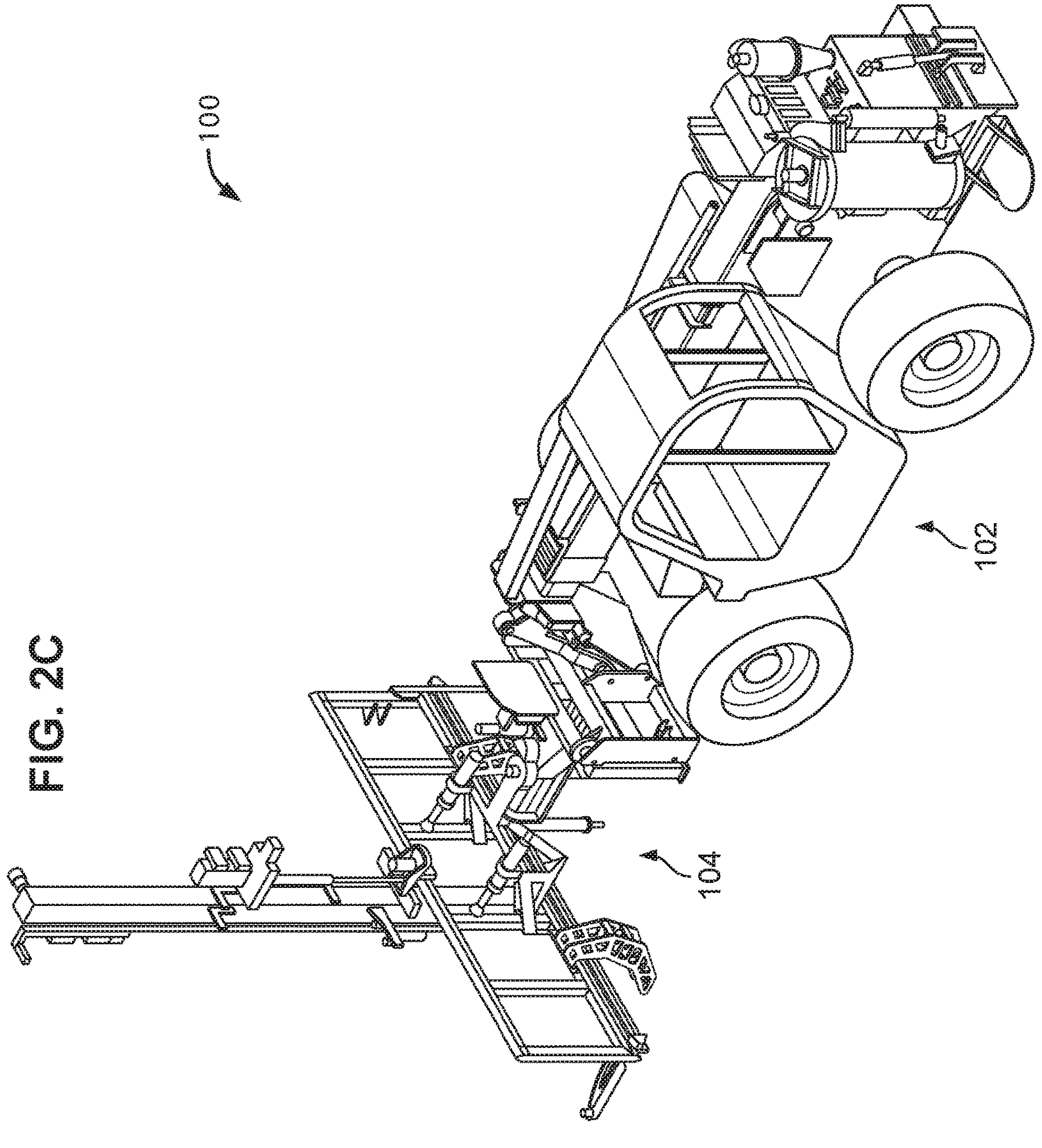


FIG. 2C

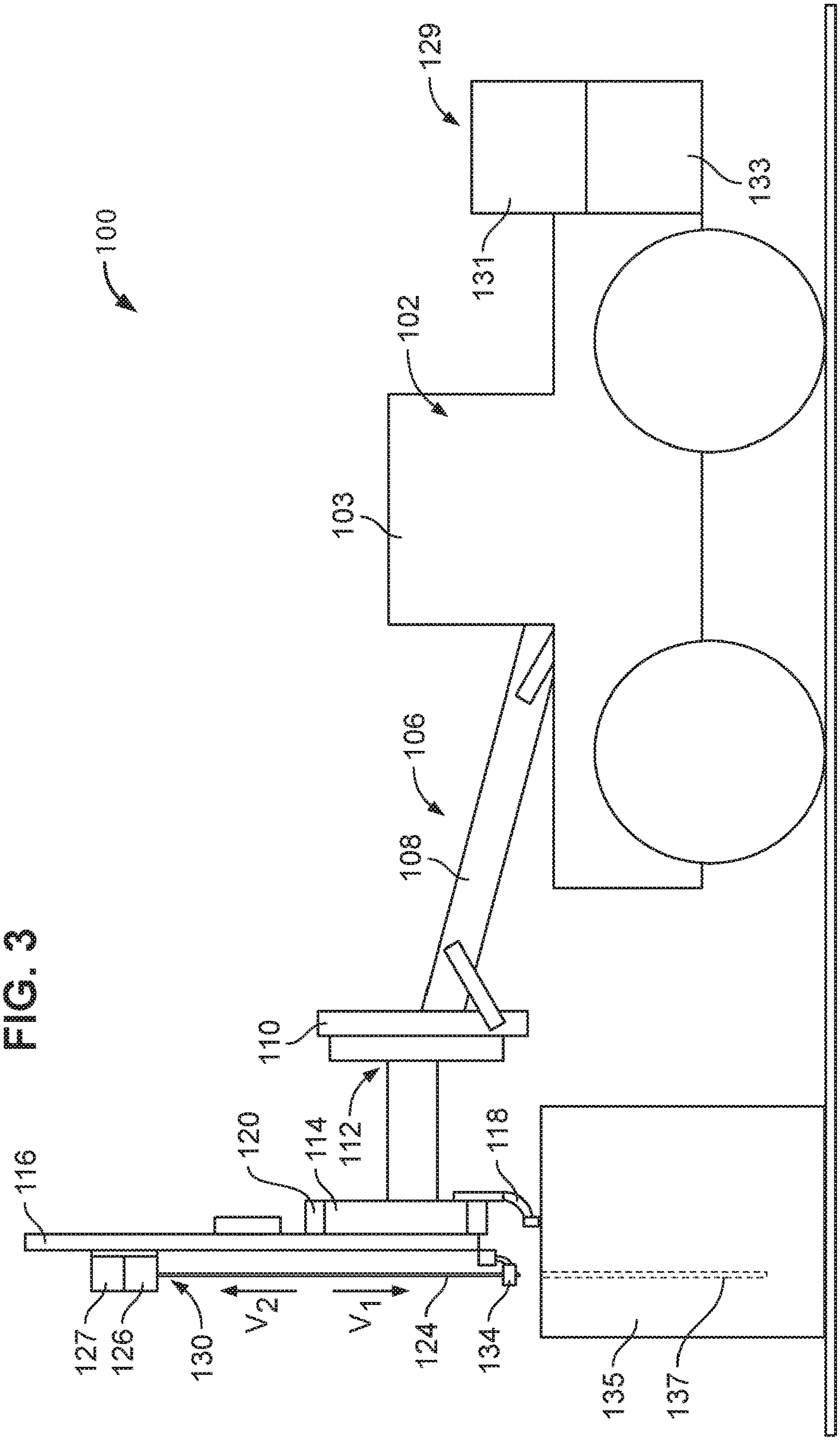

100
102
103
106
108
110
112
114
116
118
120
124
126
127
129
130
131
133
134
135
137
V_1
V_2

FIG. 3

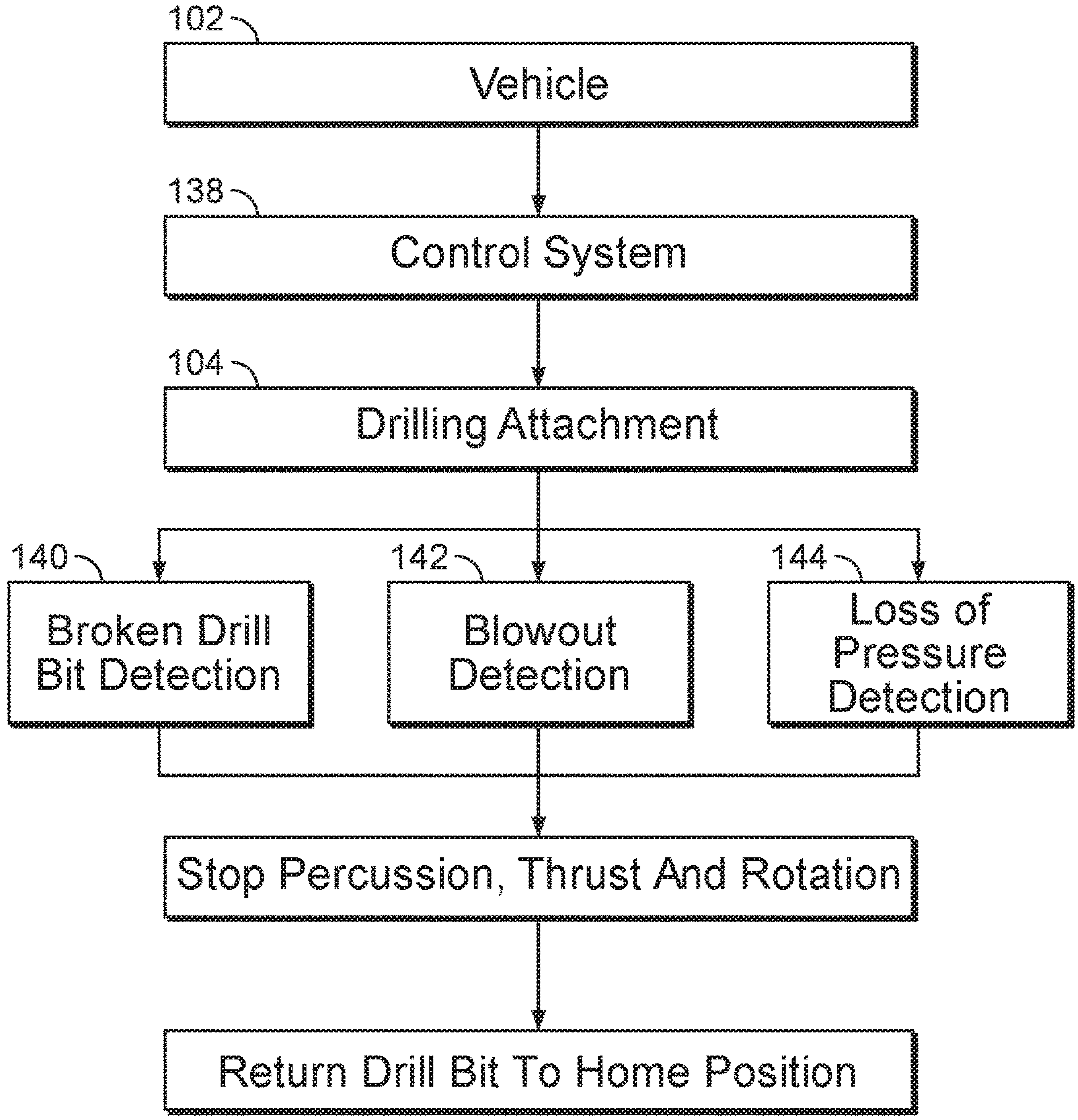

102
Vehicle
138
Control System
104
Drilling Attachment
140
Broken Drill Bit Detection
142
Blowout Detection
144
Loss of Pressure Detection
Stop Percussion, Thrust And Rotation
Return Drill Bit To Home Position

FIG. 4

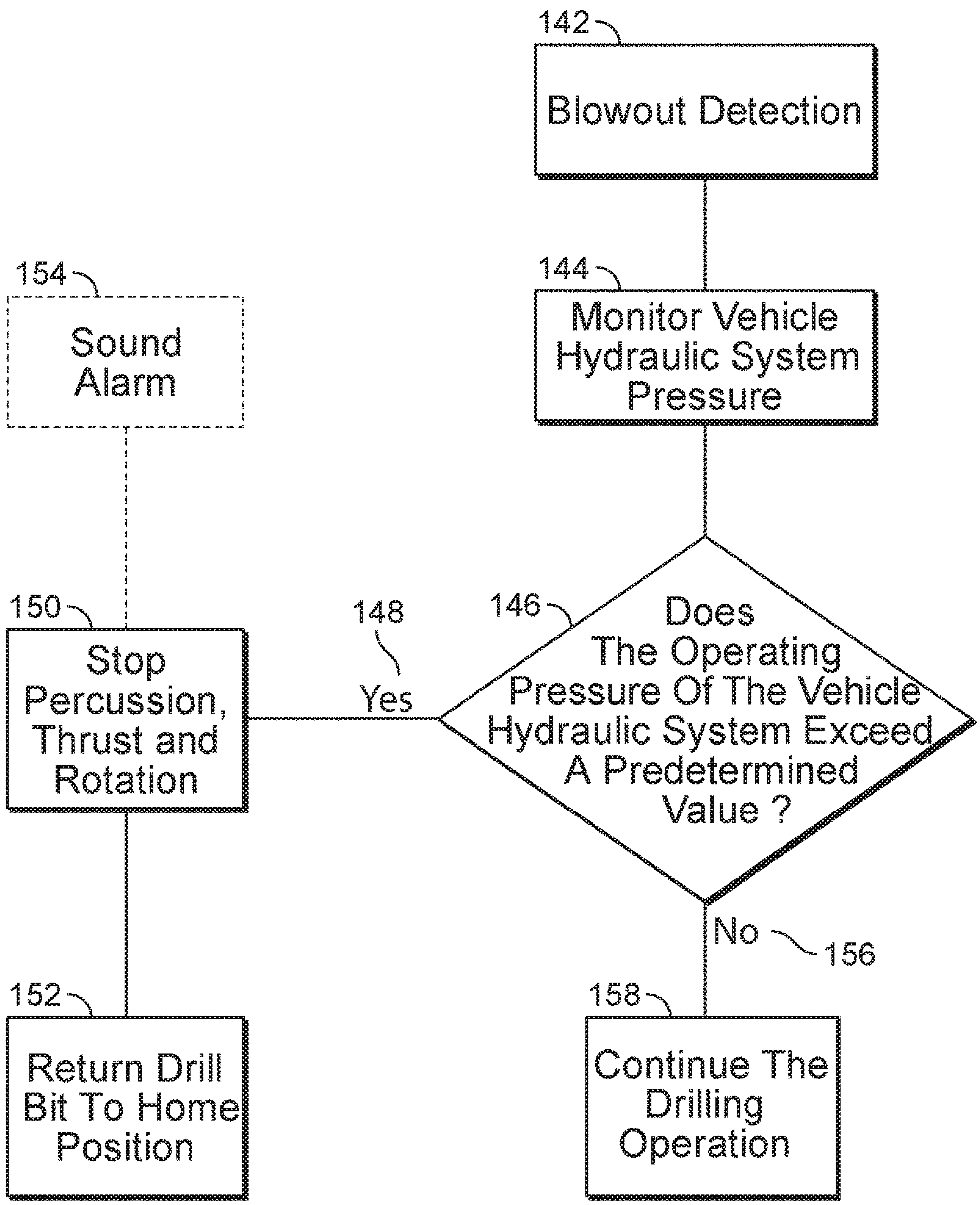

142
Blowout Detection
144
Monitor Vehicle Hydraulic System Pressure
146
Does The Operating Pressure Of The Vehicle Hydraulic System Exceed A Predetermined Value ?
148
Yes
150
Stop Percussion, Thrust and Rotation
154
Sound Alarm
152
Return Drill Bit To Home Position
No
156
158
Continue The Drilling Operation

FIG. 5

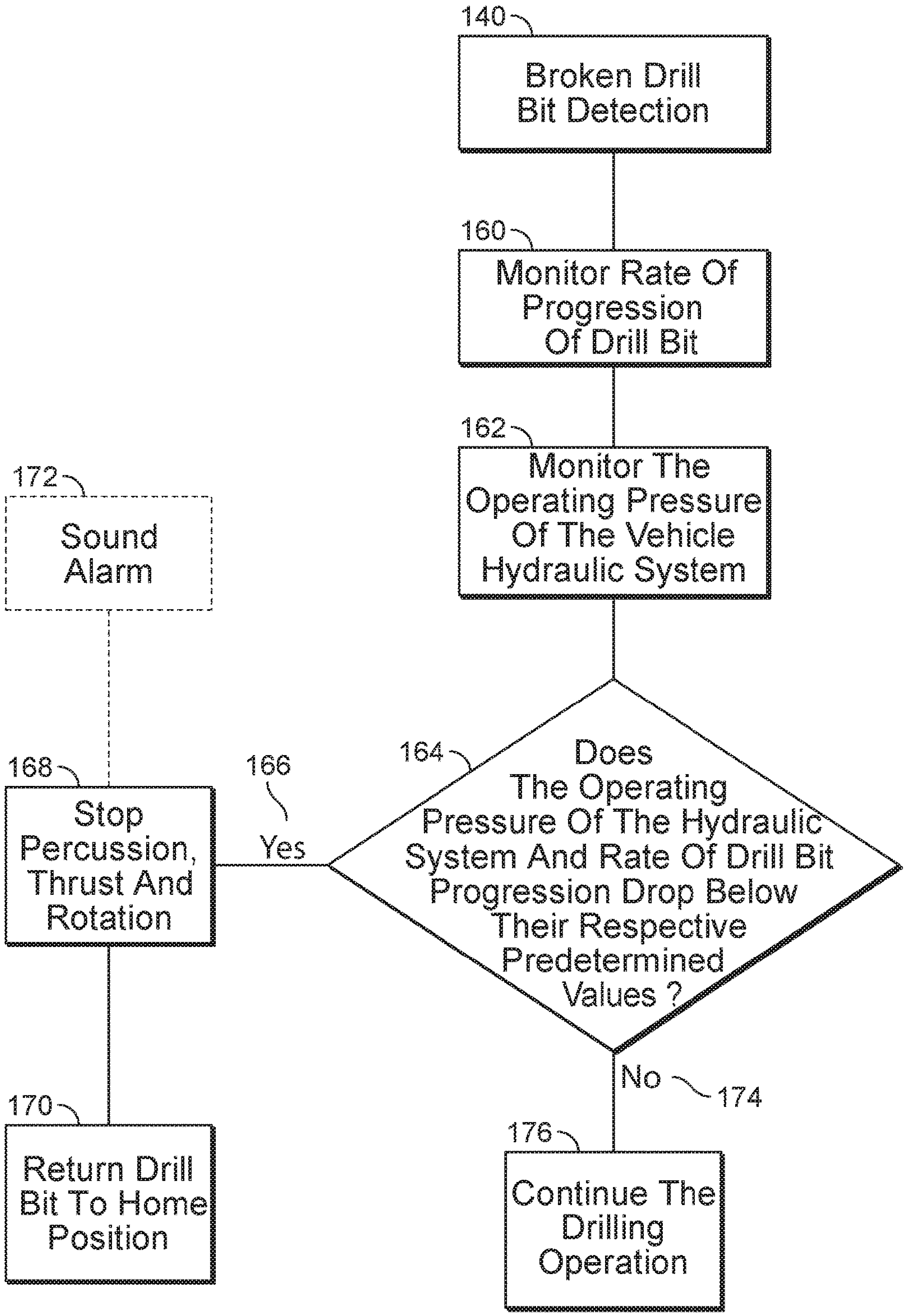

140
Broken Drill Bit Detection
160
Monitor Rate Of Progression Of Drill Bit
162
Monitor The Operating Pressure Of The Vehicle Hydraulic System
172
Sound Alarm
168
Stop Percussion, Thrust And Rotation
166
Yes
164
Does The Operating Pressure Of The Hydraulic System And Rate Of Drill Bit Progression Drop Below Their Respective Predetermined Values ?
No
174
170
Return Drill Bit To Home Position
176
Continue The Drilling Operation

FIG. 6

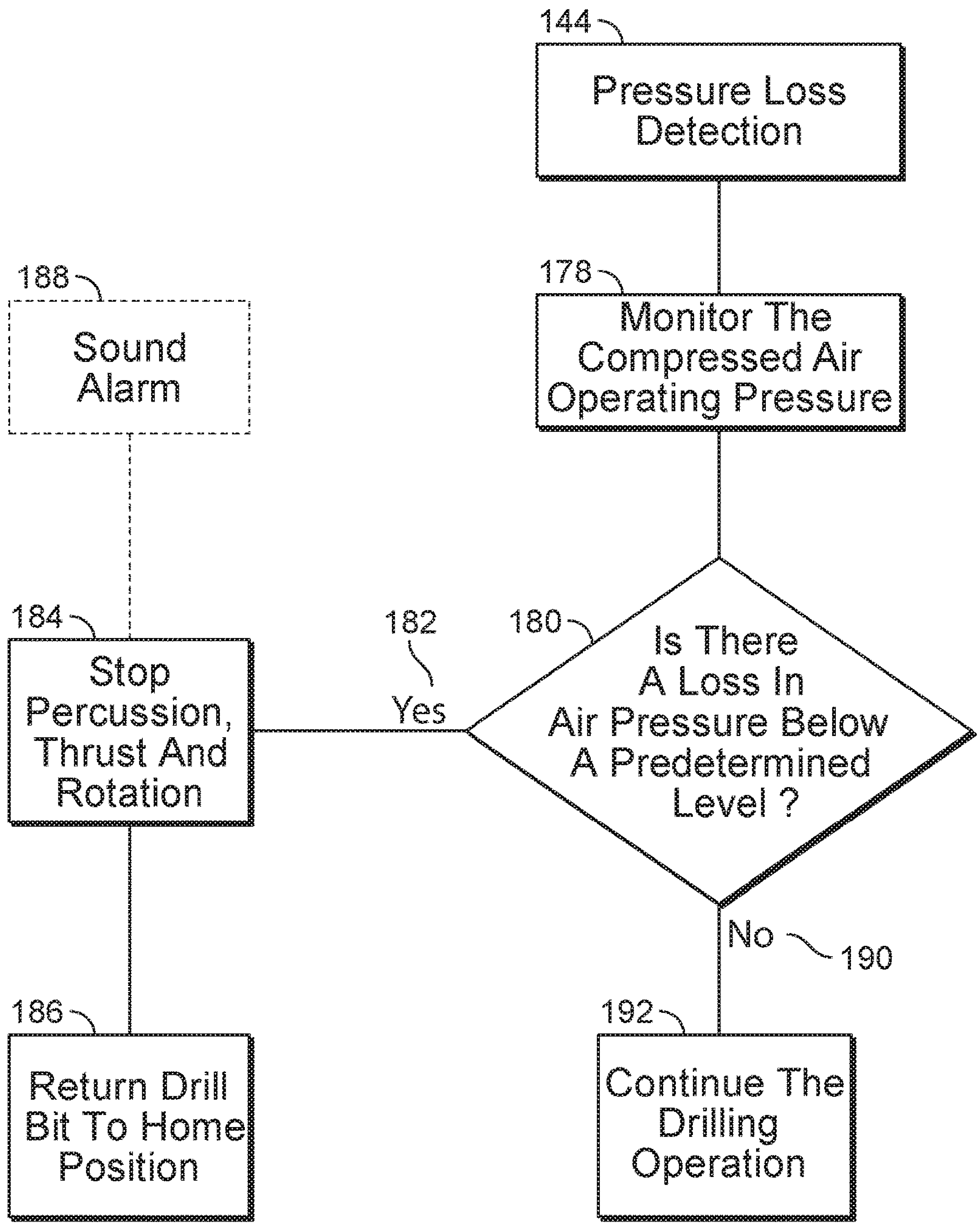

144
Pressure Loss Detection
178
Monitor The Compressed Air Operating Pressure
180
Is There A Loss In Air Pressure Below A Predetermined Level ?
182
Yes
No
190
188
Sound Alarm
184
Stop Percussion, Thrust And Rotation
186
Return Drill Bit To Home Position
192
Continue The Drilling Operation

FIG. 7

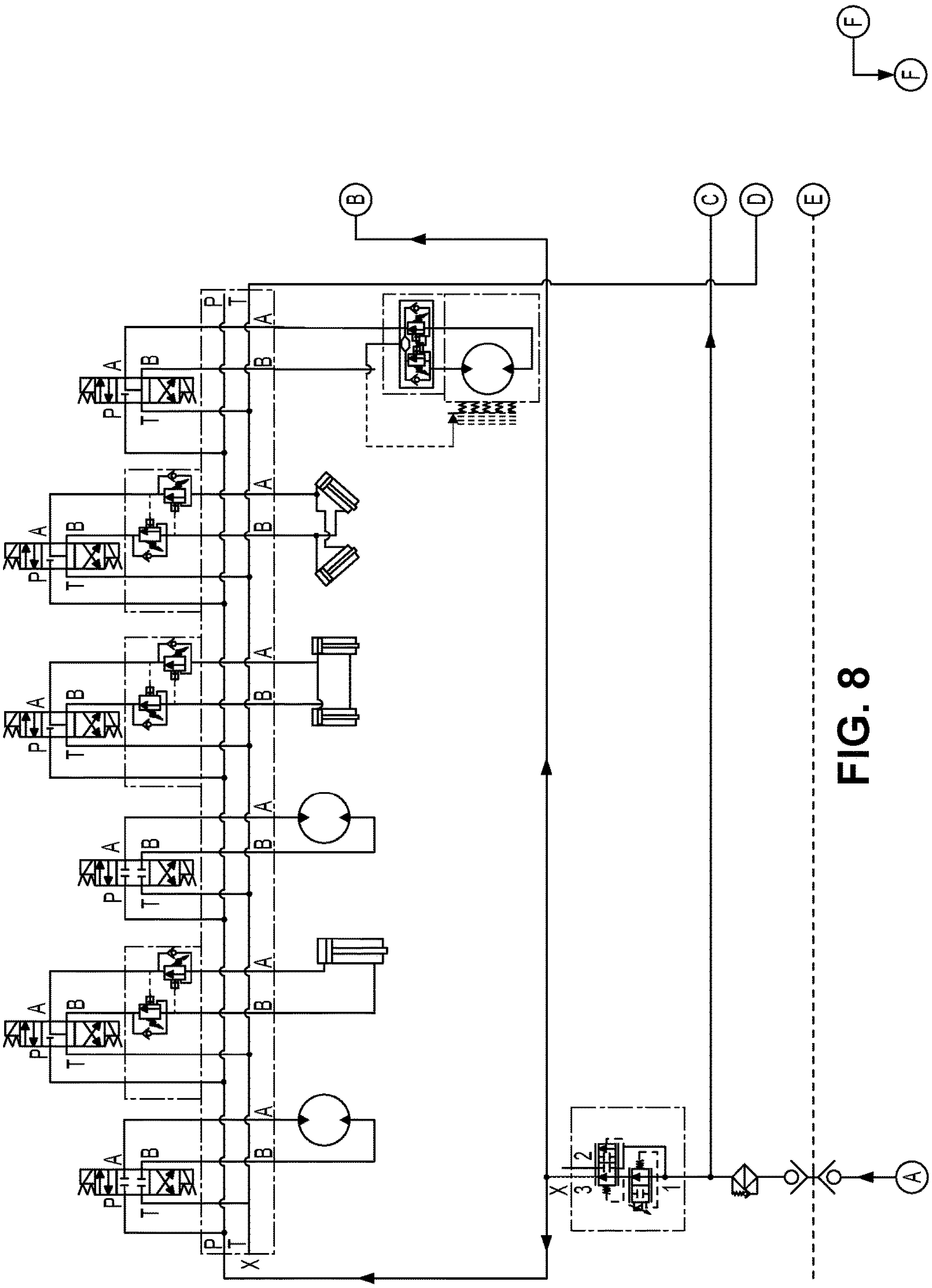


FIG. 8

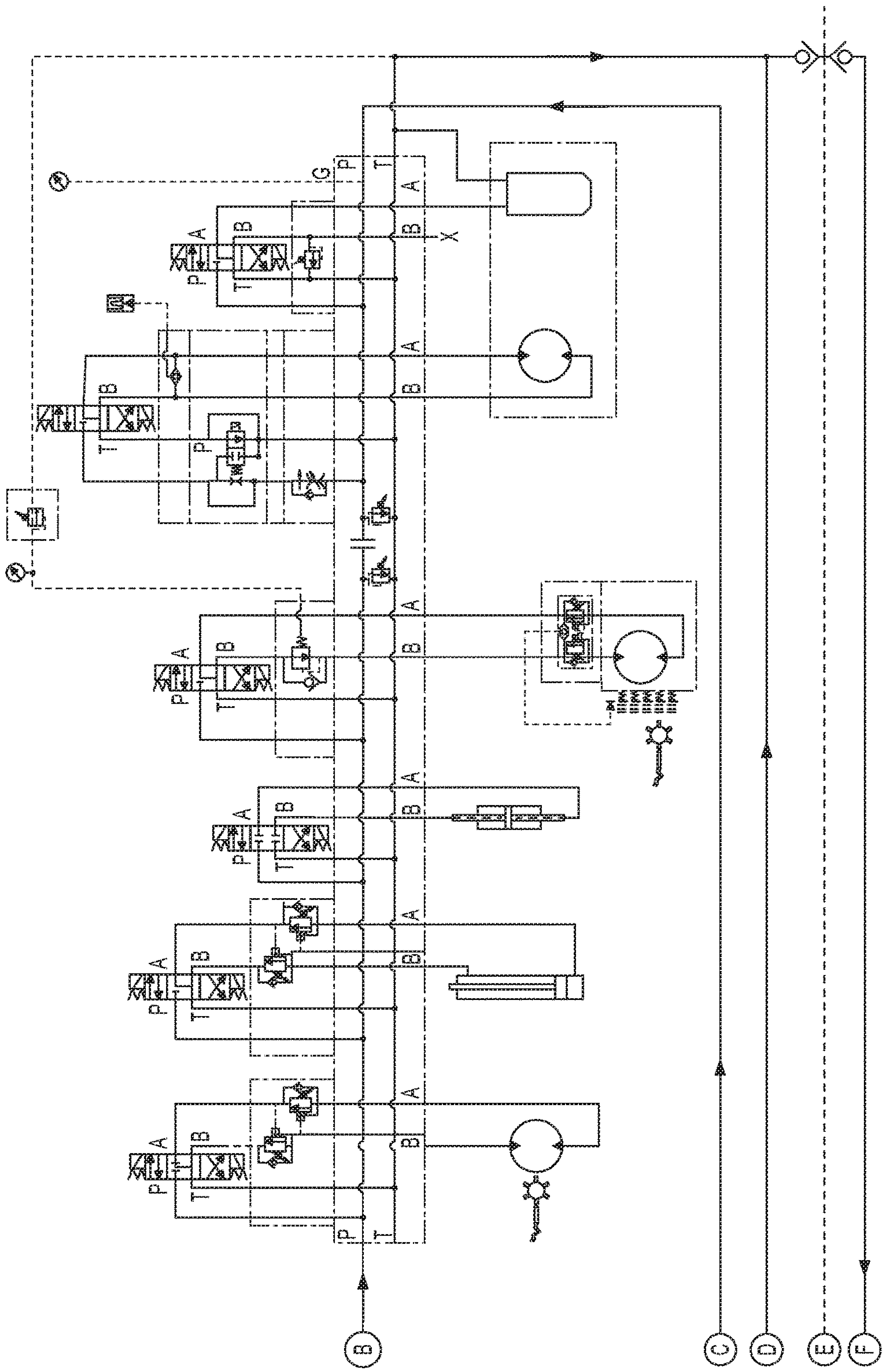


FIG. 8 (Cont.)

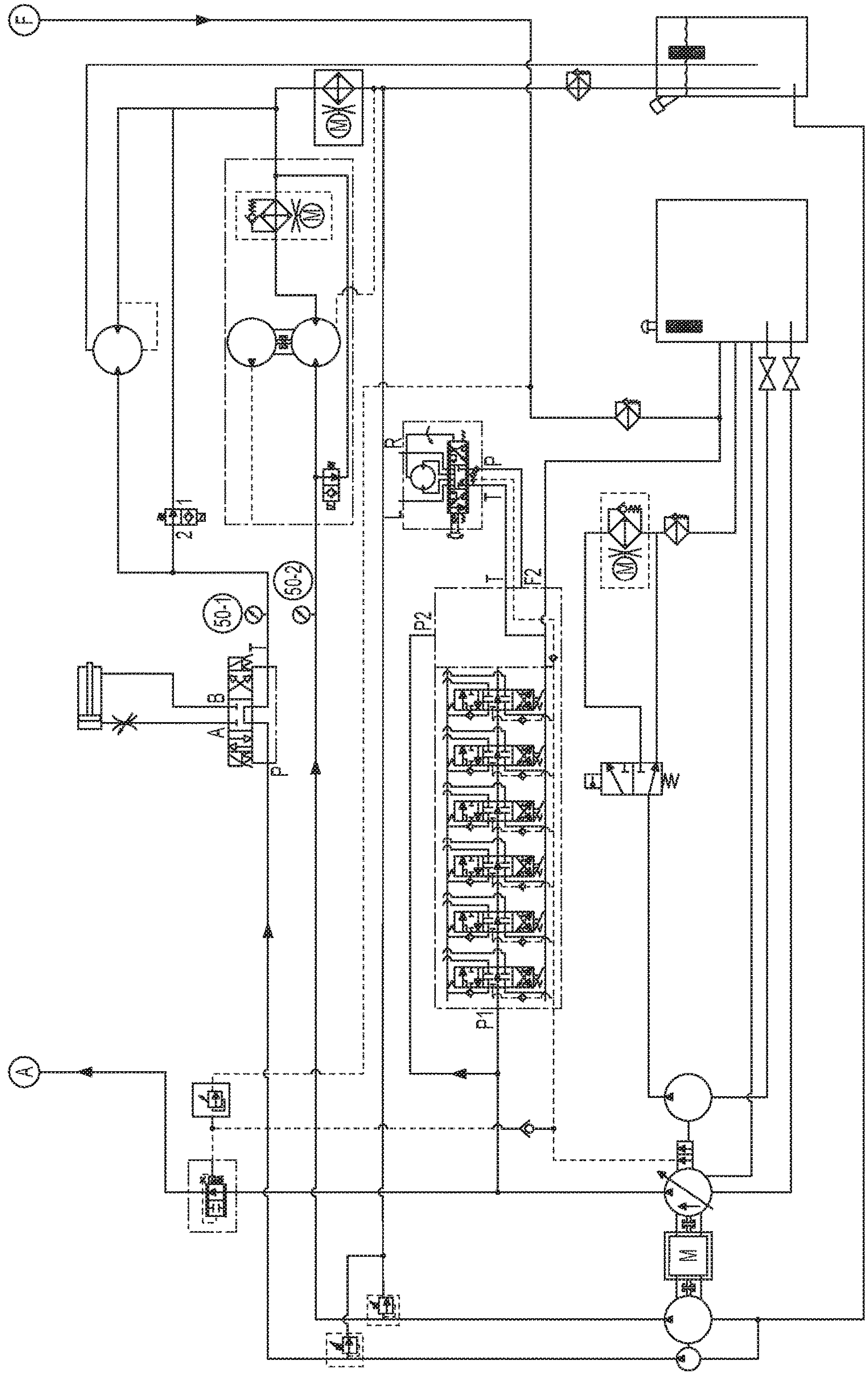


FIG. 8 (Cont.)

PERCUSSIVE/ROTATING DRILL WITH BLOW-OUT, BROKEN BIT, AND PRESSURE LOSS DETECTION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Patent Provisional Application No. 62/235,099, filed Sep. 30, 2015, which application is hereby incorporated by reference in its entirety.

BACKGROUND

In quarrying operations, large blocks of stone are often harvested from the ground. However, because the large blocks of stone are too heavy and large to transport easily, the large blocks of stone need to be methodically broken into smaller blocks so that they can be handled and transported reasonably. It is common practice in quarrying operations to use a rock drill to drill a series of spaced-apart bores/holes into the large blocks of stone so that they may be easily split while minimizing waste. However, drilling into stone/rock is a difficult task. Due to the hardness of the rock, drill bits can break during the drilling process, which can lead to downtime for the drilling machine, thereby decreasing productivity and efficiency.

Additionally, when drilling such holes close to an edge of a large block of rock, drill bits can travel out of the side (defining the edge) of the large blocks causing what is known as a blow-out event. When a blow-out event occurs, the drill bit does not tend to stay in its programmed straight path. The drill bit is forced out the side of the large rock block and is deflected in the process. Such deflection can cause the drill bit to bind in the hole and potentially break.

Improvements in systems to monitor the drill bit activity during drilling operations are needed.

SUMMARY

The present disclosure relates generally to a rock drill attachment. In one possible configuration, and by non-limiting example, the rock drill attachment is configured to monitor a variety of different operative aspects of the rock drill attachment so as to prevent damage to the rock drill attachment.

In a first aspect of the present disclosure, a method of using a hydraulic system of a percussive drill as a sensing system is disclosed. The method includes sensing a drill bit blow-out event by measuring changes in the operating hydraulic fluid pressure in the hydraulic system used to operate the percussive drill.

In a second aspect of the present disclosure, a drilling attachment configured to attach to a vehicle is disclosed. The drilling attachment includes a drill bit and a first motor for rotating the drill bit. The drilling attachment also includes a second motor for controlling the thrust applied to the drill bit. The first and second motors include hydraulic connections for attaching to an external hydraulic system. The drilling attachment further includes a drill bit blow-out sensing system operatively connected to the first and second motors. The drill bit blow-out sensing system senses a drill bit blow-out event based on a change in an operational hydraulic pressure within at least one of the first and second motors.

In a third aspect of the present disclosure, a drill bit monitoring system for a percussive drill is disclosed. The

drill bit monitoring system includes a vehicle that includes an engine and a hydraulic system. The hydraulic system includes a pump at least partly powered by the engine. The vehicle further includes a boom operated by the hydraulic system. The drill bit monitoring system also includes a drilling attachment removably attached to the boom of the vehicle. The drilling attachment includes a drill bit, a first motor for rotating the drill bit, and a second motor for controlling the thrust applied to the drill bit. The first and second motors are connected to the hydraulic system of the vehicle. The drilling attachment also includes a drill bit blow-out sensing system operatively connected to the first and second motors. The drill bit blow-out sensing system senses a drill bit blow-out event based on a change in an operational hydraulic pressure within at least one of the first and second motors.

A variety of additional aspects will be set forth in the description that follows. The aspects can relate to individual features and to combinations of features. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the broad inventive concepts upon which the embodiments disclosed herein are based.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of particular embodiments of the present disclosure and therefore do not limit the scope of the present disclosure. The drawings are not to scale and are intended for use in conjunction with the explanations in the following detailed description. Embodiments of the present disclosure will hereinafter be described in conjunction with the appended drawings, wherein like numerals denote like elements.

FIG. **1** illustrates a schematic side view of a drilling system according to one aspect of the present disclosure;

FIG. **2** illustrates a schematic front view of a portion of the drilling system of FIG. **1**;

FIGS. **2**A-**2**C illustrate various perspective views of the vehicle and the drill attachment of the drilling system of FIGS. **1**-**2**;

FIG. **3** illustrates a schematic side view of a drilling system of FIG. **1** resting on a work piece;

FIG. **4** shows a schematic block diagram of the control system of the drilling system, according to one aspect of the present disclosure;

FIG. **5** shows a schematic block diagram of the blow-out detection system according to one aspect of the present disclosure;

FIG. **6** shows a schematic block diagram of the broken drill bit detection system according to one aspect of the present disclosure;

FIG. **7** shows a schematic block diagram of the pressure loss detection system according to one aspect of the present disclosure; and

FIG. **8** schematically illustrates a circuit of an example hydraulic system for use with the drilling system of FIGS. **1**-**3**, separated into multiple pages.

DETAILED DESCRIPTION

Various embodiments will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the claims attached hereto. Additionally, any examples set forth in this specification are not intended to be limiting and merely set forth some of the many possible embodiments for the appended claims.

The drill attachment disclosed herein has several advantages. By attaching the drilling machine to a vehicle, the drill attachment becomes mobile so that it can be used in a variety of different worksite environments. Further, the drill attachment is powered by the power systems of the vehicle (i.e., hydraulic and electrical). This reduces the overall costs of the drill attachment. Additionally, the disclosed drill attachment includes a control system that configured to monitor a variety of different operational characteristics of the drill attachment during a drilling operation. Specifically, the control system is configured to monitor the activity of the hydraulic system in order to sense a blow-out event, a broken drill bit, or other system failure. Upon sensing an event, the control system is configured to alter the operation of the drill attachment so as to prevent further damage to the drill bit or drill attachment itself. In some embodiments, the control system uses preexisting sensors of the hydraulic system of the vehicle to monitor for particular events in the drilling operation.

A drilling system **100** is schematically shown in FIGS. **1** and **2**. The drilling system **100** includes a vehicle **102** and a drill attachment **104**. The drill attachment **104** is removably attached to and operable by the vehicle **102**. The drilling system including the vehicle **102** and the drill attachment **104** are shown in various perspective views in FIGS. **2**A-**2**C. In some embodiments, the operations of the drill attachment **104** may be controlled by remote control. This allows the operator to stand a safe distance from the worksite.

The vehicle **102** is just one type of vehicle that can be used to operate the drill attachment **104**. The vehicle **102** shown helps illustrate the inventive aspects of the drill attachment **104**. As depicted, the vehicle **102** is a four-wheeled vehicle operable by a user from a cab **103** and powered by an engine. In some embodiments, the vehicle **102** may be mounted to tracks instead of wheels. The engine can be a combustion engine, an electric motor, or a hybrid power system. Additionally, the engine of the vehicle **102** powers a pump that provides fluid flow to an onboard vehicle hydraulic system. The vehicle hydraulic system is configured to operate a variety of vehicle operations including the movement of a boom **106**. In addition, the vehicle hydraulic system is connected to the drill attachment **104**. An example of a hydraulic system for use with the drilling system **100** of the present disclosure is shown schematically in FIG. **8**.

The boom **106** of the vehicle **102** includes an arm member **108** and an attachment member **110**. The attachment member can **110** can pivot with respect the arm member **108**, and the arm member **108** can be raised and lowered so that the attachment member **110** can be maneuvered. In some embodiments, the arm member **108** is also extendable. The attachment member can include a universal quick attachment system so as to be able to quickly couple and decouple a variety of attachments (e.g., the drill attachment **104**, a bucket, a fork, etc.).

The drill attachment **104** is attached to the attachment member **110** of the boom **106** of the vehicle **102**. Such attachment allows the drill attachment **104** to be raised and lowered so that the drill attachment **104** may be rested upon a large rock block in preparation for a drilling operation (see FIG. **2**). The drill attachment **104** includes a main frame member **112**, a stabilizing member **114**, and a drill bit tower **116**.

The main frame member **112** is attached to the attachment member **110** of the boom **106**. In some embodiments, the main frame member **112** uses a universal quick attachment mechanism to attach to the attachment member **110**. In such an embodiment, the universal attachment mechanism is configured for quick coupling and decoupling of the main frame member **112** with respect to the attachment member **110**. In some embodiments, the main frame member **112** includes a pivot joint that allows the main frame member **112** to pivot at the pivot joint so as to allow for more maneuverability of the drill attachment **104**.

The stabilizing member **114** is attached to the end of the main frame member **112**, opposite of where the main frame member **112** is attached to the attachment member **110** of the boom **106**. In the depicted embodiment, the stabilizing member **114** includes a pair of feet **118** that are configured to rest on a work surface during a drilling operation. The feet **118** of the stabilizing member **114** help to level the drill attachment **104** and also help to reduce movement of the drill attachment **104** during drilling operations.

The stabilizing member **114** also includes a pair of rails **120** to which the drill bit tower **116** is movably attached (see FIG. **2**). In some embodiments, the stabilizing member **114** includes two or more rails. In other embodiments, the stabilizing member **114** includes only a single rail.

With reference to FIGS. **1** and **2**, the drill bit tower **116** includes a drill bit track **122**. Mounted to the drill bit tower **116** is a drill bit **124**, a drill bit rotational motor **126**, a percussive hammer motor **127**, and a drill bit thrust motor **128**. As shown in FIG. **2**, the drill bit tower **116** is configured to move along the rails **120** of the stabilizing member **114** in directions D**1** and D**2** so as to allow the drill attachment **104** to drill a series of bores (in a linear configuration) in the work piece. During a normal drilling operation, the drill bit **124** travels in directions V**1** and V**2** along the drill bit tower **116** as the drill bit **124** drives into and out of a work piece.

The drill bit tower **116** provides vertical support for the drill bit **124** as the drill bit **124** progresses into a work piece during a drilling operation. Specifically, the drill bit rotational motor **126**, which is mounted at a top end **130** of the drill bit **124**, is mounted to a carriage **132**. The carriage **132** is mounted within the drill bit track **122** and movable within the track **122** by the drill bit thrust motor **128**. In the depicted embodiment, the drill bit **124** is supported with a bearing assembly **134** at a lower end **136** of the drill bit track **122**. The bearing assembly **134** is configured to rest on or near the work piece so as to provide support to the drill bit **124** proximate to a drilling hole site.

The drill bit **124** can be of a variety of different sizes and made from a variety of different materials.

The drill bit rotational motor **126** is attached to the drill bit **124** so as to rotate the drill bit **124** during a drilling operation. In some embodiments, the drill bit rotational motor **126** is a hydraulic motor and operable by the hydraulic system of the vehicle **102**. The drill bit rotational motor **126** can also include a pressure sensor so as to be able to monitor the operational hydraulic fluid pressure within the motor.

The percussive hammer motor **127** is also in communication with the drill bit **124**. The percussive hammer motor **127** is configured to deliver a series of pulses to the drill bit **124** during a drilling operation so as to assist the drill bit **124** in drilling through rock. In the depicted embodiment, the percussive hammer motor **127** is powered by compressed air and connected to a compressor **131** that is mounted to the vehicle **102**. In other embodiments, the percussive hammer motor **127** is power by a fluid, such as hydraulic fluid.

The drill bit thrust motor **128** is configured to provide a thrust force to the drill bit **124**. The drill bit thrust motor **128** is a hydraulic motor that is powered by the hydraulic system of the vehicle **102**. The drill bit thrust motor **128** is connected to the carriage **132** that rides within the track **122**. In the depicted embodiment, the drill bit thrust motor **128** controls a chain drive that runs within the track **122**. When the drill bit thrust motor is activated, it exerts a force on the carriage **132**, which then exerts a force on the drill bit **124**.

In some embodiments, a dust collection system **129** also may be included as part of the drill attachment **104**. The dust collection system **129** is configured to remove dust from near the drilling hole worksite. The dust collection system **129** is operated by the onboard compressor **131**, which creates a vacuum near the worksite hole to remove dust and small particulates from the worksite area. The dust and particulates are then routed through a conduit (not shown) to a collection area **133**. In the depicted embodiment, the dust collection system **129** is positioned at an opposite end of the vehicle **102** than the drill attachment **104**.

The drilling system **100** is shown schematically in FIG. **3** in a position in preparation for a drilling operation. A drilling operation is generally carried out in the following manner. In some embodiments, the drill operation can be completely automated. First, once the drill attachment **104** is attached to the vehicle **102**, the vehicle **102** is positioned near a work piece **135** (e.g., a large stone block). The boom **106** of the vehicle **102** is then operated so as to lift the drill attachment **104** above the work piece **135**. The boom **106** is maneuvered into position and then lowered so that the feet **118** of stabilizing member **114** of the drill attachment **104** rest on the work piece **135**. The drill bit rotational motor **126**, the drill bit thrust motor **128**, and the dust collection system **129** are then powered up. The drill bit thrust motor **128** is then operated so to move the drill bit **124** into contact with the work piece **135** in the direction **V1**. Once in contact with the work piece **135**, the drill bit thrust motor **128** moves the rotating drill bit **124** in the direction **V1** down the drill bit tower **116** and through work piece **135** causing the drill bit **124** to bore a hole **137** through work piece **135**. When a desired depth is reached by the drill bit **124** within the work piece **135**, the drill bit thrust motor **128** reverses the drill bit **124** and retracts the drill bit **124** from the newly drilled hole **137** in the direction **V2**. In some embodiments, the drill bit rotational motor **126** is also reversed so as to rotate the drill bit **124** in a an opposite direction from the drilling direction. Once removed from the hole **137**, the drill bit tower **116** moves along the rails **120** of the stabilizing member (e.g., in the direction **D1** as shown in FIG. **2**) so as to prepare for a new drilling operation. Once a desired distance is reached from the first drilled hole **137**, the drill operation is repeated in its entirety. This process is repeated until a desired amount of holes are bored in the work piece **135**. The drill attachment **104** and vehicle **102** can then be removed from the work piece **135**, and the work piece **135** can be split.

In operating the drill attachment **104** during the drilling operation, the drill attachment **104** includes a control system **138** that monitors a variety of different parameters and controls the function of the components of the drill attachment **104**.

FIG. **4** shows a schematic representation of the control system **138** of the drill attachment **104**. The control system **138** is in overall communication with the vehicle **102**. This is so that the control system **138** can monitor the operational parameters of the vehicle **102**, specifically the hydraulic system. While the control system **138** controls operational aspects of the drilling attachment **104**, it also includes a detection system that helps to reduce failure and damage to the drill attachment **104** during certain events that can occur during the drilling operation.

The control system **138** monitors the drill attachment **104** for a broken drill bit event **140**, a drill bit blow-out event **142**, and a pressure loss event **144**. Upon recognizing the presence of any one of these events, the control system **138** stops the drill bit rotational motor **126**, the percussive hammer motor **127**, and the drill bit thrust motor **128**. After the percussion, thrust, and rotation are stopped, the control system **138** returns the drill bit **124** of the drill attachment **104** to a home/neutral position. The home position can be predefined by the user to be a position outside of the hole the drill bit **124** is currently boring, or it could be a position of the drill bit **124** prior the event being sensed by the control system **138** (i.e., a safe position).

FIG. **5** shows schematic representation of the operation of the control system **138** when monitoring for a blow-out event **142**. Due to the deflection imparted on the drill bit **124** when the drill bit **124** encounters a blow-out event **142**, the operating pressure in the vehicle's hydraulic system incurs a spike. This spike is caused by an increased load in the drill bit rotational motor **126** or the drill bit thrust motor **128** as both motors attempt to continue to bore a hole while the drill bit **124** is experiencing a deflection caused by the blow-out event **142**.

Therefore, in order to monitor for a blow-out event **142**, the control system **138** monitors the operating pressure in the hydraulic system **144**. The control system **138** then compares the operating pressure of the hydraulic system to a predetermined pressure value at step **146**. The predetermined pressure value is set by the user and this value can depend on the type of drill bit **124** being used, the type of rock the drill bit **124** is being operated in, current weather conditions, other loads on the hydraulic system, and a variety of other factors. In some embodiments, the predetermined value is a change in operational pressure. This allows the system to take into consideration a momentary pressure spike that may be caused by a blow-out event. If the operating pressure exceeds the predetermined value at step **148**, the control system **138** will promptly stop percussion, thrust, and rotation at step **150** and return the drill bit to the home position at step **152**.

In some embodiments, after the operating pressure exceeds the predetermined value, the control system **138** can also sound an alarm at step **154**. If the operating pressure does not exceed the predetermined value at step **156**, the control system **138** continues the drilling operation at step **158**.

FIG. **6** shows schematic representation of the operation of the control system **138** in monitoring for a broken drill bit event **140**. When a drill bit **124** breaks during a drilling operation, operational pressure drops and progression of the drill bit **124** within the work piece slows considerably.

Therefore, in order to monitor for a broken drill bit event **140**, the control system **138** monitors the rate of progression of the drill bit at step **160** along with the operating pressure in the hydraulic system at step **162**. To monitor the rate of progression, the control system **138** can include a sensor on the drill bit tower **116** and/or the drill bit thrust motor **128**. In some embodiments, the control system **138** can monitor the progression of the carriage **132** within the track **122** of the drill bit tower **116**.

The control system **138** then compares the rate of progression of the drill bit **124** with a predetermined rate value, and also compares the operating pressure of the hydraulic system to a predetermined pressure value at step **164**. As noted above, the predetermined values are normally set by the user and can depend on a variety of different factors. If both the operating pressure and rate of progression drop below their corresponding predetermined values at step **166**, the control system **138** will promptly stop percussion, thrust, and rotation at step **168** and return the drill bit to the home position at step **170**.

In some embodiments, the control system **138** can also sound an alarm at step **172**. If both the operating pressure and rate of progression do not drop below their corresponding predetermined values at step **174**, the control system **138** continues the drilling operation at step **176**.

FIG. **7** shows schematic representation of the operation of the control system **138** when monitoring for a pressure loss event **144**. If a loss of air pressure occurs in the system, the percussive hammer motor **127** is likely to malfunction. A loss of air pressure can occur if there is a malfunction with the compressor **131** that powers the percussive hammer motor **127**, if there is a broken/unattached hose in the system, or any other malfunction in the compressed air system. This can lead the drill bit **124** to operate without percussive force, which can decrease its drilling effectiveness when drilling in rock. Additionally, without percussion, the drill bit **124** may wear more rapidly.

Therefore, in order to monitor for a pressure loss event **144**, the control system **138** monitors the operating air pressure in the percussive hammer motor at step **178**. The control system **138** then compares the operating air pressure in the percussive hammer motor to a predetermined pressure value at step **180**. The predetermined pressure value is set by the user and its value can depend on a variety of factors, such as the recommended operating parameters of the components within the percussive hammer motor **127**. If the operating air pressure drops below the predetermined value at step **182**, the control system **138** will promptly stop percussion, thrust, and rotation at step **184** and return the drill bit to the home position at step **186**.

In some embodiments, after the operating air pressure drops below the predetermined value at step **182**, the control system **138** can also sound an alarm at step **188**. If the operating air pressure does not drop below the predetermine value at step **190**, the control system **138** continues the drilling operation at step **192**.

FIG. **8** schematically illustrates an example hydraulic circuit broken into separate pages for use with the drilling system **100**. In some examples, the hydraulic system **100** utilizes a plurality of different valve assemblies for different operations of the hydraulic system **100**. In some examples, the lateral and vertical movement can be controlled at least partially by separate valve assemblies. In other examples, the lateral and vertical movement can be controlled at least partially by the same valve assembly. In some examples, the drill rotation and drill percussion are controlled in the same valve assembly.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the claims attached hereto. Those skilled in the art will readily recognize various modifications and changes that may be made without following the example embodiments and applications illustrated and described herein, and without departing from the true spirit and scope of the following claims.

What is claims is:

1. A drilling attachment configured to attach to a vehicle, the drilling attachment comprising:

a drill bit;

a first motor for rotating the drill bit;

a second motor for controlling the thrust applied to the drill bit, wherein the first and second motors include hydraulic connections for attaching to an external hydraulic system; and

a drill bit blow-out sensing system being operatively connected to the first and second motors, wherein the drill bit blow-out sensing system senses a drill bit blow-out event based on a change in an operational hydraulic pressure within at least one of the first and second motors, wherein the drill bit blow-out event occurs when the drill bit exits a bore hole formed by the drill bit, and

wherein the drill bit blow-out sensing system senses the drill bit blow-out event by comparing the change in the operational hydraulic pressure within at least one of the first and second motors to a predetermined value, and, if the change in the operational hydraulic pressure within at least one of the first and second motors exceeds the predetermined value, the drill bit blow-out sensing system stops the operation of the drill bit.

2. The drilling attachment of claim **1**, further comprising a dust collection system for removing dust near the drill bit, the dust collection system including a compressor.

3. The drilling attachment of claim **1**, wherein the drill bit blow-out sensing system also senses a broken drill bit event by monitoring a hydraulic pressure loss within at least one of the first and second motors.

4. The drilling attachment of claim **1**, wherein the drill bit blow-out sensing system is configured to sound an audible alarm when a blow-out event is sensed.

5. A drill bit monitoring system for a percussive drill comprising:

a vehicle including:

an engine;

a hydraulic system having a pump at least partly powered by the engine; and

a boom operated by the hydraulic system;

a drilling attachment removably attached to the boom of the vehicle, the drilling attachment including:

a drill bit;

a first motor for rotating the drill bit;

a second motor for controlling the thrust applied to the drill bit, wherein the first and second motors are connected to the hydraulic system of the vehicle; and

a drill bit blow-out sensing system being operatively connected to the first and second motors, wherein the drill bit blow-out sensing system senses a drill bit blow-out event based on a change in an operational hydraulic pressure within at least one of the first and second motors, wherein the drill bit blow-out event occurs when the drill bit exits a bore hole formed by the drill bit, and wherein the drill bit blow-out sensing system senses the drill bit blow-out event by comparing the change in the operational hydraulic pressure within at least one of the first and second motors to a predetermined value, and, if the change in the operational hydraulic pressure within at least one of the first and second motors exceeds the predetermined value, the drill bit blow-out sensing system stops the operation of the drill bit.

6. The drill bit monitoring system of claim **5**, further comprising a dust collection system for removing dust near the drill bit, the dust collection system including a compressor.

7. The drill bit monitoring system of claim **5**, wherein the drill bit blow-out sensing system is an integral part of the hydraulic system of the vehicle.

8. The drill bit monitoring system of **5**, wherein the drill bit blow-out sensing system also senses a broken drill bit event by monitoring an operational hydraulic pressure loss within at least one of the first and second motors.

9. The drill bit monitoring system of **5**, wherein the drill bit blow-out sensing system is configured to sound an audible alarm when a blow-out event is sensed.

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