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**Skinner et al.**

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(54) **POWER TOOL**

(56) **References Cited**

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U.S. PATENT DOCUMENTS

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5,113,679	A	5/1992	Ferraro et al.
5,727,417	A	3/1998	Moffatt et al.
6,378,194	B1	4/2002	Nghiem
6,457,338	B1	10/2002	Frenken
6,501,719	B1	12/2002	Hada et al.
6,662,621	B1	12/2003	Amherd
8,056,473	B2	11/2011	Frenken
9,180,583	B2	11/2015	Frenken
2001/0032490	A1	10/2001	Goop
2003/0066324	A1	4/2003	Goop

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FOREIGN PATENT DOCUMENTS

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OTHER PUBLICATIONS

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Form PCT/ISA/220, Notification of Transmittal of the International  
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ing Authority, or the Declaration, dated Jan. 3, 2018.

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<b>B25B 27/02</b>	(2006.01)
<b>B25B 28/00</b>	(2006.01)
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(57) **ABSTRACT**

A power tool including a moveable piston, a motor capable  
of driving the moveable piston to perform work on a work  
piece, and a distance sensor configured to sense a movement  
of the moveable piston. The distance sensor operable to  
provide sensor information indicative of the movement of  
the piston. A controller receives the sensor information from  
the distance sensor. The controller operates the motor to  
perform work on the work piece based in part on the sensor  
information that the controller receives from the distance  
sensor.

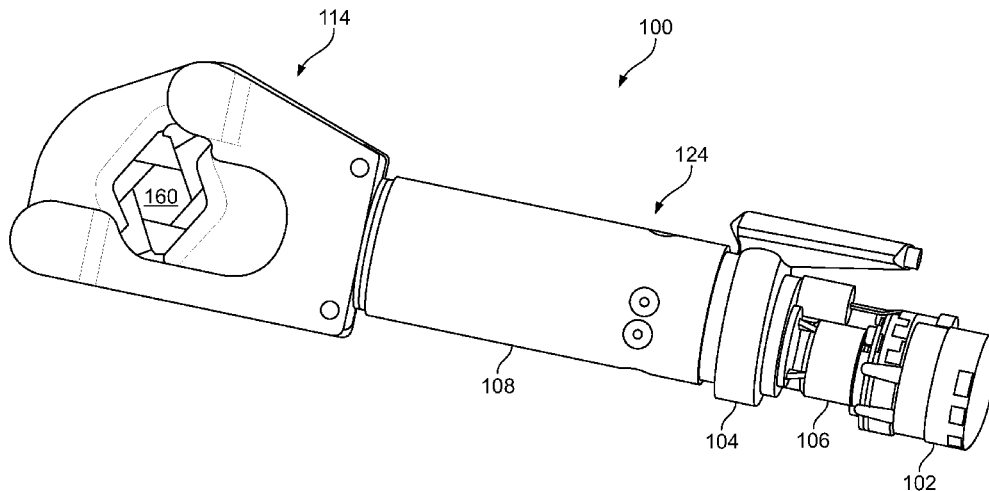
(52) **U.S. Cl.**

CPC ..... **B21D 39/048** (2013.01); **B25B 27/026**  
(2013.01); **B25B 28/00** (2013.01); **B26B 27/00**  
(2013.01)

**22 Claims, 13 Drawing Sheets**

(58) **Field of Classification Search**

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See application file for complete search history.



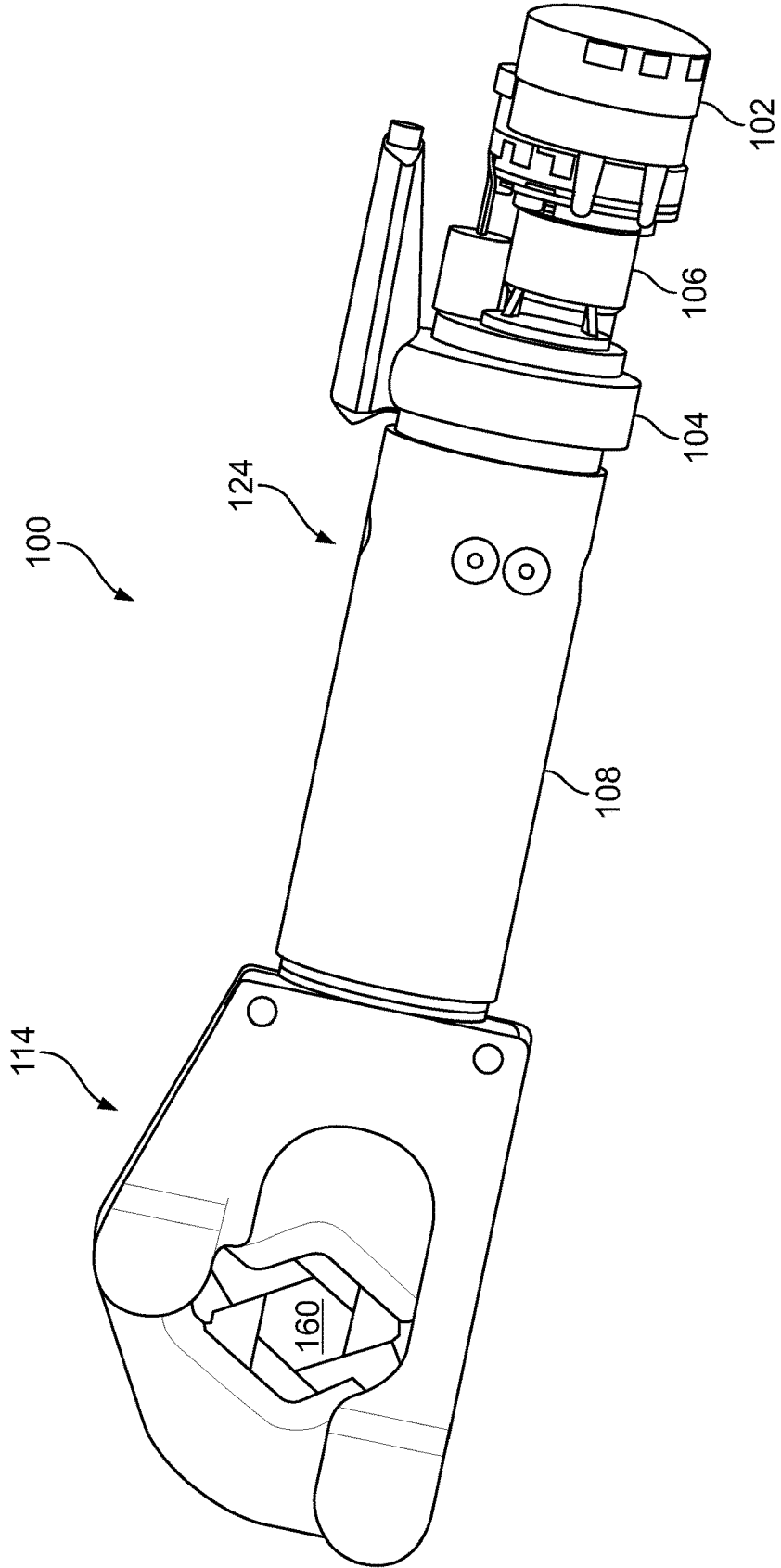


FIG. 1

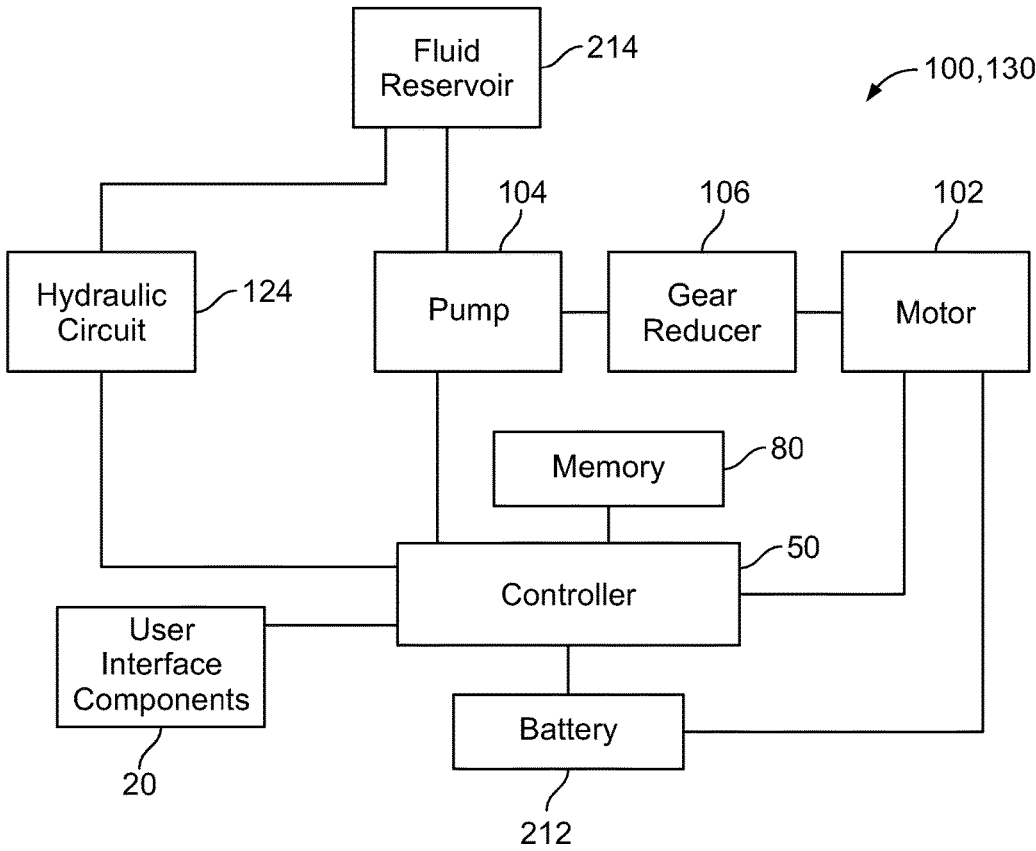


FIG. 2

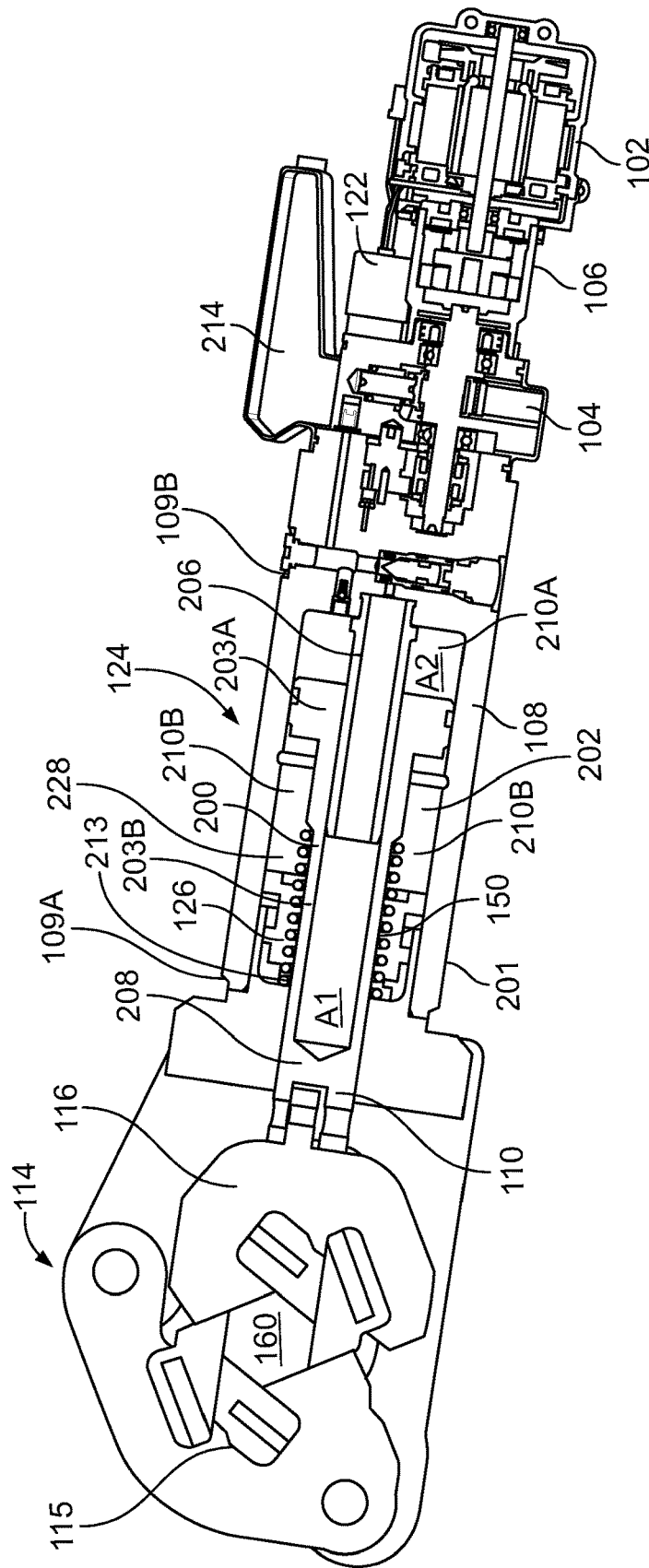


FIG. 3

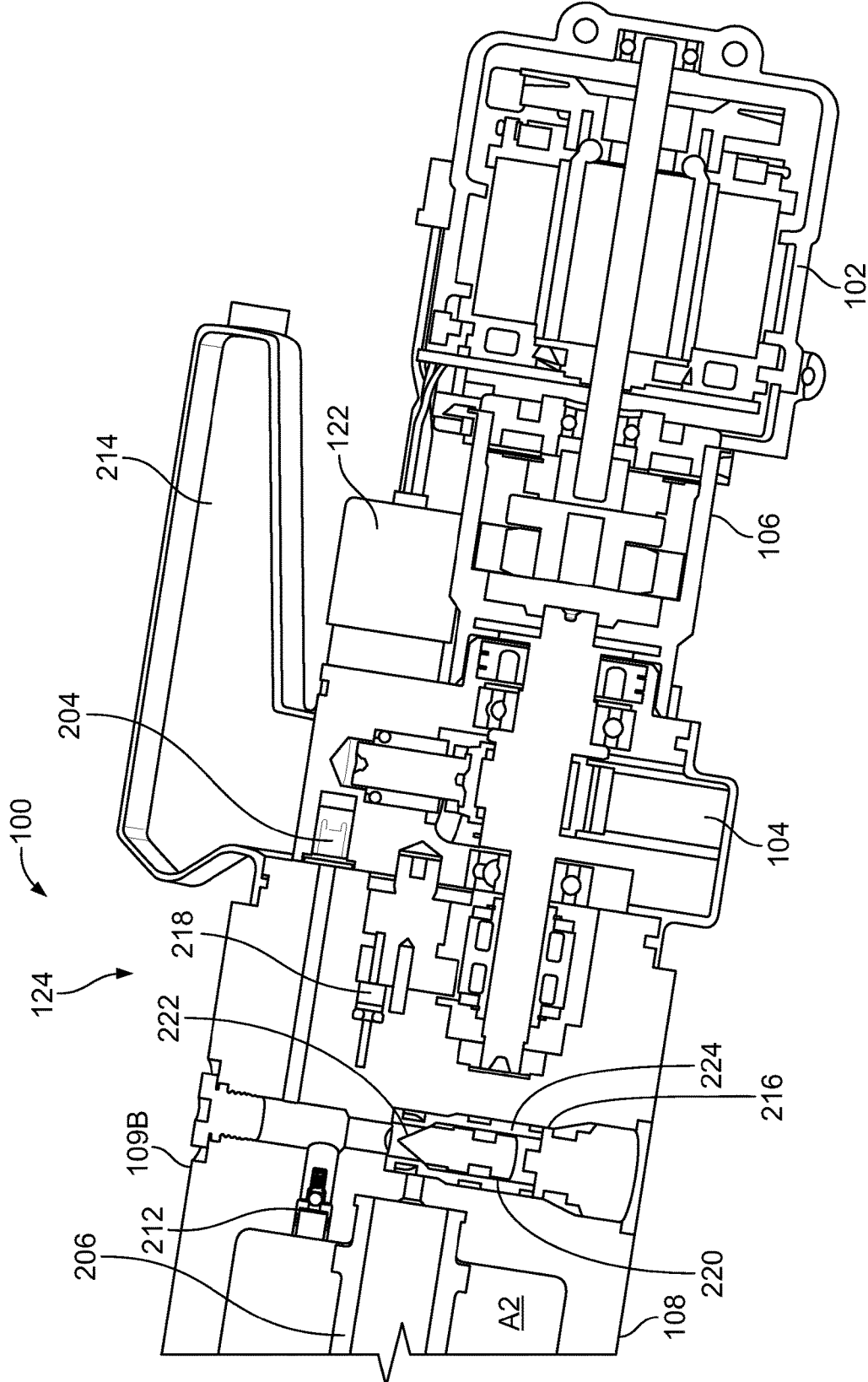


FIG. 4

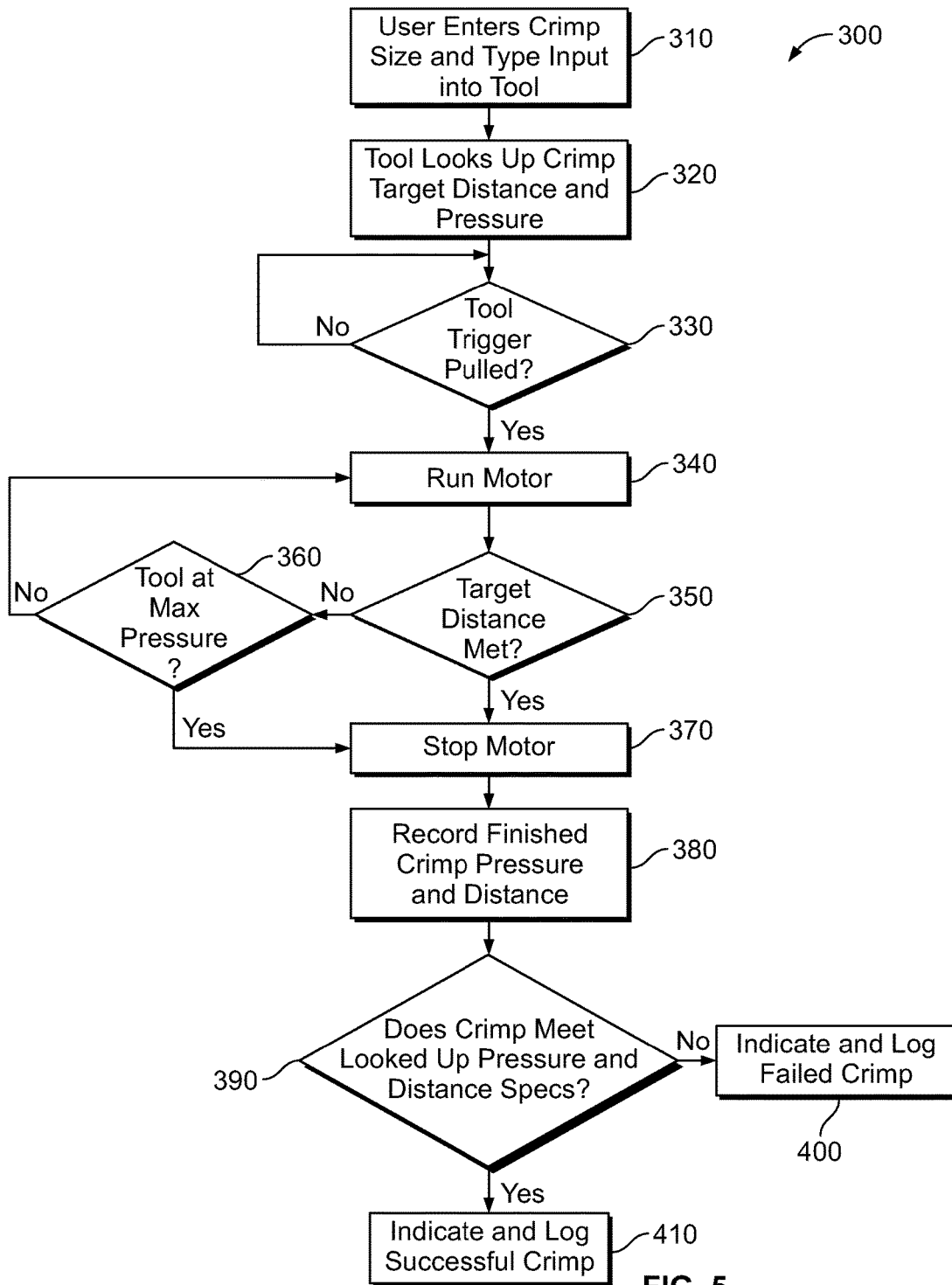


FIG. 5

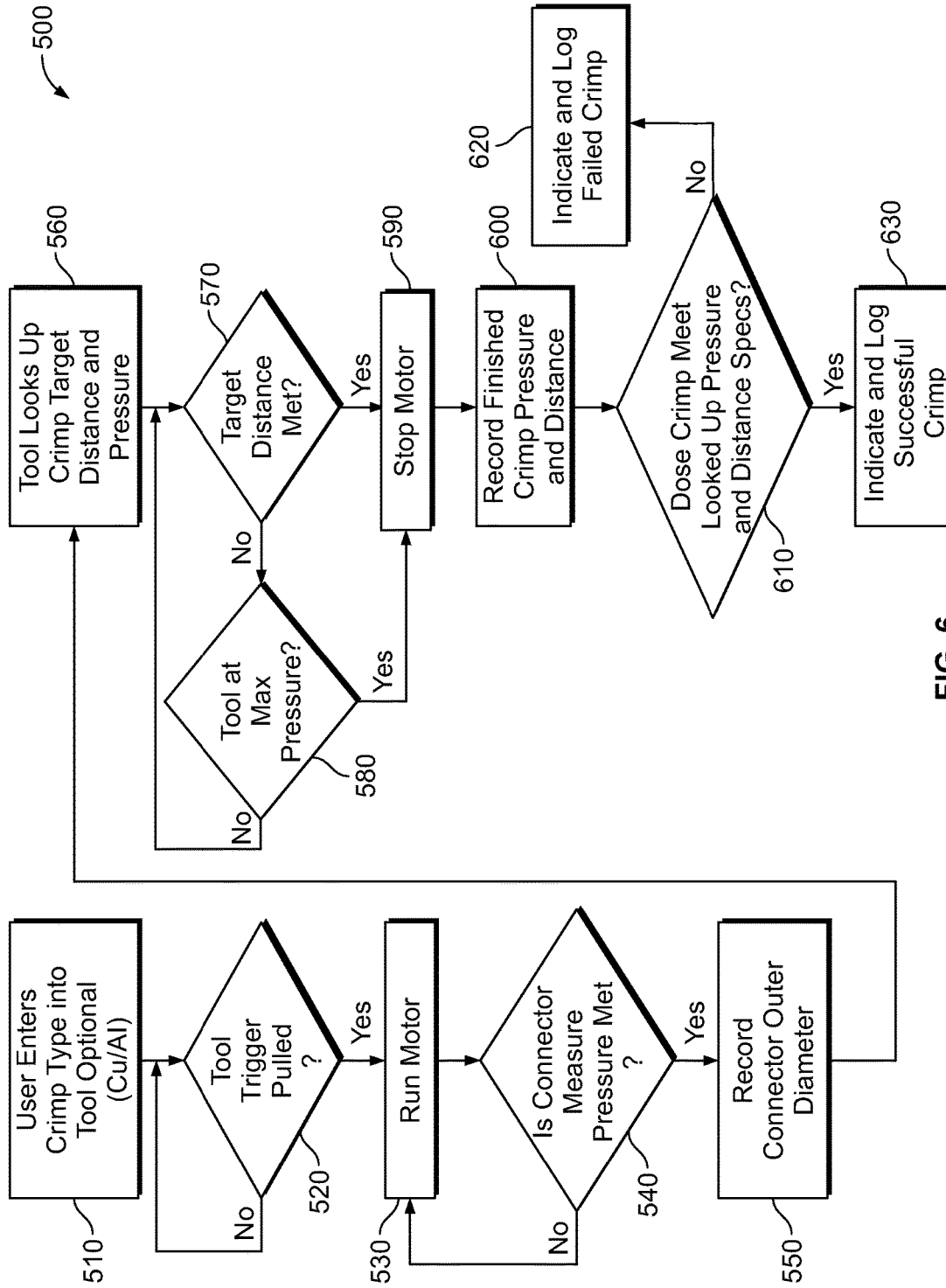


FIG. 6

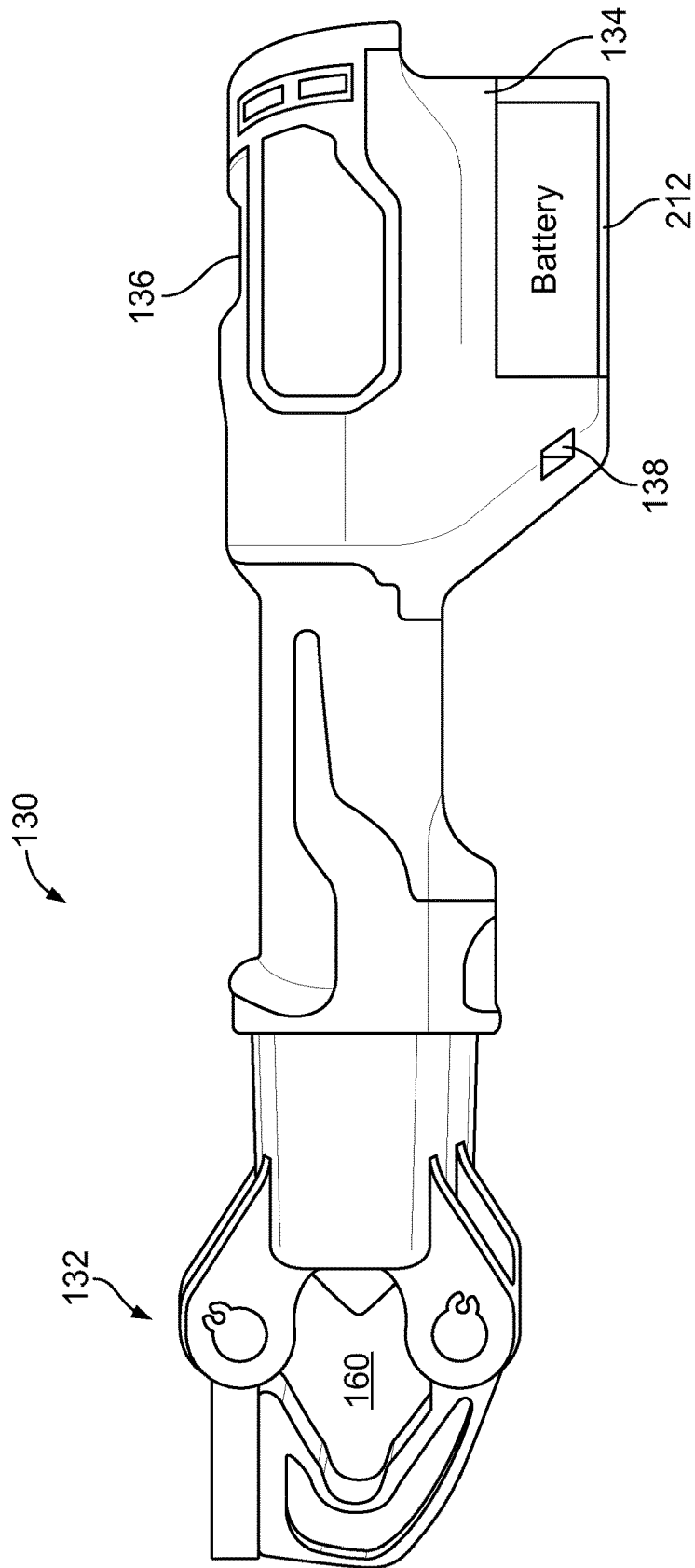


FIG. 7



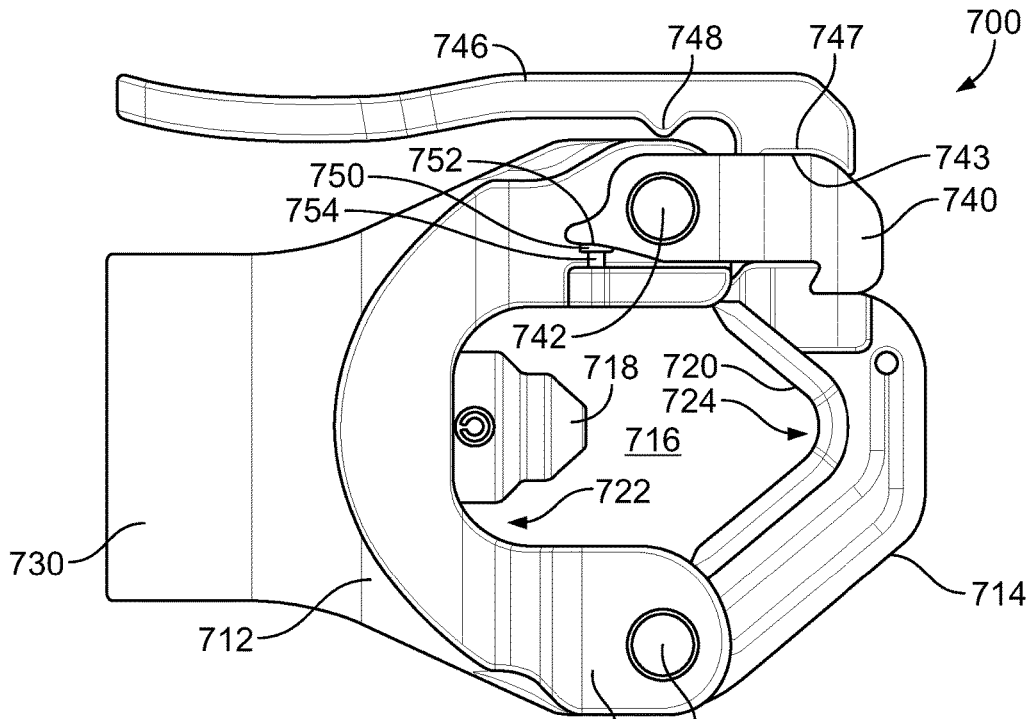


FIG. 8

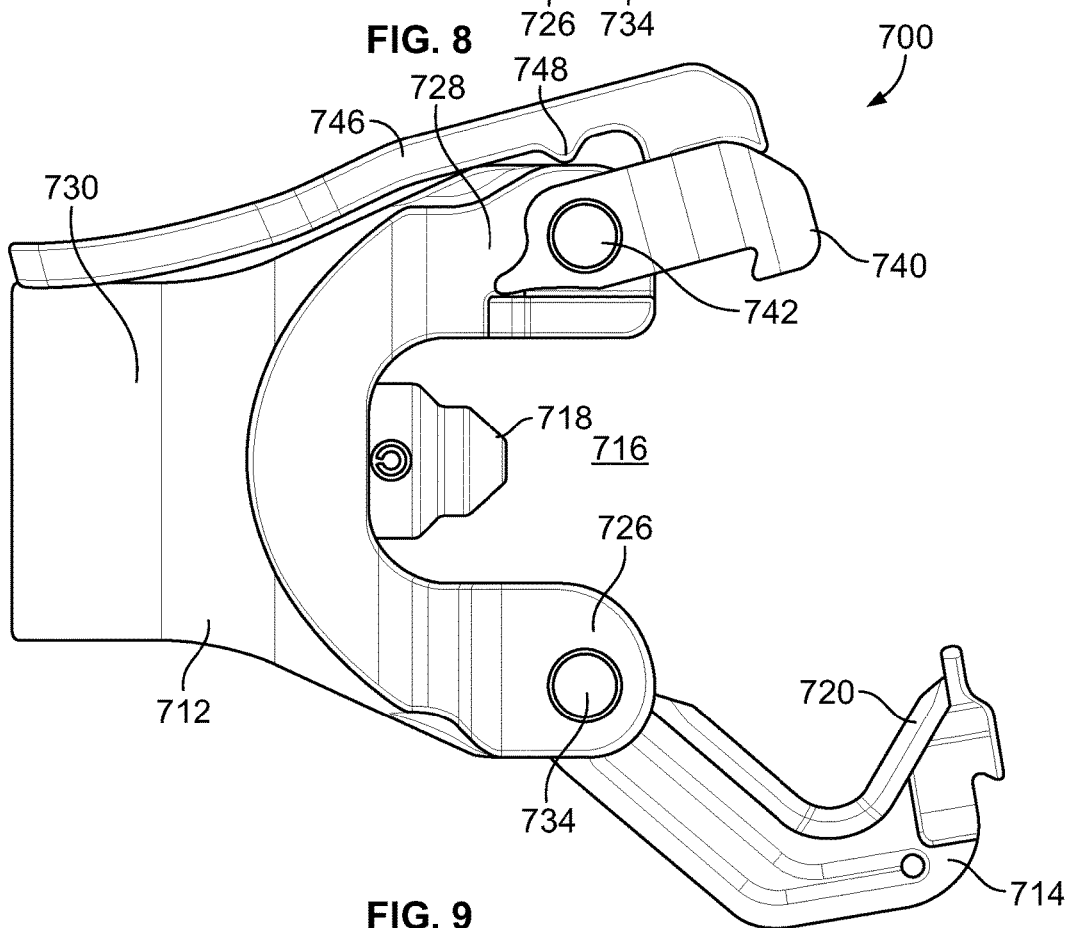


FIG. 9



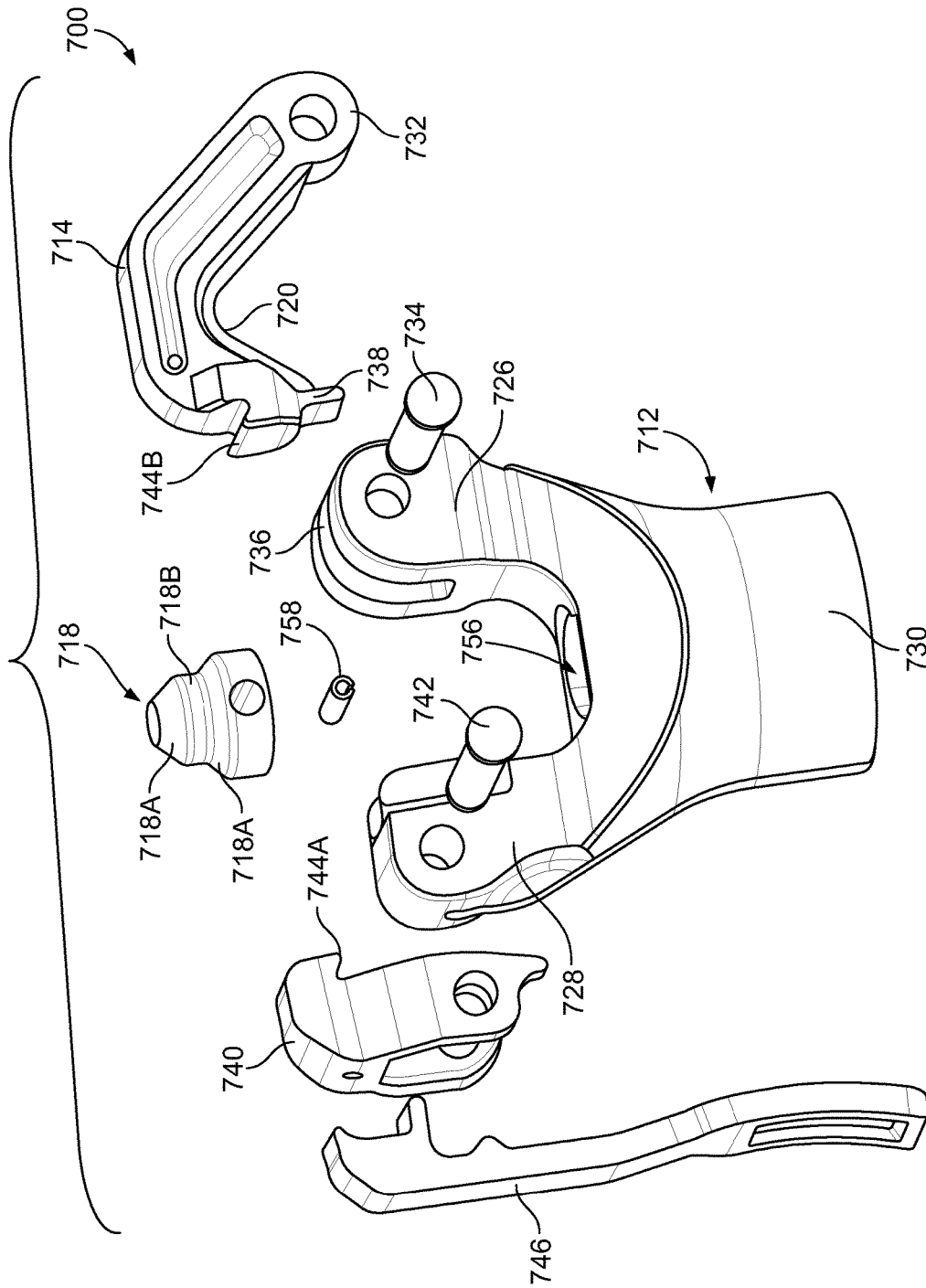


FIG. 10

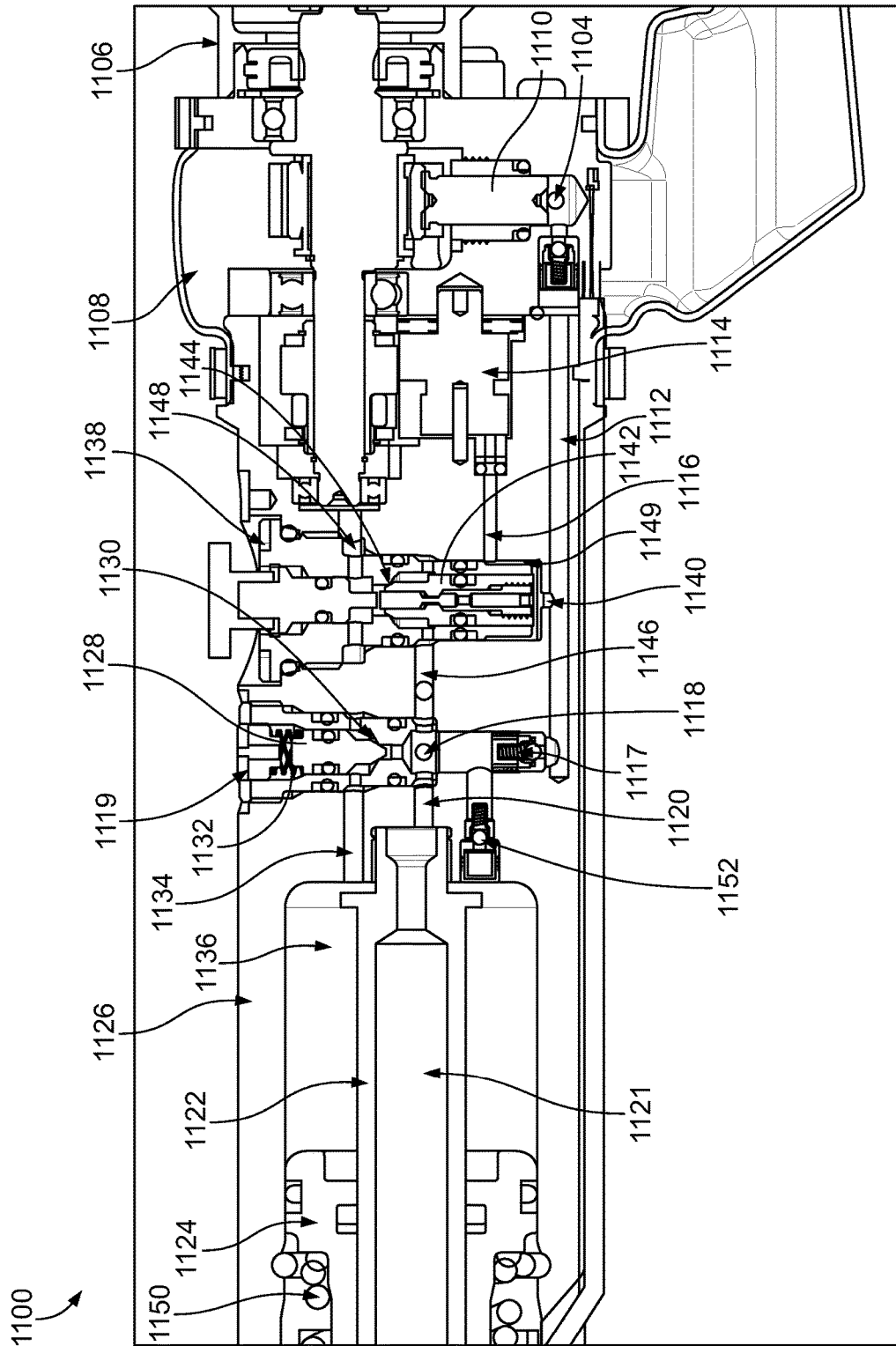


FIG. 11A

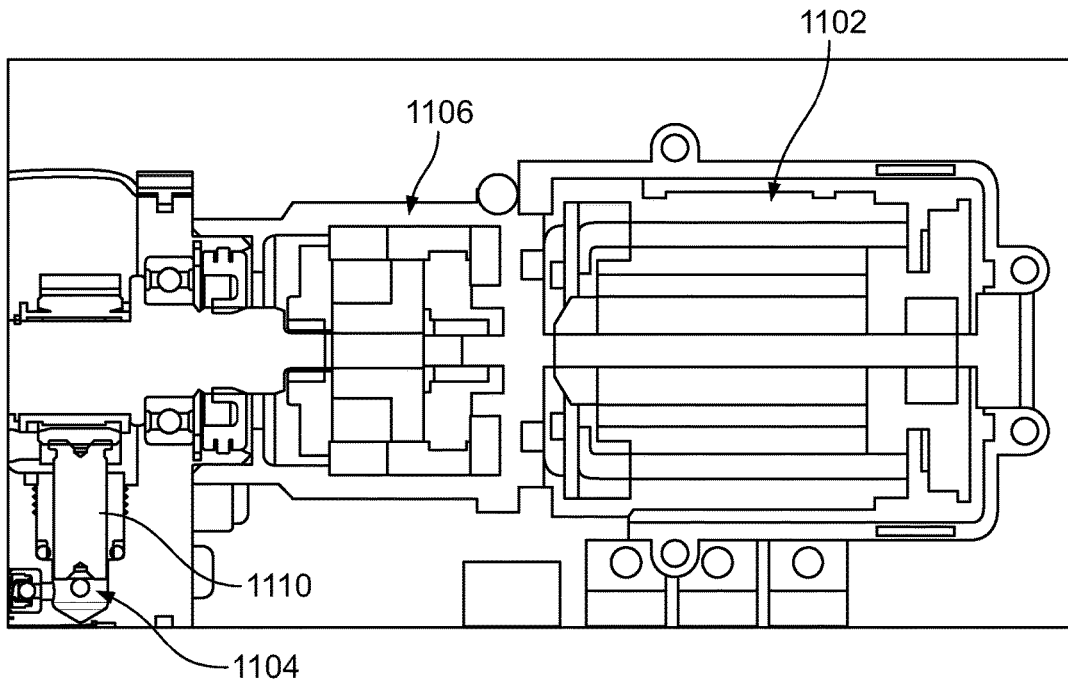


FIG. 11B

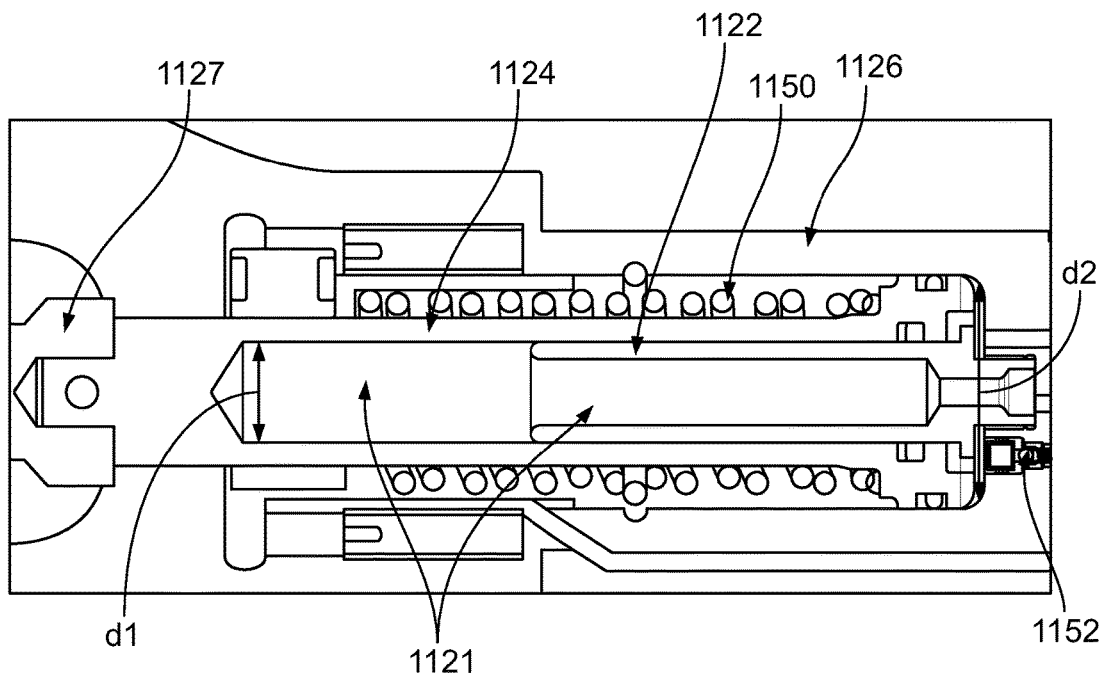


FIG. 11C

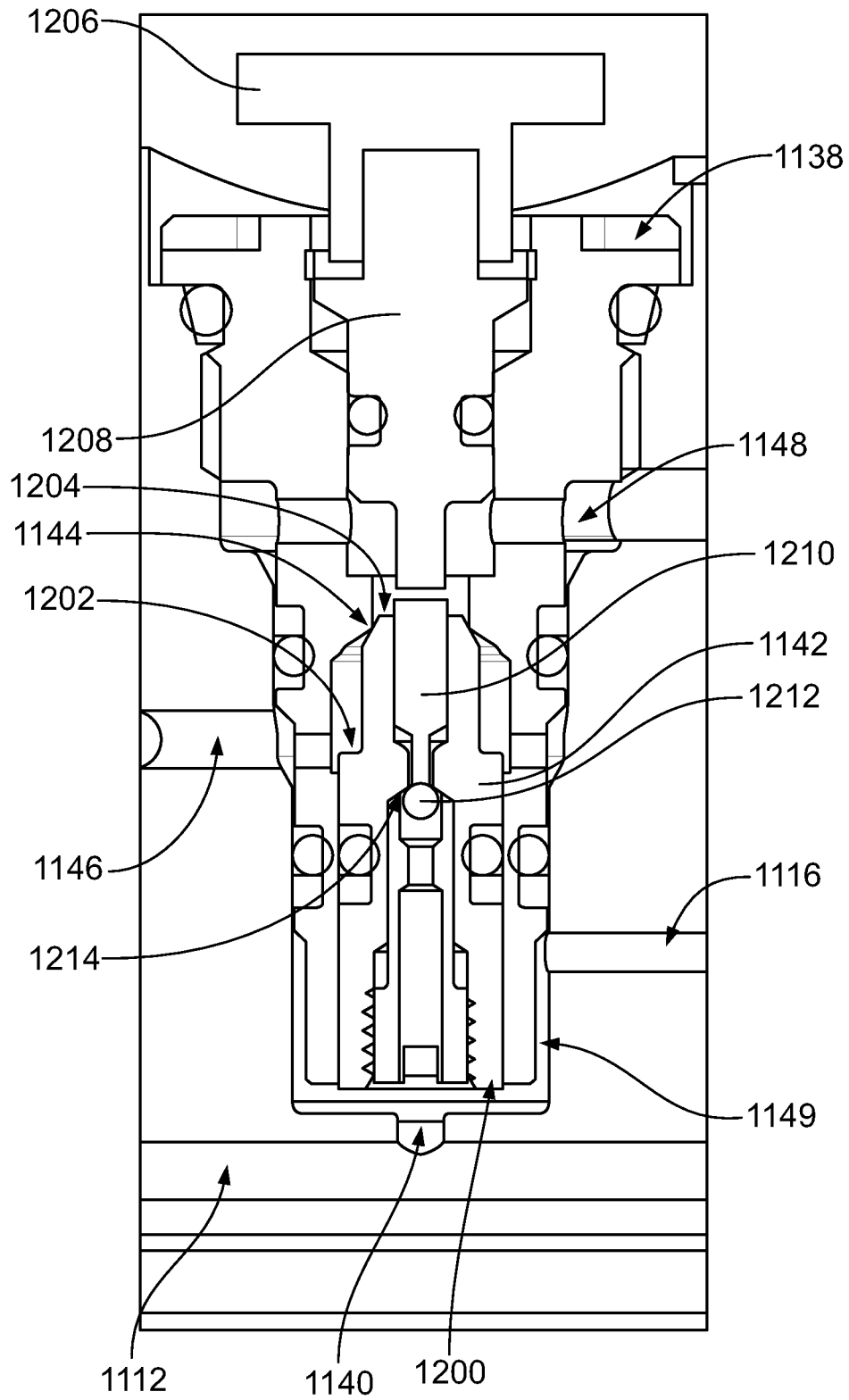


FIG. 12

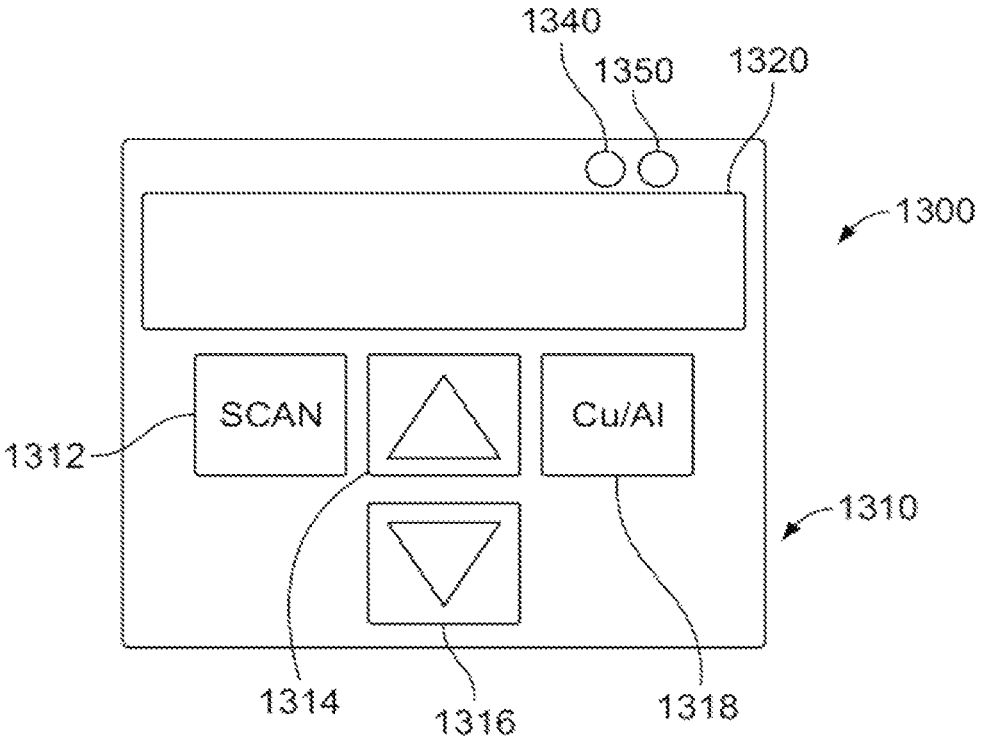


FIG. 13

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## POWER TOOL

### FIELD

The present disclosure relates generally to power tools. More particularly, the present disclosure relates to a die-less power crimping tool that utilizes a linear sensor to track and identify ram assembly movement. This crimping power tool enables a user to apply a proper crimp pressure and enables accurate linear movement of a piston during a crimping process.

### BACKGROUND

Hydraulic crimpers and cutters are different types of hydraulic power tools for performing work (e.g., crimping or cutting) on a work piece by way of a work head, such as a crimping head or a cutting head. In such tools, a hydraulic tool comprising a hydraulic pump is utilized for pressurizing hydraulic fluid and transferring it to a cylinder in the tool. This cylinder causes an extendable piston or ram assembly to be displaced towards the work head. Where the power tool comprises a hydraulic crimper, the piston exerts a force on the crimping head of the power tool, which may typically include opposed crimp dies with certain crimping features. The force exerted by the piston may be used for closing the crimp dies to perform crimp or compression on a work piece at a desired crimp location.

Crimping can result in a crimp taking place at an undesired crimp location and also taking place with an improper amount of pressure being exerted during the crimp process. As such, there is a general need for a hydraulic crimp tool that enables a more efficient and more robust resultant crimp.

### SUMMARY

According to an exemplary arrangement, a power tool comprises a moveable piston, a motor capable of driving the moveable piston to perform work on a work piece, and a distance sensor configured to sense a movement of the moveable piston. The distance sensor is operable to provide sensor information indicative of the movement of the piston. A controller is configured to receive the sensor information. The controller operates the motor to perform work on the work piece based in part on the sensor information that the controller receives from the distance sensor. In one arrangement, the distance sensor is configured to continuously sense the movement of the moveable piston.

According to an exemplary arrangement, the distance sensor detects a linear displacement of the moveable piston. The distance sensor may detect the linear displacement of the moveable piston when the power tool performs work on the work piece. For example, the distance sensor may detect the linear displacement of the moveable piston when the power tool performs a crimping action.

According to an exemplary arrangement, the distance sensor detects a linear displacement of the moveable piston during a crimping action. In one arrangement, during the crimping action, the distance sensor generates an output signal that is communicated to the controller. The output signal may be representative of a distance that the moveable piston traveled from a reference position. In one arrangement, the reference position comprises a moveable piston home position. In one arrangement, the reference position

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comprises a retracted position of the moveable piston. Such a retracted position may be a fully or completely retracted position.

In one arrangement, the output signal is representative of a direction of motion of the moveable piston. For example, the direction of motion of the piston may comprise a direction of the moveable piston towards a working head of the power tool. In one arrangement, the direction of motion of the moveable piston comprises a direction motion away from the working head.

In one arrangement, the working head of the power tool comprises a crimping head. For example, the crimping head of the power tool may comprise a die-less crimping head. In one arrangement, the working head of the power tool comprises a cutting head.

In one arrangement, the linear sensor comprises a hall effect sensor. For example, the hall effect sensor may detect a contour provided along an outer surface of the moveable piston.

In one arrangement, the power tool further comprises a pump, and a gear reducer, wherein the electric motor is configured to drive the pump by way of the gear reducer.

In one arrangement, the distance sensor is mounted within a cylindrical bushing of the power tool. For example, the cylindrical bushing may be mounted within a frame of the power tool.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and descriptions thereof, will best be understood by reference to the following detailed description of one or more illustrative embodiments of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates a perspective view of an hydraulic tool, according to an example embodiment;

FIG. 2 illustrates a block diagram of certain components of the hydraulic tool illustrated in FIG. 1,

FIG. 3 illustrates another perspective view of the hydraulic tool illustrated in FIG. 1;

FIG. 4 illustrates another perspective view of the hydraulic tool illustrated in FIG. 1;

FIG. 5 illustrates a flowchart of an example crimping method utilizing a hydraulic tool, according to an example embodiment;

FIG. 6 illustrates a flowchart of an example crimping method utilizing a hydraulic tool, according to an example embodiment; and

FIG. 7 illustrates an alternative hydraulic tool 130 comprising a punch-style crimping head;

FIG. 8 is a plan side view of a crimping tool head in a closed state according to an example embodiment;

FIG. 9 is a plan side view of a crimping tool head in an open state according to the example embodiment of FIG. 8;

FIG. 10 is an exploded view of the crimping tool head according to the example embodiment of FIG. 8;

FIG. 11A illustrates a hydraulic circuit that may be used with a hydraulic tool;

FIG. 11B illustrates a portion of the hydraulic circuit illustrated in FIG. 11A;

FIG. 11C illustrates a portion of the hydraulic circuit illustrated in FIG. 11A;

FIG. 12 illustrates a portion of the hydraulic circuit illustrated in FIG. 11A; and

FIG. 13 illustrates an exemplary operator panel that may be used with a hydraulic tool.

#### DETAILED DESCRIPTION

The following detailed description describes various features and functions of the disclosed systems and methods with reference to the accompanying figures. The illustrative system and method embodiments described herein are not meant to be limiting. It may be readily understood that certain aspects of the disclosed systems and methods can be arranged and combined in a wide variety of different configurations, all of which are contemplated herein.

Further, unless context suggests otherwise, the features illustrated in each of the figures may be used in combination with one another. Thus, the figures should be generally viewed as component aspects of one or more overall implementations, with the understanding that not all illustrated features are necessary for each implementation.

Additionally, any enumeration of elements, blocks, or steps in this specification or the claims is for purposes of clarity. Thus, such enumeration should not be interpreted to require or imply that these elements, blocks, or steps adhere to a particular arrangement or are carried out in a particular order.

By the term “substantially” it is meant that the recited characteristic, parameter, or value need not be achieved exactly, but that deviations or variations, including for example, tolerances, measurement error, measurement accuracy limitations and other factors known to skill in the art, may occur in amounts that do not preclude the effect the characteristic was intended to provide.

FIG. 1 illustrates certain components of a hydraulic tool 100, in accordance with an example implementation. Although the example implementation described herein references an example crimping tool, it should be understood that the features of this disclosure can be implemented in other similar tools, such as cutting tools. In addition, any suitable size, shape or type of elements or materials could be used. As just one example, the illustrated hydraulic tool 100 comprises a working head that utilizes a hex or six sided crimping head 114. However, alternative styled crimping heads may also be used. As just one example, a punch-style or die less crimping head may also be used. For example, FIG. 7 illustrates an alternative hydraulic tool 130 comprising a punch-style crimping head 132.

Returning to FIG. 1, the hydraulic crimping tool 100 includes an electric motor 102 configured to drive a pump 104 by way of a gear reducer 106. The pump 104 is configured to provide pressurized hydraulic fluid to a hydraulic circuit 124 comprising a hydraulic actuator cylinder 108, which includes a piston slidably accommodated therein. The electric motor 102 is configured to drive a pump 104 by way of a gear reducer 106. The pump 104 is configured to provide pressurized hydraulic fluid to a hydraulic actuator cylinder 108, which includes a piston or ram that is slidably accommodated therein.

The hydraulic tool also comprises a controller 50. For example, FIG. 2 illustrates a block diagram of certain components of the hydraulic tools 100 and 130 illustrated in FIGS. 1 and 7. As illustrated in FIG. 2, the tool 100, 130

comprises the fluid reservoir 214 that is in fluid communication with the hydraulic circuit 124 and the pump 104. The hydraulic circuit 124 and the pump 104 provide certain operating information and operational data to the controller 50 wherein the pump 104 is operated by way of the gear reducer 106.

The controller 50 may include a processor, a memory 80, and a communication interface. The memory 80 may include instructions that, when executed by the processor, cause the controller 50 to operate the tool 100. In addition, the memory 80 may include a plurality of look up table of values. For example, at least one stored look up table may comprise work piece information or data, such as connector data. Such connector data may include, as just one example, connector type (e.g., Aluminum or Copper connectors) and may also include a preferred crimp distance for certain types of connectors and certain sizes of connectors. Such a preferred crimp distance may comprise a distance that the piston 200 and therefore the moveable crimping die 116 moves towards the crimp target area 160 in order to achieve a desired crimp for a particular connector type having a specific size.

In one arrangement, the controller communication interface enables the controller 50 to communicate with various components of the tool 100 such as the user interface components 20, the motor 102, memory 80, the battery 212, and various components of the hydraulic circuit 124 (e.g., a pressure sensor 122, and a linear distance sensor 150) (see, e.g., FIG. 3).

The battery 212 may be removably connected to a portion of the hydraulic tool, such as a bottom portion 134 of the hydraulic tool. By way of example, as illustrated in FIG. 7, the battery 212 may be removably connected to a bottom portion 134 of the hydraulic tool 130, away from the working head 132. However, the battery 212 could be removably mounted to any suitable position, portion, or location on the frame of the hydraulic tool 130.

As illustrated in FIG. 2, the hydraulic tool 100 may further comprise user interface components 20 that provide input to the power tool, such as the controller 50 of the power tool. As will be described, such user interface components 20 may be used to operate the hydraulic tool 100. For example, such user interface components 20 may comprise an operator panel, one or more switches, one or more push buttons, one or more interactive indicating lights, soft touch screens or panels, and other types of similar switches such as a trigger switch. As just one example, and as illustrated in FIG. 7, the user interface 136 may reside along a top surface of the hydraulic tool 136. The hydraulic tool may also comprise a trigger switch 138 mounted along the bottom portion of hydraulic tool, near the battery 212.

FIG. 13 illustrates an exemplary operator panel 1300 that may be used with a hydraulic tool, such as the hydraulic tool illustrated in FIG. 7. In this operator panel arrangement 1300, the operator panel comprises a plurality of soft-touch operator buttons 1310 residing below a display 1320, such as a liquid crystal display (LCD). In this illustrated arrangement, four buttons are provided: a first button 1312 comprising a scan button, a second button 1314 comprising an increase button 1314, and a third button comprising a decrease button 1316.

A fourth button 1318 comprising a select connector type button may also be provided. For example, prior to a crimp, a user can use the fourth button 1318 to either select a Cu connector, an Al connector or other connector type. The operator panel 1300 further comprises a first LED 1340 and a second LED 1350. The first LED may be some other color



than the second LED. For example, the first LED **1340** may comprise a green LED and the second LED may comprise a red LED. Alternative LED configurations may also be used.

FIG. 3 illustrates another perspective view of the hydraulic tool illustrated in FIG. 1 and FIG. 4 illustrates another perspective view of the hydraulic tool illustrated in FIG. 1. And now referring to FIGS. 3 and 4, positioned near the piston **200** is a linear distance sensor **150**. In this illustrated arrangement, the linear distance sensor **150** is mounted within a cylindrical bushing **126** that surrounds the piston rod **203A** of the piston **200**. This linear distance sensor **150** will operate to detect a linear displacement of the piston **200** during a crimping action. Specifically, based on the movement of the piston **200** during a crimping action, the linear distance sensor **150** will generate an output signal that is communicated to the controller **50**. This output signal is representative of a distance that the piston **200** has traveled from a particular reference point position of the ram or piston **200**. In one preferred arrangement, this particular reference point will be the position of the piston **200** when the piston **200** has been completely retracted to a most proximal position (e.g., a home position), as illustrated in FIGS. 1 and 3.

The linear distance sensor **150** also provides information as to the direction of motion of the piston **200**. That is, the linear distance sensor **150** can make a determination if the piston **200** is moving or extending towards a crimp target or if the piston **200** is moving away from or retracting away from the crimp target. This direction motion information may also be communicated to the controller **50**. The controller **50** may operate the tool based in part on this information, such as controlling the position of the piston during a crimp sequence. For example, the controller **50** may utilize this information to retract of the moveable ram to a predetermined position such that the controller controls the return position of the ram so subsequent crimps can be made without a full ram retraction, back to a home position. In addition, the controller **50** may utilize this information to drive or move the moveable ram to a predetermined position, for example, to hold a connector in place at a given position before a crimp sequence.

Exemplary linear distance sensors include, but are not limited to, linear variable differential transformer sensors, photoelectric distance sensors, optical distances sensors, and hall effect sensors. For example, such a hall effect sensor may comprise a transducer that varies its output voltage in response to a magnetic field created by an outer contour of an outer surface **213** of the moveable piston **200**. As just one example, grooves, slots and/or protrusions **215** may be machined, etched, engraved, or otherwise provided (e.g., by way of a label) along the outer surface **213** of the piston **200**.

In this illustrated hydraulic tool example, a frame and a bore of the tool **100** form the hydraulic actuator cylinder **108**. The cylinder **108** has a first end **109A** and a second end **109B**. The piston is coupled to a mechanism **110** that is configured to move the moveable crimp head **116** of a crimp head **114**. The first end **109A** of the cylinder **108** is proximate to the crimp head **116**, whereas the second end **109B** is opposite the first end **109A**.

When the piston is retracted, the moveable head **116** may be pulled back to a fully retracted or a home position as shown in FIGS. 1 and 3. Alternatively, the moveable head **116** may be pulled back to a partially retracted position.

When pressurized fluid is provided to the cylinder **108** by way of the pump **104**, the fluid pushes the piston **200** inside the cylinder **108**, and therefore the piston **200** extends

towards the crimp target placed within a work area **160**. As the piston **200** extends through the cylindrical bushing **126**, the linear sensor **150** senses the movement of piston **200** and provides this information to the controller **50**.

In one preferred arrangement, the linear sensor **150** continuously senses the movement of the piston **200**. As just one example, the linear sensor **150** may continuously sense the movement of the piston **200** during one or more of the entire crimp process as the ram assembly moves towards the crimping head, performs the crimp, and then retracts. However, as those of ordinary skill in the art will recognize, alternative sensing arrangements may also be utilized. As just one example, in certain arrangements, the controller may utilize the linear sensor **150** to sense the movement of the piston **200** only during a specified period of time (e.g., only during when the piston rod **200** is driven towards the work piece or only during a crimping action). In yet an alternative arrangement, the linear sensor **150** may be utilized to only periodically sense the movement to the piston **200**.

As the piston **200** extends, the link mechanism **110** causes the moveable crimp head **116** to move towards the stationary head **115**, and may therefore cause the working heads **115**, **116** to act upon or crimp a connector that has been placed in the crimp work area **160**. When the crimping operation is performed, the controller **50** can provide instructions to the hydraulic circuit **124** to stop the motor **102** and thereby release the high pressure fluid back to a fluid reservoir **214** as described in greater detail herein.

As mentioned, to increase the efficiency of the hydraulic tool **100**, it may be desirable to have a tool where the piston **200** could move at non-constant speeds and apply different loads based on a state of the tool, the crimping operation, and/or the type of crimp that is desired. For instance, the piston **200** may be configured to advance rapidly at a fast speed while travelling within the cylinder **108** before the moveable crimping head **116** reaches a connector to be crimped. Once the moveable crimping head **116** reaches the connector, the piston **200** may slow down, but cause the moveable crimp head **116** to apply a large force to perform the crimp operation. Described next is an exemplary hydraulic circuit **124** that is configured to control the crimping operation of the hydraulic tool **100**.

Returning to FIGS. 3 and 4, the tool **100** includes a partially hollow piston **200** moveably accommodated within the cylinder **108**, which is formed by a frame **201** and a bore **202** of the tool **100**. The piston **200** includes a piston head **203A** and a piston rod **203B** extending from the piston head **203A** along a central axis direction of the cylinder **108**. As shown, the piston **200** is partially hollow. Particularly, the piston head **203A** is hollow and the piston rod **203B** is partially hollow, and thus a cylindrical cavity **230** is formed within the piston **200**.

The motor **102** drives the pump **104** to provide pressurized fluid through a check valve **204** to an extension cylinder **206**. The extension cylinder **206** is disposed in the cylindrical cavity formed within the partially hollow piston **200**. The piston **200** is configured to slide axially about an external surface of the extension cylinder **206**. However, the extension cylinder **206** is affixed to the cylinder **108** at the second end **109B**, and thus the extension cylinder **206** does not move with the piston **200**.

The piston **200**, and particularly the piston rod **203B**, is further coupled to a ram **208**. The ram **208** is configured to be coupled to and drive the moveable crimp head **116**.

The piston head **203A** divides an inside of the cylinder **108** into two chambers: a first chamber **210A** and a second

chamber 210B. The chamber first 210A is formed between a surface of the piston head 203A that faces toward the ram 208, a surface of the piston rod 203B, and a wall of the cylinder 108 at the first end 109A. The second chamber 210B is formed between the a surface of the piston head 203A that faces toward the motor 102 and the pump 104, the external surface of extension cylinder 206, and a wall of the cylinder 108 at the second end 109B. Respective volumes of the first chamber 210A and the second chamber 210B vary as the piston 200 moves linearly within the cylinder 108. The second chamber 210B includes a portion of the extension cylinder 206.

The pump 104 is configured to draw fluid from the fluid reservoir 214 to pressurize the fluid and deliver the fluid to the extension cylinder 206 after a user initiates a crimp command. Such a crimp command may come by way of the user entering such a command by way of the user interface components 20 (see, FIG. 2). For example, a crimp command could be initiated by the user entering a crimp command by way of the user interface 136 or the toggle switch 136 as illustrated in FIG. 7.

The reservoir 214 may include fluid at a pressure close to atmospheric pressure, e.g., a pressure of 15-20 pounds per square inch (psi). Initially, the pump 104 provides low pressure fluid to the extension cylinder 206. The fluid has a path through the check valve 204 to the extension cylinder 206. The fluid is blocked at high pressure check valve 212 and a release valve 216, which is coupled to, and actuable by the controller 50.

The fluid delivered to the extension cylinder 206 applies pressure on a first area  $A_1$  within the piston 200. As illustrated, the first area  $A_1$  is a cross section area of the extension cylinder 206. The fluid causes the piston 200 and the ram 208 coupled thereto to advance rapidly. Particularly, if the flow rate of the fluid into the extension cylinder 206 is  $Q$ , then the piston 200 and the ram 208 move at a speed equal to  $V_1$ , where  $V_1$  could be calculated using the following equation:

$$V_1 = \frac{Q}{A_1} \quad (1)$$

Further, if the pressure of the fluid is  $P_1$ , then the force  $F_1$  applied on the piston 200 could be calculated using the following equation:

$$F_1 = P_1 A_1 \quad (2)$$

Further, as the piston 200 extends within the cylinder 108, hydraulic fluid is pulled or drawn from the reservoir 214 through a bypass check valve 218 into the chamber 210B. As the piston 200 begins to extend, pressure in the second chamber 210B is reduced below the pressure of the fluid in the fluid reservoir 214, and therefore the fluid in the fluid reservoir 214 flows through the bypass check valve 218 into the chamber 210B and fills the second chamber 210B. Preferably, the controller 50 is monitoring both the pressure hydraulic fluid by way of the pressure sensor 122 and is also monitoring the movement of the piston 200 based on input that it receives from the linear distance sensor 150.

As the piston 200 and the ram 208 extend, the moveable crimping die 116 and stationary crimping die 115 move toward each other in preparation for crimping a connector placed within the crimping area 160. As the moveable die 116 reaches the connector, the connector resists this motion.

Increased resistance from the connector causes pressure of the hydraulic fluid provided by the pump 104 to rise.

The tool 100 includes a sequence valve 120 that includes a poppet 220 and a ball 222 coupled to one end of the poppet 220. A spring 224 pushes against the poppet 220 to cause the ball 222 to prevent flow through the sequence valve 120 until the fluid reaches a predetermined pressure set point that exerts a force on the ball exceeding the force applied by the spring 224 on the poppet 220. For example, the predetermined pressure set point that causes the sequence valve 120 to open could be between 350 and 600 psi; however, other pressure values are possible. This construction of the sequence valve 120 is an example construction for illustration, and other sequence valve designs could be implemented.

Once the pressure of the fluid exceeds the predetermined pressure set point, fluid pressure overcomes the spring 224 and the sequence valve 120 opens, thus allowing the fluid to enter the second chamber 210B. As such, the fluid now acts on an annular area  $A_2$  of the piston 200 in addition to the area  $A_1$ . Thus, the fluid acts on a full cross section of the piston 200 ( $A_1 + A_2$ ). For the same flow rate  $Q$ , used in equation (1), the piston 200 and the ram 208 now move at a speed equal to  $V_2$ , where  $V_2$  could be calculated using the following equation:

$$V_2 = \frac{Q}{A_1 + A_2} \quad (3)$$

As indicated by equation (3),  $V_2$  is less than  $V_1$  because of the increase in the area from  $A_1$  to ( $A_1 + A_2$ ). As such, the piston 200 and the ram 208 slow down to a controlled speed that achieves a controlled, more precise working operation. However, the pressure of the fluid has increased to a higher value, e.g.,  $P_2$ , and thus the force applied on the piston 200 also increases and could be calculated using the following equation:

$$F_2 = P_2 (A_1 + A_2) \quad (4)$$

$F_2$  is greater than  $F_1$  because of the area increase from  $A_1$  to ( $A_1 + A_2$ ) and the pressure increase from  $P_1$  to  $P_2$ . Thus, when the sequence valve 120 opens, high pressure hydraulic fluid can enter both the extension cylinder 206 and the chamber 210B to cause the ram 208 to apply a large force that is sufficient to crimp a connector at a controlled speed.

Higher pressure fluid is now filling the chamber 210B due the opening of the sequence valve 120. The high pressure fluid pushes a ball of the bypass check valve 218 causing the bypass check valve 218 to close, thus preventing fluid from the chamber 210B to flow back to the fluid reservoir 214. In other words, the bypass check valve 218 has fluid at reservoir pressure on one side and high pressure fluid in the chamber 210B on the other side. The high pressure fluid shuts off the bypass check valve 218, which thus does not allow fluid to be drawn from the reservoir 214 into the chamber 210B.

The tool 100 includes a pressure sensor 122 configured to provide sensor information indicative of pressure of the fluid. The pressure sensor 122 may be configured to provide the sensor information to the controller 50.

As will be described in greater detail with reference to the flowcharts of FIGS. 5 and 6, once the piston 200 begins to experience an increased pressure as it exerts an initial crimp force on an outer surface of the connector, the controller 50 will be directed to a lookup table for certain desired values.

In one arrangement, based on user input information, the controller 50 will extract the desired crimp distance and a desired crimp pressure. The controller 50 then operates the motor 102 and the hydraulic circuit 124 so as to drive the piston 200 to this targeted crimp distance and to this targeted crimp pressure. When the linear distance sensor 150 senses that the piston 200 has moved to this targeted crimp distance, the controller 50 can then determine that the initiated crimp of the identified connector is complete.

Once the connector is crimped and the piston 200 reaches an end of its stroke within the cylinder 108, hydraulic pressure of the fluid increases because the motor 102 may continue to drive the pump 104. The hydraulic pressure may keep increasing until it reaches a threshold pressure value. In an example, the threshold pressure value could be 8500 psi; however, other values are possible. Once the controller 50 receives information from the pressure sensor 122 that the pressure reaches the threshold pressure value, the controller 50 may shut off the motor 102 so as to retract the piston and the ram 208 back to a desired position, such as a home or fully retracted position.

In one example, the tool 100 includes a return spring 228 disposed in the first chamber 210A. The spring 228 is affixed at the end 109A of the cylinder 108 and acts on the surface of the piston head 203A that faces toward the piston rod 203B and the ram 208. When piston retraction has been actuated, the spring 228 pushes the piston head 203A back. Also, pressure of fluid in the extension cylinder 206 and the second chamber 210B is higher than pressure in the reservoir 214. As a result, hydraulic fluid is discharged from the extension cylinder 206 through the release valve 216 back to the reservoir 214. At the same time, hydraulic fluid is discharged from the second chamber 210B through the high pressure check valve 212 and the release valve 216 back to the reservoir 214, while being blocked by the check valve 218 and the check valve 204. Particularly, the check valve 204 prevents back flow into the pump 104.

FIG. 5 shows a flowchart of an example method 300 for crimping a connector by using a die less hydraulic crimper, according to an example embodiment. Method 300 shown in FIG. 5 presents an embodiment of a method that could be used using the hydraulic tool as shown in FIGS. 1-4, and 7, for example. Further, devices or systems may be used or configured to perform logical functions presented in FIG. 5. In some instances, components of the devices and/or systems may be configured to perform the functions such that the components are actually configured and structured (with hardware and/or software) to enable such performance. In other examples, components of the devices and/or systems may be arranged to be adapted to, capable of, or suited for performing the functions, such as when operated in a specific manner. Method 300 may include one or more operations, functions, or actions as illustrated by one or more of blocks 310-410. Also, the various blocks may be combined into fewer blocks, divided into additional blocks, and/or removed based upon the desired implementation.

It should be understood that for this and other processes and methods disclosed herein, flowcharts show functionality and operation of one possible implementation of present embodiments. Alternative implementations are included within the scope of the example embodiments of the present disclosure in which functions may be executed out of order from that shown or discussed, including substantially concurrent or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art.

At block 310, the method 300 includes the step of a user entering certain information required for a desired crimp into the hydraulic tool. Such information may be entered into the tool via user interface components 20 as previously described. For example, at block 310, a user may enter a type of connector that will be crimped. That is, the user may enter that an Aluminum connector is being crimped or that a Copper connector is being crimped. In addition, once the type of connector is selected and input into the tool, the user may be called upon to enter the size of the connector size into the hydraulic tool. Based on this entered data, the controller 50 of the hydraulic tool 100, 130 will be able to determine a targeted crimp pressure to ensure a proper crimp. In addition, based on this entered data, the controller 50 of the hydraulic tool 100, 130 will also be able to determine a targeted crimp distance that the piston 200 will move in order to perform the desired crimp.

For example, once this data has been entered into the tool, at block 320, the method 300 includes the step of the controller 50 looking up the crimp target distance and the crimp pressure that is to be used for the specific information input at block 310. The method 300 utilizes, at least in part, the information that a user inputs at block 310 to look up these crimp target distance and crimp pressures. Such crimp information may be contained in a look up table that is stored in the memory 80 that is accessible by way of a controller 50. (See, e.g., FIG. 2).

At block 330, the method 300 queries by way of the controller 50 whether a tool trigger has been pulled in order to commence or initiate a crimp. For example, such a tool trigger may comprise the tool trigger 138 as illustrated in FIG. 7. If at block 330, the controller 50 determines that the tool trigger has not been pulled, then the method 300 returns back to the start of block 330 and waits a certain period of time to query again whether the tool trigger has been pulled.

If at block 330, the controller 50 determines that the tool trigger has been pulled, a crimping action commences. That is, the method 300 will proceed to block 340 where the controller 50 initiates activation of the hydraulic tool motor 102. After the motor 102 has been activated, as herein described, internal pressure within the hydraulic tool will begin to increase. Once the ram or piston 200 begins to move in a distal direction or in a crimping direction, the controller 50 will detect and monitor the movement of the piston 200 as it moves in this direction. Specifically, piston 200 movement will be detected and monitored by way of the linear distance sensor 150 in order to determine if the piston 200 moves the targeted crimp distance, as previously determined by the controller 50 at block 320. After the piston 200 begins its movement towards the crimping target as herein described, at block 350, the controller 50 monitors whether the piston 200 achieves its target crimp distance. In one preferred arrangement, the target crimping distance may be determined by the controller 50 by analyzing position information that it receives from the linear distance sensor 150 as described herein. If at block 350 the controller 50 determines that the piston 200 has not yet reached the target crimp distance, the method 300 proceeds to block 360. At block 360 of the method 300, the controller 50 determines if the hydraulic circuit 124 of the hydraulic tool 100 resides at maximum hydraulic pressure, preferably by way of a pressure transducer (e.g., pressure transducer 122). If at block 360 the method 300 determines that the maximum hydraulic pressure has not been reached, then the method 300 returns to block 340 and the controller 50 continues to operate the

motor **102** so to increase fluid pressure within the hydraulic circuit **124** so as to continue to drive the piston **200** towards the crimp work area **160**.

Alternatively, if at block **360**, the controller **50** determines that a tool maximum pressure has been reached, then the method **300** proceeds to block **370** where the motor **102** is stopped.

After the motor has been stopped at block **370**, the method **300** proceeds to block **380** where certain operating parameters may be recorded by the controller **50**. For example, at block **370**, the controller **50** may record the final crimp pressure as well as the crimp distance that the piston **200** traveled in order to complete the desired crimp. Thereafter, the method **300** proceeds to block **390** where the controller **50** may make a determination if the resulting crimp met the desired looked up crimp pressure and the desired crimp distance. For example, in one arrangement, the controller **50** would compare the recorded finished pressure and distance recorded at block **380** with the target crimp distance and target crimp pressure that the controller **50** pulled from the look up table at block **320**. If these pressure and/or distance values do not compare favorably, the method **300** proceeds to block **400** where the resulting failed crimp failure is indicated and then perhaps logged. Alternatively, if these values do favorably compare, then the method **300** proceeds to block **410** wherein a successful crimp may be indicated to the user, as described herein. In one arrangement, the controller **50** may also store this successful crimp in memory **80** and may also be logged in a tracking log, also stored in memory **80**.

In addition, the successful crimp may be visually and/or audibly noted to a user of the power tool **100** by way of some type of human interface device: e.g., illumination of a green light emitting diode of some other similar indication by way of one of the user interface components **20**. Alternatively, or additionally, an operator interface may be provided along a surface of the tool housing that provides such a visual and/or graphical confirmation that the previous crimp comprises a successful crimp. This could be the same or different operator interface that the user utilized at block **310** where the user enters crimp size and connector type information prior to crimp initiation.

FIG. 6 shows a flowchart of an alternative method **500** for crimping by using a die less hydraulic crimper, according to an example embodiment that does not require initial user input prior to initiating a crimp. Method **500** shown in FIG. 6 presents an embodiment of a method that could be used using the hydraulic tools **100**, **130** as shown in FIGS. 1-4 and 7, for example. Method **500** may include one or more operations, functions, or actions as illustrated by one or more of blocks **510-630**. Also, the various blocks may be combined into fewer blocks, divided into additional blocks, and/or removed based upon the desired implementation.

At block **510**, the method **500** includes an optional step of a user entering certain information prior to initiation of a desired crimp. For example, at block **510**, a user may enter a type of connector that will be crimped. For example, the user may enter that either an Aluminum connector is being crimped or that a Copper connector is being crimped.

At block **520**, the controller **50** of the hydraulic tool queries whether the tool trigger has been pulled in order to initiate a crimping operation. If at block **520**, the hydraulic tool controller **50** determines that no tool trigger has yet been pulled, the method **500** cycles back to block **510** and waits a certain period of time before this query is made again.

If at block **520** the controller **50** determines that the tool trigger has been pulled, a crimping action is initiated. That

is, the method **500** proceeds to block **530** where the controller **50** starts the motor **102** such that hydraulic tool pressure will increase within the hydraulic circuit **124**, as described herein. After hydraulic pressure increases within the hydraulic circuit **124**, the piston **200** begins to move in the distal direction, towards the crimping head **114**. After movement of the piston **200**, the hydraulic tool **100** will detect and monitor the internal pressure of the tool **100**, as determined at block **540**. For example, pressure may be monitored by the controller **50** as it receives feedback information from the pressure sensor **122**. Specifically, the controller **50** will monitor the pressure to determine if a threshold pressure is detected. This threshold pressure will determine whether the piston **200** has first engaged an outer surface of a connector to be crimped. After the piston **200** begins its distal movement towards the crimping target, at block **540**, the controller **50** determines whether and when the tool achieves the threshold pressure also referred to as connector measure pressure.

If the controller **50** determines that the connector measure pressure has been met, and that therefore the piston **200** is starting to exert a force upon the outer diameter of the connector being crimped, the method proceeds to block **550**. At block **550**, a connector outer diameter is measured. In one preferred arrangement, this connector outer diameter may be measured by utilizing the linear distance sensor **150**. For example, the linear distance sensor **150** may provide distance information as to how far the piston **200** has traveled from a reference position (i.e., the piston home or retracted position). And since the controller **50** can determine the relative position of the piston **200** at that point in time, the controller **50** will therefore be able to determine the connector outer diameter. The controller **50** can therefore record this outer diameter in memory **80**.

After the connector outer diameter has been determined at block **550**, the controller **50** looks up a target crimp distance and a target crimp pressure via a lookup table, preferably stored in memory **80**. Pressure within the hydraulic circuit **124** continues to increase so that the piston **200** continues to move towards the crimping head **114** so as to complete the crimp. Next, at block **570** of method **500**, the controller **50** queries whether the targeted crimp distance has been achieved by the piston **200**. As previously described herein, in one arrangement, the controller **50** would receive this distance information regarding the targeted crimp distance from the linear distance sensor **150**.

If the controller **50** determines from the distance information provided by the linear distance sensor **150** that the targeted crimp distance has not yet been achieved, the method proceeds to block **580**. At block **580**, the controller **50** determines if the hydraulic tool resides **100** at a maximum hydraulic tool pressure. Preferably, the controller **50** receives pressure information from the pressure sensor **122** for this determination. If at block **580**, the controller **50** determines that the maximum hydraulic tool pressure has been reached, then the method **500** proceeds to block **590** where the controller **50** initiates a stoppage of the tool motor **102**.

Alternatively, if at block **570**, the controller **50** determines that a target crimp distance has been achieved (i.e., that the piston has indeed traveled the desired crimp target distance), then the method **500** proceeds to block **590** where the controller **50** issues an action to stop the motor **102**. As a result, the hydraulic circuit **124** will act as described herein so as to return the hydraulic fluid back to the fluid reservoir **214**.

After the motor **120** has been stopped at block **590**, the method **500** proceeds to block **600** where certain operating parameters may be recorded and/or information logged. For example, at block **600**, the controller **50** may record the final crimp pressure within the hydraulic circuit **124** as well as the final crimp distance that the piston **120** traveled so as to complete the crimp. Thereafter, the method **500** proceeds to block **610** wherein the controller **50** makes a determination as to whether the completed crimp conforms with the looked up pressure and the distance that was determined at block **560**. For example, the controller **50** could compare the recorded finished pressure and distance recorded at block **600** with the targeted distance and pressure determined at block **560**.

If these pressure and/or distance values do not compare favorably, the method **500** proceeds to block **620** where a crimp failure is indicated and then logged as a failed crimp. Alternatively, if these values do favorably match, then the method **500** proceeds to block **630** wherein a successful crimp is indicated to the user. In one arrangement, the controller **50** may store this successful crimp in memory **80** and may also be logged in a tracking log.

In addition, the successful crimp may be visually and/or audibly noted to a user of the power tool **100** by way of some type of human interface device: illumination of a green light emitting diode of some other user interface component **20**. Alternatively, or additionally, an operator interface may be provided along a surface of the tool housing that provides such a visual and/or graphical confirmation that the previous crimp comprises a successful crimp. This could be the same or different operator interface that the user utilized at block **510** where the user enters crimp size and connector type information prior to crimp commencement was entered into the power tool prior to crimp initiation.

FIGS. **8-10** depict a crimping tool head **700** according to an example embodiment of the present disclosure. As just one example, the crimping tool head or work head **700** may be utilized with a hydraulic tool as disclosed herein, such as the hydraulic tool **10** illustrated in FIG. **1** and the hydraulic tool **130** illustrated in FIG. **7**. Specifically, FIG. **8** depicts a side view of the crimping tool head **700** in a closed state, FIG. **9** depicts a side view of the crimping tool head **700** in an open state, and FIG. **10** depicts an exploded view of the crimping tool head **700**.

As shown in FIGS. **8-10**, the cutting tool head **700** includes a first frame **712** and a second frame **714**. The second frame **714** is movable relative to the first frame **712** such that the crimping tool head **700** can be (i) opened to insert one or more objects into a crimping zone **716** of the crimping tool head **700**, and (ii) closed to facilitate crimping the object(s) in the crimping zone **716**. In particular, to crimp an object and/or a work piece positioned within the crimping zone **716**, the crimping tool head **700** includes a ram **718** slidably disposed in the first frame **712** and a crimping anvil **720** on the second frame **714**. The ram **718** is movable from a proximal end **722** of the crimping zone **716** to the crimping anvil **720** at a distal end **724** of the cutting zone **716**. The ram **718** and the crimping anvil **720** can thus provide a compression force to the object(s) (e.g., metals, wires, cables, and/or other electrical connectors) positioned between the ram **718** and the crimping anvil **720** in the crimping zone **716**.

As shown in FIGS. **8-10**, the ram **718** can have a shape that generally narrows in a direction from the proximal end **722** towards the distal end **724**. As such, a cross-section of a distal-most end of the ram **718** can be smaller than a cross-section of a proximal-most end of the ram **718**. As one

example, the ram **718** can have a generally pyramidal shape. As another example, the ram **718** can have a plurality of sections, including one or more inwardly tapering sections **718A** and one or more cylindrical sections **718B** (see FIG. **10**).

As also shown in FIGS. **8-10**, the crimping anvil **720** can have a shape that generally narrows in the direction from the proximal end **722** towards the distal end **724**. As examples, the crimping anvil **720** can have a generally V-shaped surface profile or a generally U-shaped surface profile. In some implementations, the shape and/or dimensions of the ram **718** can generally correspond to the shape and/or dimensions of the crimping anvil **720**, and vice versa. Due, at least in part, to the narrowing shape of the ram **718** and the crimping anvil **720**, the crimping tool head **700** can advantageously crimp object(s) with greater force over a smaller surface area than other tool heads (e.g., crimping tools having a generally flat ram and a generally flat crimping anvil). This, in turn, can help to improve electrical performance of objects coupled by the crimping operation.

As described above, the crimping head tool **700** can be coupled to an actuator assembly, which is configured to distally move the ram **718** to crimp the object(s) in the crimping zone **716**. For example, the actuator assembly can include a hydraulic pump, and/or an electric motor that distally moves the ram **718**. Additionally, for example, the actuator assembly can include a switch, which is operable to cause the ram **718** to move between the proximal end **722** and the distal end **724**. For instance, the switch can be movable between a first switch position and a second switch position. When the switch is in the first switch position, the actuator assembly causes the ram **718** to be in a retracted position (e.g., at the proximal end **722**). Whereas, when the switch is in the second switch position, the actuator causes the ram **718** to move toward the crimping anvil **724** to crimp the object(s) in the crimping zone **716**.

Additionally, as shown in FIGS. **8-10**, the first frame **712** has a first arm **726** and a second arm **728** extending from a base **730**. The first arm **726** is generally parallel to the second arm **728**. The first arm **726** and the second arm **728** are also generally of equivalent length. In this configuration, the first frame **712** is in the form of a clevis (i.e., U-shaped); however, the first frame **712** can have a different form in other examples. Additionally, although the first frame **712** is formed from a single piece as a unitary body in the illustrated example, the first frame **712** can be formed from multiple pieces in other examples.

As noted herein, the second frame **714** includes the crimping anvil **720**. In FIGS. **8-10**, the crimping anvil **720** is integrally formed as a single piece unitary body with the second frame **714**. In an alternative example, the crimping anvil **720** can be coupled to the second frame **714**. For instance, the crimping anvil **720** can be releasably coupled to the second frame **714** via one or more first coupling members, which extend through one or more apertures in the crimping anvil **720** and the second frame **714**. By releasably coupling the crimping anvil **720** to the second frame **714**, the crimping anvil **720** can be readily replaced and/or repaired.

The second frame **714** is hingedly coupled to the first arm **726** at a first end **732** of the second frame **714**. In particular, the second frame **714** can rotate between a closed-frame position as shown in FIG. **8** and an open-frame position as shown in FIG. **9**. In the closed-frame position, the second frame **714** extends from the first arm **726** to the second arm **728** such that the crimping zone **716** is generally bounded by the ram **718**, the crimping anvil **720**, the first arm **726**, and the second arm **728**. In the open-frame position, the second

frame 714 extends away from the second arm 728 to provide access to the crimping zone 716 at the distal end 724.

In FIGS. 8-10, the second frame 714 is hingedly coupled to the first arm 726 via a first pin 734 extending through the first end 732 of the second frame 714 and a distal end portion of the first arm 726. The distal end portion of the first arm 726 includes a plurality of prongs 736 separated by a gap, the first end 732 of the second frame 714 is disposed in the gap between the prongs 736. This arrangement can help to improve stability and alignment of the second frame 714 relative to the first frame 712. This in turn helps to improve alignment of the ram 718 and the crimping anvil 720 during a crimping operation. Despite these benefits, the second frame 714 can be hingedly coupled to the first arm 726 differently in other examples.

A second end 738 of the second frame 714 is releasably coupled to the second arm 728, via a latch 740, when the second frame 714 is in the closed-frame position. In general, the latch 740 is configured to rotate relative to the second arm 728 between (i) a closed-latch position in which the latch 740 can couple the second arm 728 to the second frame 714 as shown in FIG. 8 and (ii) an open-latch position in which the latch 740 releases the second arm 728 from the second frame 714 as shown in FIG. 9. For example, the latch 740 can be hingedly coupled to the second arm 728 via a second pin 742, and the latch 740 can thus rotate relative to the second arm 728 about the second pin 742. Although FIG. 9 shows the latch 740 in the open-latch position while the second frame 714 is in the open-frame position, the latch 740 can be in the open-latch position when the second frame 714 is in other positions. Similarly, the latch 740 can be in the closed-latch position when the second frame 714 is in the open-frame.

To releasably couple the latch 740 to the second frame 714, the latch 740 and the second frame 714 include corresponding retention structures 744A, 744B. For example, in FIG. 8, the latch 740 includes a proximally-sloped bottom surface 744A that engages a distally-sloped top surface 744B of the second frame 714 when the latch 740 is in the closed-latch position and the second frame 714 is in the closed-frame position. The pitch of the sloped surfaces 744A, 744B is configured such that the surface 744A of the latch 740 can release from the surface 744B of the second frame 714 when the latch 740 moves to the open-latch position. Similarly, the pitch of the sloped surfaces 744A, 744B is configured such that the engagement between the surface 744A and the surface 744B prevents rotation of the second frame 714 when the second frame 714 is in the closed-frame position and the latch 740 is in the closed-latch position.

A release lever 746 is coupled to the latch 740 and operable to move the latch 740 from the closed-latch position to the open-latch position. For example, a proximal portion 747 of the release lever 746 can be coupled to a proximal portion 743 of the latch 740 (e.g., via a coupling member such as, for example, a screw or releasable pin). As such, the release lever 746 can be rotationally fixed relative to the latch 740.

The release lever 746 also includes a projection 748 that extends from the release lever 746 towards the second arm 728 of the first frame 712. As shown in FIGS. 8-9, the projection 748 can engage against the second arm 728 of the first frame 712, when the release lever 746 is coupled to the latch 740. In this way, the projection 748 can act as a fulcrum about which the release lever 746 can rotate.

In this arrangement, rotation of the release lever 746 about the projection 748 and towards the second arm 728 causes

corresponding rotation of the latch 740 about the second pin 742 and away from the second frame 714. The release lever 746 is thus operable by a user to release the second frame 714 from the latch 740 and the second arm 728 so that the second frame 714 can be moved from the closed-frame position shown in FIG. 7 to the open-frame position shown in FIG. 9.

The latch 740 can be biased towards the closed-latch position by a biasing member. For example, the biasing member can be a spring 750 extending between the second arm 728 and the latch 740 to bias the latch 740 toward the closed-latch position. FIG. 8 shows the spring 750 when the latch 740 is in the closed-latch position and FIG. 9 shows the spring 750 when the latch 740 is in the open-latch position. As shown in FIGS. 8-9, the spring 750 extends between a first surface 752 on a proximal portion of the latch 740 and a second surface 754 on the second arm 728. In an example, the second surface 754 can be a lateral protrusion on the second arm 728. Because the second arm 728 is fixed and the latch 740 is rotatable, the spring 750 applies a biasing force directed from the second arm 728 to the proximal portion of the latch 740. In this arrangement, the spring 750 thus biases the latch 740 to rotate clockwise in FIGS. 8-9 toward the closed-latch position.

As shown in FIG. 10, the first frame 712 further includes a passage 756 extending through the base 730. When the crimping tool head 700 is coupled to the actuator assembly, a portion of the actuator assembly can extend through the passage 756 and couple to the ram 718 in the first frame 712. In this way, the actuator assembly can move distally through the passage 756 to thereby move the ram 718 toward the crimping anvil 720. As one example, the ram 718 can be releasably coupled to the actuator assembly by one or more second coupling members 758 (e.g., a releasable pin or a screw). This can allow for the ram 718 to be replaced and/or repaired, and/or facilitate removably coupling the crimping tool head 700 to the actuator assembly.

The crimping tool head 700 can further include a return spring (such as the return spring 228 illustrated in FIG. 3) configured to bias the ram 718 in the proximal direction towards the retracted position shown in FIGS. 8-9. The return spring can thus cause the ram 718 to return to its retracted position upon completion of a distal stroke of the ram 718 (during a crimping operation).

FIGS. 11A, 11B, and 11C illustrate a hydraulic circuit 1100, in accordance with an example implementation. Such a hydraulic circuit 1100 may be used with a hydraulic tool, such as the hydraulic crimping tool 100 illustrated in FIG. 1 and/or the hydraulic tool 130 illustrated in FIG. 7.

The hydraulic tool 1100 includes an electric motor 1102 (shown in FIG. 11B) configured to drive a hydraulic pump 1104 via a gear reducer 1106. The hydraulic tool 1100 also includes a reservoir or tank 1108, which operates as reservoir for storing hydraulic oil at a low pressure level (e.g., atmospheric pressure or slightly higher than atmospheric pressure such as 30-70 psi). As the electric motor 1102 rotates in a first rotational direction, a pump piston 1110 reciprocates up and down. As the pump piston 1110 moves upward, fluid is withdrawn from the tank 1108. As the pump piston 1110 moves down, the withdrawn fluid is pressurized and delivered to a pilot pressure rail 1112. As the electric motor 1102 rotates in the first rotational direction, a shear seal valve 1114 remains closed such that a passage 1116 is disconnected from the tank 1108.

The pressurized fluid in the pilot pressure rail 1112 is communicated through a check valve 1117 and a nose 1118 of a sequence valve 1119, through a passage 1120 to a

chamber 1121. As shown in FIG. 11C, the chamber 1121 is formed partially within the inner cylinder 1122 and partially within a ram 1124 slidably accommodated within a cylinder 1126. The ram 1124 is configured to slide about an external surface of the inner cylinder 1122 and an inner surface of the cylinder 126. The inner cylinder 1122 is threaded into the cylinder 1126 and is thus immovable. As show in FIG. 11C, the pressurized fluid entering the chamber 1121 applies a pressure on the inner diameter “d<sub>1</sub>” of the ram 1124, thus causing the ram 1124 to extend (e.g., move to the left in FIG. 11C). A die head 1127 is coupled to the ram 1124 such that extension of the ram 1124 (i.e., motion of the ram 1124 to the left in FIG. 11) within the cylinder 1126 causes a working head of the tool to move toward a working head, such as the crimper head 114 illustrated in FIG. 1.

Referring back to FIG. 11A, the sequence valve 1119 includes a poppet 1128 that is biased toward a seat 1130 via a spring 1132. When a pressure level of the fluid in the pilot pressure rail 1112 exceeds at threshold value set by a spring rate of the spring 1132, the fluid pushes the poppet 1128 against the spring 1132, thus opening a fluid path through passage 1134 to a chamber 1136. The chamber 1136 is defined within the cylinder 1126 between an outer surface of the inner cylinder 1122 and an inner surface of the cylinder 1126. As a result, referring to FIG. 11C, pressurized fluid now acts on the inner diameter “d<sub>1</sub>” of the ram 1124 as well as the annular area of the ram 1124 around the inner cylinder 1122. As such, pressurized fluid now applies a pressure on an entire diameter “d<sub>2</sub>” of the ram 1124. This causes the ram 1124 to apply a larger force on an object being crimped.

As illustrated in FIG. 11A, the hydraulic tool 1100 further includes a pilot/shuttle valve 1138. The pressurized fluid in the pilot pressure rail 1112 is communicated through a nose 1140 of the pilot/shuttle valve 1138 and acts on a poppet 1142 to cause the poppet 1142 to be seated at a seat 1144 within the pilot/shuttle valve 1138. As long as the poppet 1142 is seated at the seat 1144, fluid flowing through the check valve 1117 is precluded from flowing through the nose 118 of the sequence valve 1119 and passage 1146 around the poppet 1144 to a tank passage 1148, which is fluidly coupled to the tank 1108. This way, fluid is forced to enter the chamber 1121 via the passage 1120 as described herein.

Further, fluid in the pilot pressure rail 1112 is allowed to flow around the pilot/shuttle valve 1138 through annular area 1149 to the passage 1116. However, as mentioned above, when the shear seal valve 1114 is closed, the passage 1116 is blocked, and fluid communicated to the passage 1116 is precluded from flowing to the tank 1108.

The crimper 1100 includes a pressure sensor (such as pressure sensor 122 FIG. 3) in communication with a controller of the crimper 1100. The pressure sensor is configured to measure a pressure level within the cylinder 1126, and provide information indicative of the measurement to the controller. As long as the measured pressure is below a threshold pressure value, the controller commands the electric motor 1102 to rotate in the first rotational direction. However, once the threshold pressure value is exceeded, the controller commands the electric motor 1102 to stop and reverse its rotational direction to a second rotational direction opposite the first rotational direction. Rotating the electric motor 1102 in the second rotational direction causes the shear seal valve 1114 to open, thus causing a fluid path to form between the pilot pressure rail 1112 through the annular area 1149 and the passage 1116 to the tank 1108. As a result of fluid in the pilot pressure rail

1112 being allowed to flow to the tank 1108 when the shear seal valve 1114 is opened, the pressure level in the pilot pressure rail 1112 decreases.

FIG. 12 illustrates a close up view of the hydraulic tool 1100 showing the pilot/shuttle valve 1138. Once the pilot pressure rail 1112 is depressurized as a result of the shear seal valve 1114 being opened, pressure level acting at a first end 1200 of the poppet 1142 is decreased. At the same time, pressurized fluid in the chamber 1121 is communicated to the passage 1146 through the nose 1118 of the sequence valve 1119 and acts on a surface area of a flange 1202 of the poppet 1142. As such, the poppet 1142 is unseated (e.g., by being pushed downward).

A return spring 1150 encloses the ram 1124, and the return spring 1150 pushes the ram 1124 (e.g., to the right in FIGS. 11A, 11C). As a result, fluid in the chamber 1121 is forced out of the chamber 1121 through the nose 1118 of the sequence valve 1119 to the passage 1146, then around a nose or second end 1204 of the now unseated poppet 1142 to the tank passage 1148, and ultimately to the tank 1108. Similarly, fluid in the chamber 1136 is forced out of the chamber 1136 through a check valve 1152, through the nose 1118 of the sequence valve 1119 to the passage 1146, then around the nose or second end 1204 of the poppet 1142 to the tank passage 1148, and ultimately to the tank 1108. The check valve 1117 blocks flow back to the pilot pressure rail 1112. Flow of fluid from the chambers 1121 and 1136 to the tank 1108 relieves the chambers 1121 and 1136 causing the ram 1124 to return to a start position, and the crimper 1100 is again ready for another cycle.

In some cases, the shear seal valve 1114 might not operate properly. In these cases, when the electric motor 1102 is commanded to rotate in the second rotational position, the shear seal valve 1114 might not open a path from the passage 1116 to the tank 1108, and pressure level in the pilot pressure rail 1112 is not relieved and remains high. In this case, the poppet 1142 might not be unseated, and fluid in the chambers 1121 and 1136 is not relieved. As such, the ram 1124 might not return to the start position. To relieve the chambers 1121 and 1136 in the case of a failure of the shear seal valve 1114, the hydraulic tool 1100 may be equipped with an emergency relief mechanism that is described herein.

As shown in FIG. 12, a mechanical switch or button 1206 is coupled to a poppet 1208 disposed within the pilot/shuttle valve 1138. In an emergency or failure situation, the button 1206 may be pressed (downward), which causes the poppet 1208 to be pushed further within the pilot/shuttle valve 1138 (e.g., move downward in FIG. 12). As the poppet 1208 moves, it contacts a pin 1210 that is disposed partially within the poppet 1142.

The pin 1210 is in contact with a check ball 1212 disposed within the poppet 1142. The check ball 1212 is seated at a seat 1214 within the poppet 1142 as long as the pilot pressure rail 1112 is pressurized and the poppet 1142 is seated at the seat 1144. However, when the button 1206 is pressed and the poppet 1208 moves downward contacting and pushing the pin 1210 downward, the check ball 1212 is unseated from the seat 1214. As a result, pressurized fluid in the pilot pressure rail 1112 is allowed to flow through the poppet 1142, around the check ball 1212, around the pin 1210 and the poppet 1208 to the tank passage 1148, and ultimately to the tank 1108. This way, the pressure in the pilot pressure rail 1112 is relieved in the case of failure of the shear seal valve 1114 via pressing the button 1206. Relieving pressure in the pilot pressure rail 1112 allows the poppet

1142 to be unseated under pressure of fluid in the passage 1146, thus relieving the chambers 1121 and 1136 as described above.

Advantageously, the configuration illustrated in FIGS. 11 and 12 combines the operation of the emergency relief mechanism with the pilot/shuttle valve 1138 as opposed to including a separate lever mechanism and associated separate valve to allow for relieving pressure in the case of a hydraulic circuit malfunction.

The description of the different advantageous embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

We claim:

1. A power tool comprising:
  - a moveable piston that is movable between a distal-most position and a proximal-most position, wherein the moveable piston is fully retracted in the proximal-most position;
  - a motor capable of driving the moveable piston to perform work on a work piece,
  - a distance sensor configured to sense a movement of the moveable piston, the distance sensor operable to provide sensor information indicative of the movement of the moveable piston; and
  - a controller configured to receive the sensor information from the distance sensor,
 wherein the controller is configured to:
  - operate the motor to perform work on the work piece based in part on the sensor information that the controller receives from the distance sensor, and
  - after the work is performed on the work piece, use the sensor information to cause the moveable piston to partially retract to a partially-retracted position such that a stroke of the moveable piston starts from the partially-retracted position to perform work on a next work piece, and
 wherein the partially-retracted position is distal of the proximal-most position.
2. The power tool of claim 1, wherein the distance sensor detects a linear displacement of the moveable piston.
3. The power tool of claim 2, wherein the distance sensor detects the linear displacement of the moveable piston when the power tool performs work on the work piece.
4. The power tool of claim 3, wherein the distance sensor detects the linear displacement of the moveable piston when the power tool performs a crimping action.
5. The power tool of claim 1, wherein the distance sensor detects a linear displacement of the moveable piston during a crimping action.
6. The power tool of claim 5, where during the crimping action, the distance sensor generates an output signal that is communicated to the controller.

7. The power tool of claim 6, wherein the output signal is representative of a distance that the moveable piston traveled from a reference position.
8. The power tool of claim 7, wherein the reference position comprises a moveable piston home position.
9. The power tool of claim 8, wherein the reference position comprises a completely retracted position of the moveable piston.
10. The power tool of claim 6, wherein the output signal is representative of a direction of motion of the moveable piston.
11. The power tool of claim 10, wherein the direction of motion of the piston comprises a direction of the moveable piston towards a working head of the power tool.
12. The power tool of claim 11, wherein the working head of the power tool comprises a crimping head.
13. The power tool of claim 12, wherein the crimping head of the power tool comprises a die-less crimping head.
14. The power tool of claim 11, wherein the working head of the power tool comprises a cutting head.
15. The power tool of claim 10, wherein the direction of motion of the piston comprises a direction motion away from the working head.
16. The power tool of claim 1, wherein the distance sensor comprises a hall effect sensor.
17. The power tool of claim 16, wherein the hall effect sensor detects a contour provided along an outer surface of the moveable piston.
18. The power tool of claim 1, further comprising a pump, and a gear reducer, wherein the motor is configured to drive the pump by way of the gear reducer.
19. The power tool of claim 1, wherein the distance sensor is mounted within a cylindrical bushing of the power tool.
20. The power tool of claim 19, wherein the cylindrical bushing is mounted within a frame of the power tool, and wherein the cylindrical bushing surrounds a piston rod of the piston.
21. The power tool of claim 1, wherein the distance sensor configured to continuously sense the movement of the moveable piston.
22. A power tool comprising:
  - a moveable piston;
  - a motor configured to cause a hydraulic fluid to be supplied to the moveable piston to perform work on a work piece,
  - a distance sensor configured to sense a movement of the moveable piston, the distance sensor operable to provide sensor information indicative of the movement of the moveable piston;
  - a pressure sensor configured to sense a pressure of the hydraulic fluid supplied to the moveable piston; and
  - a controller configured to:
    - receive the sensor information from the distance sensor and the pressure sensor,
    - determine, based on the sensor information received from the pressure sensor, that the hydraulic fluid has achieved a threshold pressure at a point in time,



wherein the threshold pressure is indicative that the piston is starting to exert a force on the work piece, determine, based on the sensor information received from the distance sensor for the point in time, an outer diameter of the work piece, 5  
determine, based on the determined outer diameter, at least one of a target distance or a target pressure, and operate the motor to perform work on the work piece based on the sensor information and the at least one of the target distance or the target pressure. 10

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