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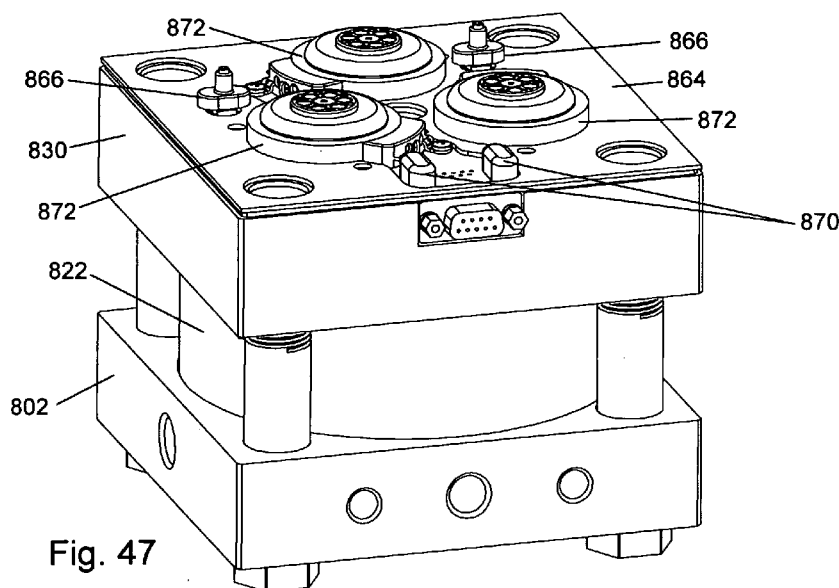


Fig. 47

(57) Abstract: Fast-acting and low-inertia actuators (10) useable in various applications where a high force must be applied very quickly are disclosed. Power tools with detection systems configured to detect a dangerous condition between a person and a cutting tool are disclosed. In power tools, for example in a woodworking machine, a fast-acting and low-inertial actuator (10) as disclosed herein can be used to retract a blade (400) upon detection of a dangerous condition by a detection system. The actuator includes a charge of pressurized fluid and one or more electromagnets (42) to selectively retain or release the pressurized fluid.

ACTUATORS FOR POWER TOOL SAFETY SYSTEMS

Cross-Reference to Related Application

This application claims the benefit of and priority from U.S. Provisional Patent
5 Application Serial No. 61/278,111, filed October 2, 2009.

Technical Field

The present disclosure relates to fast-acting and low-inertia actuators. More
specifically, the disclosure relates to fast-acting and low-inertia actuators useable in various
applications where a high force must be applied very quickly.

Background Art

10 Safety systems for power tools are disclosed in International Application Number
PCT/US00/26812, filed September 29, 2000, and published as International Publication
Number WO 01/26064 A2 on April 12, 2001, the disclosure of which is hereby incorporated
by reference. That application claims priority to a number of priority documents, including
15 U.S. Provisional Patent Application Serial Number 60/157,340, filed October 1, 1999. The
safety systems disclosed in that application include a detection system adapted to detect a
dangerous condition between a person and a working portion of a machine, such as accidental
contact with the working portion, and a reaction system associated with the detection system
to cause a predetermined action to take place relative to the working portion upon detection
20 of the dangerous condition by the detection system. The reaction system may be a retraction
system to retract the working portion. Machines equipped with safety systems are also
disclosed.

Retraction systems for use in power equipment are also disclosed in U.S. Patent
7,509,899, filed August 13, 2001 and issued March 31, 2009, and that patent is also hereby
25 incorporated by reference. The retraction systems disclosed in that patent are configured to
retract a cutting tool at least partially away from a cutting region upon detection of a
dangerous condition by a detection system.

Power tool safety mechanisms are also disclosed in International Application Number
PCT/US02/21790, filed July 11, 2002, and published as International Publication Number
30 WO 03/006213 A2 on January 23, 2003. That application claims priority to a number of
priority documents, including U.S. Provisional Patent Application Serial Number 60/304,614,
filed July 11, 2001. That application discloses a sensing mechanism for detecting user contact
with an active portion of a power tool, and a system to rapidly displace the active portion

away from a user extremity, or alternatively, to rapidly urge an extremity of the user away from the active portion of the power tool.

Other retraction systems for power tools are disclosed in U.S. Patent 6,922,153, filed May 13, 2003 and issuing on July 26, 2005. That patent discloses using a pyrotechnic and propellant to pivot a saw blade down or using a flywheel to do so.

A pyrotechnic drop mechanism for power tools is disclosed in U.S. Patent 7,628,101, filed October 30, 2006 and issued December 8, 2009. That patent discloses using a pyrotechnic to move a piston and retract a saw blade.

At least as early as March 19, 2010, a German company called Altendorf posted on the Internet an article describing a hand detection sensor for use on wood processing machinery. That system uses a near-infrared sensor that purportedly can tell the difference between human skin and wood and other materials. Upon detection of human skin, a deflector or shutter stops the user's hand from reaching the saw blade.

German patent document DE 196 09 771 A1, with a publication date of June 4, 1998, describes a safety system for a circular saw bench in which a Theremin oscillator purportedly detects the proximity of a hand to a blade and a pneumatic cylinder then retracts the blade.

Brief Disclosure

Fast-acting and low-inertia actuators are useable in safety systems for power tools such as table saws, sliding table saws, jointers, up-cut saws and other similar machinery. For example, the actuator may be used to retract a blade or other cutting tool quickly to protect the user against serious injury if a dangerous or triggering condition is detected, such as contact with or proximity to the blade or cutting tool by the user's body. The actuator may include a moveable and resettable piston mechanically linked to the cutting tool so that upon actuation of the actuator, the piston moves to retract the blade or other cutting tool. In certain embodiments of the actuators described herein, forces on the order of thousands of pounds (thousands to tens of thousands of Newtons) can be applied within around 600 microseconds.

Generally, the embodiments of fast-acting, low-inertia actuators described herein include a chamber of pressurized fluid (such as air) that is closed by a cap. The cap may be a piston head or a separate component. The cap is held in place by an electromagnet. When the electromagnet is turned off, the cap is released, allowing the pressurized fluid to escape and apply a force. The force of the escaping fluid may be used, for example, to move a piston and the movement of the piston may perform a task, such as retracting a blade in a table saw. In order to achieve the desired speed and performance, the actuator must be designed to hold

fluid at high pressure, the cap that opens to release the pressurized fluid must have low inertia relative to the force applied to it by the pressurized fluid while remaining sufficiently strong and rigid to close the chamber and withstand the pressure within the chamber, the electromagnet must be sufficiently strong to retain the cap against the pressure of the fluid within the chamber, and the electromagnet must be designed to turn off quickly without residual magnetism slowing the movement of the cap, or in other words, the magnetic field produced by the electromagnet must terminate quickly. Fast-acting, low-inertia actuators and implementations of those actuators are illustrated in the attached figures.

A power tool as disclosed herein may include a cutting tool for cutting workpieces, a motor configured to drive the cutting tool, a detection system configured to detect a dangerous condition between a person and the cutting tool, support structure associated with the cutting tool and configured to allow the cutting tool to retract, and an actuator linked to the support structure and adapted to retract the cutting tool upon detection of the dangerous condition by the detection system, where the actuator includes a charge of pressurized fluid.

Brief Description of Drawings

Fig. 1 shows a fast-acting, low-inertia actuator.

Fig. 2 shows a top view of the actuator of Fig. 1.

Fig. 3 shows a sectional view of the actuator of Fig. 1 with a cap closed.

Fig. 4 shows a sectional view of the actuator of Fig. 1 with a cap open.

Fig. 5 shows a base of the actuator of Fig. 1.

Fig. 6 shows a base and a conversion plate of the actuator of Fig. 1.

Fig. 7 shows the top of a conversion plate.

Fig. 8 shows the bottom of a conversion plate.

Fig. 9 shows a base, conversion plate, and electromagnet of the actuator of Fig. 1.

Fig. 10 shows part of an electromagnet.

Fig. 11 shows a cross-section of parts of an electromagnet.

Fig. 12 shows an electromagnet.

Fig. 13 shows the bottom of an electromagnet.

Fig. 14 shows a base, conversion plate, electromagnet and cap of the actuator of

Fig. 1.

Fig. 15 shows a cap.

Fig. 16 shows an exploded view of a cap.

Fig. 17 shows grooves in the bottom of a cap.

Fig. 18 shows an actuator.

Fig. 19 shows a magnet keeper or housing.

Fig. 20 shows a top view of a magnet keeper or housing.

Fig. 21 shows a bottom view of a magnet keeper or housing.

5 Fig. 22 shows a coil used in an electromagnet.

Fig. 23 shows a schematic circuit.

Fig. 24 shows a piston cylinder.

Fig. 25 shows a piston and actuator.

Fig. 26 shows a piston.

10 Fig. 27 shows a cross-sectional view of an actuator and piston.

Fig. 28 shows a table saw.

Fig. 29 is a schematic drawing of a retraction system.

Fig. 30 is a schematic drawing of another retraction system.

Fig. 31 is still another schematic drawing of a retraction system.

15 Fig. 32 is yet another schematic drawing of a retraction system.

Fig. 33 is a schematic drawing of a retraction system using two actuators.

Fig. 34 is a schematic drawing of a retraction system using a 4-bar linkage.

Fig. 35 is a schematic drawing of a retraction system using nested spline shafts.

Fig. 36 shows a base of an actuator.

20 Fig. 37 also shows a base of an actuator.

Fig. 38 shows a base of an actuator with an air chamber.

Fig. 39 shows an actuator body.

Fig. 40 shows a magnet mount of an actuator.

Fig. 41 shows a bolt.

25 Fig. 42 shows an actuator body with a circuit board.

Fig. 43 shows a circuit board.

Fig. 44 also shows a circuit board.

Fig. 45 shows an actuator body with a foam layer.

Fig. 46 shows a foam layer.

30 Fig. 47 shows an actuator with three electromagnets.

Fig. 48 shows a plunger.

Fig. 49 also shows a plunger.

Fig. 50 shows a circuit board with three electromagnets.

Fig. 51 shows an electromagnet.

Fig. 52 shows an exploded view of an electromagnet.

Fig. 53 shows an electromagnet.

Fig. 54 also shows an electromagnet.

5 Fig. 55 shows a cross-sectional view of the electromagnet of Fig. 54.

Fig. 56 shows an electromagnet housing and insert.

Fig. 57 shows an electromagnet insert.

Fig. 58 shows an electromagnet.

Fig. 59 shows a cross-sectional view of the electromagnet of Fig. 58.

10 Fig. 60 shows an electromagnet.

Fig. 61 shows a cap.

Fig. 62 shows a contact disk.

Fig. 63 shows an actuator.

Fig. 64 shows a cap retainer.

15 Fig. 65 also shows a cap retainer.

Fig. 66 shows an actuator and piston.

Fig. 67 shows an actuator and piston head.

Fig. 68 also shows an actuator and piston head.

Fig. 69 shows an actuator and piston shaft.

20 Fig. 70 shows the base of an actuator.

Fig. 71 shows a fitting.

Fig. 72 also shows a fitting.

Fig. 73 shows a piston.

Fig. 74 shows an exploded view of the piston of Fig. 73.

25 Fig. 75 shows a piston head.

Fig. 76 shows a knob.

Fig. 77 shows a system to provide pressurized air to a reservoir in an actuator.

Detailed Description and Best Mode(s) of the Disclosure

30 Figures 1 and 2 show an actuator 10 which has a base 12, a conversion plate 14, a magnet keeper 16, and a cap 18. Cross-sectional views of actuator 10, taken along the line A-A in Figure 2, are shown in Figures 3 and 4. Figure 3 shows a cross-sectional view with the cap closing a chamber, and Figure 4 shows a cross-sectional view with the cap raised and the chamber open.

Base 12 includes a hole or channel 20 through what may be thought of as the front side of the base, as shown in Figure 5. Channel 20 opens into a cylindrical fluid or air chamber 22 in the center of the base. Hole 20 serves as an inlet through which air is pumped into the air chamber by an air compressor. The top of the air chamber is open and is surrounded by four holes 26 which will be used to attach the base to the rest of the assembly. Base 12 also includes four holes 27 which may be used to attach a cylinder to the base, as will be described below.

A conversion plate 14, shown in Figures 6-8, fits over base 12 and helps enclose the air chamber. The conversion plate has a hole 28 in the center and four holes 30 that line up with holes 26 in the base. The bottom of the conversion plate has a cylindrical recessed area 32 that is positioned over air chamber 22 in the base but has a slightly smaller diameter than air chamber 22, as shown in Figure 4. Recessed area 32 is surrounded by flat surface 34. A large o-ring fits into a circular groove 36 in the base and extends around air chamber 22. When the conversion plate is attached to the base, the o-ring in groove 36 contacts flat surface 34 of the conversion plate and seals air chamber 22 at the interface. Two small holes 38 are drilled through both the base and conversion plate outside of the air chamber and are used to pass electrical wires to and from the interior of the actuator, as will be described below.

Conversion plate 14 also has two small holes 40 closely surrounding the center hole 28. These two holes are used to mount an electromagnet 42, as shown in Figure 9. Electromagnet 42 is composed of a first steel cylinder 43 with a hole 44 through the center, as shown in Figures 10 and 11. A second steel cylinder 45 is positioned concentrically over and around the upper portion of first cylinder 43 and is sized to create a gap or space 46 between the outer surface of the first cylinder and the inner surface of the second cylinder. Second steel cylinder 45 can be held in place by a press fit, threads, welding, gluing, screws, etc.

A coil 52 of copper wire is wound around the upper portion of first cylinder 43 and second cylinder 45 is placed over the coil so the coil fills gap 46, as shown in Figures 9 and 12. The copper wire forming coil 52 has two ends 54 and those ends thread down through holes 56 in first cylinder 43 and out the bottom of each side of the electromagnet, one end through each hole. There is a recessed area 58 at the bottom of the electromagnet below each hole to leave space for the wire to exit the bottom of the electromagnet. The wires are routed around the outside of electromagnet 42 and through holes 38 in the conversion plate and base so they may be connected to an electric circuit to control the electromagnet.

Two screws extend up through holes 40 in the conversion plate into threaded holes 62 in the bottom of the electromagnet to attach the electromagnet to the conversion plate. Screw holes 40 are encircled by grooves 60 on the top of the conversion plate, and an o-ring fits into each groove to seal the air chamber. Similarly, groove 68 encircles hole 28 and another o-ring fits into that groove to further seal the air chamber at the interface between the conversion plate and the electromagnet.

Hole 44 through first cylinder 43 is an extension of air chamber 22 in base plate 12, as shown in Figure 4, and hole 44 extends up through the center of electromagnet 42. As shown in Figure 14, cap 18 is positioned on top of the electromagnet and covers hole 44. When the electromagnet is turned on, the cap is magnetically attracted to the electromagnet and seals air chamber 22 and hole 44. Cap 18 is a flat, somewhat thin, circular piece of steel with a rounded edge 70 around the perimeter that slopes downward so that the bottom surface of the cap has a larger diameter than the top, as shown in Figure 15. A hole 80 is in the center of the cap, and a screw 82 passes through the hole and into a corresponding hole 84 in the center of a guide 86 to attach the guide to the bottom surface of the cap, as shown in Figure 16. In the depicted embodiment, the guide is a plastic part with a flat, round top surface and with hole 84 in the center. Three flat, long fins 88 extend down below the top. The fins help keep the cap from tilting when it moves up or down and they are long enough that about three-quarters of the length of the fins remains in hole 44 when the cap is fully raised. The fins are arranged so their outer edges are vertical and separated by 120 degrees. The bottom of each fin is cut at an angle so that the outside edge is longer than the inside edge. This minimizes the weight of the guide.

The bottom of the cap has two circular grooves 72 and 74, as shown in Figure 17, and those grooves are concentric with the center of the cap. O-rings are fitted into the grooves and the o-ring in outer groove 72 seals against first cylinder 43 of the electromagnet when the cap is down. The o-ring in inner groove 74 seals against the top of guide 86 around hole 80 in the center of the cap. The top of the guide is of a diameter such that it overlaps the o-ring in outer groove 72 over approximately half of the width of the o-ring to hold the o-ring in place. Guide 86 is used to keep the cap aligned with hole 44 so that as the cap moves up and down, the o-ring in groove 72 will always align with the edge of hole 44 so that the air chamber can be sealed reliably.

A magnet keeper 16, shown in Figures 18-21, fits over the electromagnet and conversion plate. The magnet keeper is a generally cylindrical housing with a hole 90 through

the top center. Hole 90 is large enough to fit over cap 18 with sufficient clearance for the cap to move up and down. A shallow cutout 92 on the bottom of the magnet keeper, which is concentric with but has a slightly larger diameter than hole 90, allows some room around the bottom of the magnet for the two ends 54 of the wire from the electromagnet. Cut out 92 joins another recessed area 94 which extends over the two holes 38 in the conversion plate and base plate through which the two ends of wire 54 are routed. The magnet keeper is mounted over the conversion plate and to the base plate by screws that extend up through holes 26 in the base and holes 30 in the conversion plate to thread into holes 96 in the magnet keeper.

As shown in Figures 18, 19 and 20, the top of the magnet keeper is designed to allow air from the air chamber to escape when the cap is released, while also providing abutments to stop the upward movement of the cap. Four equally spaced ducts or air outlets 100 are formed around hole 90. Air outlets 100 consist of cut outs with slanted bottoms and rounded corners that slant down and inward toward the perimeter of hole 90. Between the air outlets, the top surface of the magnet keeper extends towards the center with a decreasing thickness forming shoulders or fingers 102. The fingers 102 are curved underneath to match the curvature along the top edge of the cap. The four fingers 102 extend toward and slightly over the rounded edge of cap 18 to form abutments or catches to stop the upward movement of the cap. In this embodiment, fingers 102 allow the cap to move upward about one quarter of an inch. The disclosed embodiment uses four channels and four fingers to help keep the cap from tilting when it abuts the fingers, although more or less fingers and channels could be used. When the cap is raised, the top surface of the cap is flush with the top surface of the magnet keeper.

Figure 22 shows a cross-sectional view of electromagnet 42 and helps illustrate how the electromagnet works to hold and release cap 18. In this figure, the wire loops forming coil 52 are represented by dots and Xs. In use, the coil is connected to a voltage source so that current flows in the wire and around the coil. The dots in Figure 22 represent current flowing out from the page on the left side of the coil and the Xs represent current flowing into the page on the right side of the coil. That current flow creates a magnetic field that points up inside the coil, wraps around the top of the coil, and then comes back down on the outside of the coil. With the cap in place, the magnetic field is able to trace a looped path within metal creating a closed-loop magnetic circuit, as represented by arrows 150 in Figure 22, which

makes the magnetic field much stronger than if there were a non-metal gap that the magnetic field had to travel across to complete a loop.

Generally, an electromagnet creating as much holding force as possible is desired so that the air chamber can be pressurized as high as possible. However, physically larger
5 electromagnets that create higher holding forces also release the cap slower because the residual magnetic field takes time to dissipate after the current passing through the coil is turned off. This is in part due to the inductance of the coil and to eddy currents generated in the metal supporting and surrounding the coil when the coil current is shut off. Accordingly, the electromagnet must be designed to achieve a desired balance of holding force and release
10 time. Electromagnets creating approximately 50 to several 1000 lbs of force may be designed for different applications. In some of the applications described subsequently concerning table saws, one or more electromagnets, each having a diameter of approximately 2.5 inches, a coil having on the order of hundreds of loops, and an electric current on the order of 1 amp or less, is sufficient to generate a holding force on the order of hundreds of pounds each.
15 Smaller electromagnets, however, will have smaller fluid outlets and thereby will be limited in the volume of pressurized fluid that can be released quickly to perform a task. Using multiple small electromagnets is one way to overcome that limitation because multiple electromagnets will have multiple outlets. For any size of electromagnet, using high resistance steel or other high resistance metal for the electromagnet causes eddy currents to
20 dissipate more quickly due to the higher resistance, and thereby minimizes the time to release the cap. Also, to maximize the holding force of the electromagnet, sufficient electric current should be supplied to the coil to generate enough magnetic field to saturate the metal surrounding the coil. Additionally, electromagnets with double coils or multiple coils could be used.

25 In order to decrease the release time of cap 18, a current can be forced through the coil in the opposite direction for a brief amount of time to speed the decay of the dissipating magnetic field. The counteracting or "turn off" current is only applied for a brief amount of time because otherwise it will begin to re-magnetize the magnet with the magnetic field pointing in the opposite direction.

30 Figure 23 shows conceptually how to energize the electromagnet and provide a current in the opposite direction to speed the decay of the dissipating magnetic field. In this figure, the electromagnet is represented as an inductor and V1 is the voltage source that supplies the current to the electromagnet. Closing the "Hold" switch turns the electromagnet

on to hold cap 18 in place. Opening the "Hold" switch causes the magnetic field to dissipate and release cap 18. Closing the "Release" switch at the same time the "Hold" switch is opened connects a capacitor charged to a high voltage, labeled "Pulse Cap," to the electromagnet and provides a pulse of current in the opposite direction to speed the decay of the dissipating magnetic field to more quickly release cap 18. By way of example, 100 to 1,000 volts can be applied to cause the reverse current and induce large reverse eddy currents. Capacitances ranging from 1 microfarad to 100 microfarads are typical values for the capacitor, depending on the magnet and other factors.

In addition to reversing the current in the electromagnet, the magnetic field can also be more quickly dissipating by constructing the electromagnet core out of laminated strips of metal layered together such that there are a series of non-metallic interruptions in the inner and outer cylinders perpendicular to the direction of the current. The laminations interrupt the metal so that large eddy current loops cannot form.

An actuator as described above may be used to quickly accelerate a piston. In Figures 24 and 25, actuator 10 is shown incorporated in a piston system where the base 12 of the actuator forms the base of the piston system. The bottom of a large cylinder 160 fits in a groove 162 on the top of base 12. The top of the cylinder fits into a similar groove in a cover 164 which covers the top of the cylinder. Four rods or long bolts, such as bolt 166, connect base 12 to cover 164 to hold cylinder 160 in place. The bolts pass through holes 27 in the base and thread into corresponding holes in the cover.

Cover 164 also includes a hole 168 through which a piston rod 170 extends. A piston head 172 is attached to the other end of rod 170 within cylinder 160. The piston head is a round, flat piece thick enough to be solid and resist warping. There is a groove 174 around the side of the piston head, as shown in Figure 26, and an o-ring fits into the groove. The o-ring contacts the inner side of cylinder 160 to create a seal between the piston head and the cylinder so that air or gas expanding under the piston head does not escape.

Figure 27 shows a cross-sectional view of actuator 10 and the piston system described above. In this figure, air chamber 22 and hole 44 are sealed by cap 18, and piston head 172 rests on the top of magnet keeper 16. To operate the piston, the electromagnet is turned on to seal chamber 22 and the chamber is filled with air through the inlet 20 at the front of the base of the actuator. This may be done with an air compressor that is followed by one or more boosters to get the air pressure up to the desired level. To fire the piston, the electromagnet is turned off so that cap 18 moves upward releasing air from chamber 22 through outlets 100 at

the top of the magnet keeper. The air expands under the piston head driving the piston upward. In an alternative embodiment, the piston head may include a portion that extends below the top surface of the magnet keeper and toward the cap (or the cap may include a portion that extends up toward the piston head) so that when the cap moves up, the cap strikes the piston head and imparts at least some of its energy to the piston head before the cap is stopped by the magnet keeper.

The volume of chamber 22 is sized according to the volume that is to be filled under the piston head once the air is released. This, in turn, will depend on the mass of the piston, the mass of the load the piston is to move and the velocity the piston is to acquire in a certain distance. A chamber filled with a charge of air at a desired pressure but which is too small will not be able to supply enough air to move a heavy load far enough for it to reach an expected velocity under the acceleration imparted to it by the expanding gas. The combined cross-sectional area of the four outlets through which the air is released is sized according to how fast the air is to be released since there is a limit as to how fast air can move and if the outlets are too small, the airflow will be restricted.

The idea of a charge of fluid stored locally or near the piston is significant when the actuator is used in a safety system for power equipment. A remote source of air cannot be relied upon in that situation because the relatively slow speed of sound in air of about 1 foot per millisecond means it would take too long for a remote charge of pressurized air to reach the piston and start it moving. A person could be seriously injured in the time it took for the remote charge of pressurized air to reach the piston. A charge of pressurized air near the piston provides the fastest response; one cannot achieve the same results with a remote charge. Charges of pressurized fluid may be located as close as possible to the piston and/or cutting tool. For example, pressurized charges may be located less than one meter or less than one half meter from the cutting tool. Charges of pressurized fluid may be located within a housing enclosing the structure supporting the cutting tool in a piece of power equipment, such as within the cabinet of a table saw.

Once the air is released and the piston is driven upward under the force of the expanding gas, the air in the volume in the cylinder above the piston will become pressurized and cause the piston to decelerate. The height of the cylinder is sized according to how far the piston is to be moved and how soon it is to decelerate. It is desirable to decelerate a piston that is moving fast so that it does not jolt and potentially damage other parts connected to the piston. Ideally, both the acceleration and the deceleration of the piston would be constant.

The air above the piston forms an air spring which helps to decelerate the piston but the piston can be decelerated even more quickly and more evenly after the piston has reached a desired height by adding one or more pressure outlets to the side of cylinder 160, such as pressure outlet 180 shown in Figure 24. The pressure outlets are pressure-sensitive valves
5 that open to allow air below the piston head to be escape. They are positioned on the cylinder at a height just above the desired height the piston is to reach under the pressure of the expanding gas so that as soon as the piston passes the pressure outlets the air under the piston head is allowed to escape through the pressure outlets thus aiding the deceleration of the piston.

10 An actuator and piston assembly as described above can be used in a safety system for various power tools, including a table saw. A table saw is a woodworking tool that includes a table and a circular blade that extends up through the table, as shown in Figure 28. Table saws are described in U.S. Patent Publications 2007/01514330A1 and 2010/0050843A1 and in U.S. Patent 7,707,920, which are incorporated herein by reference. A piece of wood, or
15 other material to be cut, is placed on the table and pushed into contact with the spinning blade to make a cut. Unfortunately, it is common for users of table saw to accidentally contact the spinning blade and be seriously injured. To address these injuries, the saw or other power tool can be equipped with a system to detect contact with or dangerous proximity to the blade, as has been described in various patents, including but not limited to US Patents 7,055,417,
20 7,210,383, 7,284,467, and 7,600,455, all of which are incorporated herein by reference. Upon detection of such a dangerous condition, an actuator and piston assembly as described herein can be triggered to retract the blade quickly to mitigate any injury. A system to retract a blade is particularly applicable in machines where the blade or cutting tool has substantial inertia making it difficult to stop the blade quickly.

25 Figure 29 shows one example of how an actuator and piston assembly can be implemented to retract a spinning blade in a table saw. In Figure 29, a circular blade 400 is mounted on a rotating shaft or arbor 420. The arbor, in turn, is supported by an arbor support 422, and the arbor support is mounted in the machine so that it can pivot around point 424.

A detection system 220 is adapted to detect a user coming into contact with blade 400.
30 The detection system includes a sensor assembly, such as contact detection plates 440 and 460, capacitively coupled to blade 400 to detect any contact between the user's body and the blade. Typically, the blade, or some larger portion of the machine is electrically isolated and the detection system imparts an electrical signal to the blade through detection plate 440 and

monitors that signal for changes indicative of contact through detection plate 460. The detection system transmits a signal to a control system 260 when contact between the user and the blade is detected.

Control system 260 includes one or more instruments 480 that are operable by a user to control the motion of blade 400. Instruments 480 may include start/stop switches, speed controls, direction controls, light-emitting diodes, etc. Control system 260 also includes a logic controller 500 connected to receive the user's inputs via instruments 480. Logic controller 500 is also connected to receive a contact detection signal from detection subsystem 220. Further, the logic controller may be configured to receive inputs from other sources (not shown) such as blade motion sensors, work piece sensors, etc. In any event, the logic controller is configured to control operation of the saw in response to the user's inputs through instruments 480. However, upon receipt of a contact detection signal from detection subsystem 220, the logic controller overrides the control inputs from the user and triggers an actuator and piston assembly to retract the blade. An exemplary control system for a fast-acting safety system is disclosed in U.S. Patent 7,600,455, which is incorporated herein by reference.

In Figure 29 an actuator and piston assembly is shown at 800 connected to logic controller 500 by line 502. A piston rod 600 is mechanically coupled to arbor support 422 so that when the actuator is fired, the piston rod pulls the arbor support downward to retract the blade. In this embodiment, two electromagnets in one actuator are used to drive the piston. Alternatively, two actuators could be used. In Figure 29, piston rod 600 extends past two electromagnets and through a reservoir, and the actuator is configured to pull the piston rod down.

Once the actuator has fired, it can be reset by turning on the electromagnet to close the cap and re-charging the air chamber. A spring or other mechanism can be used to move the piston back against the magnet keeper and cap. A spring can also be used to bias the cap to a position where the air chamber is closed. An actuator as described herein can be cycled (i.e., triggered and reset) repeatedly. This is a significant feature because it allows a system using the actuator, such as a safety system in woodworking equipment, to be repeatedly triggered without a user having to replace parts of the safety system.

Other examples of how an actuator and piston assembly can be implemented to retract a spinning blade in a table saw are shown in Figures 30-35. These figures show piston structures configured in different ways and oriented in different directions. In Figure 30, a

piston rod 600 is shaped to extend around an actuator so the actuator can pull the piston rod down. In Figures 31 and 32 piston rods and actuators are configured so that the piston rods are pushed away from the actuators.

Figure 33 shows a configuration for a table saw that has both a main blade 401 and a scoring blade 402. Each blade is supported by a somewhat "L" shaped arbor 403 mounted in a saw to pivot around point 404. Each arbor includes an arm 405 and an actuator 406 is operatively connected to arm 405 so that when the actuator fires, the piston moves out and pushes arm 405. Pushing arm 405 causes the blade to pivot down around point 404, thereby to retract the blade and minimize danger. In this embodiment, two separate actuators are used, one to retract the main blade and the other to retract the scoring blade.

Figure 34 shows an embodiment where one actuator is used to retract both a main blade and a scoring blade. The actuator is connected to the blade through a 4-bar linkage with anchor points in the linkage identified at each "X". Figure 35 shows an embodiment where a single actuator is connected to two blades by nested and splined shafts. The linkages between the actuators and blades in these embodiments provide a structure to retract the blades in case of danger, while allowing an elevation mechanism to raise and lower the blades to accommodate workpieces of varying thicknesses.

The fundamental idea of using an actuator and piston assembly as described herein in a safety system for table saws or other power tools is to move the blade away from the hand of a user faster than the hand can move into the blade. Typically, the speed at which a human can flinch to move a hand is around 2 meters per second. Even assuming a person's hand could move at a speed of 6 meters per second, an actuator and piston assembly as described herein can be constructed with a charge size sufficient to move the blade away faster. An actuator as described herein can accelerate a piston, blade and arbor support of around 10 kilograms at an acceleration on the order of 50 to 200 Gs or more.

One factor in maximizing the effectiveness of an acceleration on the order of 50 to 200 Gs, or even 50 to 1000 Gs or more, is to minimize the decay time of the magnetic field so that the acceleration is applied as quickly as possible. One way to minimize the decay time is to chose a magnet material of a higher bulk resistance, for example, stainless steel rather than plain steel. The higher resistance increases the ohmic loss and dissipation of eddy currents and thereby reduces the time required for the magnetic field to release the cap to allow the pressurized fluid to exit the reservoir. Although stainless steel has a higher resistance and

thereby can be used to minimize the decay time of the magnetic field, plain steel can also be used.

Another way to minimize the decay time of the magnetic field is to minimize the thickness of the steel supporting and surrounding coil 52. Minimizing the thickness of the surrounding steel reduces the time required for field changes to propagate via eddy current formation and dissipation. Putting a port or channel through the center of the magnet, such as hole 44 in first steel cylinder 43, also reduces the decay time of the magnetic field by reducing the pole wall thickness while still allowing a sufficiently large pole area for the cap to seal the reservoir.

The time required to release the pressurized fluid can be shortened by minimizing the inertia associated with the cap. A cap as described herein is used instead of the piston itself to seal the pressurized chamber because the cap has significantly less inertia, and therefore, the release of the pressurized fluid can be as fast as possible. Also, minimizing the volume of the space between the cap and the piston by positioning the bottom of the piston with the top surface of the magnet keeper minimizes the volume that needs to be filled at activation so that the piston starts moving as soon as possible.

As mentioned earlier, the distance between the reservoir and the piston is minimized to thereby minimize the delay in the pressure wave of the released fluid of about 1ms/ft due to the limitation of the speed of sound. Accordingly, a remote reservoir would release substantially more slowly.

In an actuator as disclosed herein, operating the magnet close to saturation (i.e., at a current level where an increase in the current does not produce any significantly greater magnetic force) allows the magnet to be as small as possible. Also, designing the electromagnet so that it produces a magnetic force sufficient to hold the cap in place against the pressure in the reservoir, but not significantly more, means the cap will break away from the electromagnet as soon as possible when the current to the electromagnet is turned off, thereby releasing the pressurized fluid as quickly as possible. In some embodiments, the electromagnet may be designed to produce a holding capacity approximately 25% greater than the expected pressure in the reservoir, although other amounts may be selected.

Once activated, the piston is accelerated as the pressurized fluid from the reservoir pushes against the piston head. At the same time, the air or fluid on the other side of the piston compresses and creates back pressure. The cylinder containing the piston can be sized so that there is a sufficient volume of air or fluid on the other side of the piston to slow it

down smoothly. The piston will decelerate smoothly if, for example, the cylinder is long enough for the piston to pass through the point of equilibrium where the pressure on one side of the piston head is equal to the pressure on the other side. Alternatively, as mentioned earlier, a vent can be positioned to allow air to escape after the piston has moved a certain distance so that the piston can decelerate more smoothly. A bumper can also be used to stop the piston and absorb energy.

As mentioned earlier, the actuator can be reset after activation by some mechanism such as a spring which draws the piston back to its starting position. Alternatively, a valve can be placed near one end of the piston cylinder so that low pressure air can be used to drive the piston to its original position. An optional breather vent can be installed on the side of the magnet keeper and connected to a small conduit leading into the area beyond the piston. A breather vent is a vent with a filter that keeps dust and other particles from entering the actuator from outside. The conduit and associated hole for the breather vent would be small enough so that there would be only a negligible amount of leakage through the hole as the pressurized fluid is released from the reservoir, but large enough to provide an outlet for air to escape as the piston is reset to its original position.

Figures 36 through 41 show another embodiment of an actuator. The base 802 of the actuator, shown in Figure 36 is a square metal block about 1.5 inches thick and about six inches along each side. Three holes 804, 805 and 806 are drilled along the front side horizontally into the base, with hole 805 in the middle of the front side and one hole on either side of the middle hole. Each of the holes along the front side meets a hole drilled vertically down into the base from the top about an inch in from the front side, as shown at 808, 810 and 812, so to create three conduits from the side of the base to the top of the base. Base 802 may also include one or more holes at different locations, such as hole 813, to mount the actuator in a saw or other machine. Another hole 814 passes all the way through the center of the base and a groove is cut into the inner surface of hole 814 just below the top surface of the base within which an o-ring 816 is installed. Another circular groove 818 of a larger diameter, wider cut and concentric with hole 814 is carved into the top surface of base 802. On the bottom surface of groove 818 along the inner radius lays another groove for another o-ring 820. Seated within the larger groove 818 and over the o-ring 820 is the base of a short cylinder 822, as shown in Figure 37. Hole 814 has an upper portion that is of larger diameter than the rest of the hole, and seated within the upper portion of hole 814 and within o-ring

816 is a smaller cylinder 824 of slightly greater length than outer cylinder 822, as shown in Figure 38.

The tops of cylinders 822 and 824 fit within corresponding groove 826 and hole 828 on the underside of another metal block 830 called the magnet mount of similar dimensions to the base only thicker, as shown in Figures 39 and 40. Hole 828 has a lower portion of larger diameter in which inner cylinder 824 resides. Groove 826 and hole 828 are equipped with o-rings 832 and 834 in a manner similar to the o-rings in the base. The o-rings help create a seal for the volume enclosed between outer cylinder 822 and inner cylinder 824 which forms an air chamber 836 similar to air chamber 22 described earlier. Magnet mount 830 is attached to base 802 by four bolts 838, shown in Figures 39 and 41, which are inserted into holes 840 in the base, one hole located at each of the four corners of the base. The bolts are inserted from the underside of the base and extend vertically upward where they are then screwed into threaded holes 842 in the magnet mount. Three large holes 844 pass through the magnet mount from the top surface vertically downward opening into air chamber 836. A groove 846 is carved along the top edge of each hole 844 to hold an o-ring and to create a shelf or ledge around the perimeter of each hole to support a magnet as will be seen later. Figure 42 shows a printed circuit board 848 placed on top of magnet mount 830. Circuit board 848 is shown isolated in Figures 43 and 44. Four holes 850, align above holes 842 in the magnet mount and a hole 852 located at the center of the board aligns above hole 828 in the magnet mount. A nine pin D-sub connector 854 is mounted on the bottom of the circuit board along, and at the middle, of the front edge of the board such that the connector projects out from the front edge of the board. The D-sub connector fits within an area 856 carved out along the top and front edge of the magnet mount so that the circuit board may lie flat against the top surface of the magnet mount.

Two tactile or tact switches 858 are mounted to the circuit board, one towards the right rear corner and the other towards the left rear. Electrical traces run from each tact switch to the D-sub connector, as shown in Figure 44. The tact switches are positioned so that when a piston is fully lowered or retracted the piston compresses the tact switches. In this manner the tact switches are used to indicate to a control system the presence of a piston and that the piston is in the proper position for firing.

Circuit board 848 also has three large holes 860 that are shaped generally like a circle with a small rectangle along the side. A magnet similar to the magnet described earlier fits into each of the holes so that the actuator has three magnets, each magnet with its own cap.

Two electrical contacts 862 are provided for each magnet, one for each end of the magnet coil, and traces run from each contact to pins on the D-sub connector to supply power to the magnets, as seen in Figure 44.

As shown in Figure 45, a piece of foam 864 is placed over the circuit board and has cutouts for the magnets, tact switches, screws and other holes so that the foam lies flat. Foam 864 is shown isolated in Figure 46. The foam prevents dust and other contaminants from entering the actuator.

As shown in Figure 47, adjustable plungers 866, shown isolated in Figures 48 and 49, are positioned over the tact switches, one sitting on top of each tact switch. The adjustable plungers provide a mechanism for the piston to depress each switch as the piston moves down. The adjustable plungers have vertically oriented set screws 868 whose height can be adjusted. The plungers are made of a material such as plastic so that when a piston retracts, the piston contacts the set screws and pushes the plunger against the tact switches. The height of each set screw is adjustable so that each screw can be set to contact its tact switch as desired. The plungers are held in position by a cap retainer described below.

Two plastic caps 870 are placed on the surface of the circuit board over the bottoms of the screws that attach the D-sub connector to the circuit board. The plastic caps protrude up above the circuit board to electrically isolate the screws so that they do not make contact with other parts of the actuator.

Also shown in Figure 47 are three magnets and cap assemblies 872 installed in the actuator. Magnet and cap assemblies 872 are shown connected to circuit board 848 in Figure 50 and isolated in Figure 51. The upper part of each magnet is of a larger diameter than the rest of the magnet and this creates a lip that sits on the shelf or ledge created by groove 846 around the top of each of the large holes 844 in the magnet mount. As shown in Figure 51, each magnet has a plastic molded extension 874 attached along the side at the top of the magnet. Extension 874 attaches to the side of the magnet housing by a screw 908 which passes through a hole 910 along the front of extension 874 and into a hole 912 on the side of the magnet housing, as shown in Figures 51 and 52. Each extension, in turn, has electrical contacts 876 embedded in the plastic, and holes 878 extend through the plastic so that the two ends of the magnet coil can extend out and connect to the electrical contacts 876. The electrical contacts are then attached to the circuit board by screws 880, as shown in Figure 50. Cavities 882, as well as cavity 856, carved down into the top surface of the magnet mount provide clearance for the ends of the screws to extend beyond the bottom of the printed

circuit board without touching the magnet mount. As mentioned earlier, electrical traces or power planes connect each screw to a pin on the D-sub connector and supply power to the magnets.

Figure 52 shows an exploded view of magnet and cap assembly 872. The magnet
5 includes an outer cylindrical housing 888 and an inner cylindrical insert 890. The housing and inserts are shown together in Figures 53-55 and shown in cross-section in Figure 55. Outer housing 888 is in the shape of a cylinder enclosed at the bottom except for a hole 891 in the bottom center. Near the top a section 892 of the cylinder has a larger outer diameter than the rest of the cylinder while maintaining the same inner diameter so that there is a shelf
10 created around the top of the housing which is used to mount the magnet, as explained. Section 892 is positioned slightly below the top of the housing so that the top surface 894 of the housing is of the same radial thickness as the housing below section 892. Top surface 894 forms the magnetic pole to which the magnet cap is attracted. Keeping the radial thickness of
15 top surface 894 the same as the housing below section 892 helps minimize the time for the magnetic field at the top surface to decay, thereby releasing the cap as quickly as possible, as explained previously.

Insert 890 is shaped like a cylinder 895 with a shoulder 896 toward the bottom. Shoulder 896 includes a groove on the underside in which an o-ring 900 is installed. A threaded section 898 extends below shoulder 896. The insert 890 is inserted into the housing
20 888 and then a nut 902 shaped like a threaded ring is screwed on the threaded end to hold the assembly together. A coil of wire is wound around insert 890 and housed in the gap between insert 890 and housing 888. Two holes 904 on the side of housing 888 extend through section 892 to allow each end of the coil to exit the housing. The wires pass through holds 878 in plastic molded extension 874 and connect to electrical contacts 876, as explained.

Figures 56 through 60 show an alternative embodiment for a magnet. In the
25 alternative embodiment insert 890 is replaced by the insert 914 and housing 888 is replaced by housing 916. Insert 914 is similar to insert 890 except that it is not threaded at the bottom. As shown in the cross-sectional view in Figure 59, the hole 891 at the bottom of housing 916 flares outward toward the bottom of the housing. Insert 914 is inserted into housing 916 and,
30 once in place, a tool is used to flare the end 918 of the insert so that it matches the flare around hole 891 in the housing, as shown in Figures 57, 59 and 60.

Figures 52 and 61 show a cap 886 similar to the cap discussed earlier except cap 886 includes a contact disk 920. Contact disk 920 is shown isolated in Figure 62. A screw 922

passes through a hole in the center of the contact disk to connect it to the top of the cap and to connect the cap to guide 924. The contact disk provides a raised surface to impact the bottom of the piston head when the actuator fires. By striking the piston head, the contact disk imparts energy to the piston to start the piston moving as quickly as possible. Additionally, transferring energy from the cap to the piston head slows the cap down so that when the cap reaches the limit of its travel by contacting fingers 102, as described earlier, the force of the contact between the cap and the fingers is lessened and the likelihood of bending the fingers or damaging the cap is decreased. Contact disk 920 is made of a hard plastic or some other hard material, although the material is softer than the piston head to prevent damage to the piston head. Holes are punched through the contact disk to minimize its mass so that the cap can accelerate as quickly as possible. In the depicted embodiment, the cap is approximately 1/8th of an inch thick (~3mm) steel to provide material for the magnetic field, and the mass of the cap is approximately 23 grams. With fins, the cap is approximately 25 grams.

With the magnets installed, another metal block or plate called a cap retainer 934 is placed flat against the magnets and sits on the magnets, as shown in Figure 63, to hold the magnets down and stop the caps. Cap retainer 934 has similar dimensions to base 802 but is thinner. Cap retainer 934 has four holes 936, one at each corner, which align with holes 842 in the magnet mount and a hole 938 in the center that aligns with hole 828 in the magnet mount. Nine socket head cap screws 940 attach the cap retainer to the magnet mount. Screws 940 pass through holes 942 in the cap retainer, shown in Figure 64, and each hole 942 has a section of smaller diameter to catch the head of the screw. The screws then pass through corresponding holes in the foam and in the circuit board and then thread into threaded holes 948 in the magnet mount. As shown in Figure 65, the underside of cap retainer 934 has cutouts 950 for the magnet assemblies 872 and cutouts 952 for the adjustable plungers so that the bottom surface of the cap retainer can lie flat against the magnets. Cutouts 952 are shaped around the adjustable plungers to capture the adjustable plungers and hold them in place and keep them from rotating when the screws are adjusted. Two small holes 954 in the cap retainer allow the heads of the set screws to protrude slightly above the top surface of the cap retainer, as shown in Figure 63, so that the piston head can contact the plungers. The cap retainer has three large holes 956, one over each magnet, with six fingers 958 around the circumference of each hole. The ends of the fingers curl and extend over the outer edge of each magnet to stop the cap, as described above with fingers 102. A very small hole 960 is drilled into the cap retainer and extends down from the top surface but does not go down to

the bottom surface. Instead, it meets the path of another hole 962 drilled horizontally in the side of the cap retainer in which is installed a breather vent 964, as shown in Figure 63. The purpose of the breather vent is described below.

There is a circular groove 968 on the top surface of the cap retainer and an o-ring 970 fits in the bottom of the groove. One end of a large cylinder 972 also fits into the groove 968, as shown in Figure 66, and on top of o-ring 970 to create an airtight seal with the cylinder.

A top metal plate 974 of similar dimension to the base only thinner and with a similar groove and O-ring fits over the top of the large cylinder. Four long bolts 976 secure the large cylinder and the rest of the assembly together. Each bolt 976 passes through a hole, one located in each corner of top plate 974, and then through holes 936 in the cap retainer, then through corresponding holes in the foam and circuit board and into holes 842 in the magnet mount. Holes 842 in the magnet mount also receive the ends of bolts 838 coming up from the base. Threaded ends of bolts 838 are hollow with additional threads on the inner surface, as shown in Figure 41, so that the threaded ends of long bolts 976 thread into the threaded holes 978 in bolts 838. Top plate 974 also has three holes along the front side, a center hole 980 and two holes on either side of the center hole, similar to the three holes on the front side of the base. Each of the three holes is connected to holes that are drilled vertically from in the underside of the top plate thus creating three separate conduits into the area enclosed by large cylinder 972. The center hole 805 along the front side of the base and the center hole 980 along the front side of the top plate are used for connecting a hose from a high pressure fluid source. Hole 805 in the base empties into air chamber 836 and is used to fill air chamber 836 with high pressure air or fluid. Likewise, hole 980 in the top plate empties into the area in the large cylinder above the piston head and may be used to release or fill, or release at one time and fill at another, this area with air or fluid to help, for example, decelerate the piston by creating an adjustable air dampener. The two holes 806 along the front side of the base and the two holes along the front side of the top plate on either side of the center hole are used to allow a set of pressure sensors 982 to measure the pressure in air chamber 836 and in the large cylinder above the piston head. Only one pressure sensor is needed for each area but a second one is added for redundancy. Information from the pressure sensors is sent to a controller. Breather vent 964, which was mentioned earlier, is also used to help decelerate the piston smoothly by allowing air to escape from underneath the piston after the actuator has fired. The hole 960 in the cap retainer is small enough that it will provide virtually no leak at all when the high pressure air is released because the air cannot escape very quickly. But after

the initial release, some air may gradually escape through the breather vent to allow the piston to return to its original or ready position.

A piston 984 is shown in Figures 67 and 68. The shaft 985 of the piston passes through center holes in the cap retainer, the foam layer, the circuit board, the magnet mount (which is lined with an o-ring), the middle of small cylinder 824, and finally through center hole 814 in the base (which is also lined with an o-ring). As shown in Figures 69 through 71, piston shaft 985 then passes through a hole 988 in a fitting 986 that is attached to the bottom of base 802 by four screws 987. Fitting 986 encases a 989 which is flush with the top surface of the fitting, as shown in Figure 71. The bushing fits around the piston shaft to reduce friction as the piston moves. (A bushing may also be used in hole 938 in the cap retainer.) Towards the bottom of fitting 986, a wiper 990 made of an elastomeric material is installed within the fitting and around the shaft of the piston, as shown in Figure 72. The wiper extends towards the shaft at an angle to help keep dust out of the actuator by rubbing against the piston shaft as the shaft moves up and down.

Figure 73 shows piston 984 isolated and Figure 74 shows an exploded view of the piston. Piston 984 consists of a shaft 985 which is attached to a piston head 991. Shaft 985 has a short section of smaller diameter at the end near the piston head which is threaded. Piston head 991 has the shape of a circular disk, as shown in Figure 75, with a hole 992 in the center. Hole 992 has an upper section of a larger diameter, a middle section of a smaller diameter and a lower section of an even smaller diameter. A knob 993, shown in Figures 74 and 76, consists of an upper circular portion on top of a lower cylinder that is of a smaller diameter. A threaded hole 994 passes through both sections. Knob 993 fits into hole 992 in the center of the piston head such that the bottom surface of the upper portion of the knob rests on the surface at the bottom of the upper section of hole 992. The bottom of knob 993 rests upon the surface at the bottom of the middle section of hole 992. Shaft 985 passes through the bottom section of hole 992 and threads into hole 994 of knob 993 to hold the piston assembly together. As shown in Figure 75, piston head 991 has generally triangular sections 995 cut out of the top surface to decrease the overall weight of the piston head without compromising structural support. An o-ring 996 fits into a groove around the outside edge of the piston.

Fig. 77 shows a schematic drawing of a system to provide pressurized air to a reservoir in an actuator. An air supply is identified at 1002, and air from that supply passes through line 1003 to a blow-off valve 1004, which may be set to operate at a preselected

pressure, such as 150 pounds per square inch (psi) or 1 megapascal (MPa). The air then passes through a particle filter 1006 to a pressure regulator 1008, and then to a three-way joint or tee 1010 in the line. Branch 1012 from the tee channels air to a pressure booster 1014 which boosts the pressure to the desired level, which for the actuator embodiments described herein will be around 300 psi (2 MPa), or more generally, 200 to 400 psi (1.4 to 2.8 MPa). A two-way valve 1016, which is normally closed, is downstream from the booster and that valve opens to supply pressurized air to the actuator through a particle filter 1018. Valve 1016 may be opened and closed by a control system that receives a signal from one or more pressure sensors, such as pressure transducers 1020, that measure the pressure within the actuator's reservoir.

A tee 1022 is positioned between valve 1016 and filter 1018 and branch 1023 from the tee leads to a two-way valve 1024 that is normally open and from there to a particle filter 1026 and then to atmosphere. This branch provides a path for pressurized air to exit the actuator, or in other words, provides a path to bleed-off air from the reservoir. Valve 1024 can be controlled by any appropriate control system.

A branch 1030 from tee 1010, which is upstream from booster 1014, provides air to a regulator 1032 and from there to a blow-off valve 1034, which may be set to operate at a preselected pressure, such as 100 psi (0.7 MPa). The air then passes through a two-way valve 1036 which is normally closed, and from there through a particle filter 1038 to the piston cylinder in the actuator. The air passing through valve 1036 is supplied to the cylinder on the side of the piston opposite the reservoir of pressurized gas or air. By providing air to this side of the piston head, the piston can be reset, as described previously. Valve 1036 can be controlled by any appropriate control system, and such a control system may include pressure switches, such as switches 1040.

As alternatives to the system described above in which booster 1014 provides pressurized air to the actuator, either a compressor or a cylinder or container of compressed air (or some other appropriate gas) can supply pressurized air directly to valve 1016 and also to regulator 1032. The components of the system downstream from valve 1016 and regulator 1032 would remain the same in the alternative embodiments. In embodiments using a compressor or cylinder of compressed air, a dryer can be inserted into the system between the compressor or cylinder and valve 1016 and regulator 1032 to dry the air, and other components such as blow-off valves can be used as needed.

An embodiment with a piston head having an area of 16 in² (0.01 m²), and using pressurized air at 300 pounds per square inch (~2MPa), results in 4,800 pounds of initial force (~21,000 N). Such an embodiment, therefore, will accelerate a 20 kg mass at roughly 1,000 meters per second, which is on the order of 100 Gs. It is believed that with a force applied within 0 to 3 milliseconds, accelerations of 20 to 500 Gs are possible and effective.

Industrial Applicability

The present disclosure is applicable to fast-acting and low-inertia actuators which may be useable in various applications where a high force must be applied very quickly, such as in safety systems for power tools. The present disclosure is particularly applicable to the power tool industry and to woodworking machines and other similar machines.

It is believed that this disclosure encompasses multiple distinct inventions with independent utility. While each of these inventions has been disclosed in its preferred form, the specific embodiments thereof as disclosed and illustrated herein are not to be considered in a limiting sense as numerous variations are possible. The subject matter of the inventions includes all novel and non-obvious combinations and sub-combinations of the various elements, features, functions and/or properties disclosed herein. No single feature, function, element or property of the disclosed embodiments is essential to all of the disclosed inventions. Similarly, where the claims recite "a" or "a first" element or the equivalent thereof, such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements.

It is believed that the following claims particularly point out certain combinations and sub-combinations that are directed to one or more of the disclosed inventions. Inventions embodied in other combinations and sub-combinations of features, functions, elements and/or properties may be claimed through amendment of the present claims or through presentation of new claims. Such amended or new claims, whether they are directed to different inventions or directed to the same inventions, whether different, broader, narrower or equal in scope to the original claims, are also regarded as included within the subject matter of the inventions of the present disclosure.

CLAIMS:

1. A power tool comprising:
a cutting tool for cutting workpieces;
5 a motor configured to drive the cutting tool;
a detection system configured to detect a dangerous condition between a person and
the cutting tool;
support structure associated with the cutting tool and configured to allow the cutting
tool to retract; and
10 an actuator linked to the support structure and adapted to retract the cutting tool upon
detection of the dangerous condition by the detection system, where the actuator includes a
charge of pressurized fluid.
2. The power tool of claim 1, further comprising a housing substantially
15 enclosing the support structure, and where the actuator includes a charge of pressurized fluid
located within the housing.
3. The power tool of claim 1, where the charge of pressurized fluid is located no
more than 1 meter from the cutting tool.
20
4. The power tool of claim 1, where the charge of pressurized fluid is located no
more than 0.5 meter from the cutting tool.
5. The power tool of claim 1, where the actuator also includes a piston and where
25 the actuator is configured to use the charge of pressurized fluid to move the piston.
6. The power tool of claim 5, where the charge of pressurized fluid is located no
more than 1 meter from the piston.
- 30 7. The power tool of claim 5, where the charge of pressurized fluid is located no
more than 0.5 meter from the piston.

8. The power tool of claim 1, where the actuator further includes a piston and an electromagnet to release the charge of pressurized fluid to move the piston.

9. The power tool of claim 1, where the actuator further includes a piston, a cap to prevent the release of the charge of pressurized fluid, and an electromagnet to produce a magnetic field to hold the cap in position to prevent the release of the charge of pressurized fluid, where dissipation of the magnetic field releases the cap to allow the charge of pressurized fluid to move the piston.

10. The power tool of claim 9, further comprising electronics to supply current to the electromagnet in a first direction to create the magnetic field and in a second direction to help dissipate the magnetic field.

11. An actuator comprising:
a reservoir for holding pressurized fluid;
a cap to close the reservoir; and
an electromagnet to hold the cap closed;
where the electromagnet can be triggered to release the cap; and
where the electromagnet is configured to release the cap so that pressurized fluid in the reservoir can apply at least 4,000 Newtons of force within 1 millisecond after the electromagnet is triggered.

12. The actuator of claim 11 where the electromagnet is configured to release the cap so that pressurized fluid in the reservoir can apply at least 4,000 Newtons of force within 600 microseconds after the electromagnet is triggered.

13. The actuator of claim 11 where the electromagnet is configured to release the cap so that pressurized fluid in the reservoir can apply at least 4,000 Newtons of force in less than 600 microseconds after the electromagnet is triggered.

AMENDED CLAIMS

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1. A power tool comprising:
a cutting tool for cutting workpieces;
5 a motor configured to drive the cutting tool;
a detection system configured to detect a dangerous condition between a person and the cutting tool;
support structure associated with the cutting tool and configured to allow the cutting tool to retract; and
10 an actuator;
where the actuator includes a charge of pressurized fluid;
where the actuator is configured to use the charge of pressurized fluid to produce at least 4,000 Newtons of force within 0 to 3 milliseconds after detection of the dangerous condition by the detection system; and
15 where the support structure and actuator are further configured so that the force produced by the actuator causes the cutting tool to retract and to reach a peak acceleration of at least 20 to 500 Gs during retraction.
2. The power tool of claim 1, where the actuator includes at least one outlet
20 through which the pressurized fluid is released, and further comprising a piston adjacent the outlet, where the release of the pressurized fluid through the outlet moves the piston, and where movement of the piston retracts the cutting tool.
3. The power tool of claim 2, where the charge of pressurized fluid is no more
25 than 1 meter from the piston.
4. The power tool of claim 2, where the charge of pressurized fluid is no more than 0.5 meter from the piston.
- 30 5. The power tool of claim 2, where the actuator further includes an electromagnet and a magnetically attractable cap, where the electromagnet holds the cap in a position to close the outlet, and where the pressurized fluid moves the cap to open the outlet when the electromagnet releases the cap.

6. The power tool of claim 5, where the electromagnet and cap are configured so that a magnetic field produced by the electromagnet is able to trace a looped path within metal to create a closed-loop magnetic circuit.

5 7. The power tool of claim 5, further comprising electronics to supply current to the electromagnet in a first direction to create a magnetic field and in a second direction to help dissipate the magnetic field.

8. The power tool of claim 7, where the current supplied in the second direction
10 is supplied by a capacitor.

9. The power tool of claim 5, where the electromagnet includes a hole through which pressurized fluid travels to reach the outlet.

15 10. The power tool of claim 5, further comprising a guide associated with the cap to guide movement of the cap when the cap is released by the electromagnet.

11. The power tool of claim 2, where the cutting tool is a circular blade, where the support structure includes an arbor on which the blade is mounted, and where the support
20 structure is configured to allow the blade and arbor to retract.

12. The power tool of claim 11, where the release of the pressurized fluid through the outlet pulls the piston to retract the circular blade and arbor.

25 13. The power tool of claim 11, where the release of the pressurized fluid through the outlet pushes the piston to retract the circular blade and arbor.

14. The power tool of claim 1, where the power tool is a table saw.

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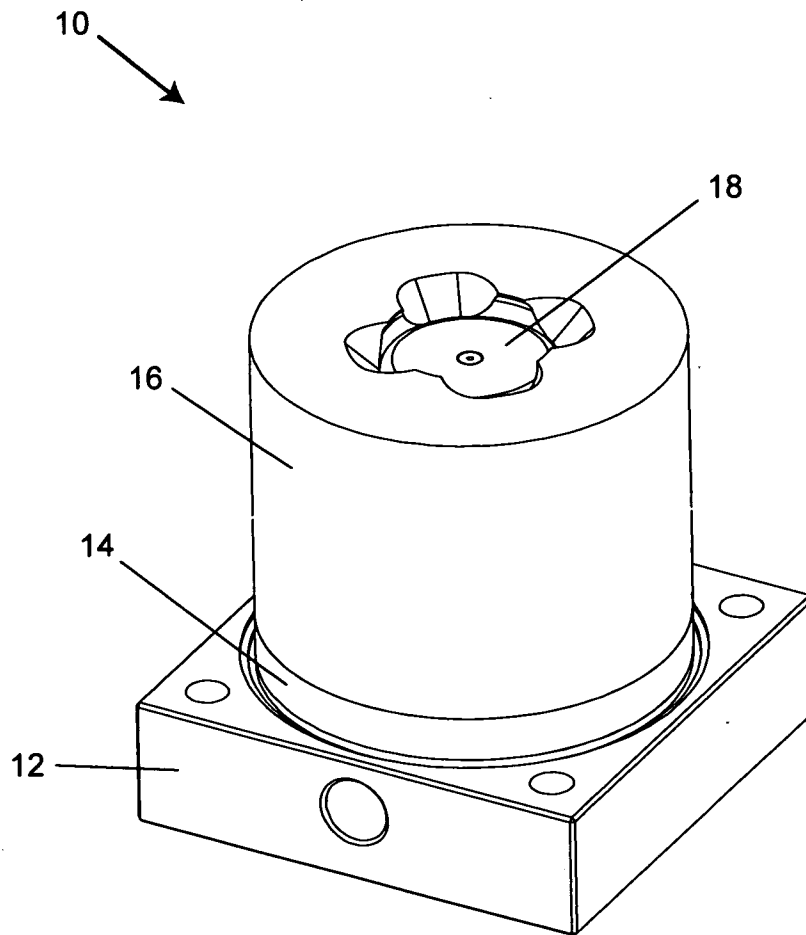


Fig. 1

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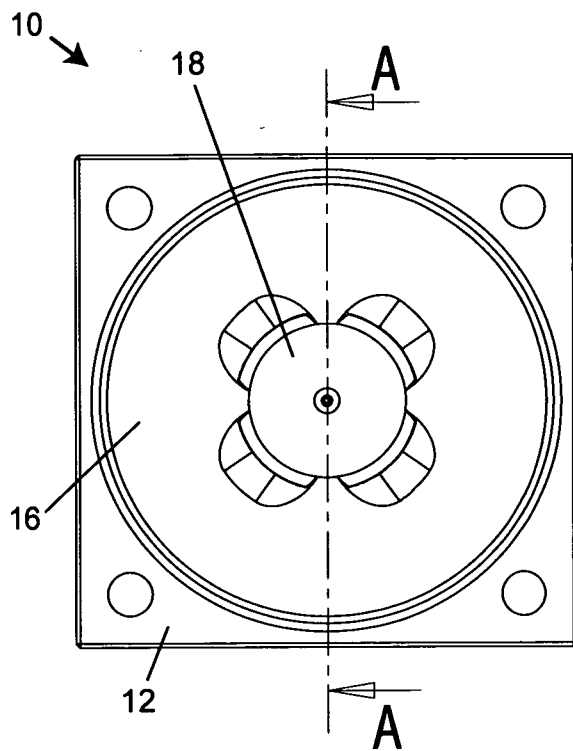


Fig. 2

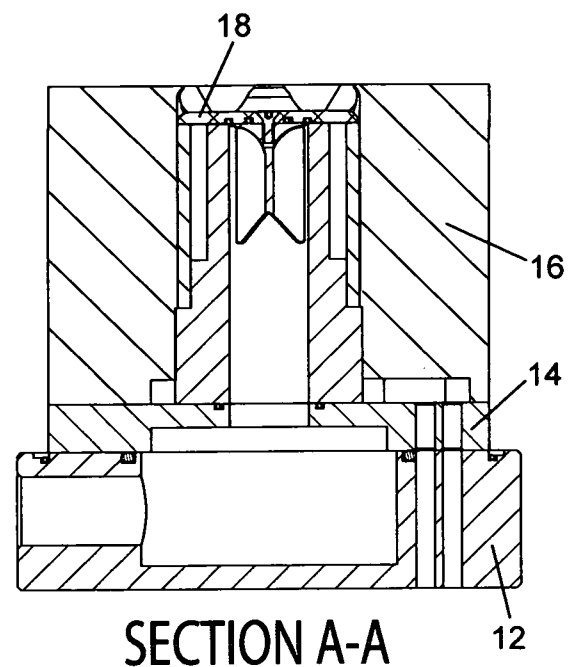


Fig. 3

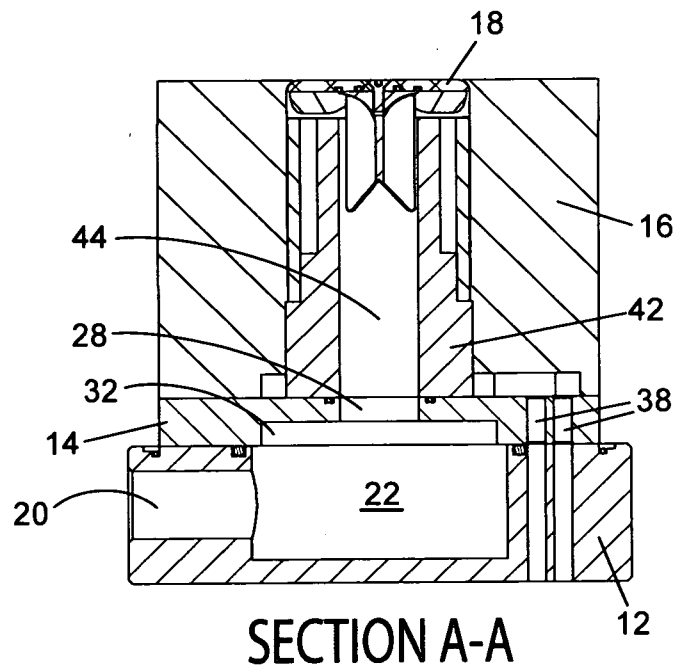


Fig. 4

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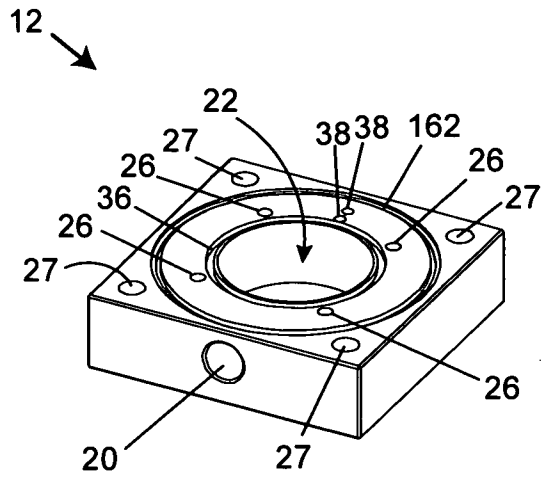


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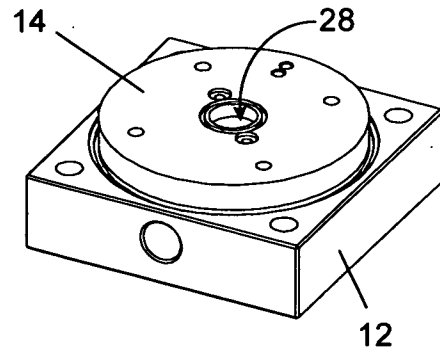


Fig. 6

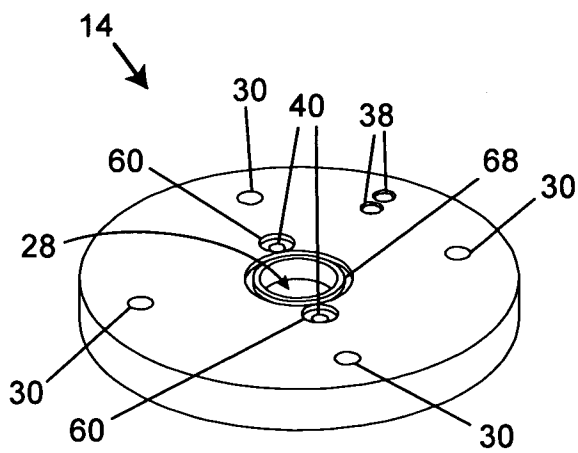


Fig. 7

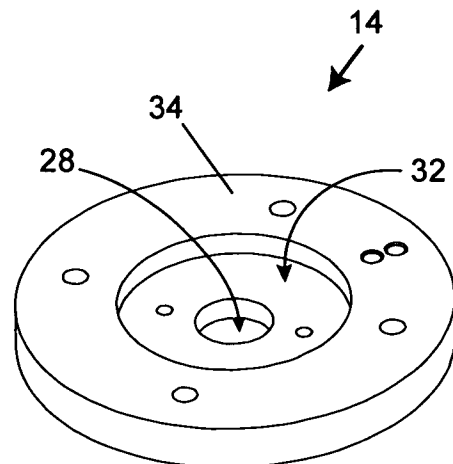


Fig. 8

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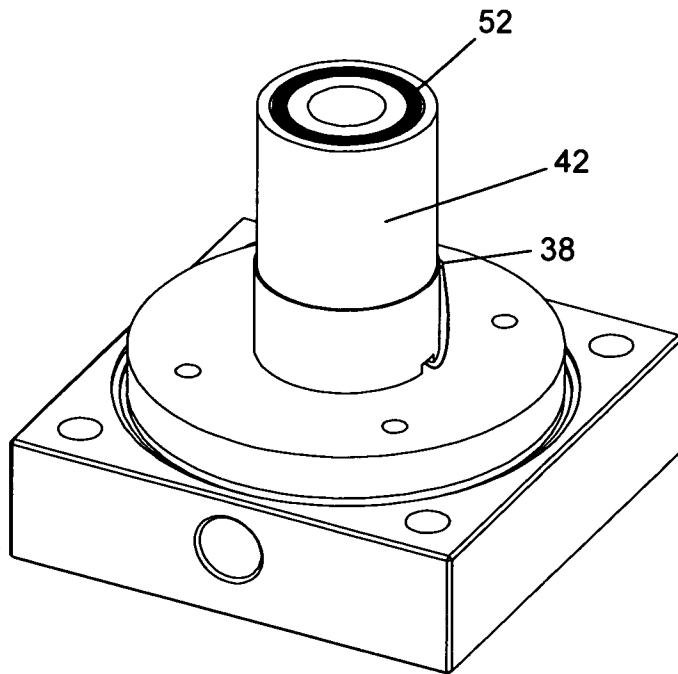


Fig. 9

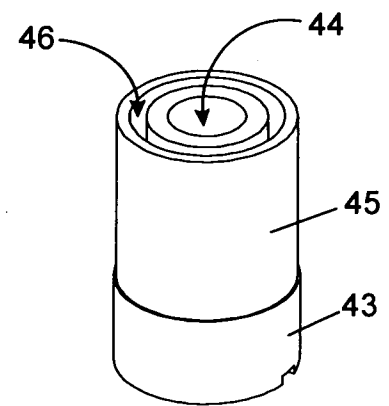


Fig. 10

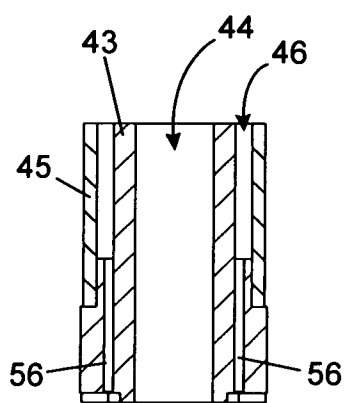


Fig. 11

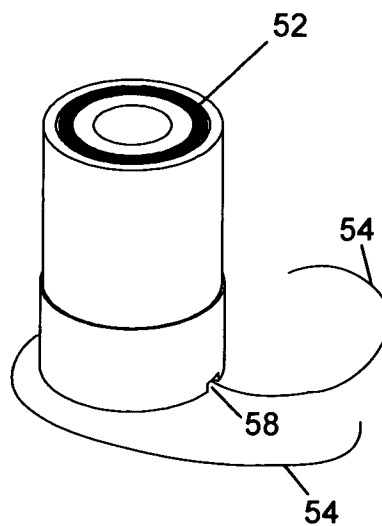


Fig. 12

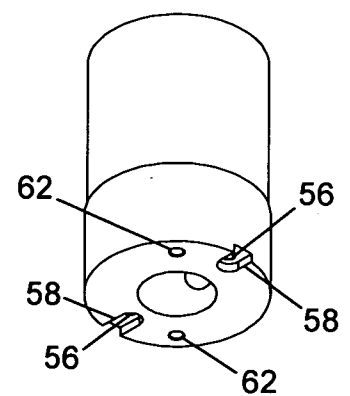


Fig. 13

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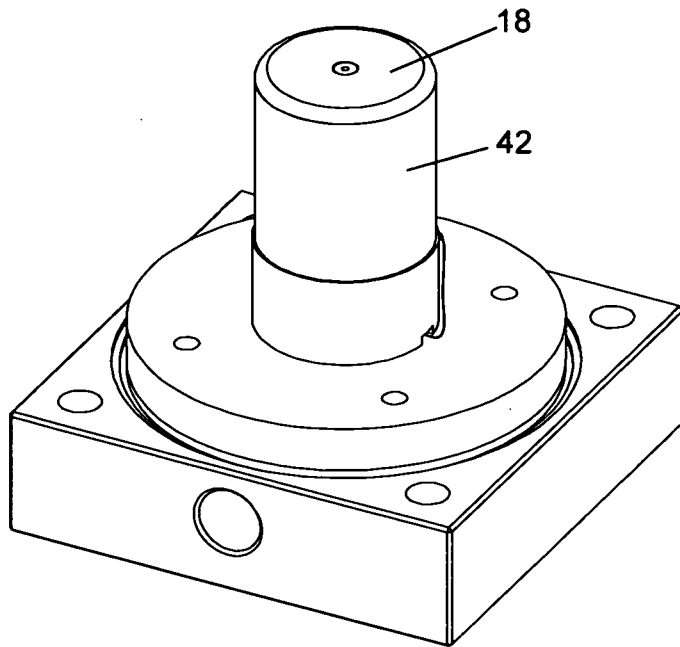


Fig. 14

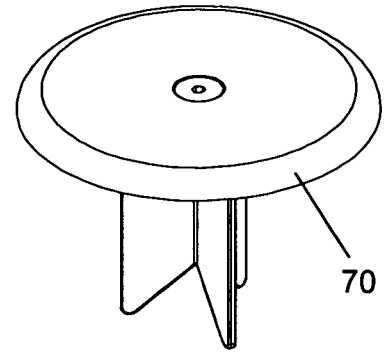


Fig. 15

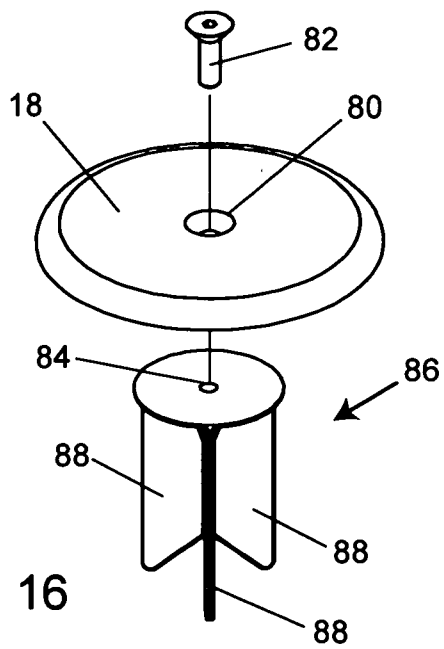


Fig. 16

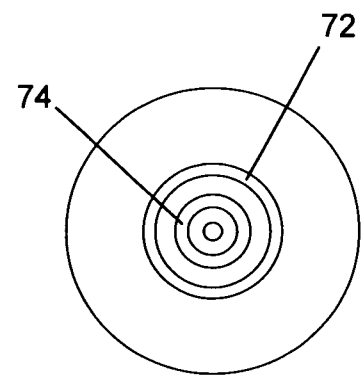
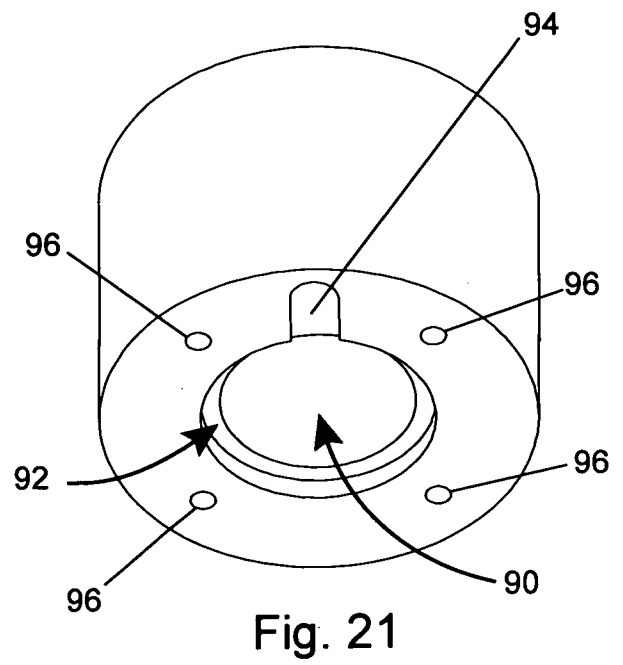
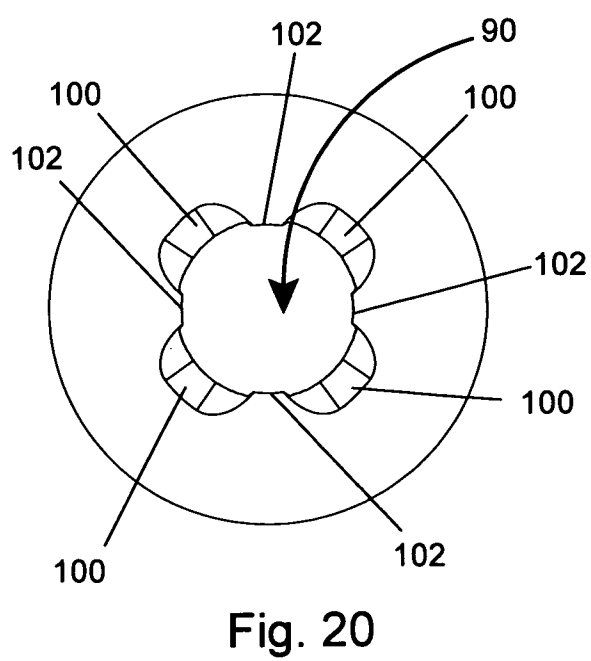
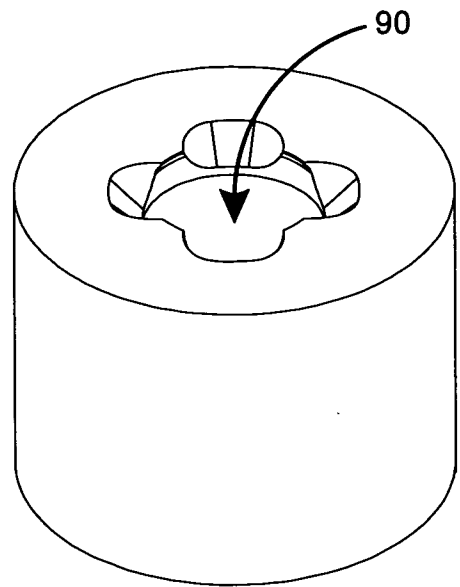
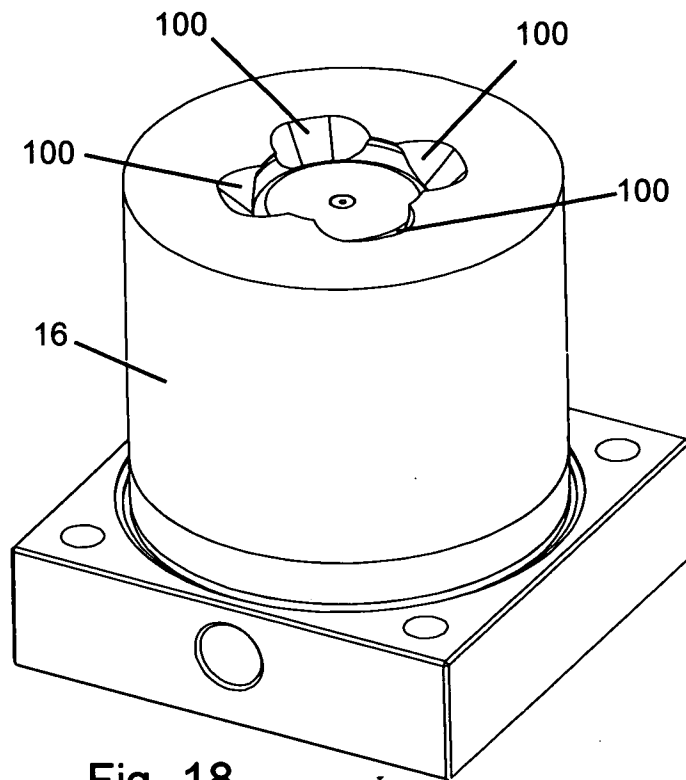


Fig. 17

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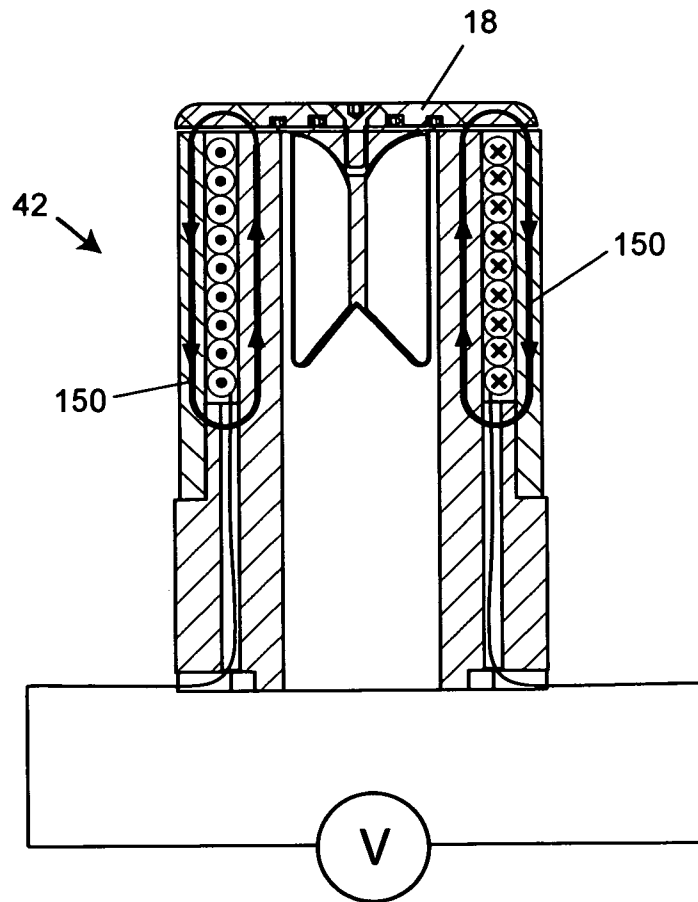


Fig. 22

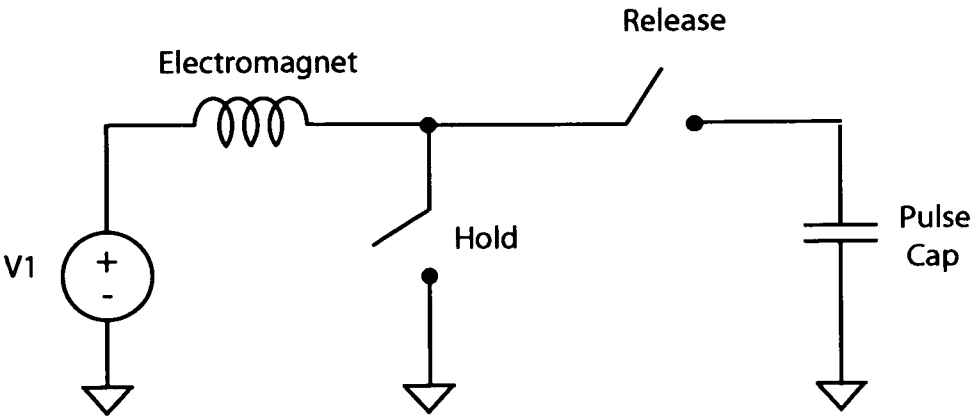


Fig. 23

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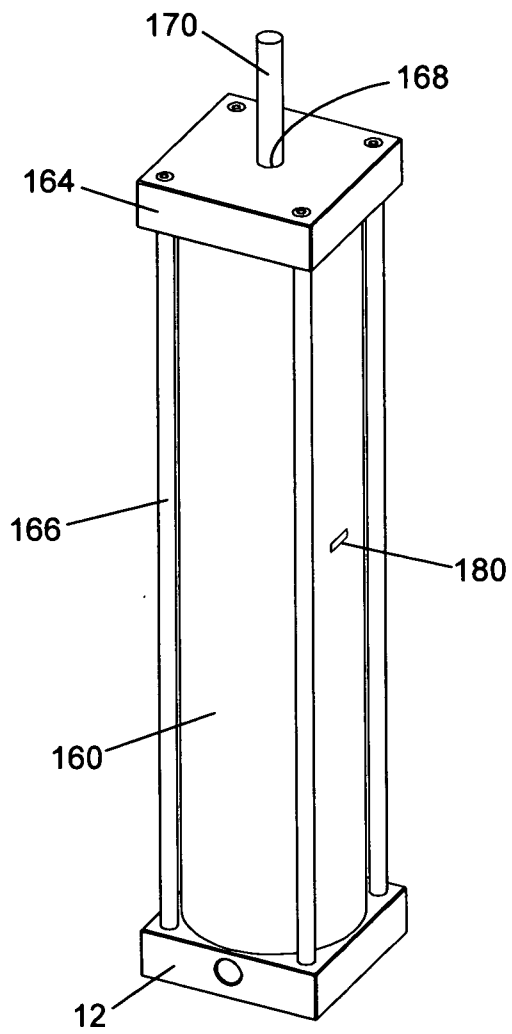


Fig. 24

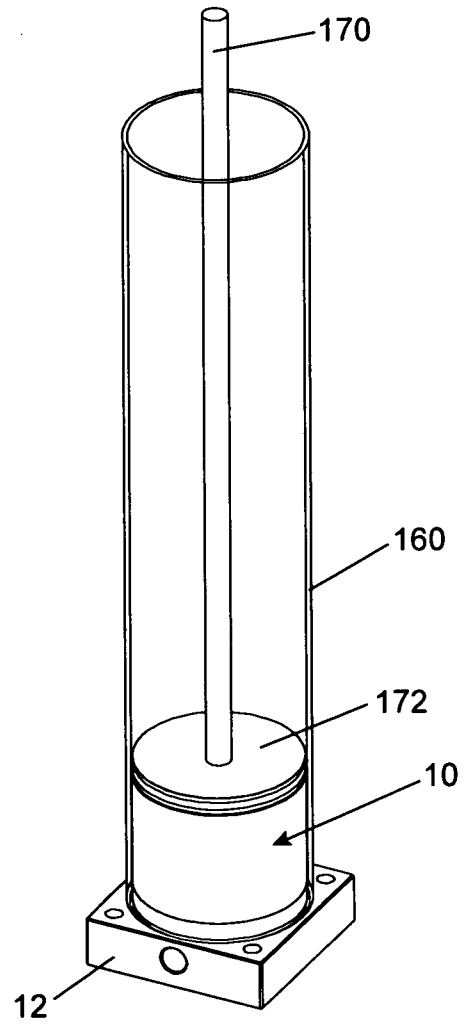


Fig. 25

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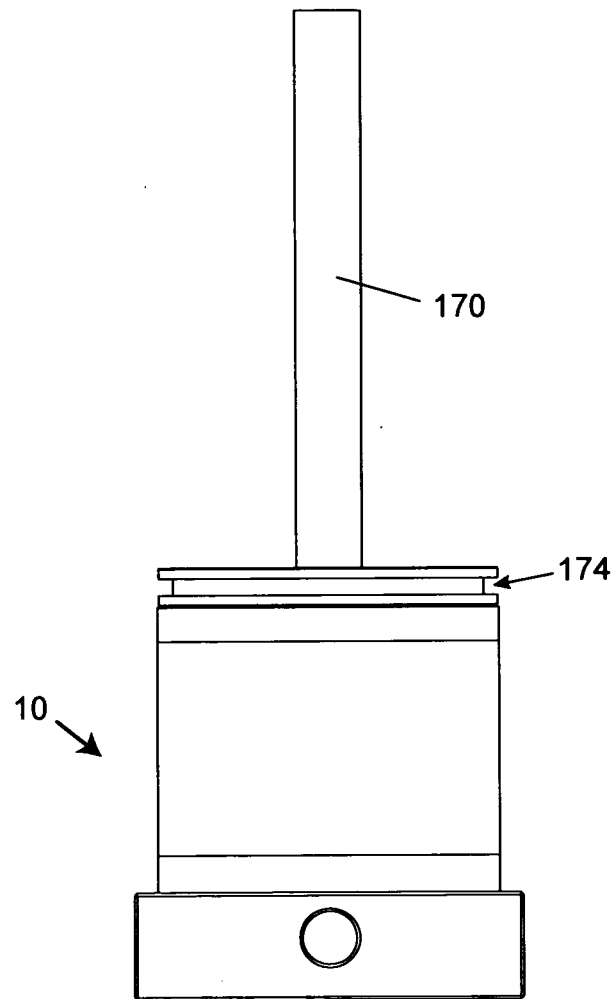


Fig. 26

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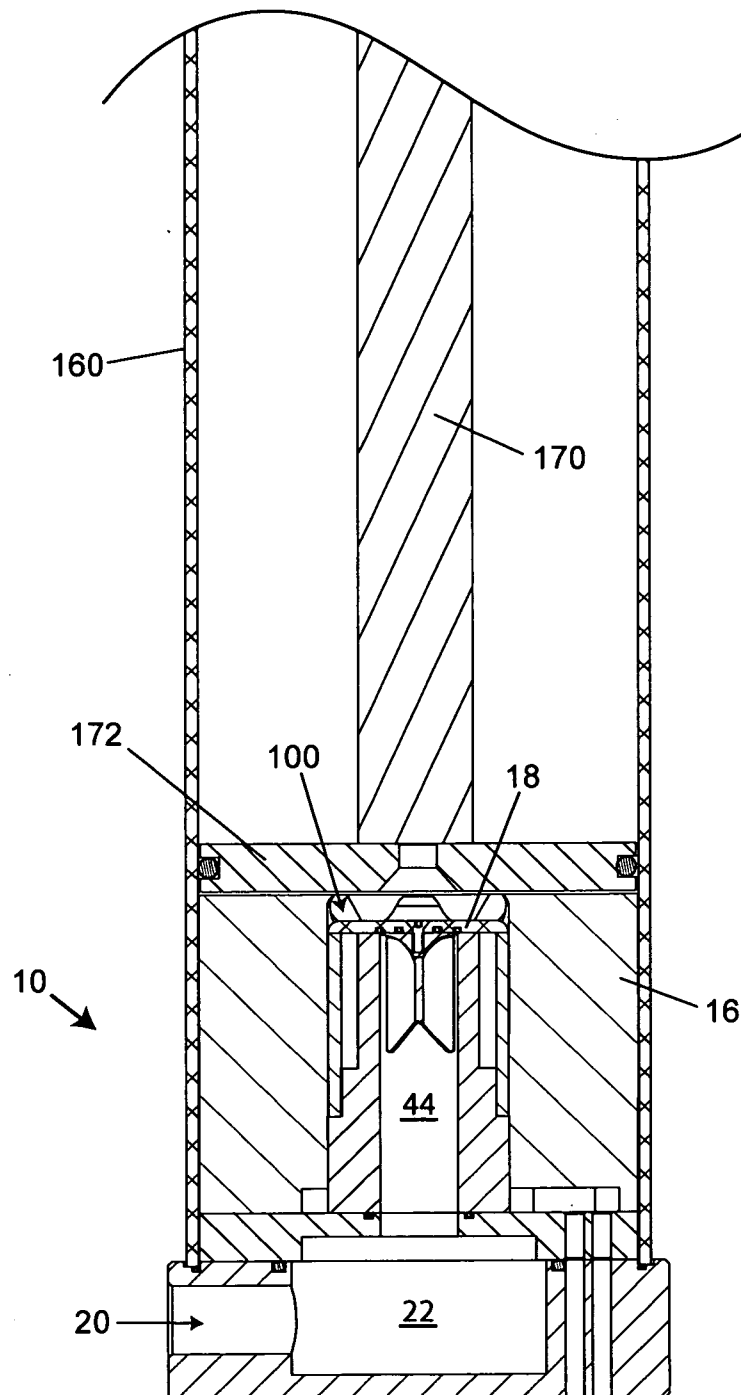


Fig. 27

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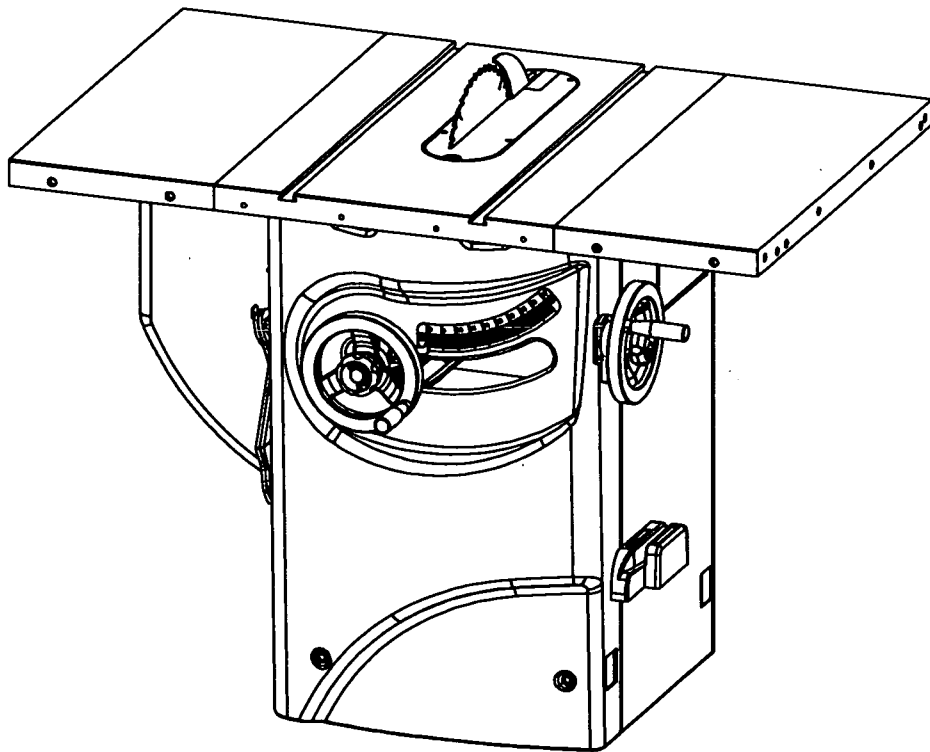


Fig. 28

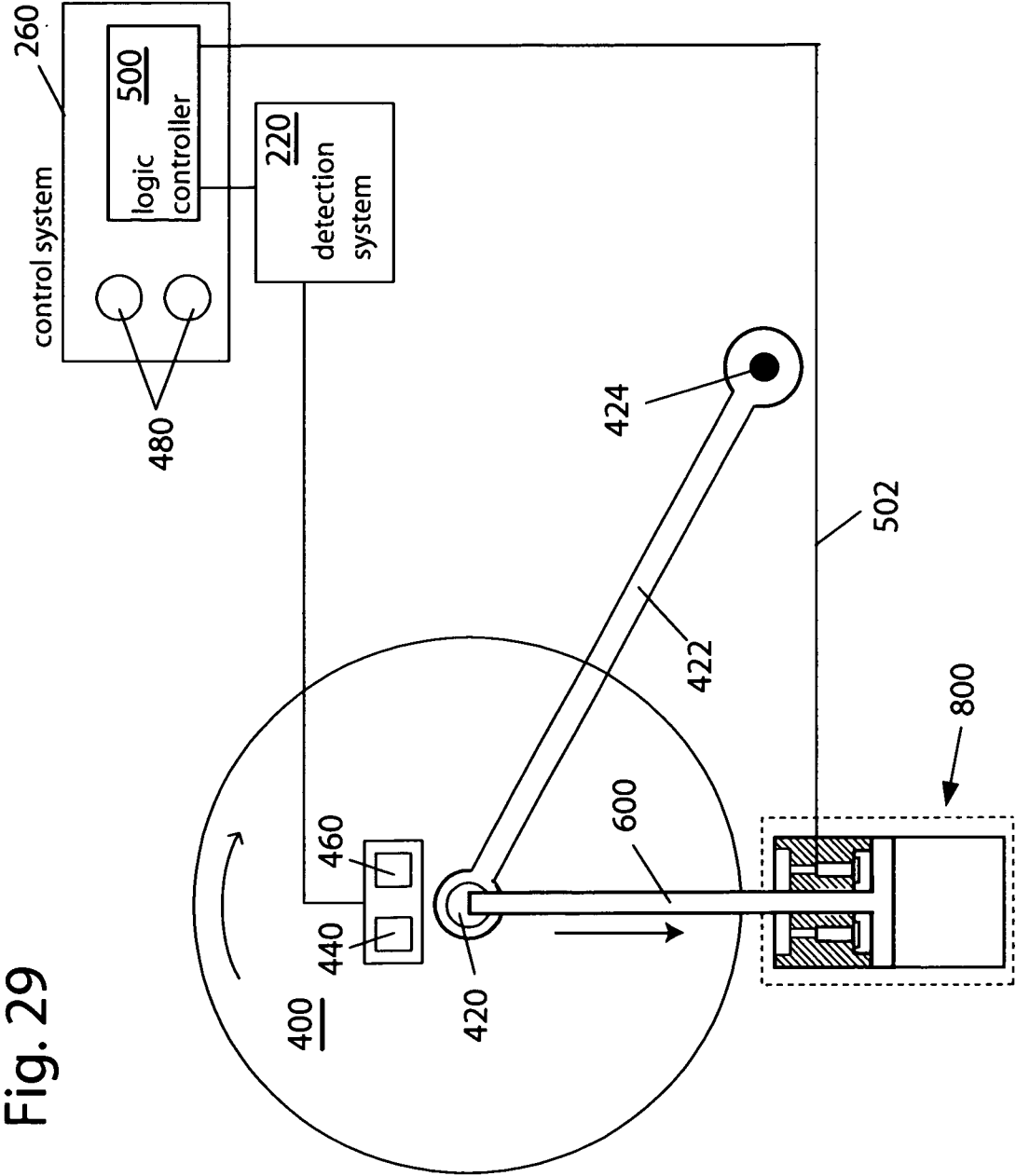
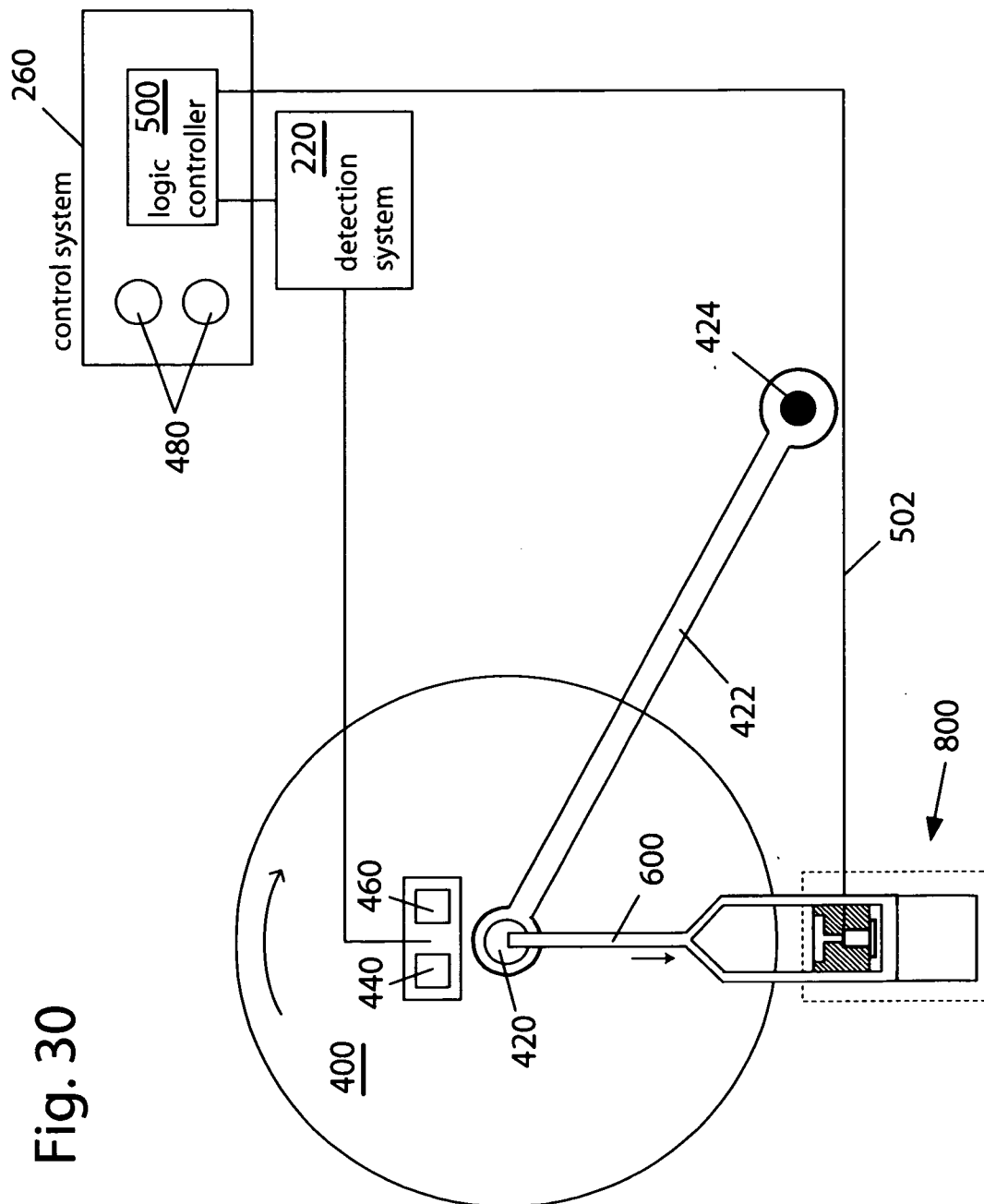


Fig. 30



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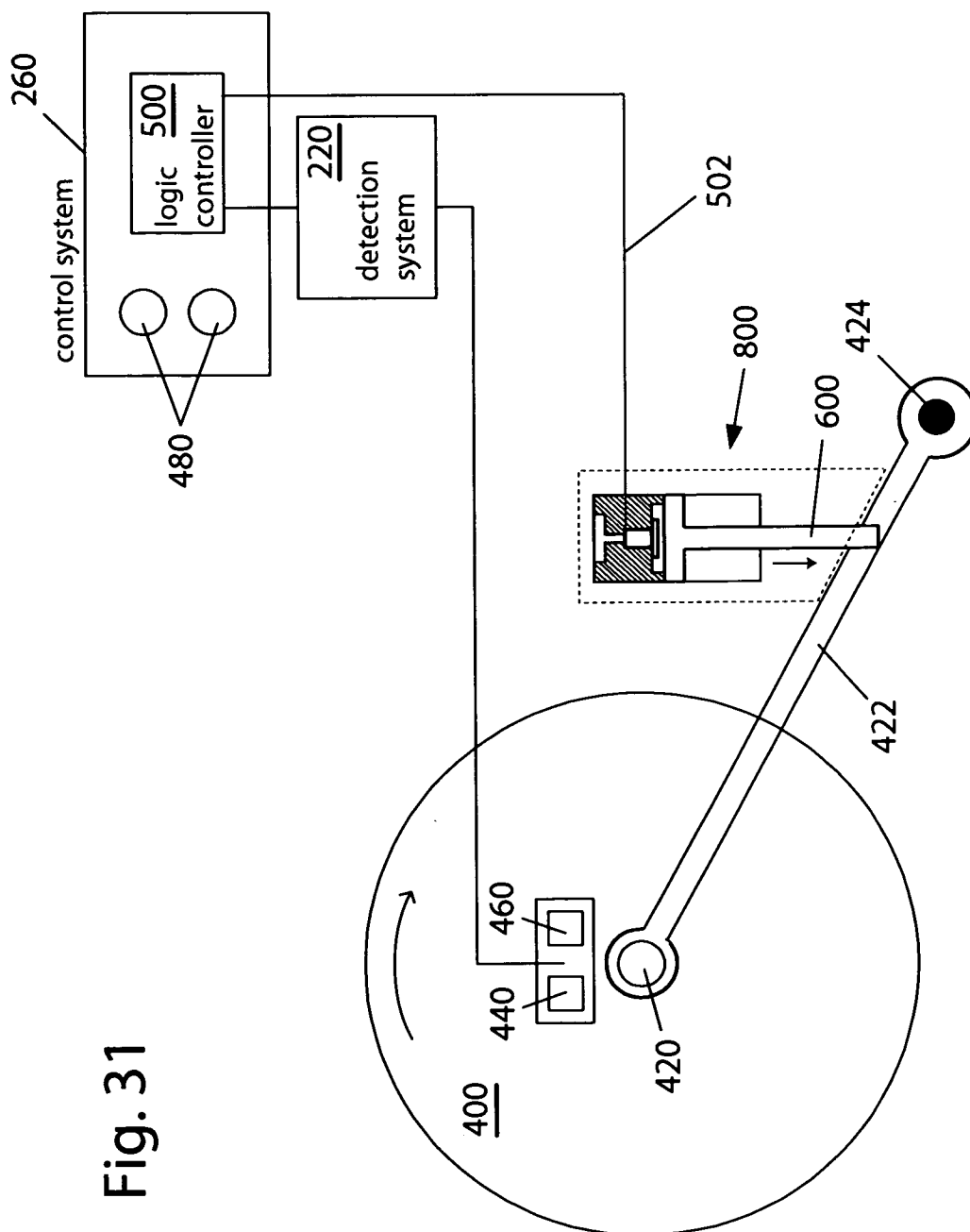


Fig. 31

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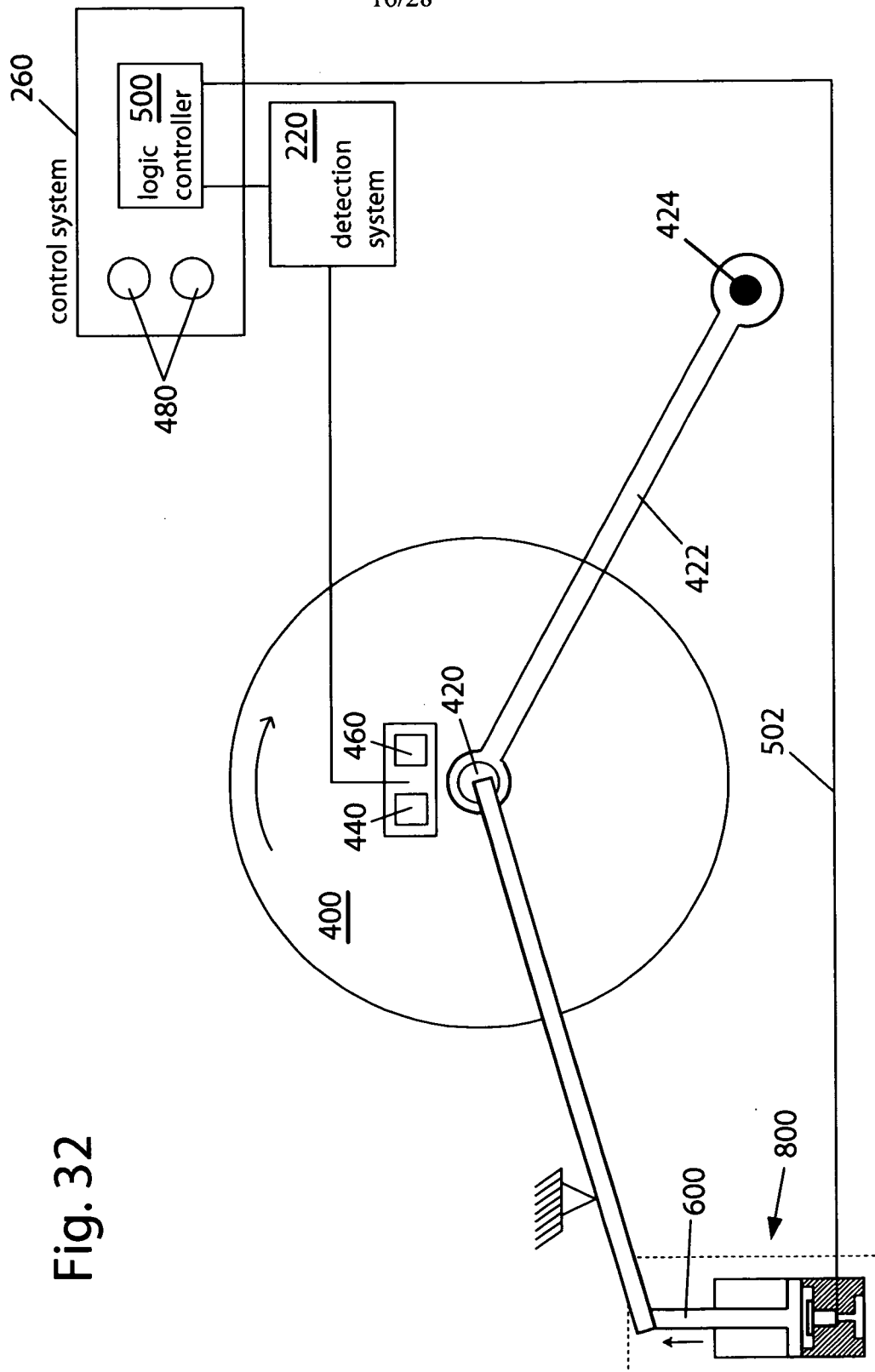


Fig. 32

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Fig. 33

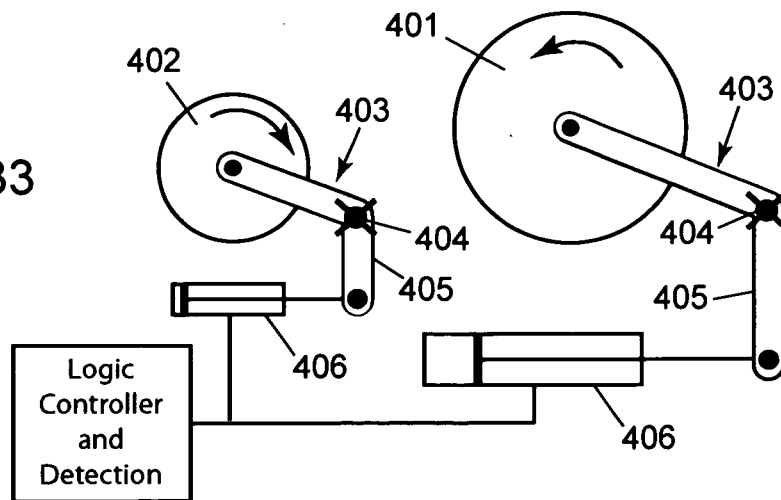


Fig. 34

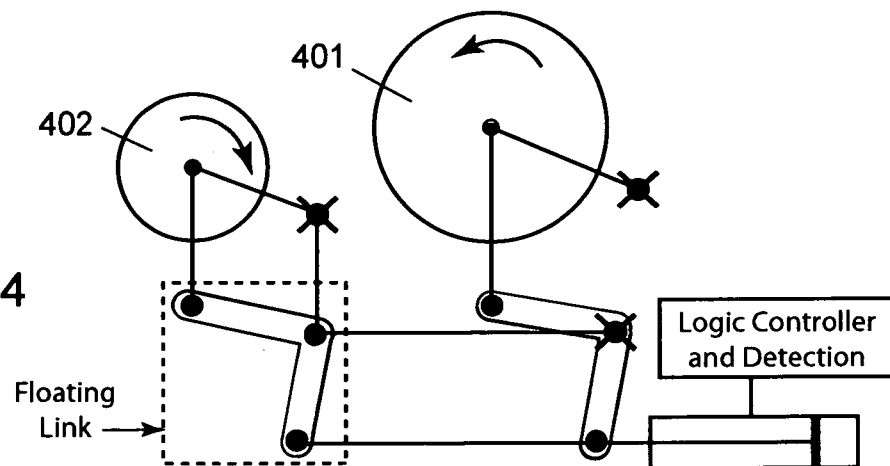
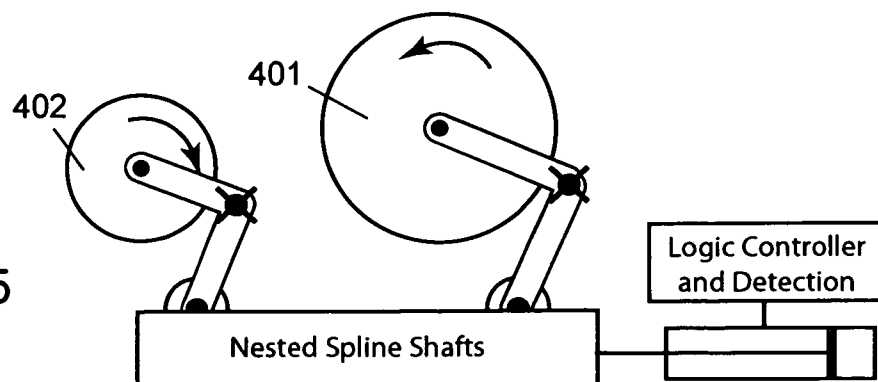


Fig. 35



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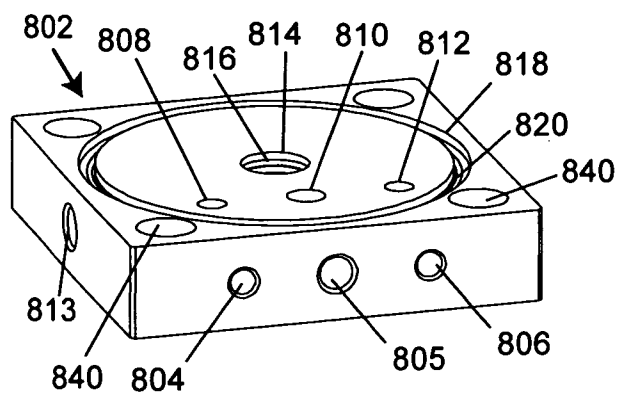


Fig. 36

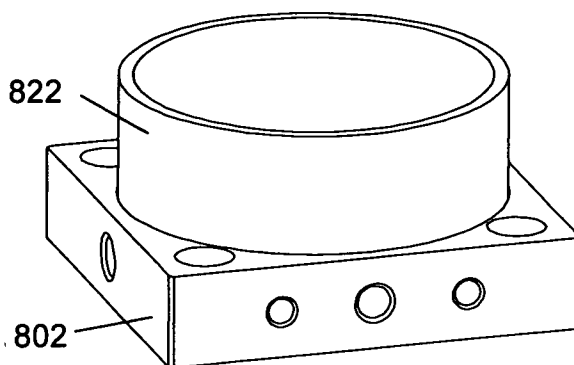


Fig. 37

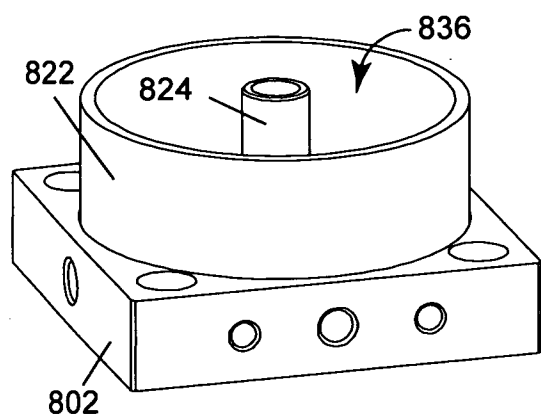


Fig. 38

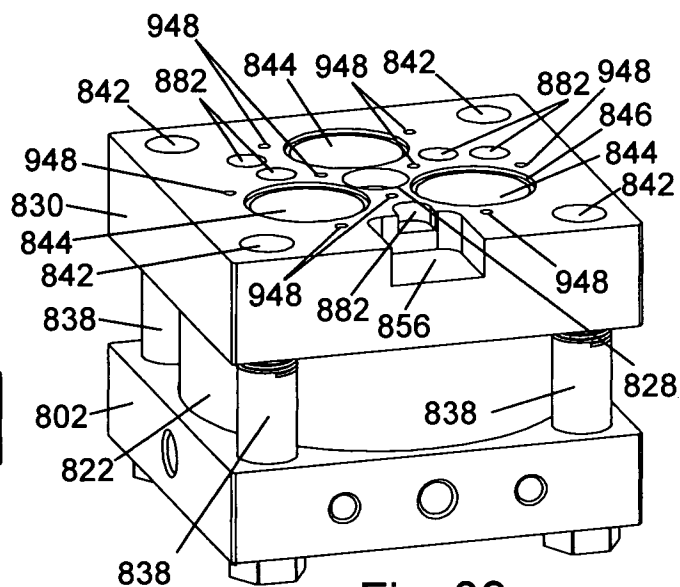


Fig. 39

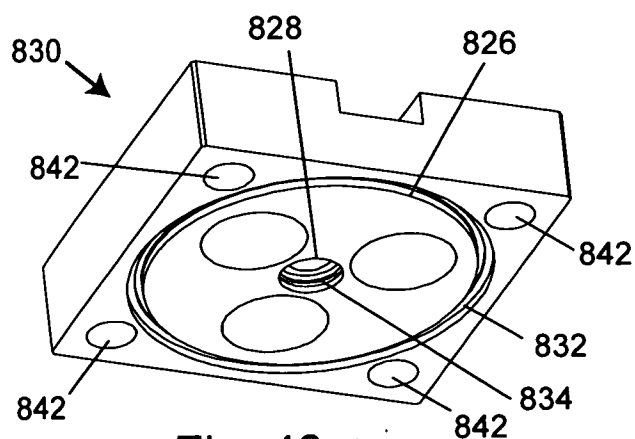


Fig. 40

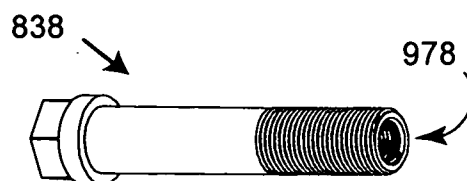


Fig. 41

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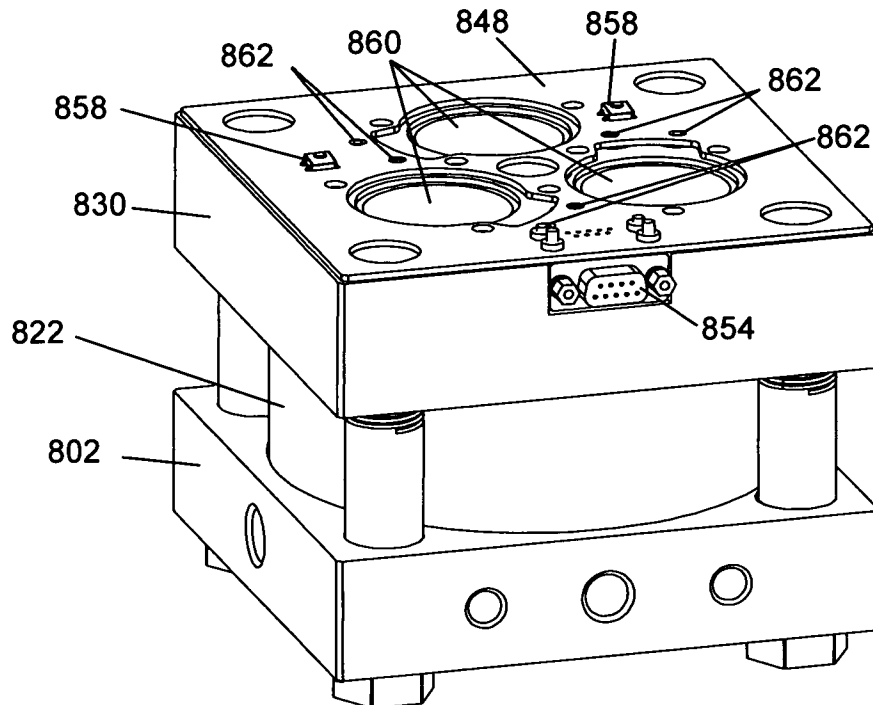


Fig. 42

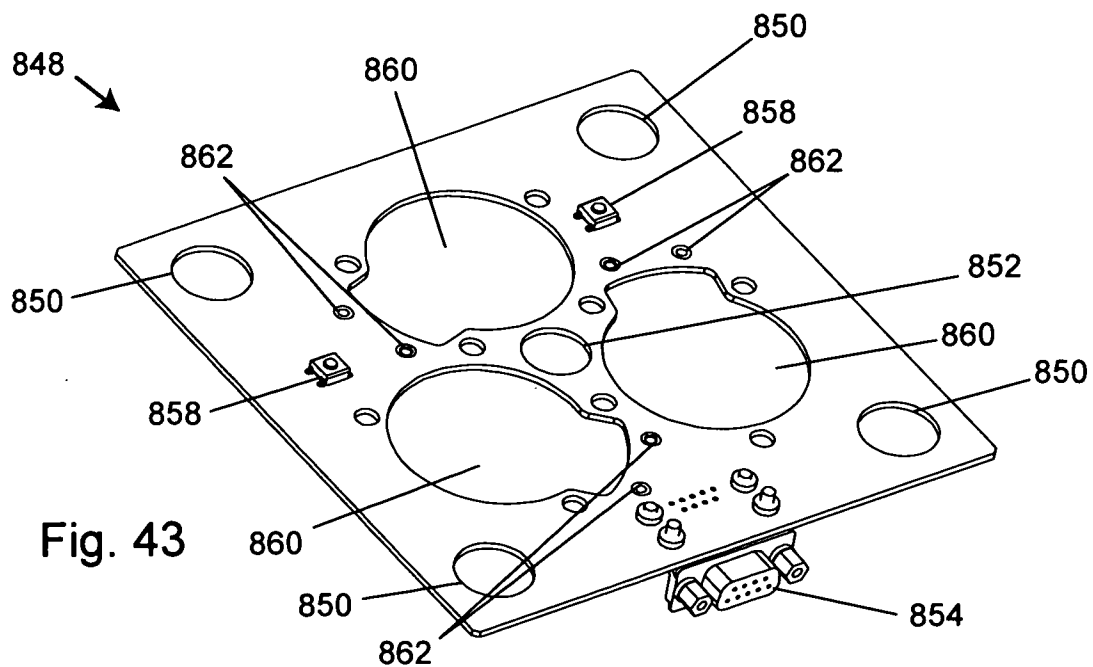


Fig. 43

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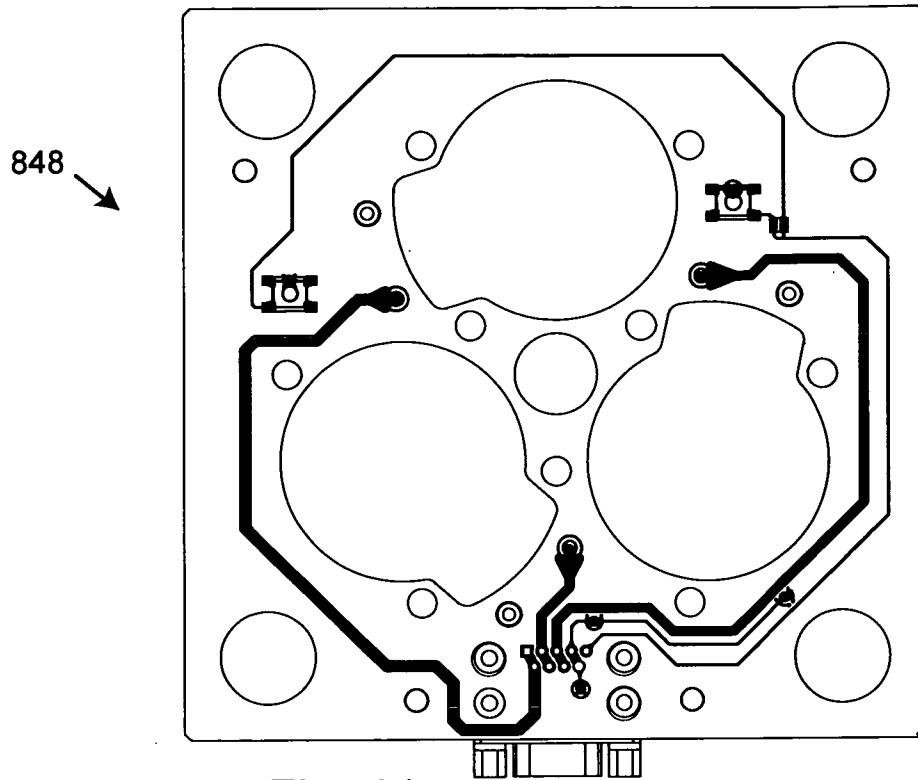


Fig. 44

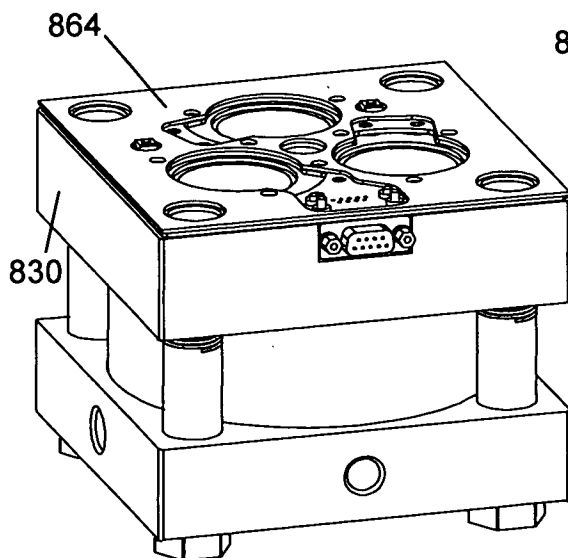


Fig. 45

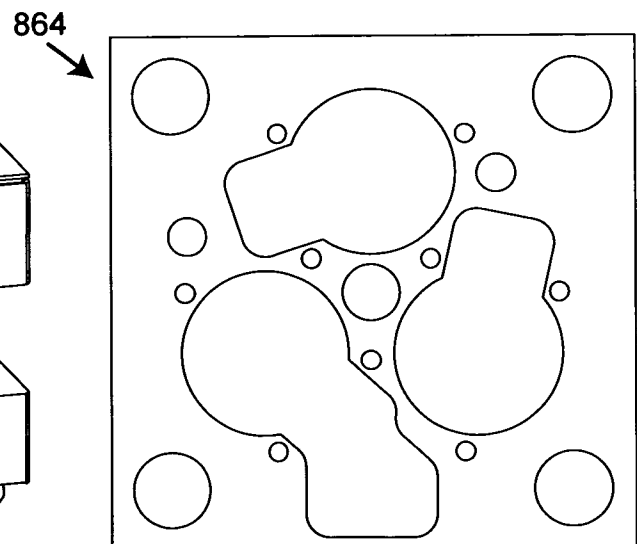
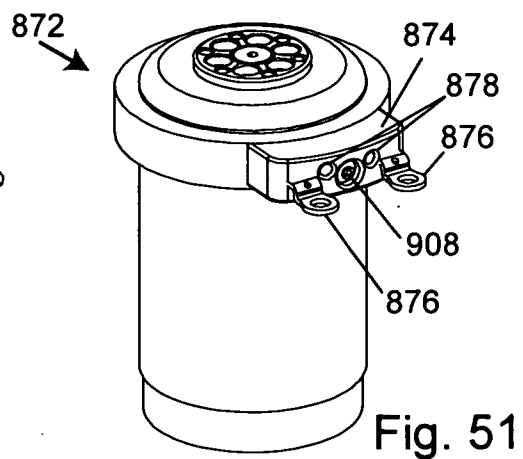
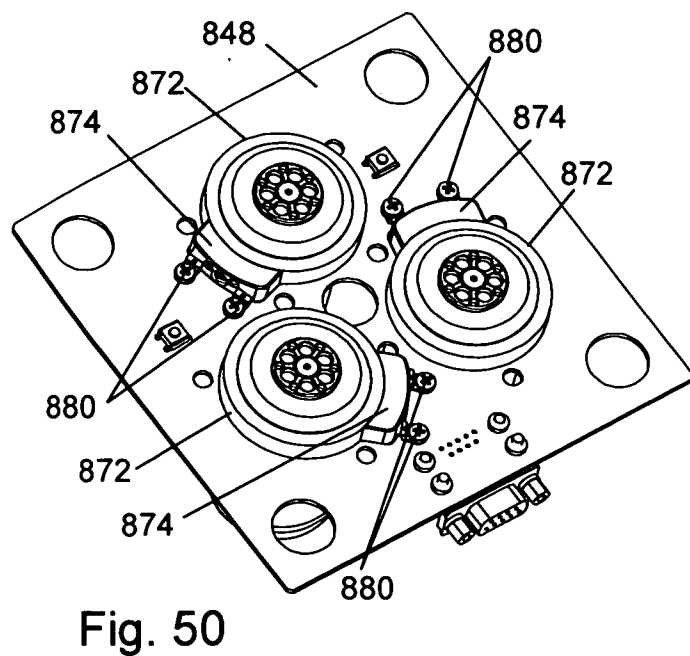
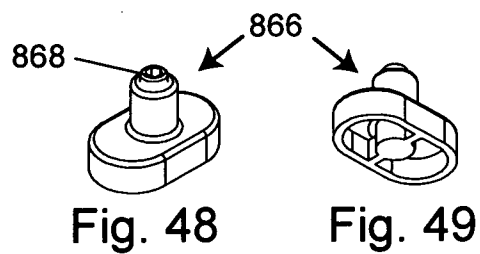
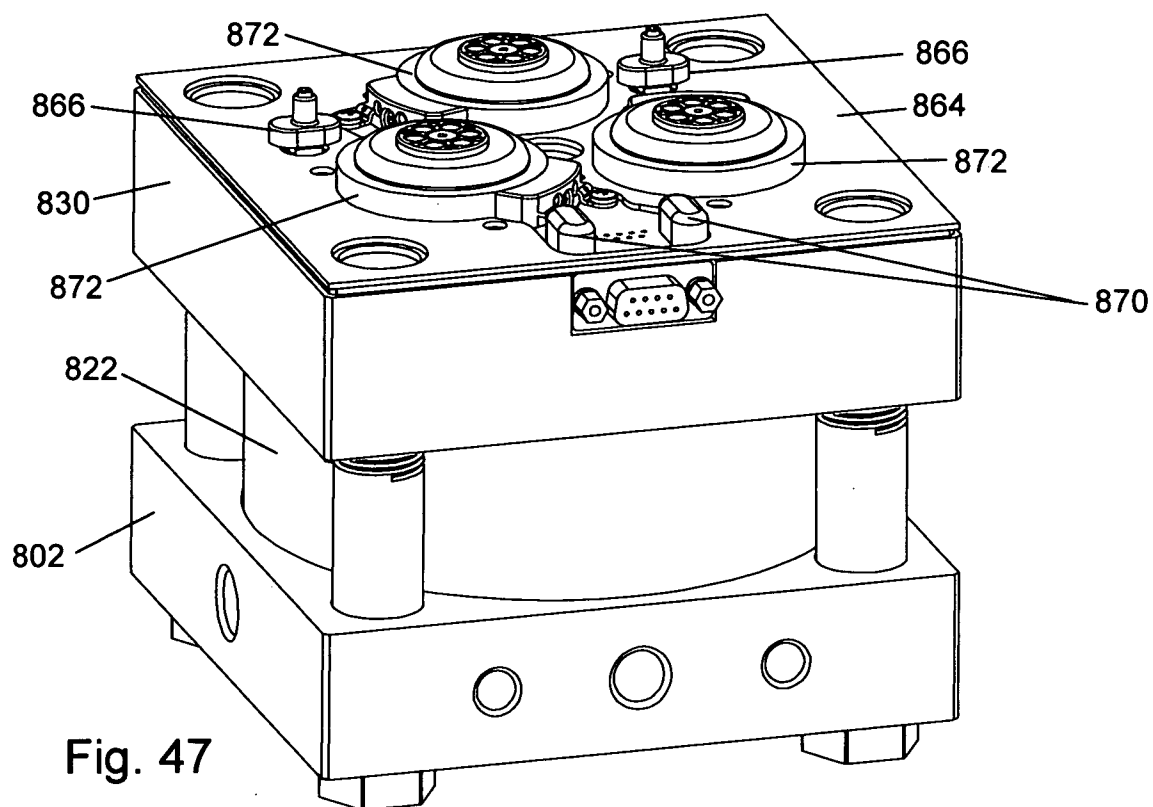


Fig. 46

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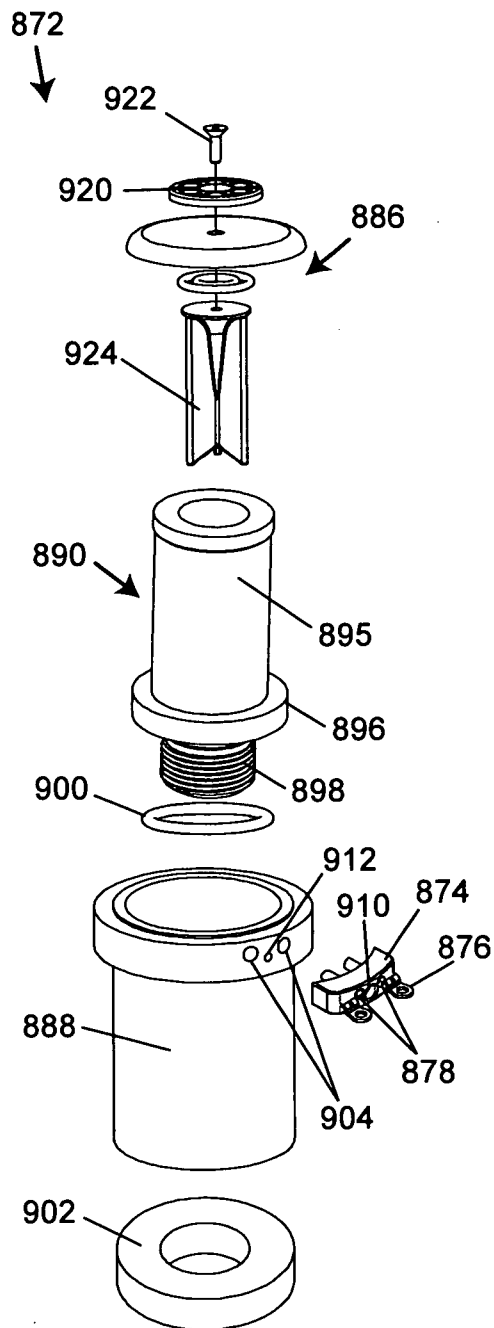


Fig. 52

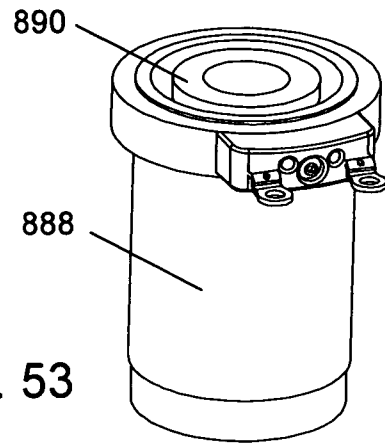


Fig. 53

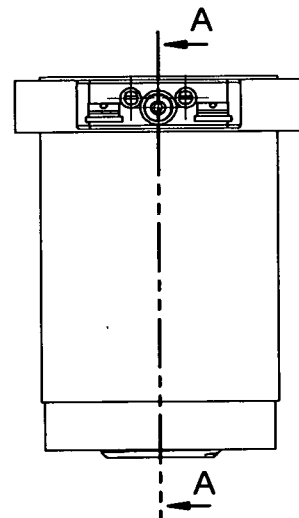


Fig. 54

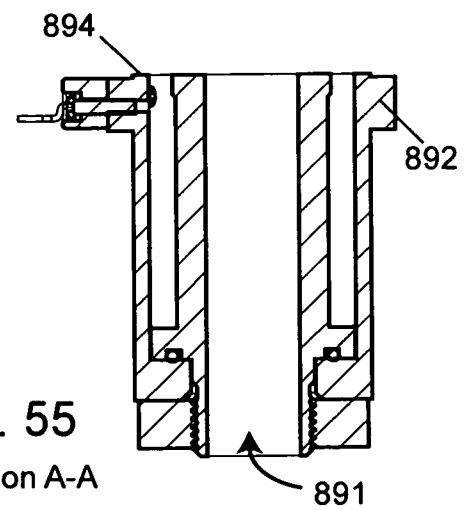


Fig. 55
Section A-A

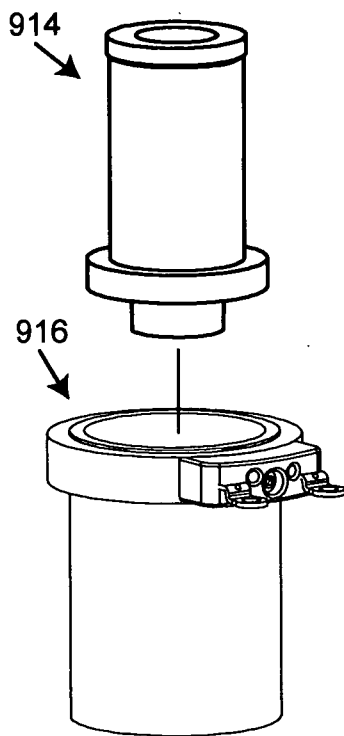


Fig. 56

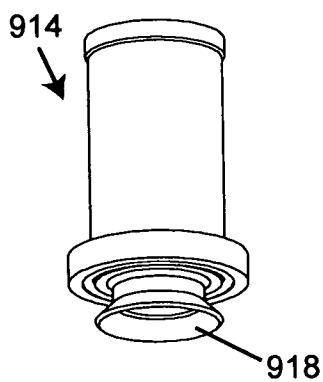


Fig. 57

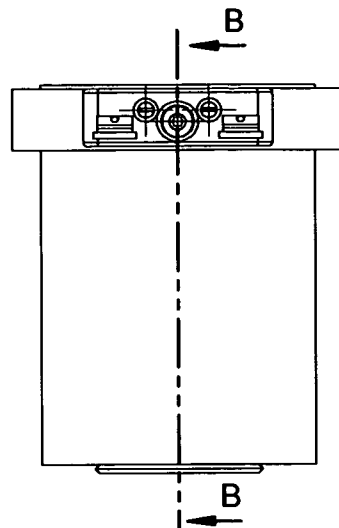


Fig. 58

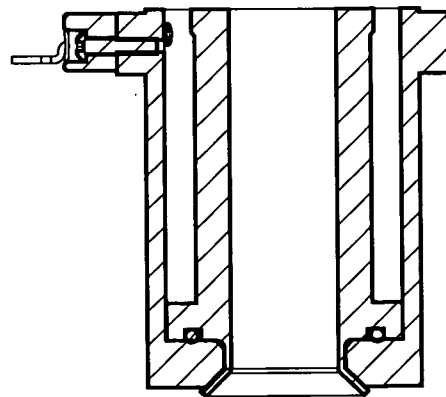


Fig. 59

Section B-B

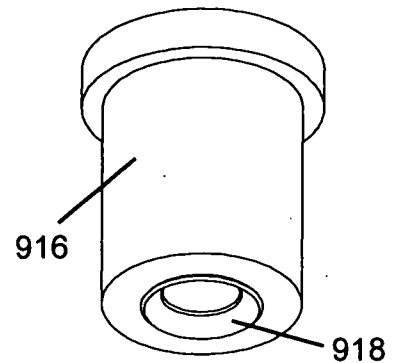


Fig. 60

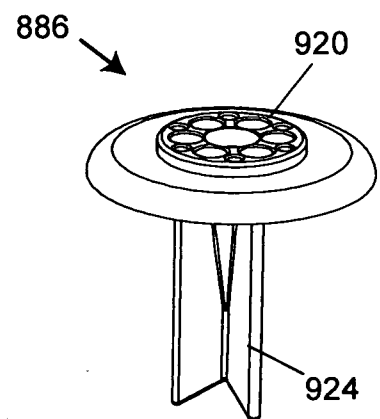


Fig. 61

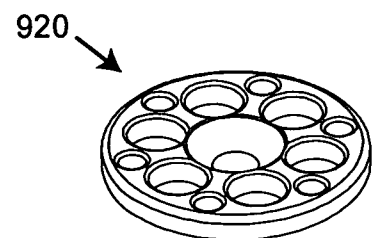


Fig. 62

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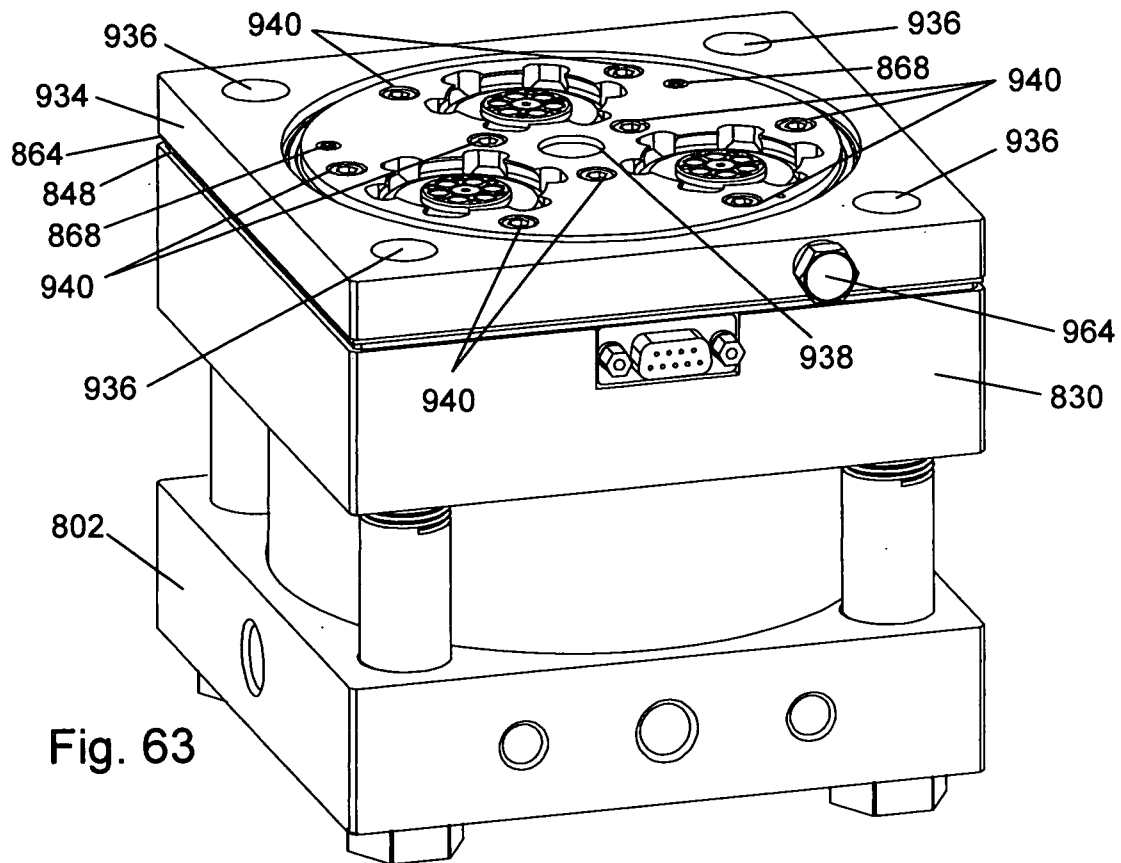


Fig. 63

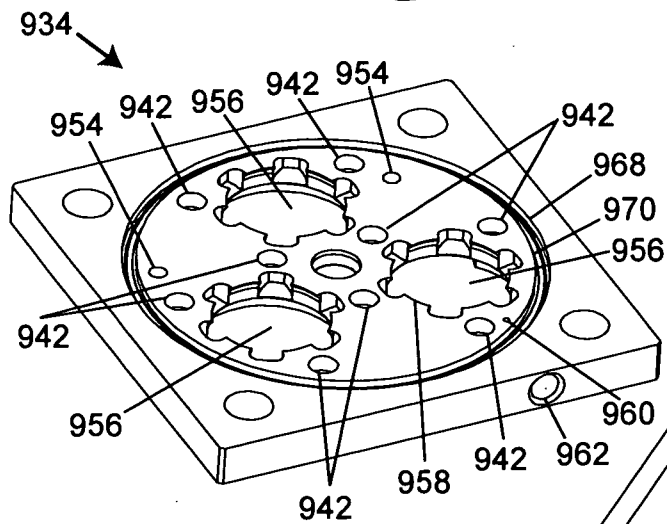


Fig. 64

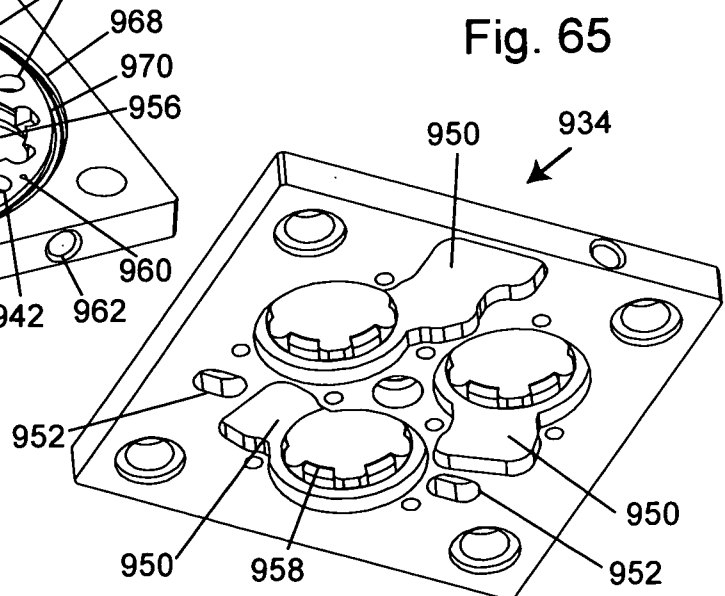


Fig. 65

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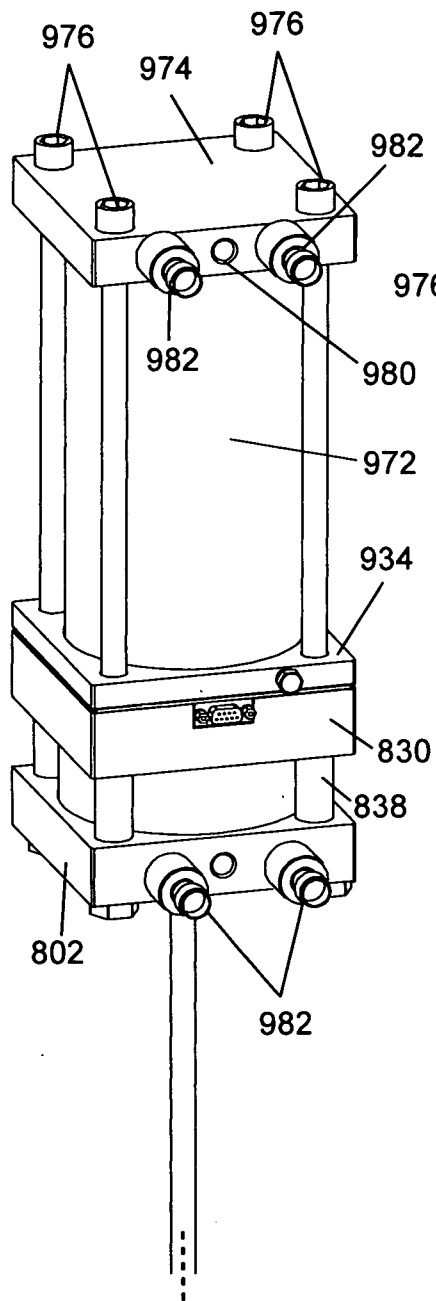


Fig. 66

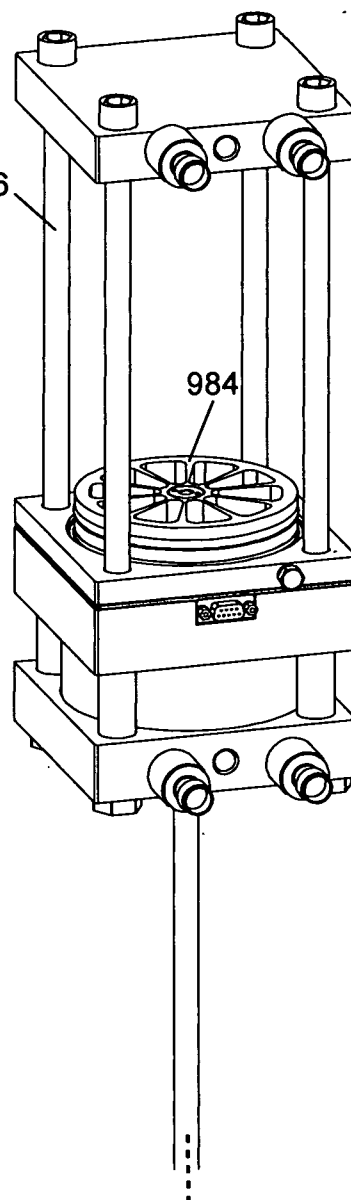


Fig. 67

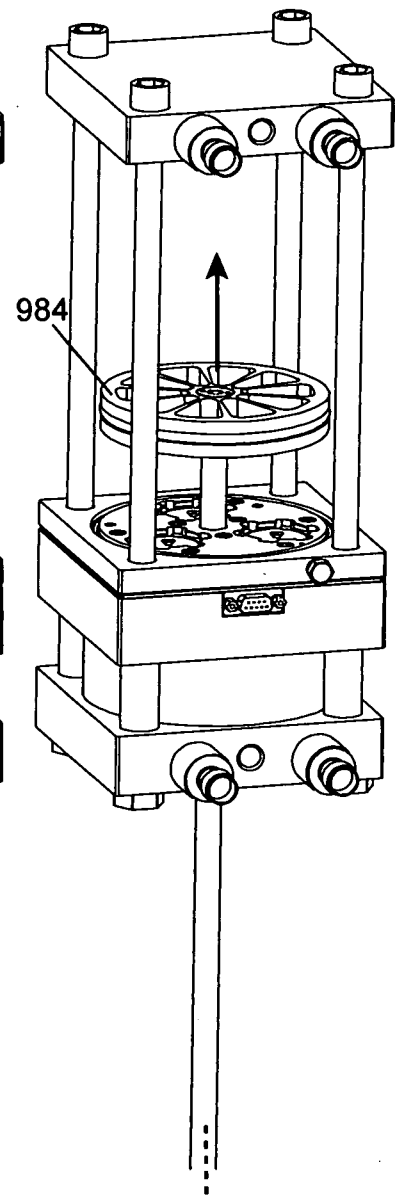
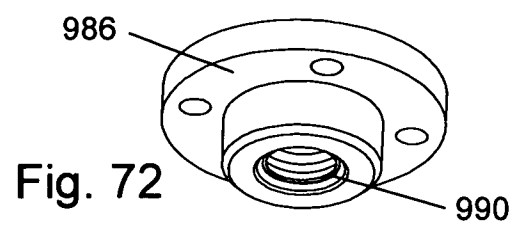
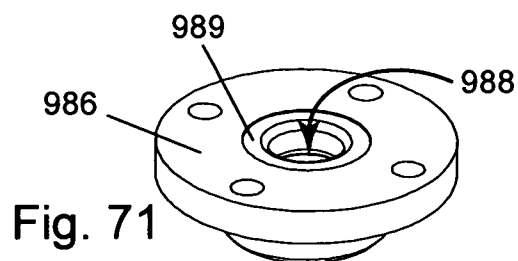
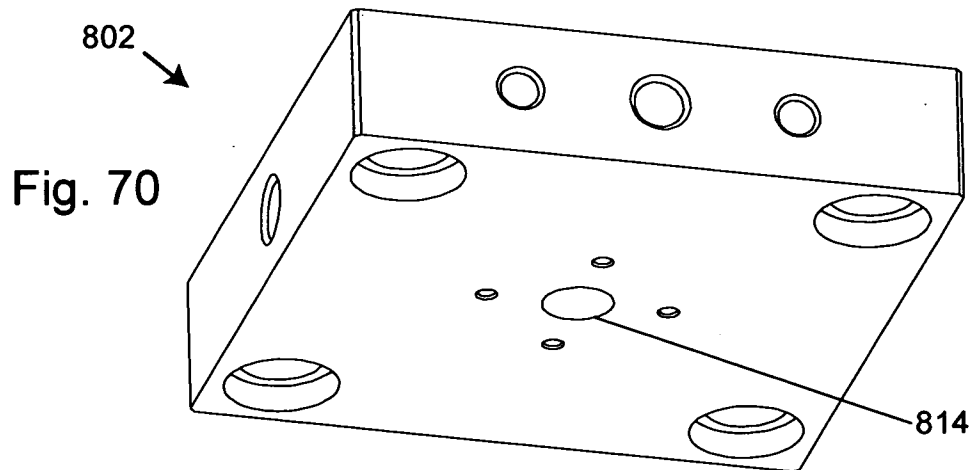
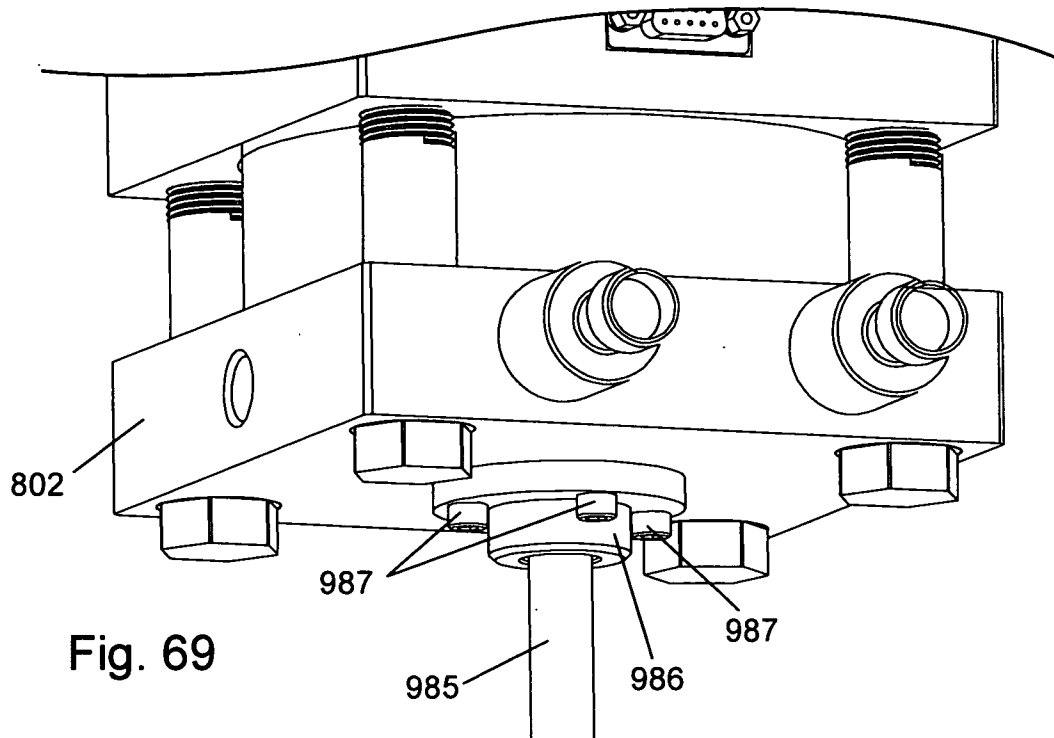
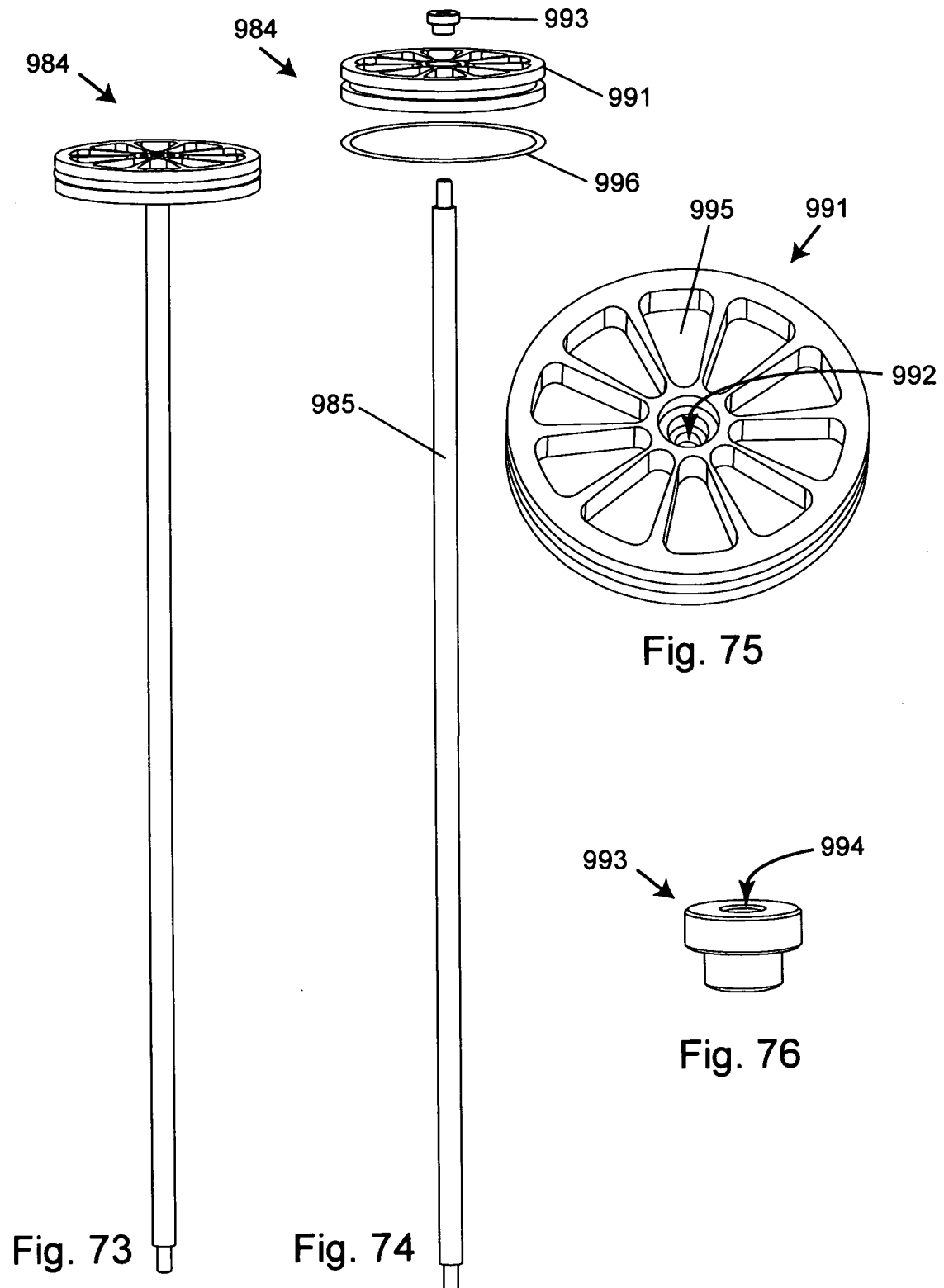


Fig. 68

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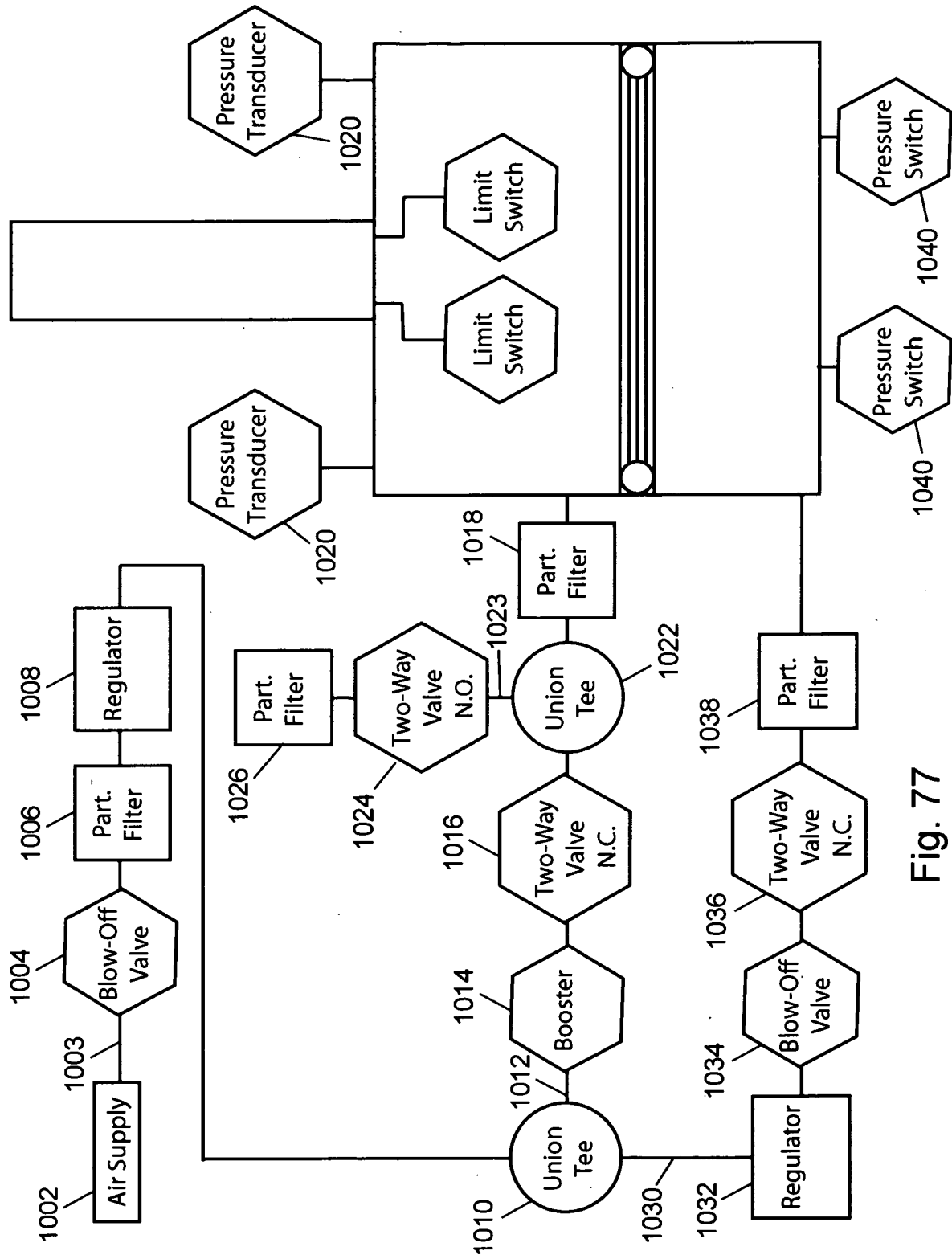


Fig. 77

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 10/02634

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B23D 47/10 (2010.01)

USPC - 83/62.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC: 83/62.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC: 83/58,62,62.1,471,471.2,477.2,477,477.1, 483,490,397.1,DIG1; 83/\$

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPTO PatFT, AppFT; PubWEST; Google Scholar. Terms: gas, air, fluid, pneumatic, hydraulic, pressur\$, compress\$, saw, tool, safety, emergency, danger\$, detect\$, sensor, electromagnet\$, actuat\$, retract\$, blade, knife, charge, reservoir, tank, chamber, piston, plunger, distance, locat\$, valve, cap, newton, psi, pound

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0029864 A1 (Bauer, et al). 10 February 2005 (10.02.2005). para [0001], [0056]-[0060]; Fig. 3.	1-13
Y	US 2006/0032352 A1 (Gass, et al) 16 February 2006 (16.02.2006). para [0020], [0022]-[0025], [0046]-[0047], [0052]-[0053], [0074]; Fig. 1, 5.	1-10
Y	US 3,894,460 A (Lurnn). 15 July 1975 (15.07.1975). col 4, ln 7-12, 42-58; Fig. 1-2A.	3-4, 6-7
Y	US 3,800,645 A (Alcock, et al). 02 April 1974 (02.04.1974). col 4, ln 32-47; col 5, ln 24-57; col 7, ln 2-9; Fig. 3, 9.	11-13

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 November 2010 (19.11.2010)

Date of mailing of the international search report

02 DEC 2010

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
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