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(54) TRANSDUCERIZED ROTARY TOOL

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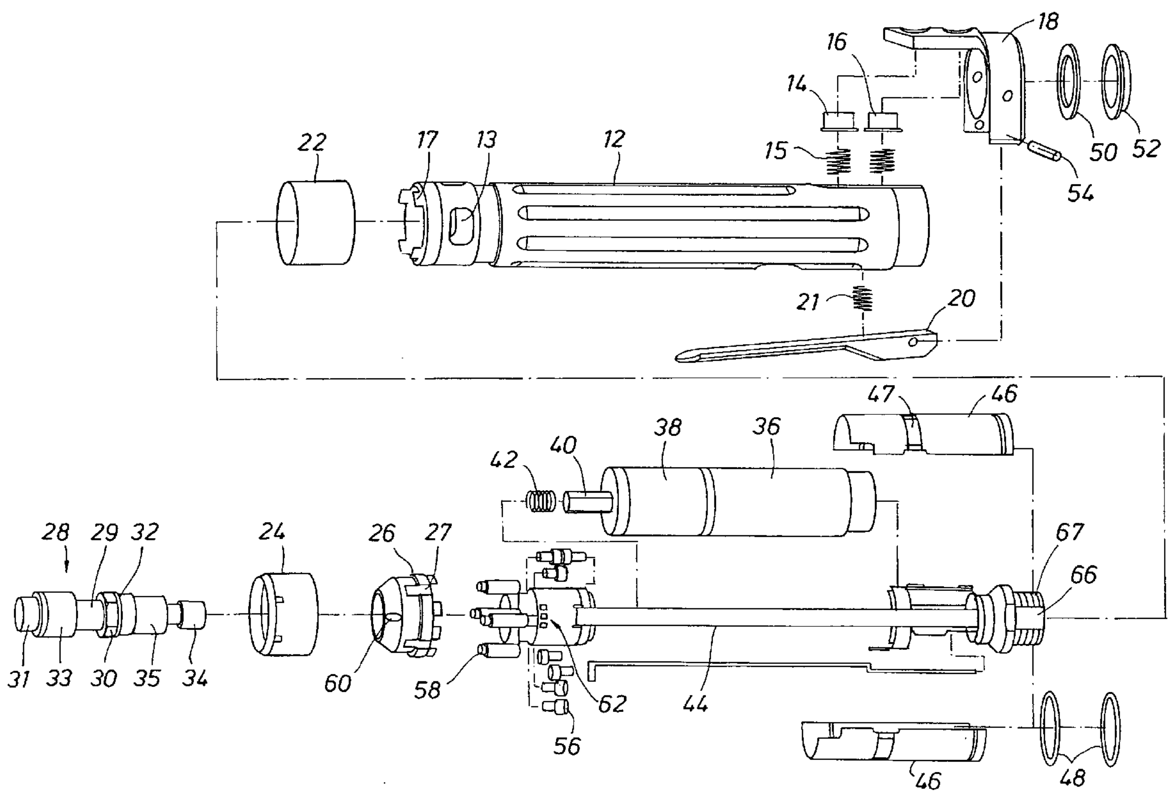
(57) ABSTRACT

Disclosed herein is a variable speed tool useful for use with securing or removing industrial fasteners. The tool also includes a means to torque the fastener to a certain precise torque. The tool can be used with an associated controller that provides control commands to the tool.



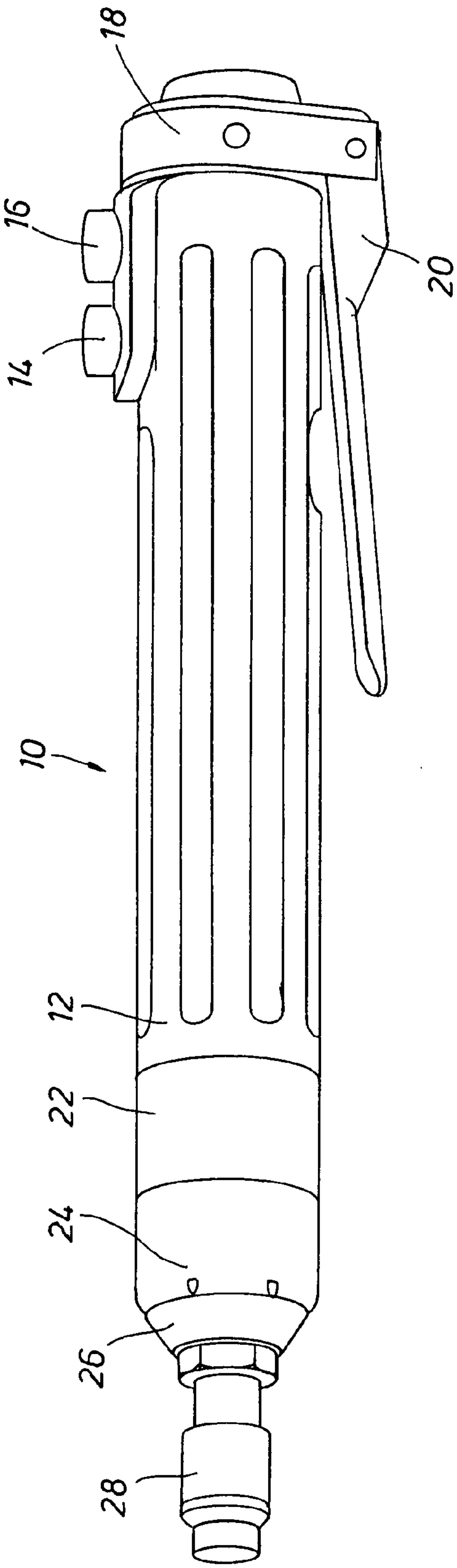


FIG.1A

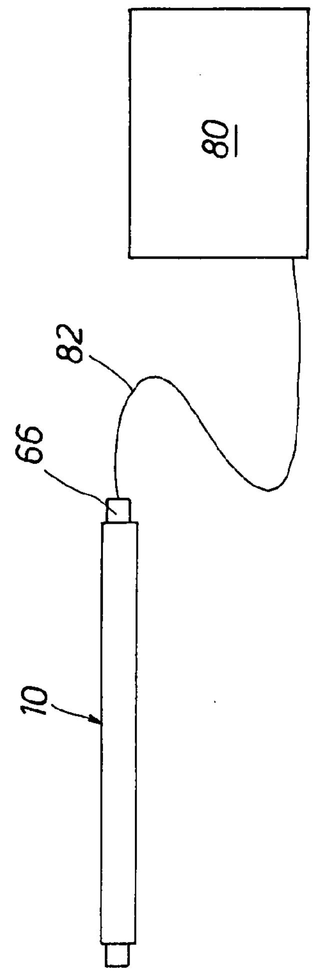


FIG.5

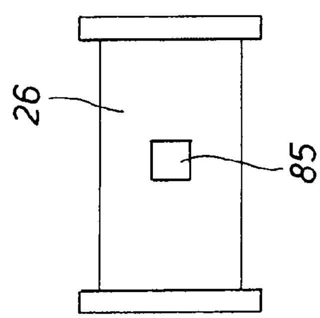


FIG.2H

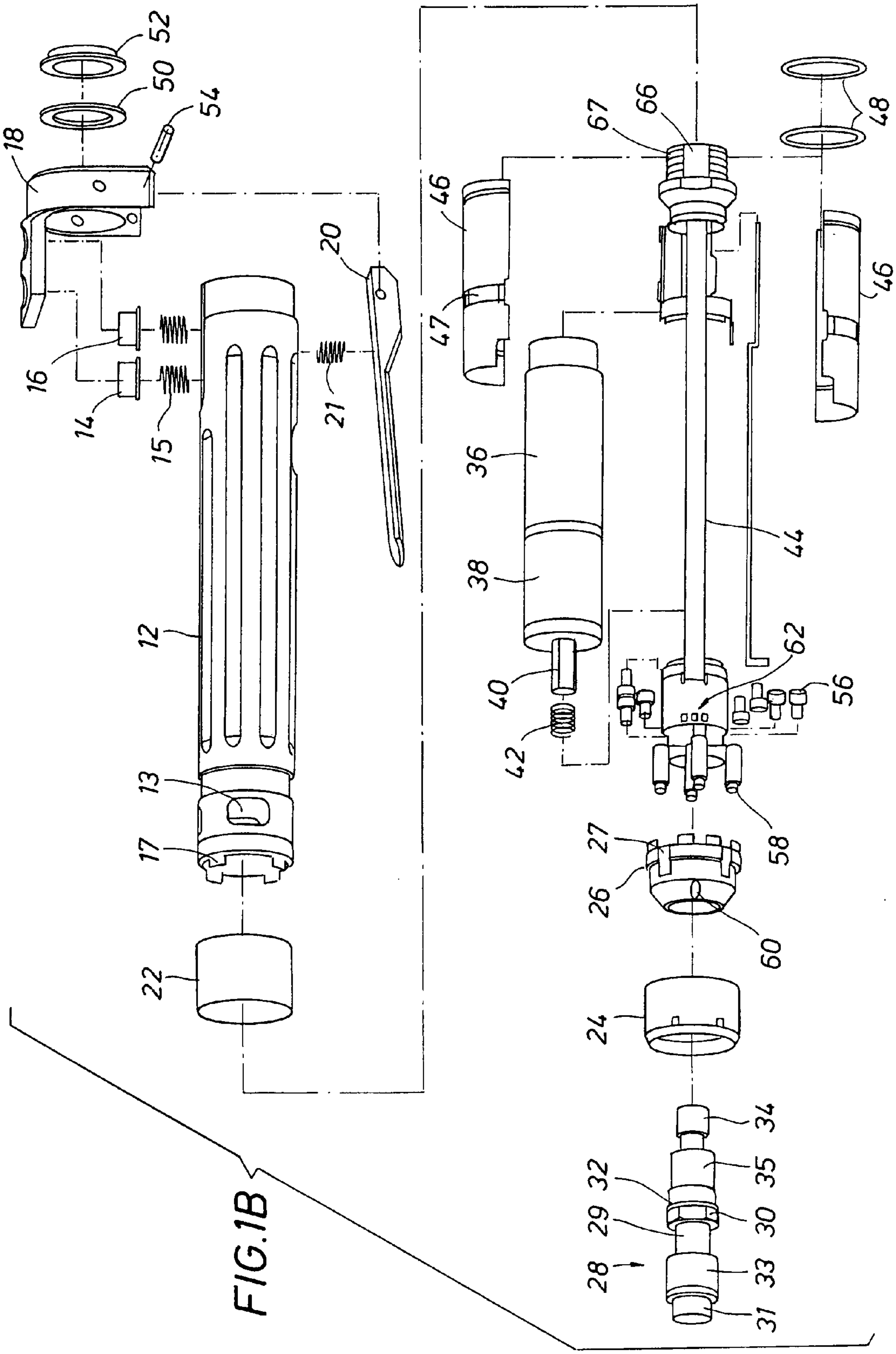

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FIG.1B

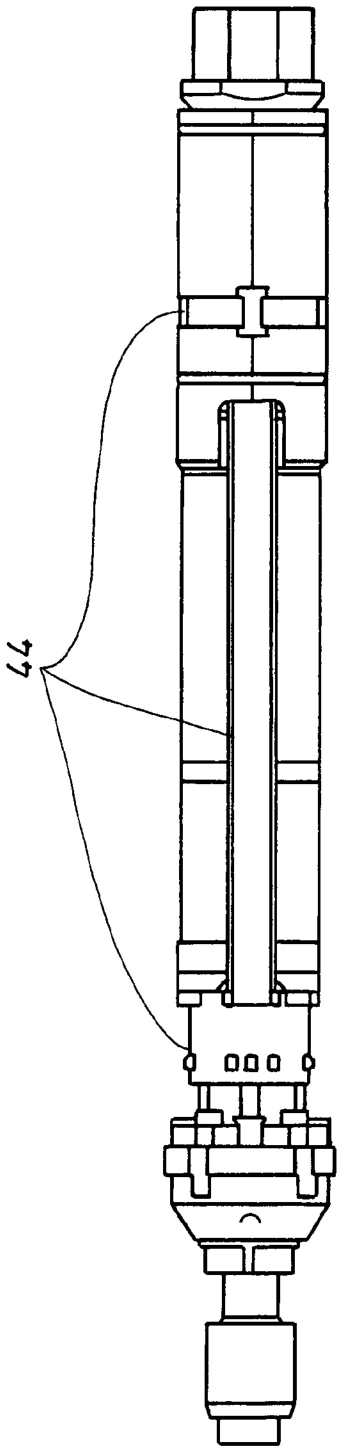


FIG. 2A

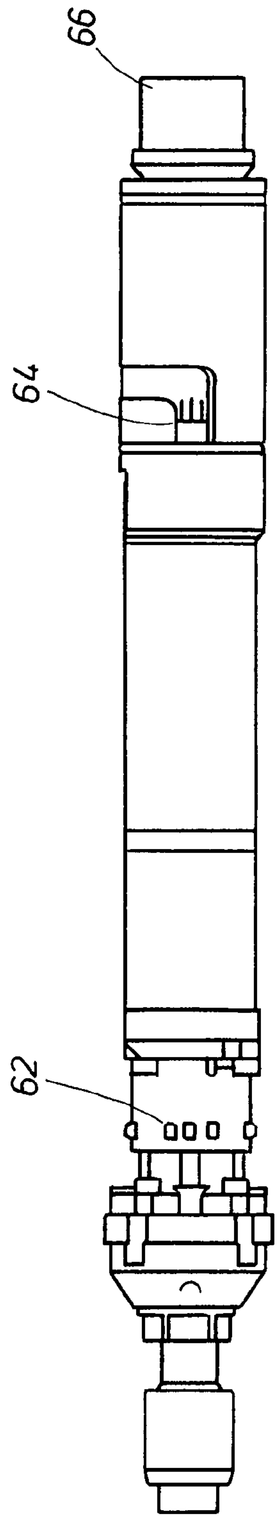


FIG. 2B

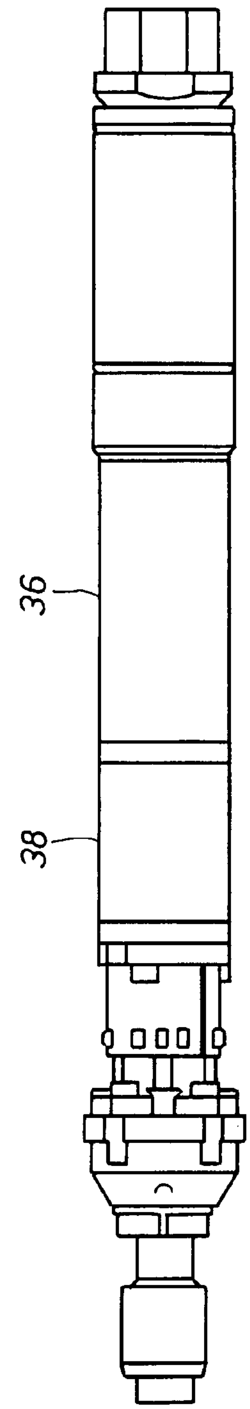


FIG. 2C

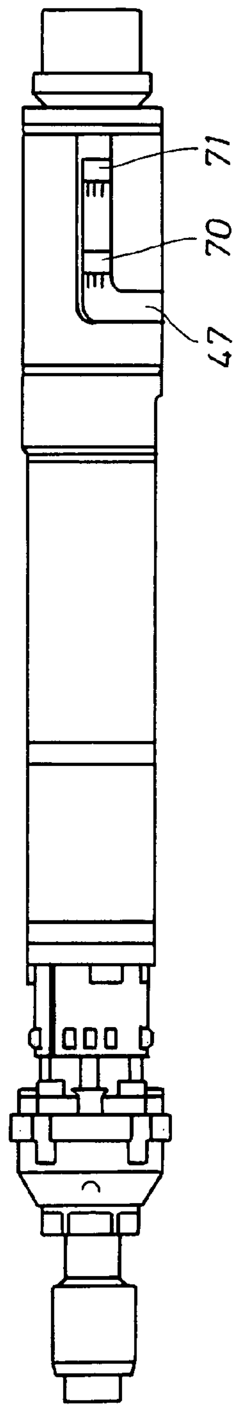


FIG. 2D

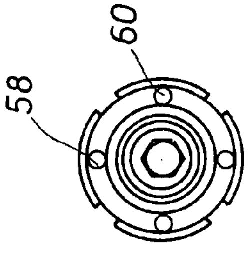


FIG. 2G

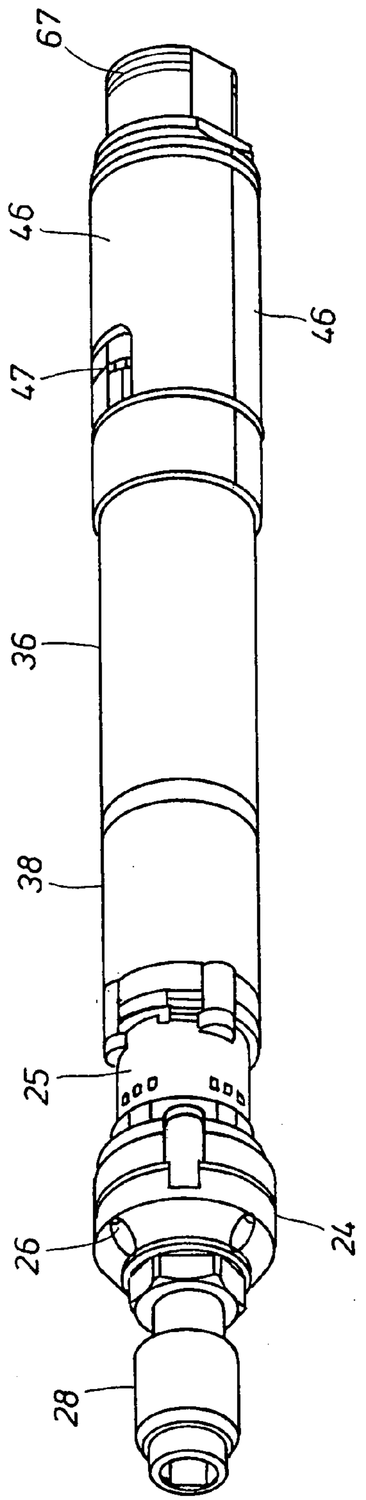


FIG. 2E

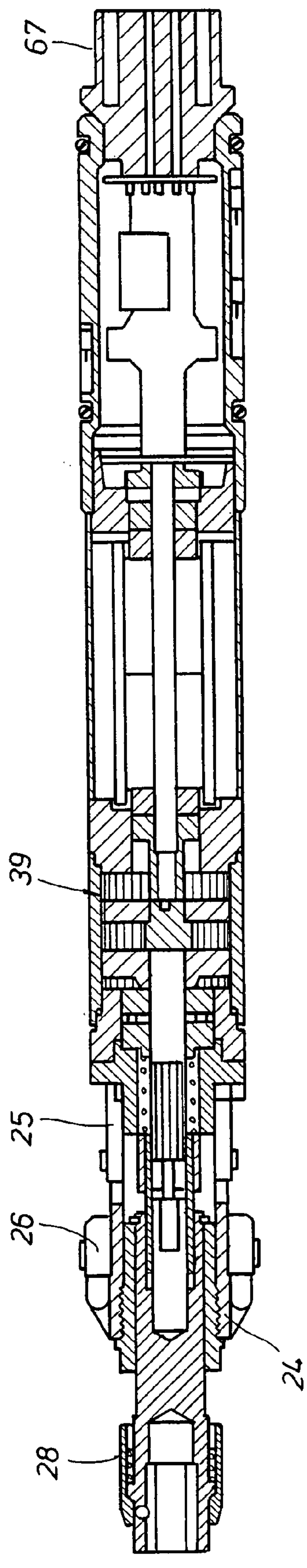


FIG. 2F

FIG. 3A

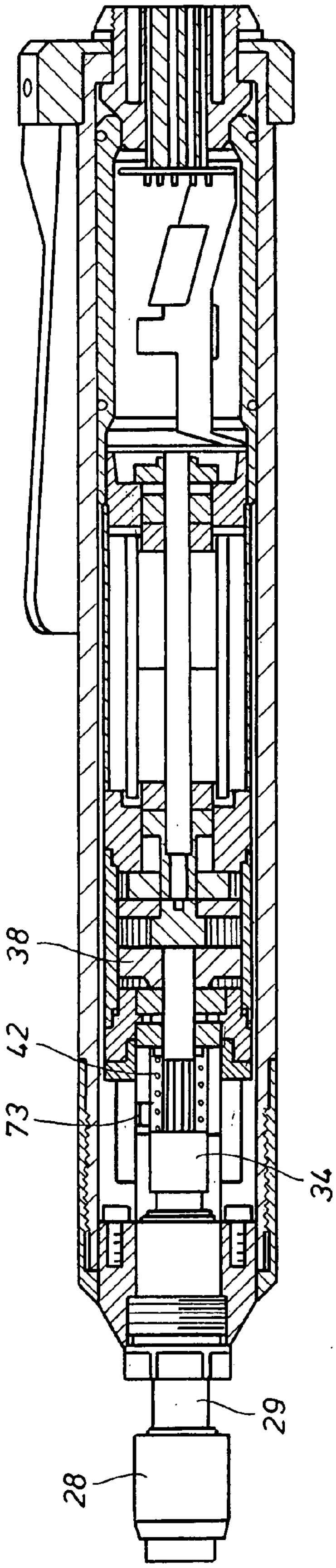
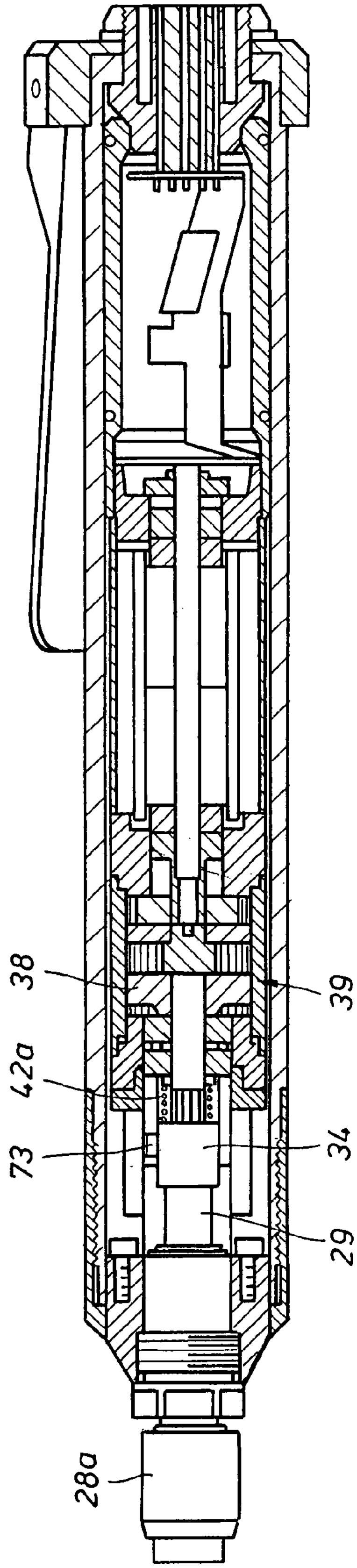


FIG. 3B



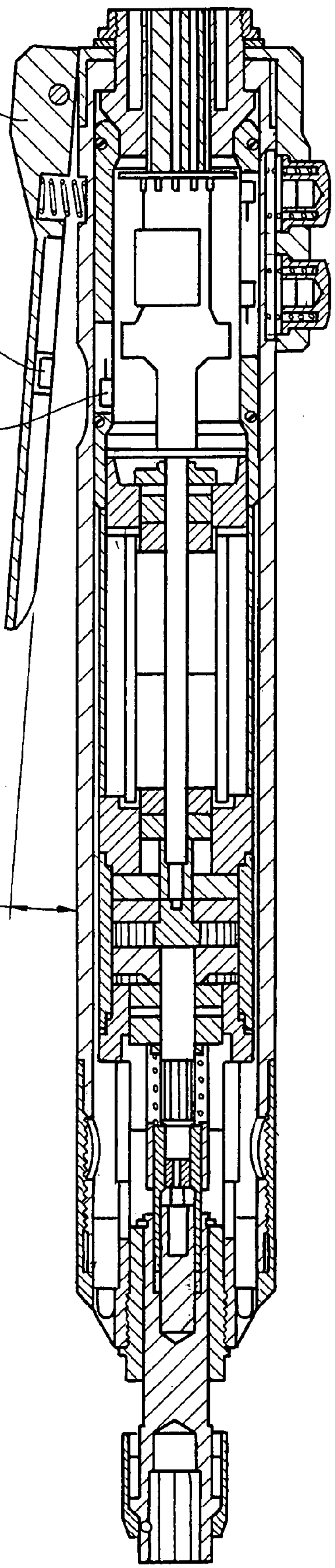


FIG. 4A

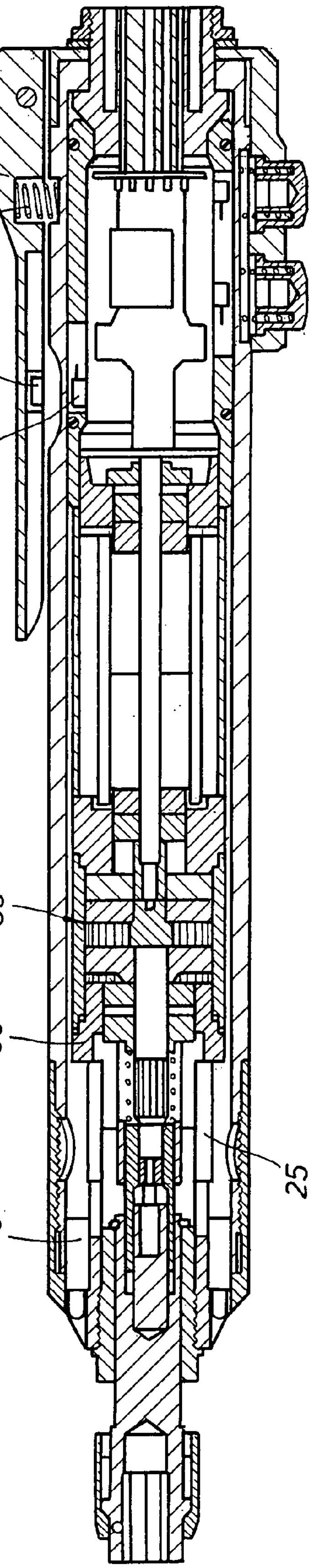


FIG. 4B

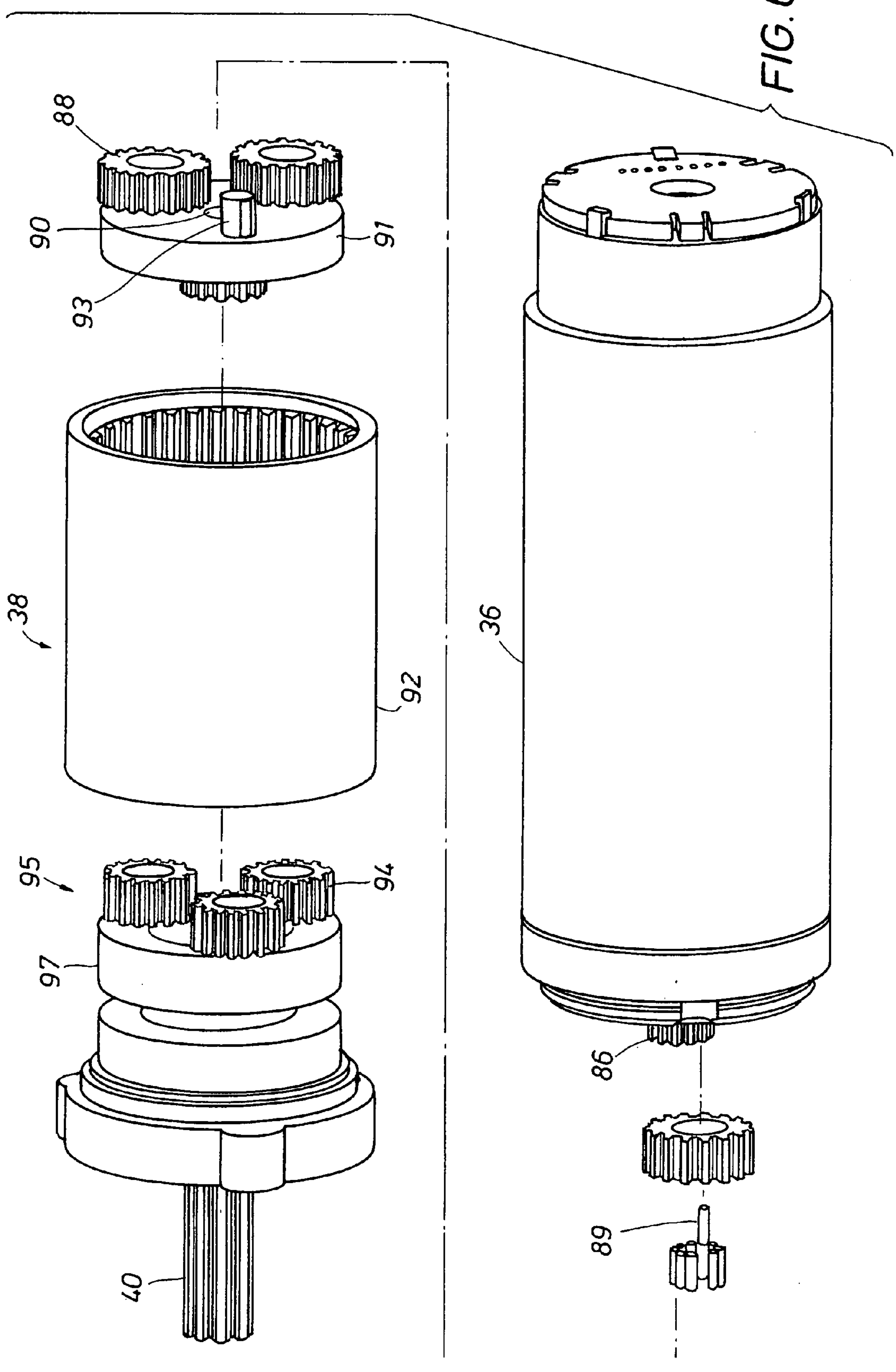


FIG. 6

FIG. 7A

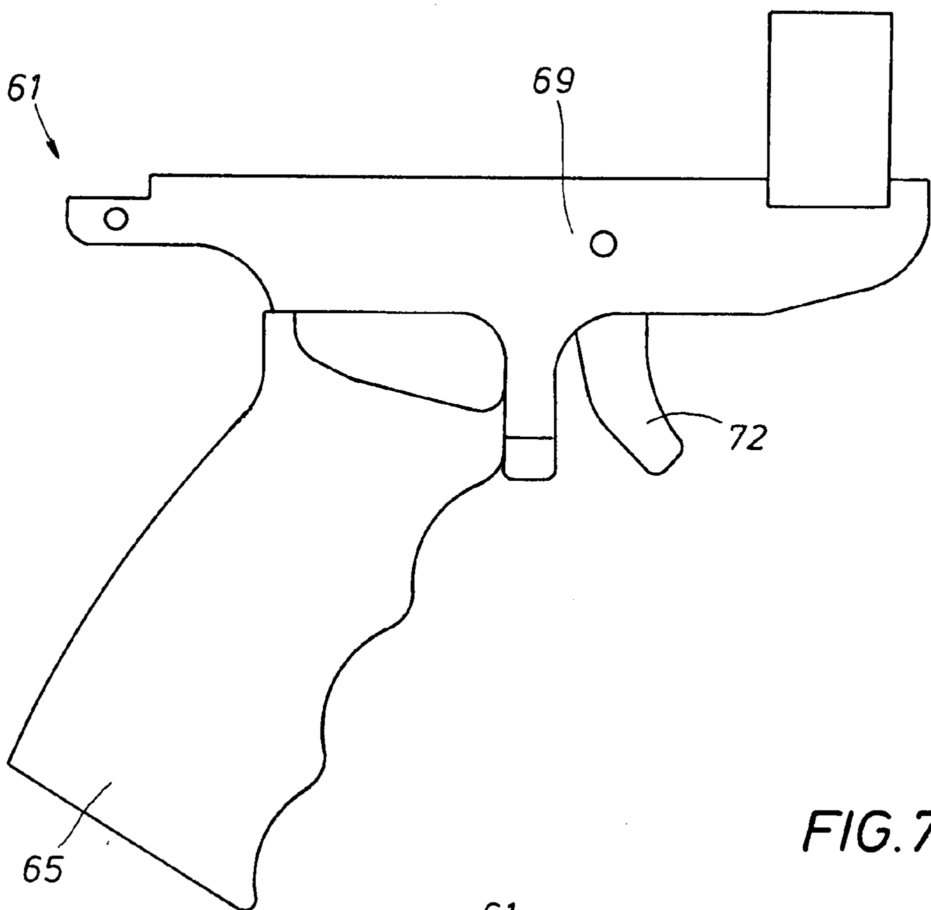
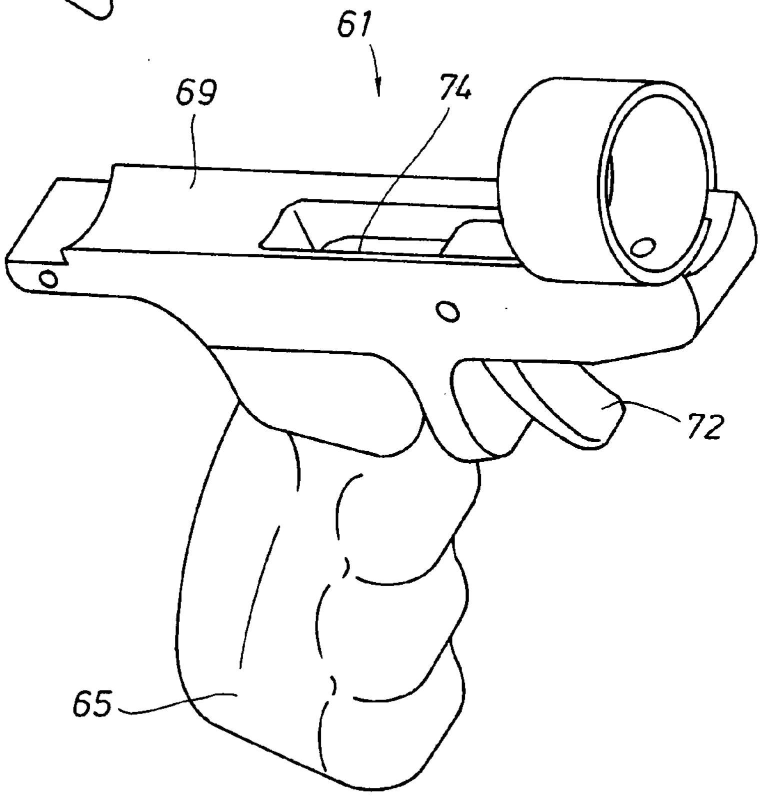


FIG. 7B



TRANSDUCERIZED ROTARY TOOL

RELATED APPLICATIONS

[0001] This application claims priority from co-pending U.S. application having Ser. No. 11/315,952 filed Dec. 22, 2005, the full disclosure of which is hereby incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates generally to the field of automatic drivers for fasteners. More specifically, the present invention relates to an apparatus for driving fasteners that is automatic and controllable. Yet more specifically, the present invention relates to a device for driving fasteners, where the apparatus delivers a specified torque.

[0004] 2. Description of Related Art

[0005] Many prior art devices exist that are capable of driving fasteners apertures, such as threaded bolt holes and the like. These tools typically require the user to activate a switch or a trigger to activate the device. Further, some prior art devices rely on power sources such as compressed air to drive the associated motor, which can limit the applicability of a device since producing compressed air requires space for a compressor and is generally impractical. Other devices that employ electrical motors produce an output whose speed and torque can vary and is not precisely controllable or not controllable at all. However many instances where it is required to employ a rotary tool, the ability to control the speed and torque is important. Some fasteners require that they be installed to a specified torque, and it is important that how much the fastener has been torqued be easily verified by the operator of the device.

[0006] Some of these devices include means to measure the rotational force, or torque, exerted by the particular device. These means range from monitoring the current consumed by the device, pressure sensors applied to working parts of the device, and included various sensors within the device. Examples of prior art devices useful for driving fasteners can be found in U.S. Pat. No. 4,487,270, U.S. Pat. No. 4,887,499, U.S. Pat. No. 6,424,799, U.S. Pat. No. 4,571,696, and U.S. Pat. No. 4,502,549.

[0007] Therefore, there exists a need for an apparatus and a method for securing fasteners that is reliable, accurate, and can precisely torque a fastener to a specified torque. An additional need exists for a tool to be durable, hand held, and provide an indication the preciseness of the directly torqued value.

BRIEF SUMMARY OF THE INVENTION

[0008] Disclosed herein is a rotary tool comprising a motor connected to a chuck assembly. Included with the tool is a variable voltage device responsive to a magnetic field. The motor may be selectively controlled by operation of the variable voltage device—where the control includes on off switching as well as motor speed control. The tool includes a push to start function; that is by urging the tool against the object being rotated the tool's rotational force and velocity is based on the urging force. Optionally, the variable voltage device can be a Hall effect sensor, either linear or digital. Also included is a gearbox connectively disposed between the motor and the chuck assembly. Lubrication comprising two parts gear oil and one part motor grease is disposed within the gearbox.

[0009] A field device is included on the chuck assembly that is capable of emitting a magnetic field. Positioning the field device by selective movement of the chuck assembly controllably drives the motor. This is done since positioning the field device manipulates the magnitude of the magnetic field provided to the variable voltage device from the field device. The magnitude of the magnetic field proportionally relates to the proximity of the variable voltage device in relation to the field device.

[0010] The rotary tool can further include a lever assembly having a field device formed thereon. The field device within the lever is also capable of emitting a magnetic field. Positioning the field device within the lever by selective movement of the lever assembly can controllably drive the motor. Positioning the field device manipulates the magnitude of the magnetic field applied to the variable voltage device from the field device within the lever. The magnitude of the magnetic field within the lever field device proportionally relates to how close the variable voltage device is in relation to the field device. Optionally, a handheld pistol grip assembly can be employed in lieu of the lever assembly.

[0011] A torque transducer may be included capable of measuring the value of the torque generated by the chuck assembly. Optionally included with the transducer is at least one strain gauge in cooperative engagement with the torque transducer. The at least one strain gauge transmits data representing the torque generated by the chuck assembly. This data monitored by the strain gage is usable to terminate operation of the driver when the torque generated by the chuck assembly reaches a predetermined amount.

[0012] Also optionally included with the rotary tool is at least one selector switch programmably capable of selectively reversing the polarity of the electrical power supplied to the driver. Additional selector switches can be included that are also programmable. The additional selector switches can be capable of selectively operating the driver in a different control mode.

[0013] Optionally, a system may be included to drive fasteners comprising a rotary tool combinable with a controller assembly. Here the rotary tool includes a motor capable of providing a rotational force, a chuck assembly operatively connectable to the motor, and a variable voltage device responsive to a magnetic field. The motor is in operative communication with the variable voltage device. The controller assembly should be capable of providing control instructions to the rotary tool where the control instructions comprise maximum torque magnitude, speed, among other operational variables.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING.

[0014] FIG. 1A depicts one embodiment of the present invention.

[0015] FIG. 1B illustrates an exploded view of one embodiment of the present invention.

[0016] FIGS. 2A-2E provide a partial cut-away version of embodiments of the present invention.

[0017] FIG. 2F provides a cutaway view of an embodiment of the present invention.

[0018] FIG. 2G illustrates a frontal view of an embodiment of the present invention.

[0019] FIG. 2H illustrates a side view of a tranducerized element.

[0020] FIGS. 3A and 3B depict a cutaway view of an embodiment of the present invention.

[0021] FIGS. 4A and 4B depict a cutaway view of an embodiment of the present invention.

[0022] FIG. 5 presents an embodiment of the present invention combined with a controller.

[0023] FIG. 6 provides an exploded view of a gear box in combination with a motor.

[0024] FIGS. 7A and 7B provide side and perspective views of embodiments of a tool grip.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Disclosed herein is a rotary tool system comprising a rotary tool combined with a controller system. With reference to the drawings herein, one embodiment of the rotary tool **10** is shown in perspective view in FIG. **1**A and an exploded view in FIG. **1**B. The rotary tool **10** is useful for driving fasteners, such as bolts, nuts, screws, self-threading screws, etc. Further, the rotary tool **10** is capable of repeatably applying fasteners to a precise specifiable torque. In the embodiment shown in FIG. **1**B, a motor **36** is included capable of initiating a force used to torque the fasteners.

[0026] In the embodiment of FIGS. **1**A and **1**B a gear box **38** is shown disposed adjacent the motor **36** is operative connected to the motor **36**. The gear box **38** contains a series of gears **39** configured into a gear train or system in mechanical cooperation with the motor **36**. The gears **39** are arranged to receive the output rotational force delivered by the motor **36** and convert that force into a specified torque at the output shaft **40** connected to the gear box **38**. In one embodiment the gear train is comprised of at least two gear stages, where each stage converts the rotational torque and speed produced by the motor **36**. The gear box **38** increases the torque delivered by the motor **36** with a corresponding decrease in the rotational speed of the motor **36**. The range of torque output at the gear box **38** ranges from about 1 in-lb to about 50 in-lb.

[0027] To maximize torque/velocity conversion while minimizing space, the gear system may be a planetary gear system comprising sun and planet gears. FIG. **6** provides an embodiment of a motor **36** combined with a gear box **38**, where the gear box **38** is shown in an exploded view. As shown, the first stage sun gear **86** is attached to the motor **36** and engages a series of three planetary gears **88**. The planetary gears **88** are all attached to a planet carrier **91**, from which extends a second sun gear **93** into a second planetary gear stage **95**. The output shaft of the second gear stage is the output shaft **40**. Sealing the gearbox **38** eliminates gear maintenance and protects the gears from foreign matter such as dirt. The lubricant used in the gearbox may be two parts gear oil with one part of motor grease. This combination of oil and grease provide an exceptional high-pressure lubricity, and low viscosity in order to minimize the amount of lubricant used, which in turn reduces viscous shear. Needle rollers **89** can be included between the annulus between the inner diameter of each planet gear (of each stage) and the outer diameter of the spindle **93** it rides on. The use of needle rollers **89** in this location of the gearbox **38** significantly reduces friction and wear. The needle rollers **89** also hold lubrication very well. The quantity of needle rollers **89** for use with each gear depends on the size of the individual gear and the gear box, it is believed that determining this quantity is within the scope of those skilled in the art.

[0028] To minimize contact between gear stages an axle bearing **90** is disposed into a conical cavity between the planets on the centerline of each planet carrier (**91** and **97**). When the mating sun gear (**86** and **93**) from the previous stage (or the motor **36**) is inserted between the planet gears (**88** and **94**), its face comes to rest against the axle bearing **90**. The axle bearing may be comprised of a hardened metal ball. Examples of metals include stainless steel and chrome steel, however this ball could be made from any number of hardenable materials. This configuration produces very little friction since the axle bearing **90** and the sun gears (**86** and **93**) are in tangential contact. When these two stages are rotating with respect to each other, the material surface velocities at the point of contact are low, which minimizes moment arm.

[0029] In order to adequately handle axial and radial loads on the output shaft **40** of the gearbox **38** as well as limit axial and radial play, a combination of two bearings is used. The bearing on the outboard most end of the gearbox is a conventional radial bearing. This bearing is meant to carry any side loads placed on the output shaft **40** as well as a small amount of axial load. The inboard bearing is an angular contact bearing. This bearings primary function is to carry the axial loads, which are transmitted down the output shaft as well as a small amount of radial load. The load coupling of these two bearings is accomplished by a small spacer of a precisely held thickness, which is sandwiched between the inner races of both bearings. These bearings, in combination, produce a very free spinning, durable and accurate mechanism.

[0030] Enhanced performance and efficiency has been realized by some of the design improvements to the gear box **38**, for example, the splined output shaft **40** was strengthened to carry more torsional load. The gearbox output shaft retainer ring (not shown) was improved to carry more axial load without breaking free. Heat treatment, such as by nitriding, was added to surfaces on the planet carriers that come into contact with rotating planet gears. High-carbon steel alloy axles were included with the planet carriers to improve fatigue properties also the thickness of rear gearbox end cap was adjusted to minimize axial gear clearances.

[0031] Table 1 provides a summary of sample configurations of gear systems providing varying output torque, included with the table are the corresponding speed and ratios of the possible stages in the particular gear system.

TABLE 1

Torque	Speed	1st stage ratio	2nd stage ratio	3rd stage ratio	combined ratio
10 in/lb	1800	4.285:1	4.285:1	none	18.36:1
20 in/lb	1100	6.75:1	4.285:1	none	28.92:1
35 in/lb	800	6.75:1	6.75:1	none	45.56:1
50 in/lb	500	4.285:1	4.285:1	4.285:1	78.68:1

[0032] Optionally the rotary tool **10** can be tranducerized to provide a real-time monitoring of the magnitude of the torque exerted onto a fastener by the rotary tool **10**. Preferably the torque monitoring system include a flexure **25** secured to the gear box **38** on the end of the gear box **38** opposite to where it is connected to the motor **36**. At least one strain gauge **85** can be included within the flexure **25** that senses the torque supplied by the motor **36** and transmits that sensed torque information to the tool controller **80**. Preferably four strain gages **85** are included with the flexure **25**. The flexure **25** is connected on its other end to the nose cap **26**. As can be seen in FIG. **1**, the nose cap **26** includes slots **27** on its outer surface that mate with tabs **17** formed on the front end of the body **12** of the rotary tool **10**. As the motor **36** supplies torque to the fastener, the motor **36** in turn transmits an identical torque value to nose cap **26**. Since the the motor **36** is mounted to the flexure **25**, the flexure **25** experiences the torque supplied by the motor **36**. Thus by positioning a strain gage **85** on the flexure **25**, the torque output of the motor **36** can be measured by the strain gage **85**. As the tool communicates with a tool controller **80**, the torque output of the strain gage **85** connects to the tool controller **80** as well. When the output torque of the motor **36** reaches a pre-selected torque, the tool controller **80** is programmable to immediately deactivate power to the rotary tool **10**, thus ensuring that the fastener being secured by the rotary tool **10** is not over tightened.

[0033] The strain gage **85** may be calibrated as an assembly using what is known as a "dead weight" calibrator. Weights, which are certified and traceable to NIHST, are used to generate a static moment by placing them on an arm at a specific distance. The calibration does not occur until the at least one strain gage **85** is combined within the rotary tool **10**. This is done in order to take into account frictional losses in the tool. Preferably, the at least one strain gage **85** can be a standard encapsulated strain gage that is modulus compensated for use on aluminum flexures. The signal produced by the detection of strain in the at least one strain gage **85** is carried to the controller **80** analog via the flex circuit **33** and the tool cable **82**. The flex circuit **33** attaches directly to the flex circuit therefore eliminating wiring in the rotary tool **10**. When four strain gages **85** are used they may be attached to each other in a wheatstone bridge configuration and optionally using fine polyester varnished wire. As shown, the four dual element strain gages **85** are located 90° from each other on the flexure **36**. Four strain gages **85** can minimize bending cross talk and improve accuracy.

[0034] A chuck assembly **28** is provided with the embodiment of FIGS. **1**A and **1**B and is connectable to the output shaft **40**, preferably through corresponding spline grooves formed on the outer surface of the shaft **40** and an aperture (not shown) formed axially within the shaft **29** of the chuck assembly **28**. As will be explained in further detail below, the length of the aperture should be long enough to allow the shaft **29** to slide back and forth along a portion of the length of the output shaft **40**. A socket **31** is provided on one end of the chuck assembly **28**, the socket **31** shown is suitable for receiving a fitting (not shown) specifically sized to fit the particular fastener being driven by the rotary tool **10**. Further, a sleeve **33** is provided that when tugged axially retracts a retaining ball within the socket **31** thereby enabling adding or removing the particular fitting for use with the rotary tool **10**. Also disposed on the chuck assembly **28** is a collar **35** slidable along the shaft **29**. The collar **35** includes threads **32** on the outer surface adjacent the nut **30** formed to fit threads (not shown) in the nose cap **26**. A ring magnet **34** is disposed on the end of the shaft **29** opposite the socket **31**. A snap ring (not shown) is included on the shaft **29** that retains the collar **35** on the shaft between the sleeve **33** and the snap ring. Thus while the collar **35** remains on the shaft **29**, it must be free to slide along the shaft **29** between the sleeve **33** and the snap ring. Accordingly when the chuck assembly **28** is screwed to the nose cap **26**, the shaft **29** can be slideably disposed in and out of the collar **35** a certain distance while still being retained within the chuck assembly **28**.

[0035] The rotary tool is useful not only for driving and securing fasteners, but can also be useful as a drill motor, a sander, a buffer, a saw, and any other application where a driving force is used. Moreover, the novel application of the push to start feature disclosed herein is applicable with all functions for which the present device can be used.

[0036] Referring now to FIGS. **3** and **4**, other electrical circuitry that can be included with the present invention include variable voltage devices (VVD) such as a Hall effect sensor. As is well known, the output voltage of the VVD depends on the magnetic flux density applied to the VVD. Thus, subjecting the VVD to a magnetic field can increase the output voltage of a VVD. Likewise, removing the magnetic field can eliminate the VVD output voltage. Accordingly a switching mechanism can be produced by combining a field device that produces a magnetic field, such as a magnet, with a VVD. A simple application of this phenomenon involves creating a voltage source by positioning a magnet (either permanent or electro) close to a Hall effect sensor. One example of a field device is a permanent magnet, and one example of a VVD is a Hall effect sensor.

[0037] In FIGS. **3**A and **3**B one example of such a switching device can be seen. As can be seen from FIG. **3**A, the chuck assembly VVD **73** is disposed on the flexure **25**. As previously pointed out, the shaft **29** is slideable within the collar **35** and is thus axially moveable with respect to the rest of the rotary tool **10**. Absent a force urging the shaft **29** inward toward the rotary tool **10**, it is pushed outward by a spring **42** and is in its extended position as seen in FIG. **3**A. When the shaft **29** is in the extended position, the magnetic field emitted by the field device **34** has little or no effect on the chuck assembly VVD **73** and the chuck assembly VVD **73** will emit no voltage. In contrast, when the shaft **29** is pushed inward into a retracted position, the field device **34** should be sufficiently proximate to the chuck assembly VVD **73** that it will emit voltage. It is preferred that when the shaft **29** is fully retracted that the interaction between the field device **34** and the chuck assembly VVD **73** be such that the chuck assembly VVD **73** emit its maximum voltage. The voltage emitted from the chuck assembly VVD **73** should be used to drive the motor **36**. Therefore, the motor **36** can be activated or deactivated by retracting and extending the shaft **29**. It should also be pointed out that like all VVDS the chuck assembly VVD **73** will begin to emit a higher voltage in response to an increase in the strength of the magnetic field applied to it by the field device **34**. Thus the closer the field device **34** is to the chuck assembly VVD **73**, the more voltage the chuck assembly VVD **73** will emit, and in turn the faster the motor **36** will operate. Accordingly, one of the many advantages of the present invention is the ability to initiate operation of the motor **36** by slowly retracting the shaft **29**, and to operate the motor **36** at variable speeds depending on how far inward the shaft **29** is retracted.

[**0038**] Alternatively, the motor **36** can be variably driven by manipulation of the lever **20**. Referring now to FIGS. **4**A and **4**B, an alternative embodiment is disclosed. Here a lever field device **76**, such as a permanent magnet, is disposed within the body of the lever **20**. The lever **20** is hingedly attached to the rotary tool **10** on one of its ends via pins **54** inserted into ports of the end cap **18**. A corresponding lever VVD **78** is preferably positioned within a groove **47** formed on the outer surface of a wiring shell **46**. Similar to the chuck assembly **28**, a spring **21** is included to urge the free end of the lever **20** outward away from the body of the rotary tool **10**. Urging the lever **21** toward the body of the rotary tool **10**, the lever field device **76** should begin to approach the proximity of the lever VVD **78**. Also similar to the operation of the chuck assembly VVD **73**, the lever VVD **78** will begin to emit voltage to the motor **36** as the lever field device **76** approaches it. Thus the motor **36** can be manipulated by depressing the lever **21** in much the same manner as it is manipulated by retracting the shaft **29**.

[**0039**] Optionally, the lever **21** can be replaced by a pistol grip assembly **61**, where the pistol grip assembly **61** comprises a handle **65**, a base **69**, and trigger **72**. The handle **65** provides a grip for the users hand. The base **69** is secured to the handle **65** and securable to the body **12** of the rotary tool **10**. The trigger **72** can be hingedly attached to the base **69** and include a trigger field device **74** disposed thereon such that when the trigger **72** is depressed the trigger field device **74** is moved towards the body **12**. The pistol grip assembly **61** should be secured to the body **12** such that the trigger field device **74** will be proximate to the lever VVD **78** when the trigger **72** is depressed. Thus the rotary tool **10** can be actuated by depressing the trigger **72**.

[**0040**] Two or more selector buttons (**14** and **16**) can optionally be provided to enhance the flexibility of the rotary tool **10** functions. Each selector button (**14** and **16**) can contain a field device, such as a permanent magnet within. When assembled, the selector buttons (**14** and **16**) should be aligned with selector button VVDS (**70** and **71**) disposed within the groove **47**. Springs **15** should be included with each selector button (**14** and **16**) to urge the buttons outward from the body **12** of the rotary tool **10** absent a force pushing the buttons inward. By programming the associated controller **80**, actuation of the selector buttons (**14** and **16**) inward can vary the function of the rotary tool **10**. For example, the controller **80** can be programmed such that inwardly pressing the first selector button **14** will toggle the polarity of the voltage delivered to the motor **36** thereby reversing the rotational direction of the chuck assembly **28**. Additional options include the requirement that the buttons (**14** and **16**) be depressed twice, similar to the operation of a mouse of a personal computer, before the requested function occur. The selector buttons (**14** and **16**) can be programmed to initiate or control any number of external devices or process either directly or indirectly related to the operation of the tool. More commonly the selector buttons (**14** and **16**) can be used to control the direction of rotation of the tool as well as changing preprogrammed tool set points or parameter sets. It is believed that the programming of the associated controller **80** can be accomplished by those skilled in the art without undue experimentation.

[**0041**] While standard wiring or circuit boards could be used, it is preferred that the circuitry of the rotary tool be included on a flex circuit **33**. The flex circuit **33** can provide a way to conduct power to drive the motor **36** and provide wiring to conduct control commands as well. As is well known, the flex circuit **33** can be comprised of a flexible resin like material, as such the flex circuit **33** can be tailored to fit within the present invention while consuming a minimum amount of space within the rotary tool **10**. Further, the illumination LEDS **58**, the indication LEDS **62**, and lever and selector button VVDS (**70**, **71**, and **78**) can be situated directly on the flex circuit **33**. Design of an appropriate flex circuit **33** for use with the present invention is well within the capabilities of those skilled in the art.

[**0042**] A digitally programmable device, such as a memory chip, may be included with the rotary tool **10**. During final assembly and calibration of the tool, the programmable device may be programmed at least with identification, calibration, and operating conditions desired by the rotary tool **10**. The information can include the model number of the specific rotary tool **10**, serial number, date of manufacture, date of calibration, maximum speed and maximum torque that the rotary tool **10** can attain, the calibration value, the motor angle counter per tool output revolution (this describes the gear ratio), and other useful operating parameters. Operation of the system requires constant realtime communication with a tool controller **80**. Programmed within the tool controller **80** are the operating parameters for the specific rotary tool **10** being used. During use the tool controller **80** interrogates the memory chip within the specific rotary tool **10** to ensure that the specific tool is capable of performing the intended task. If the tool is capable of performing the task at hand, the controller will allow the specific rotary tool **10** to be operated; otherwise the controller **80** will not activate the tool. This interrogation happens upon power up or when the specific rotary tool **10** is first connected to the controller **80**. The controller can be programmed with a lap top computer using a graphic user interface under the Windows operating system.

[**0043**] Activation by the push to start mode includes the step of first inserting the fastener where it is to be fastened. For example, if the fastener is a threaded screw, in the push to start mode the screw will be inserted into the hole (threaded or unthreaded) where it is to be secured. Then a force can be applied by the operator to the rear end of the rotary tool **10** that in turn pinches the screw between the fitting and the hole. As long as this force applied by the operator exceeds the spring constant of the spring **42**, the shaft **29** will be retracted within the collar **35**. As previously noted when the shaft is retracted within the collar **36**, the field device **34** is located proximate to the chuck assembly VVD **73**—as is illustrated in FIG. **3**B. As previously noted, when the field device **34** approaches the chuck assembly VVD **73**, voltage is emitted from the chuck assembly VVD

73 that in turn begins to drive the motor **36**. Driving the motor **36** produces rotation of the chuck assembly **28** via the gear box **38** and output shaft **42**. Rotation of the chuck assembly **28** can be used to drive the fastener into securing engagement with the associated hole by the transfer of rotational force from the chuck assembly **28** to the fastener.

[**0044**] Alternatively, the rotary tool **10** can be operated by depressing the lever **20** up against the body **12** of the rotary tool **10**. In the embodiment of the invention in FIGS. **4**A and **4**B a lever field device **76** is shown disposed within the lever **20**. As the lever **20** is depressed towards the body, the lever field device **76** approaches the lever VVD **78**. In the same manner as the push to start mode, the lever VVD **78** begins to emit a voltage whose magnitude is in relation to the strength of the magnetic field applied to it by the lever field device **76**. The voltage emitted by the lever VVD **78** can then be applied to driver the motor **36** where the magnitude of the voltage emitted by the lever VVD **78** directly corresponds to the rotational speed of the motor **36**.

[**0045**] The push to start and throttle lever can either be used individually or in combination with each other. There are however instances where they are useful in combination. One can be used as an interlock for the other. It can be configured so that the throttle lever has to be fully depressed before the push to start can be activated. This configuration prevents operation of the tool before the operator has a good grip on it. Conversely it can be configured so that the push to start has to be fully depressed before the throttle can be activated. This configuration prevents the rotation of the tool before sufficient axial load is applied to the fastener as in the case of a self tapping screw. In the case of automated operation in a fixture, the push to start can be used as a form of presence detection.

[**0046**] During the time the rotary tool **10** is driving the fastener (either by the push to start mode or by depressing the lever **20**), the magnitude of the torque delivered to the fastener by the rotary tool **10** is measured by the at least one strain gage **85** disposed within the flexure **25**. The strain gage bridge produces an analog output that is continuously monitored during tool operation. The strain gages should be arranged in such a fashion as to be only sensitive to torsion along the axis of the flexure **25**. Each strain gage **85** has two elements that are oriented 90 degrees to each other and 45 degrees to the axis of the flexure **25**. There are four gages arrayed around the circumference of the flexure in 90° intervals. Under torsion the strain gages **85** will unbalance the Wheatstone bridge therefore producing an output. Under bending, compression, or tension the loads will cancel therefore maintaining a balanced bridge and producing little or no output. The torque value measured by the at least one strain gage **85** is uploaded to the controller **80** as the controller **80** interrogates data from the rotary tool **10**. Thus, a real time measurement of the torque applied to the fastener can be obtained by the controller **80** through its constant monitoring of the at least one strain gage **85**. Further, the controller **80** can be programmed to instantaneously deactivate the rotary tool **10** when the torque measured by the at least one strain gage **85** matches the shut off torque stored in the controller **80**. More specifically, when the torque as measured by the strain gate **85** controller **80** combination reaches the preselected torque, the controller **80** immediately and actively stops rotation of the tool, thus ensuring that the fastener being secured by the tool is not over tightened. The braking or stopping of the tool is accomplished through the use of plug reversing and dynamic braking. Plug reversing involves applying full reverse power to the motor **36** until the strain gage **85** and controller **80** senses zero torque. Dynamic braking takes advantage of the fact that a motor **36** is also a generator. By shorting the power leads of the motor **36** to each other, the effect is to force the motor **36** to resist its own rotation in proportion to its rotational velocity. Therefore, one of the many advantages realized by the present invention is the ability to precisely tighten fasteners exactly to a desired torque without the danger of over or undertightening a fastener. This advantage is due in part to the real time monitoring of torque and the instantaneous response of the controller **80** actively deactivating the rotary tool **10**.

[**0047**] The controller can be programmed with a target torque and speed. Optionally the controller can be set to run the rotary tool **10** at two different speeds. The first speed would be relatively high and would run until a selected torque, which is not the target torque, is reached. The second, or downshift speed, would run slower and then stop at the target torque. For example if the target torque is 20 in-lbs the controller may be set as follows: Initial speed of 1000 rpm until a down shift torque of 12 in-lbs is reached. Then a down shift speed of 250 rpm until the target torque is reached. Additionally, angle measurement and control can be implemented. Angle control can either be substituted for torque or used in combination with torque. An AND relationship can be established with torque and angle. By setting a torque target of 20 in-lbs and an angle target of 60°, both targets have to be met or exceeded in order to count as a successfully fastened joint. The angle count is started at a threshold torque of perhaps 10 to 20 percent of the target torque. In this case that would be 2 to 4 in-lbs. Other parameters can be set to form upper and lower torque and angle limits around the targets. For example with a 20 in-lb target the limits may include a torque low limit of 18 in-lbs and a high limit of 22 in-lbs with an angle low limit of 50° with an angle high limit of 70°. These limits are used to form a window around the target for the purposes of establishing the criteria for a properly torqued fastener. If the angle is to low before achieving the target torque then the fastener has likely cross threaded. If the angle is to high then the fastener has likely stripped, broken or was not present.

EXAMPLE

[**0048**] In one embodiment of the motor **36** is coupled to a gear box **38** comprised of two gear stages, where the two stages provide a conversion of speed to torque. In one example of operation the first stage has a speed to torque ratio of about 6.75:1 and the second stage has a speed to torque ratio of about 4.285:1. To maximize torque/velocity conversion while minimizing space, the preferred gear system is a planetary gear system. In this system the first stage sun gear is attached to the motor output shaft and engages a series of three planetary gears. The planetary gears are all attached to a planet carrier, from which extends a second sun gear into the next planetary gear stage. The output shaft of the second gear stage, which has a spline gear formed thereon, mates with the output drive.

[**0049**] In one embodiment the gearboxes are in a sealed oil gearbox. Sealing the gearbox eliminates gear maintenance, helps keep the gears clean, and protects the gears from foreign matter. The light oil in lieu of a more viscous lubricant, such as grease, greatly enhances the efficiency of torque transmission. One example of lubricating oil for use with the gears comprises a mix of two parts of synthetic gear oil with one part of motor assembly grease. The synthetic gear oil weight can range from 75W90 to 75W140 and weights in between. The motor assembly grease may comprise a calcium-based grease with an anti-wear rating. A lubricating oil formed with this composition provides a balance of good high-pressure lubricity, low viscosity as compared to conventional power tool greases, and enough tackiness to require only 1 milliliter of oil therefore greatly reducing viscous shear.

[0050] With regard to the field device **34** disposed on the shaft **29**, in one embodiment the field device **34** is a ring magnet that is plastic injection molded using permanent magnet particles (such as Neodymium Iron Boron) suspended in Nylon. This configuration provides relatively high field density combined with low cost. Further, the ring magnet should be radially magnetized, the outer diameter of the ring magnet is magnetized in a first polarity and the inner diameter is oppositely polarized. This is done so that the output of the Hall sensor within the chuck assembly VVD **73** stays consistent regardless of the rotational orientation of the shaft **29**. It is preferred that the Hall output vary as a result of axial movement only. If the ring magnet were magnetized with alternating poles on the outside diameter, the chuck assembly **28** would stop rotating as the poles reversed.

[0051] The gears may be made from medium-carbon steel selected because of its hardness and heat-treating properties. Optionally, the gear material may comprise low-alloy steel optimized for nitriding. Medium-carbon steel or low-alloy steel optimized for nitriding may also be used in the planet carriers. In one embodiment, the gear axles are made from high-carbon steel that is a high strength gear material with excellent bending fatigue properties.

[0052] Some of the advantages realized by the present invention include a high degree of reliability and durability. The operating limit of many fastening tools before failure is about 500,000 cycles, in fact tools that are capable of operating up to 1,000,000 cycles without failure are considered very durable. In contrast the present invention has been found to operate in excess of 5,000,000 cycles without failure, which greatly exceeds the durability expectations of such a tool. Further, the present invention is also capable of this high number of cycles when subjected to high duty cycle applications. That is when an operating process is being repeated very quickly with many cycles per hour. Additionally, the performance of a gear box **38** produced in accordance with the specifications of this application is superior to many other gear boxes used for similar applications. For example, similar type gear boxes generally have a maximum operation rotational speed at up to 7000-8000 revolutions per minute (rpm), whereas the gear box **38** of the present invention is capable of rotational speeds up to 50,000 rpm.

[0053] The present invention described herein, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While a presently preferred embodiment of the invention has been given for purposes of disclosure, numerous changes exist in the details of procedures for accomplishing the desired results. For example, the push to start feature can be physically disabled. Also, all four torque capacities can optionally be available in fixture mount configurations. A different front end cap is supplied with the tool to allow for easier and more reliable mounting of the tool in fixtured applications. Instead of a tapered end cap with headlights, a threaded end cap with a shoulder is provided including two different styles of mounting flanges. The fixture mounted configuration allows for the minimization of center to center mounting distances. In effect the tools can be mounted on 1.125" centers 1.125" is the diameter of the tool. This is important when fasteners are located very close to each other. This is of primary concern in automated applications where there is no human interaction or when multiple tools are mounted in combination with each other in a hand operated power head. Further, the variable voltage device can be any device that responds to some external stimulus, such as voltage, current, pressure, or magnetic, or that switches at a threshold of stimulus. The variable voltage device can be selected from items such as a linear response device, or a digital response device.

[0054] These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the spirit of the present invention disclosed herein and the scope of the appended claims.

What is claimed is

1. A rotary tool comprising:

a motor;

a chuck assembly operatively connectable to said motor;

a gearbox operatively disposed between said chuck assembly and said motor; and

a lubricant in the gearbox comprising about two parts gear oil and about one part of motor grease.

2. The rotary tool of claim 1, further comprising a variable voltage device responsive to a magnetic field, wherein said motor is in operative communication with said variable voltage device and wherein selectively moving the chuck assembly varies the magnitude of the magnetic field applied to the variable voltage device and proportionally varies the power supplied to said motor and thereby variably alters the corresponding rotational speed of the chuck assembly.

3. The rotary tool of claim 1, wherein the gearbox comprises components formed by heat treatment.

4. The rotary tool of claim 3, wherein the heat treatment comprises nitriding.

5. The rotary tool of claim 1, wherein the gearbox comprises a first stage and a second stage.

6. The rotary tool of claim 5, wherein the gear ratio of the first stage and the second stage is selected from the list consisting of 4.285:1, 6.75:1, and combinations thereof.

7. The rotary tool of claim 1, wherein the gear oil comprises oil having a weight of from 75W90 to about 75W140.

8. The rotary tool of claim 1, wherein the motor grease comprises a calcium-based grease with an anti-wear rating.

9. The rotary tool of claim 2 further comprising plastic injection molded permanent magnet particles for creating the magnetic field.

10. The rotary tool of claim 9 wherein the permanent magnet particles comprise neodymium iron boron.

11. The rotary tool of claim 1 further comprising a transducer having a strain gage.

12. The rotary tool of claim 11 further comprising a flexure combined with said strain gage.

13. The rotary tool of claim 1, wherein said tool is hand held.

14. The rotary tool of claim 11, wherein said transducer provides real time feed back information of the magnitude torque of the torque applied by the tool.

15. The rotary tool of claim 11 further comprising a controller that communicates with the rotary tool.

16. The rotary tool of claim 15 wherein said transducer provides said real time feed back information to the controller.

17. The rotary tool of claim 1, wherein said tool is capable of accurately applying a magnitude of torque to a fastener that ranges from about 1 in-pounds to about 50 in-pounds.

18. The rotary tool of claim 1, wherein said tool is capable of accurately applying a magnitude of torque to a fastener that ranges from about 1 in-pounds to about 20 in-pounds.

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