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**Baker et al.**

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(54) **METHOD OF USE FOR DEBRIS REMOVAL SYSTEM FOR POWER TOOL**

USPC ..... 134/21; 15/300.1; 15/301; 15/328; 15/329; 408/67

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See application file for complete search history.

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*Primary Examiner* — Alexander Markoff

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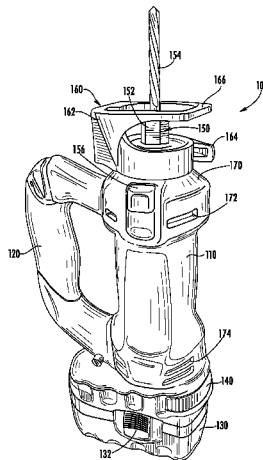
(57) **ABSTRACT**

A method of using a hand-held power tool having a debris removal attachment is provided. The method includes providing a hand-held power tool having an output shaft and selectively coupling an extension shaft to the output shaft. The method also includes coupling a first impeller to the extension shaft and providing a housing adjacent the first impeller. The method further includes rotating the first impeller to generate a pressure differential sufficient to draw debris into the housing. The extension shaft has a first end and a second end, the first end configured to couple to the output shaft of the hand-held power tool, and the second end configured to couple to a tool bit.

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

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**20 Claims, 11 Drawing Sheets**



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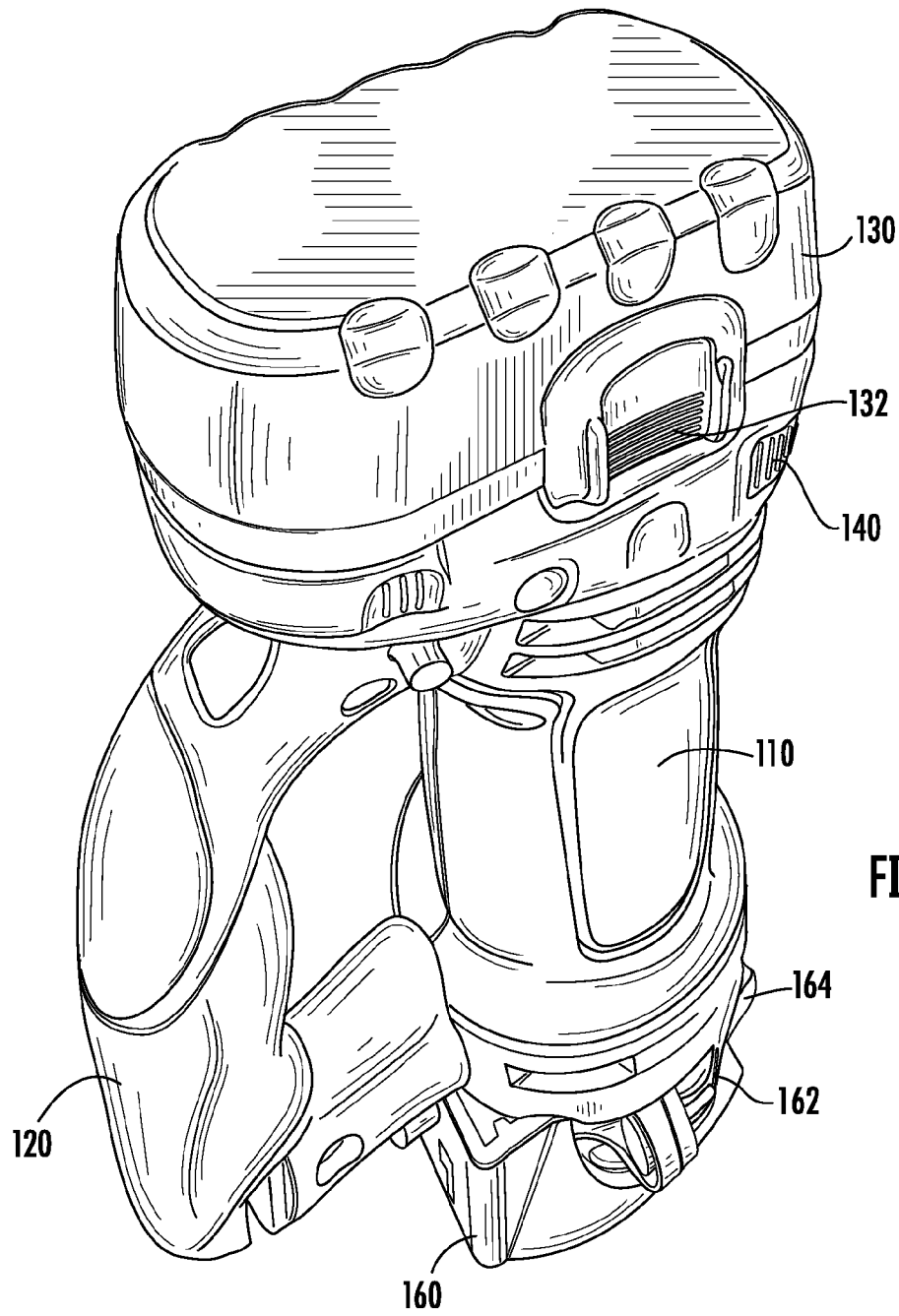
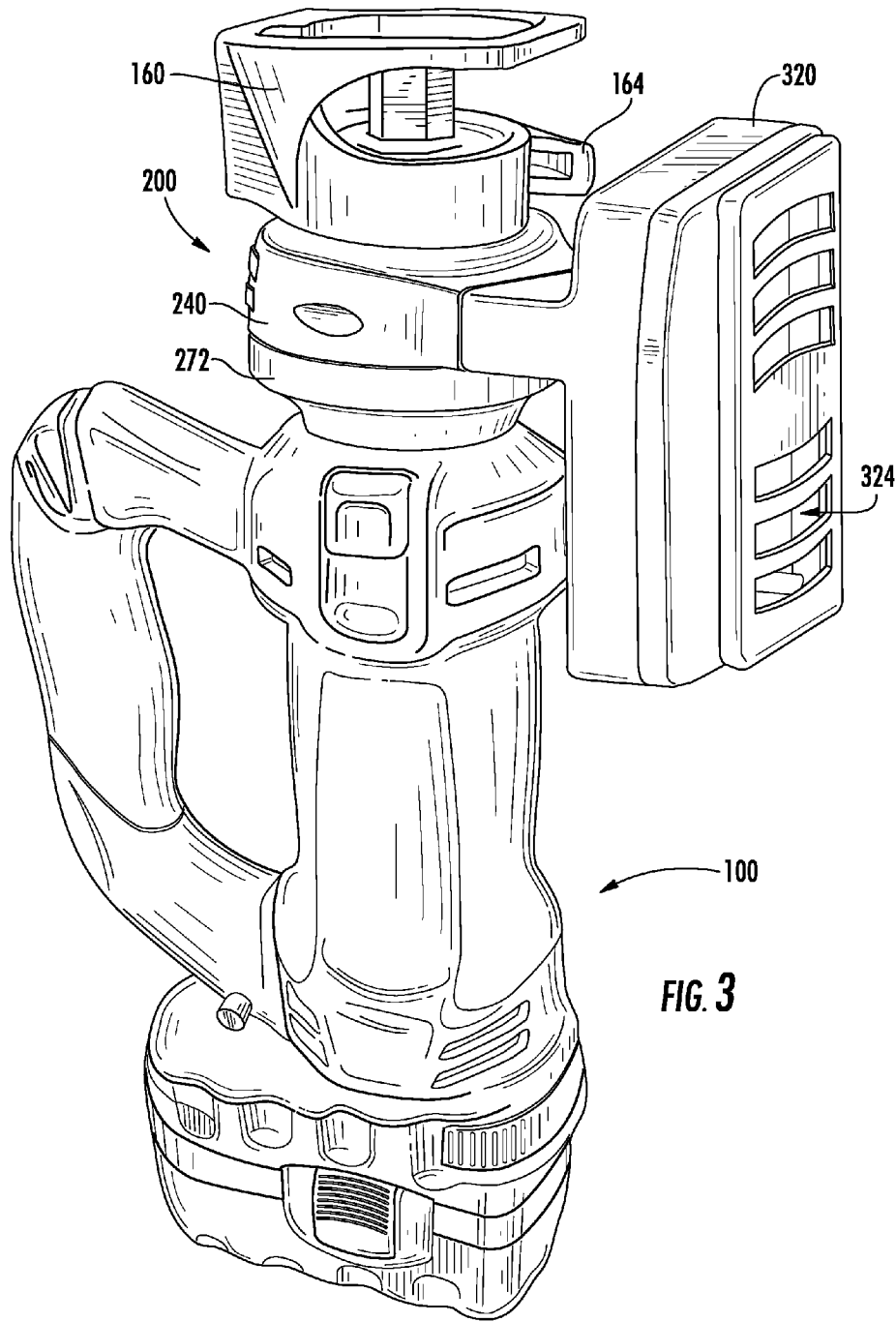


FIG. 2



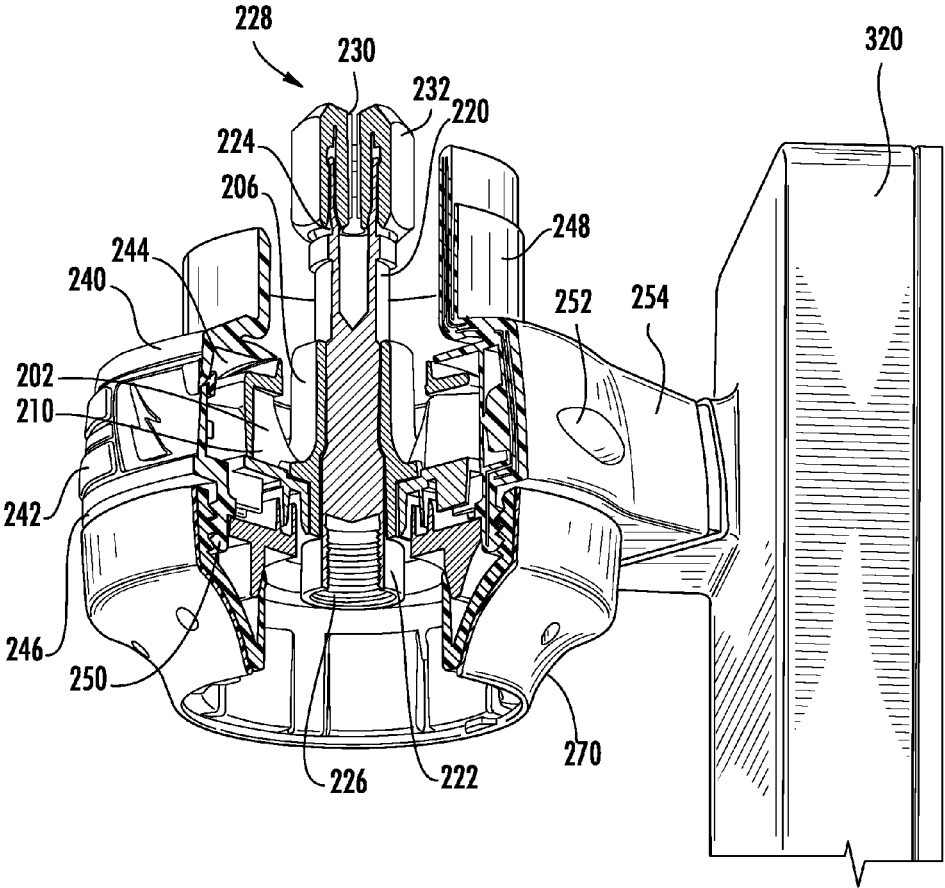


FIG. 4

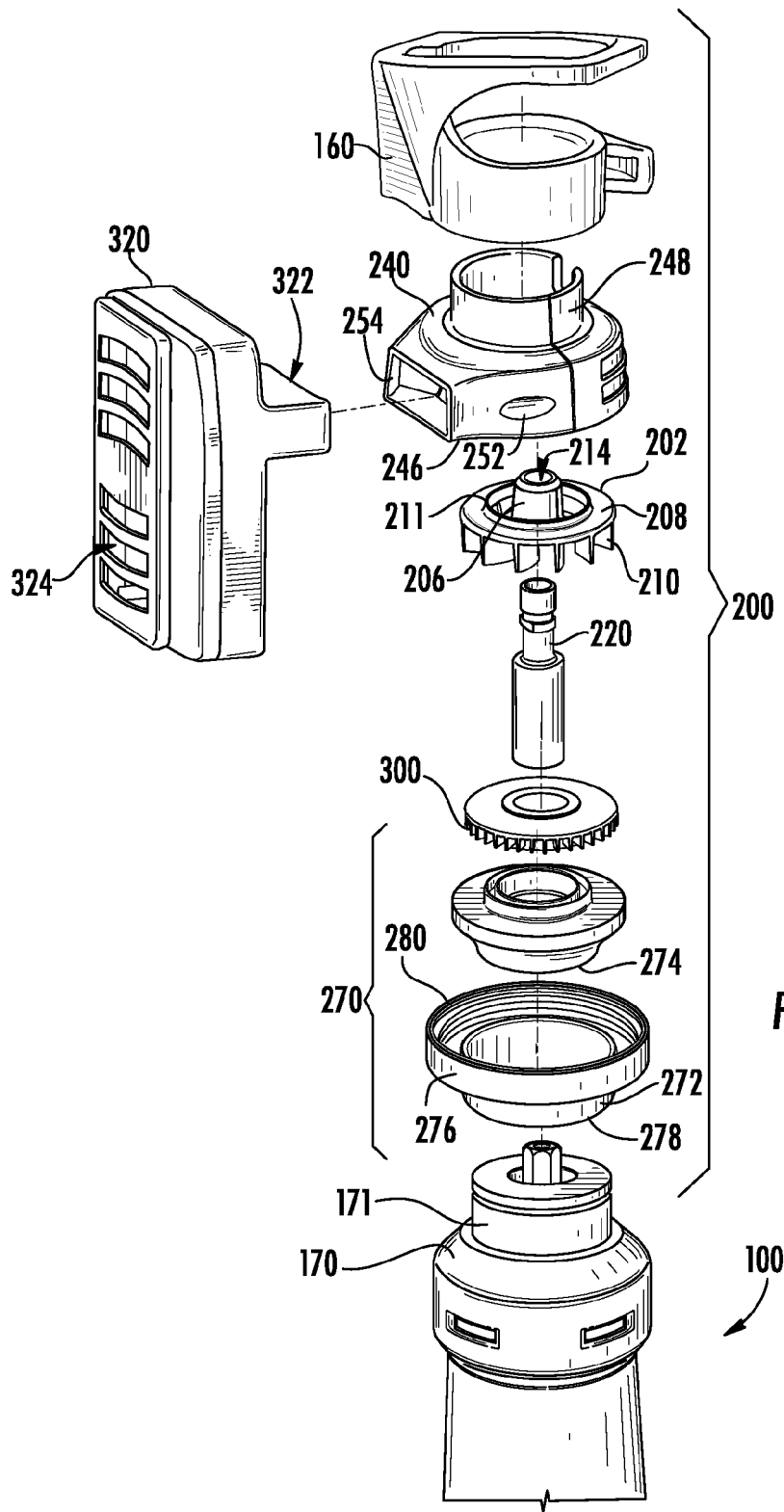


FIG. 5

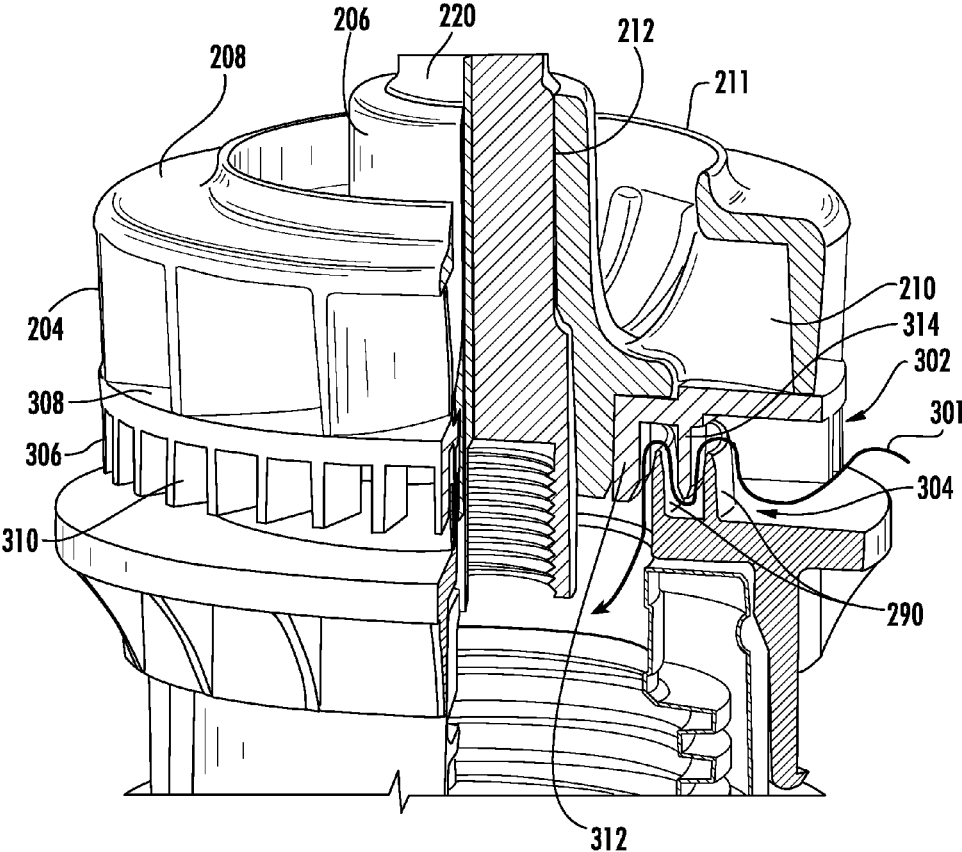
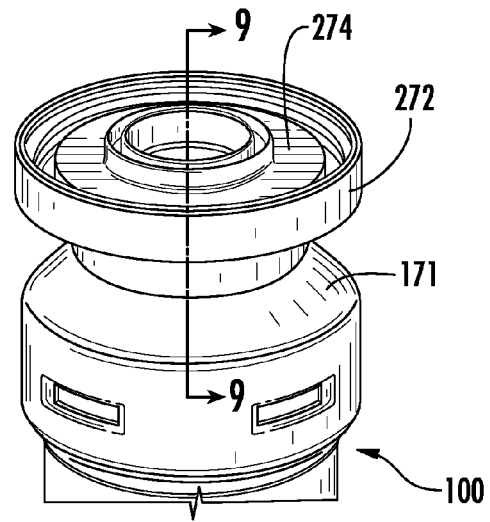
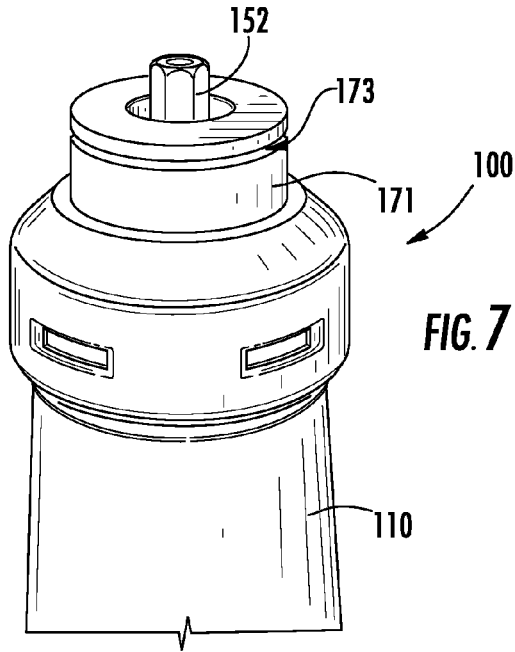


FIG. 6





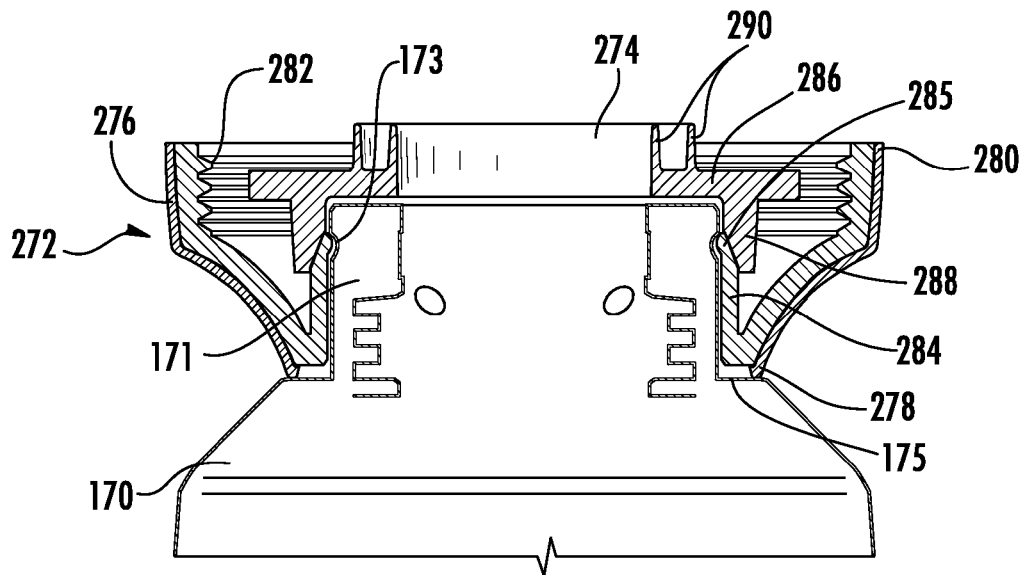
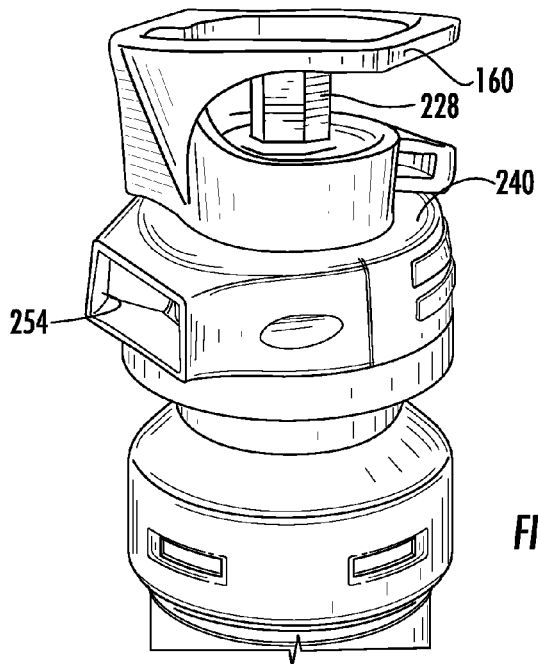
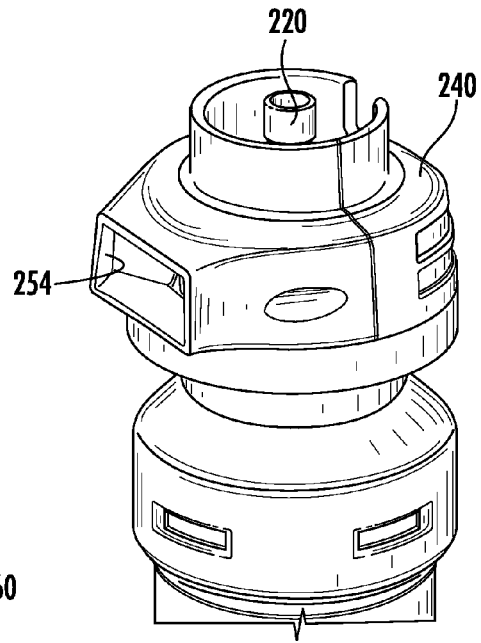
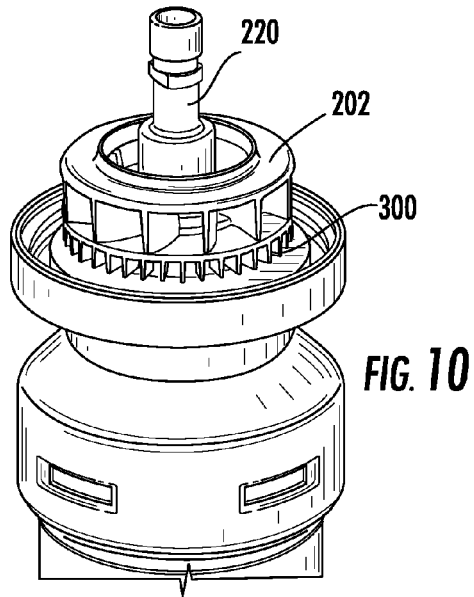


FIG. 9



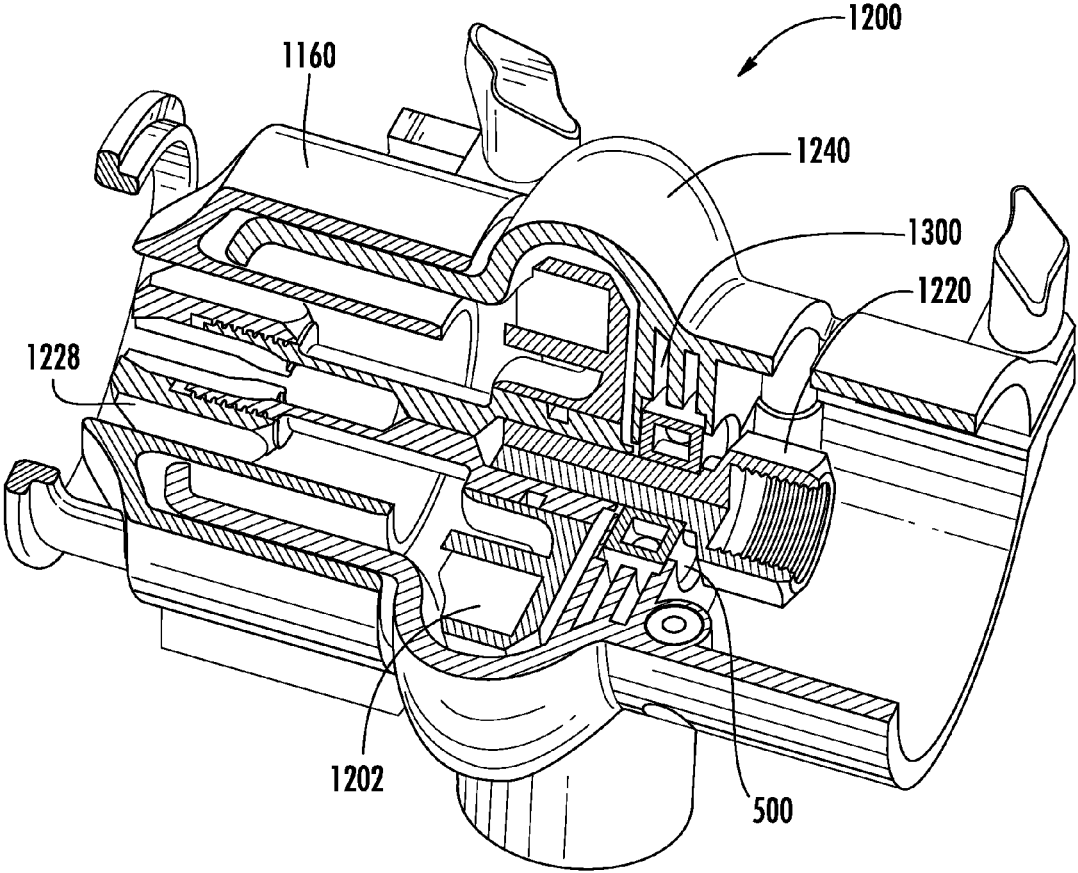


FIG. 13

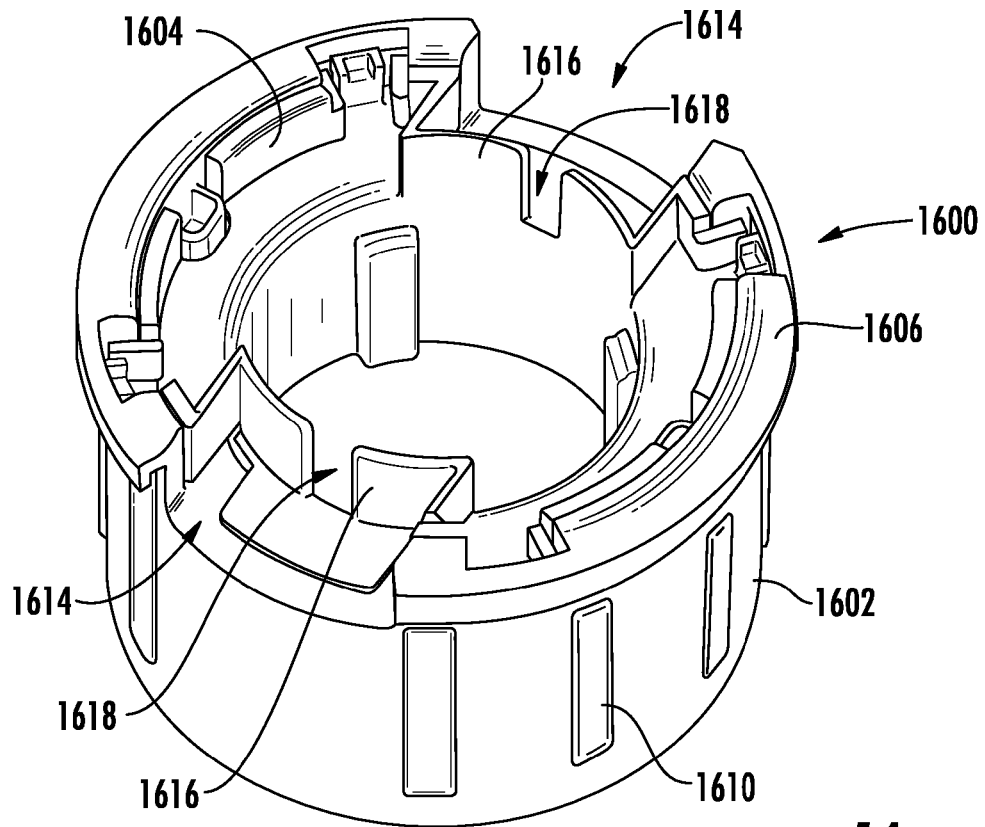


FIG. 14

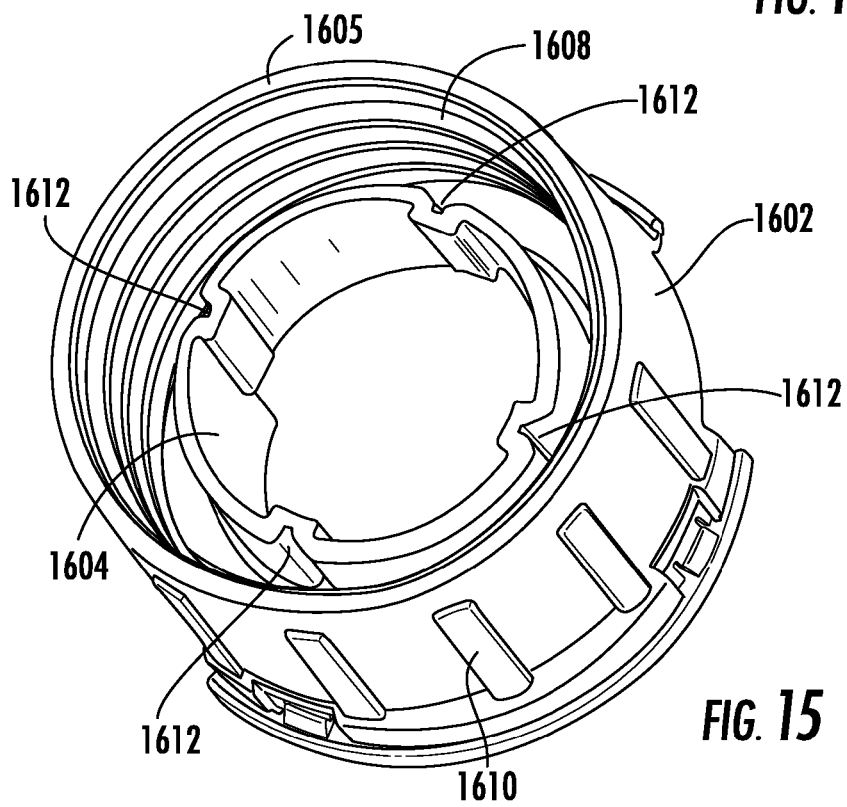


FIG. 15

1

## METHOD OF USE FOR DEBRIS REMOVAL SYSTEM FOR POWER TOOL

### CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

This application is a Divisional of U.S. patent application Ser. No. 12/633,582, filed Dec. 8, 2009, which claims priority to and the benefit of U.S. Provisional Patent Application No. 61/121,076, filed Dec. 9, 2008, both of which are incorporated herein by reference in their entireties.

### BACKGROUND

The present disclosure relates generally to the field of hand-held power tools. More specifically, the present disclosure relates to hand-held power tools that include systems for collecting or otherwise removing debris (e.g., particles, dust, sawdust, chips, etc.) generated during operation of the hand-held power tools.

Hand-held power tools, such as rotary cutout or cutting tools, generally include a housing and an electric motor contained within or at least partially enclosed by the housing. The motor is configured to move a tool bit or other cutting accessory at high speeds to form cuts in a workpiece (e.g., a piece of wood, drywall, tile, etc.). For example, a rotary cutting tool such as that disclosed in U.S. Pat. Nos. 5,813,805 and 6,443,675 to Koprass et al. (the disclosures of which are incorporated by reference herein in their entirety) is configured to rotate a helical or spiral cutting tool bit that includes a sharp cutting edge wrapped in a helix around the longitudinal axis of the bit. According to this example, the rotary cutting tool forms cuts in a workpiece by moving the tool in a direction that is substantially perpendicular to the axis of rotation of the tool bit (i.e., the rotary cutting tool is arranged substantially normal to the workpiece surface and moved parallel to the surface of the workpiece to allow the edges of the tool bit to remove material from the workpiece).

Hand-held power tools are known to generate a substantial amount of debris while cutting. Such debris may interfere with further cutting by accumulating on the workpiece, on the tool bit, and/or within the cutting tool itself. Such debris may also become airborne and be dispersed throughout the working environment. This may be particularly undesirable if the hand-held power tool is being used in a "clean" environment, such as within a finished room (e.g., decorated, furnished, carpeted, etc.) since additional cleanup may be necessary.

Some power tools employ vacuum systems connected to the tool to remove cutting debris. Such vacuum systems typically make use of an adapter that has to be connected to an external or standalone vacuum system (e.g., a shop vacuum, etc.) via a vacuum hose or conduit. Thus, use of such an adapter requires a user to obtain a standalone vacuum system. Further, requiring a hand-held power tool to be coupled to a standalone vacuum system often makes use of the hand-held power tool more cumbersome. For example, the vacuum conduit coupling the adapter to the standalone vacuum system may interfere with the mobility or range of use of the tool. Further, the vacuum conduit may disrupt the balance or feel of the tool for a user.

Some power tools employ vacuum systems which are integrally formed with the power tool. Such vacuum systems may increase the overall size and weight of the power tools. As can be appreciated, a user is likely to use a hand-held power tool for both applications in which a vacuum system would be desirable and applications in which a vacuum system would be unnecessary.

2

Thus, there is a need for a power tool having a debris removal system that is not required to be connected to a standalone vacuum system. There is also a need for a power tool having a detachable debris removal system that may be securely coupled to the power tool in a relatively simple and efficient manner. There is also a need to provide a power tool that includes a debris removal system configured to reduce the amount of debris entering the motor housing of the power tool. There is also a need for a power tool that includes a debris removal system that is driven by an already existing output shaft of the power tool.

It would be desirable to provide a power tool and/or a debris removal attachment that provides one or more of these or other advantageous features as may be apparent to those reviewing this disclosure. The teachings disclosed extend to those embodiments which fall within the scope of the appended claims, regardless of whether they accomplish one or more of the above-mentioned needs.

### SUMMARY

One exemplary embodiment relates to a method of using a hand-held power tool having a debris removal attachment. The method includes providing a hand-held power tool having an output shaft and selectively coupling an extension shaft to the output shaft. The method also includes coupling a first impeller to the extension shaft and providing a housing adjacent the first impeller. The method further includes rotating the first impeller to generate a pressure differential sufficient to draw debris into the housing. The extension shaft has a first end and a second end, the first end configured to couple to the output shaft of the hand-held power tool, and the second end configured to couple to a tool bit.

Another exemplary embodiment relates to a method of using a hand-held power tool having a debris removal attachment. The method includes providing a hand-held power tool and providing a debris removal attachment. The hand-held power tool includes a motor disposed in a motor housing and an output shaft coupled to the motor. The debris removal attachment includes an extension shaft having a first end and a second end, the second end configured to couple to a tool bit, a first impeller coupled to the extension shaft, the rotation of which is configured to generate a pressure differential sufficient to draw debris into the debris removal system, a housing substantially disposed about the first impeller, a second impeller coupled to the extension shaft, and a substantially planar member separating the first impeller and the second impeller. The method further includes detachably coupling the first end of the extension shaft to the output shaft.

Another exemplary embodiment relates to a method of using a debris removal attachment for a hand-held power tool. The method includes providing an extension shaft, coupling a first impeller to the extension shaft, providing a housing adjacent the first impeller, providing a labyrinth seal in a pathway between an exterior of the housing and an interface of the extension shaft and the output shaft, selectively coupling the first end of the extension shaft to an output shaft, and rotating the first impeller to generate a pressure differential sufficient to draw debris into the housing. The extension shaft has a first end and a second end, the first end configured to couple to an output shaft, and the second end configured to couple to a tool bit. The labyrinth seal has a plurality of spaced apart annular projections provided for disrupting the pathway.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a hand-held power tool according to an exemplary embodiment.

3

FIG. 2 is another perspective view of the hand-held power tool shown in FIG. 1.

FIG. 3 is a perspective view of a debris removal system according to an exemplary embodiment shown coupled to the hand-held power tool shown in FIGS. 1 and 2.

FIG. 4 is a partial cutaway perspective view of the debris removal system shown in FIG. 3.

FIG. 5 is an exploded partial view of the hand-held power tool and debris removal system shown in FIG. 3.

FIG. 6 is a partial cutaway perspective view of a portion of the debris removal system shown in FIG. 3.

FIG. 7 is a partial perspective view of the hand-held power tool shown in FIGS. 1 and 2 without a depth guide.

FIG. 8 is a perspective view of the portion of the hand-held power tool shown in FIG. 7 with a mounting assembly system of the debris removal system according to an exemplary embodiment.

FIG. 9 is a cross-sectional view of the mounting assembly system taken along line 9-9 of FIG. 8.

FIG. 10 is a perspective view of the portion of the hand-held power tool shown in FIG. 8 with a pressure differential generating element of the debris removal system according to an exemplary embodiment.

FIG. 11 is a perspective view of the portion of the hand-held power tool shown in FIG. 10 with a housing of the debris removal system according to an exemplary embodiment.

FIG. 12 is a perspective view of the portion of the hand-held power tool shown in FIG. 11 with a depth guide according to an exemplary embodiment.

FIG. 13 is a partial cutaway perspective view of a debris removal system according to another exemplary embodiment.

FIG. 14 is a bottom perspective view of a depth guide attachment according to an exemplary embodiment.

FIG. 15 is a top perspective view of the depth guide attachment shown in FIG. 14.

#### DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Referring generally to the FIGURES, an exemplary embodiment of a power tool, shown as a rotary cutting tool 100, is provided. Nonexclusive examples of rotary cutting tools are shown and described in U.S. Pat. Nos. 6,443,676, 6,048,260; 5,902,080; D439,484; and D439,122 and U.S. Pat. No. 6,443,675, each of which are expressly incorporated herein by reference and which are assigned to an affiliated company of Robert Bosch Tool Corporation. It should be noted that while the rotary cutout tool shown and described herein and in the patents and applications incorporated by reference are manufactured and sold by Robert Bosch Tool Corporation, tools of other makes and models may also be used in conjunction with the inventions described herein.

An exemplary embodiment relates to a debris removal attachment for use with a hand-held power tool. The attachment includes an extension shaft, a first impeller coupled to the extension shaft, and a housing provided adjacent the first impeller. The rotation of the first impeller is configured to generate a pressure differential sufficient to draw debris into the housing.

Another exemplary embodiment relates to a hand-held power tool for cutting a workpiece. The hand-held power tool includes a motor housing having a motor provided therein, an output shaft coupled to the motor, and a debris removal system. The debris removal system includes an extension shaft detachably coupled to the output shaft, a first impeller coupled to the extension shaft, and a housing substantially

4

disposed about the first impeller. The rotation of the first impeller is configured to generate a pressure differential sufficient to draw debris into the debris removal system.

Referring to FIG. 1, the rotary cutting tool 100 generally includes a casing or housing 110, a motor (not shown), an output shaft (not shown) coupled to the motor and configured for rotational movement, and a device or mechanism 150 for securing a tool bit 154 to the output shaft. According to the embodiment illustrated, the mechanism 150 for securing the tool bit 154 to the output shaft of the motor is a collet (not shown) having a collet nut 152. The housing 110 is made of an electrically insulating material, such as hard plastic and may be formed as two or more sections (e.g., first and second clamshell halves, etc.) which are joined together to form the housing 110 in a suitable manner, such as using mechanical fasteners, an adhesive, welding, or a combination thereof.

According to the embodiment illustrated, the housing 110 is generally cylindrical in shape, and is sized so that a typical user may support the rotary cutting tool 100 by grasping the housing 110. Optionally, the rotary cutting tool 100 may include one or more handles 120 coupled to the housing 110 to allow for the rotary cutting tool 100 to be grasped more firmly and comfortably by a user, to provide greater control of the rotary cutting tool 100 during operation, and/or to provide for more accurate cuts with less operator fatigue. Handle 120 is shown as being aligned substantially parallel with the longitudinal axis of the housing 110, but alternatively may be supported in any of a number of positions.

For some applications it may be desirable that the handle 120 be detached. For example, for making cuts in close quarters or obstructed areas, the handle 120 may become an obstruction, and actually interfere with the making of accurate cuts. Thus, it is desirable to provide both for securely attaching the handle 120 to the rotary cutting tool 100 when needed and for easily detaching the handle 120 from the rotary cutting tool 100 when its use would interfere with operation of the tool. According to the various alternative embodiments, the handle 120 (if provided) may be permanently coupled to the housing 110 (e.g., by being integrally formed with the housing 110, etc.).

According to the embodiment illustrated, the motor is enclosed within the housing 110. The motor receives electrical power from a battery pack 130 detachably supported by the housing 110. In this manner, the rotary cutting tool is a "cordless" power tool. A member or element 132 is provided to allow the battery pack 130 to be removed when the member 132 is depressed. According to an exemplary embodiment, the battery pack 130 includes one or more rechargeable batteries and has a fully charged voltage between 12 and 24 volts. The battery pack 130 may include any suitable type of batteries, such as nickel-metal hydride or lithium-ion batteries. According to various alternative embodiments, the tool 100 may be a "corded" or hard-wired power tool wherein the motor receives electrical power through an electrical cord coupled to an energy supply. According to other various alternative embodiments, the tool may be configured to be interchangeable between a cordless and a corded power tool.

Preferably, the rotary cutting tool 100 has an on/off switch for selectively energizing the motor. According to the embodiment illustrated, the motor is turned on and off by a power on/off switch 140. For example, the switch 140 is pulled away from the housing 110 to activate the motor and moved towards the housing 110 to deactivate the motor. According to other exemplary embodiments, the switch 140 may be otherwise configured. The motor may be configured to operate at a single speed (e.g., a speed between approximately 15,000 and 30,000 rpm) or a number of speeds (e.g.,

speeds of 15,000 rpm, 20,000 rpm, and 30,000 rpm). In a case where the motor is capable of operating at multiple speeds, the switch **140** may include multiple positions corresponding to the desired motor speed.

When energized, the motor of the rotary cutting tool **100** drives an output shaft (e.g., motor shaft, drive shaft, etc.). The output shaft of the tool **100** is generally coaxial with a central axis of the housing **110**. A cooling fan (not shown), located within the housing **110** around the location where the motor shaft emerges from the housing **110** (i.e., an operating end **170**), is preferably attached to the output shaft. As the output shaft is driven by the motor, the cooling fan is rotated to draw air through the housing **110** and across the motor. For this purpose, intake air vents **172** and exhaust air vents **174** are provided in the housing **110**. According to the embodiment illustrated, intake air vents **172** are formed on the side of the housing **110** at the operating end **170** of the housing **110** and opposite the exhaust air vents **174**. Relatively cool air is drawn by the cooling fan into the housing **110** through the air intake vents **172** to cool the motor, with relatively warm air exhausted from the housing **110** through the exhaust air vents **174**.

An end of the motor shaft extends from one end of the housing **110** along the central axis thereof. A device or mechanism **150** is provided for securing a cutting accessory (e.g., a helical cutting tool bit or other accessory) to the motor shaft. The mechanism **150** includes a collet (not shown) and the collet nut **152** for securing a tool bit **154** to the motor shaft of the rotary cutting tool **100**. According to an exemplary embodiment, the tool bit **154** includes a cutting edge wrapped around the axis of the bit in a helix or spiral. This cutting edge is designed such that the tool bit **154**, when rotated at high speed, will cut through a workpiece in a direction perpendicular to the axis of the bit.

To secure the tool bit **154** to the output shaft, a shank of the tool bit is inserted into a central aperture of the collet, after which the collet nut **152** is tightened. A shaft lock **156** is used to prevent rotation of the output shaft when the collet nut **152** is being loosened and tightened. As the collet nut **152** is tightened down on the threaded end of the output shaft, the collet is compressed within the collet nut **152** between a partially closed end of the collet nut **152** and the output shaft. The collet is slotted and has tapered ends such that when the collet is compressed between the collet nut **152** and the output shaft, the collet is compressed radially, causing the central aperture of the collet to close tightly around the shank of the tool bit. To remove the tool bit from the output shaft, the collet nut **152** is loosened until the tool bit can be removed easily from the central aperture of the collet.

To set the depth of cut to be made by the rotary cutting tool **100**, an adjustable depth guide assembly **160** may be provided. The depth guide **160** is attached to the housing **110** at the operating end **170**. As shown in FIG. 1, a depth guide bracket **162** is selectively attachable to the housing **110**, and may be attached to the housing **110** in any suitable manner. For example, the depth guide bracket **162** may be formed to have a split collar structure and a cam closing mechanism **164** (e.g., an over-center latch). The depth guide bracket **162** may be operated to close the collar tight around the end of the housing **110**, and which may be operated to loosen the collar to remove the depth guide bracket **162** from the housing **110**.

The depth of cut of the rotary cutting tool **100** may be set by moving an extending portion **166** of the depth guide **160** in an axial direction relative to the bracket **162**. A locking mechanism may then be used to lock the extending portion **166** in a fixed position relative to the bracket **162** to securely fix the depth guide **160** in place. The locking mechanism may be

implemented as a cam lever, as a threaded nut or a screw, or as any other suitable type of device or mechanism.

As a workpiece is cut using the rotary cutting tool **100**, cutting debris (e.g., particles, dust, sawdust, chips, etc.) may deposit and build up on the workpiece surface at or near the point of the cut and/or may become airborne and disperse throughout the working environment. Such debris may interfere with the visibility of the user trying to control the rotary cutting tool **100** to make a precise cut of a desired shape. For example, debris deposited on the workpiece may obscure a cut line marked on the workpiece. Simply dispersing (e.g., blowing, etc.) such debris throughout the working environment would only increase the amount of cleanup required after the cutting is completed. To collect or otherwise contain at least a portion of the cutting debris generated by the rotary cutting tool **100**, a vacuum system is added to the tool.

Referring to FIG. 3, an exemplary embodiment of the vacuum system, referred to as a debris removal system **200**, and components thereof is shown coupled to the rotary cutting tool **100**. The debris removal system **200** generally includes a pressure differential generating element configured to draw debris away from a workpiece, a drive element for operatively coupling the pressure differential generating element to the power tool, a cover disposed at least partially about the pressure differential generating element for assisting in maintaining the pressure differential created by the pressure differential generating element, a coupling element for securing the debris removal system **200** to the power tool, and a sealing element for reducing the amount debris drawn into a housing of the power tool. Optionally, the debris removal system **200** may further include a debris collection element suitable for collecting debris drawn by the pressure differential generating element.

The debris removal system **200** is shown in the form of an attachment (e.g., an adapter, module, add-on feature, optional component, etc.) that may be securely coupled to the rotary cutting tool **100** in a relatively simple and efficient manner by a user, and removed from the rotary cutting tool **100** in a similar manner when its use is no longer desired. Further, the debris removal system **200** is preferably driven (i.e., powered) by an already existing output shaft of the rotary cutting tool **100**. The pressure differential generating element of the debris removal system **200** is self-supporting (meaning that an external or standalone vacuum supply is not required to generate the pressure differential used to draw debris from the workpiece). However, in certain applications, it may be desirable to make use of an external or standalone vacuum supply.

It should be understood that, although the debris removal system **200** will be described in detail herein with reference to the rotary cutting tool **100**, the debris removal system **200** may be applied to, and find utility in, other types of power tools (e.g., hand-held power tools, etc.) as well. For example, the debris removal system **200** may be suitable for use with routers, drills, reciprocating saws, grinders, jigsaws, sanders, or any other power tool. It should further be understood that while the debris removal system **200** will be described in detail herein as being a detachable system (i.e., an attachment), according to various other exemplary embodiments, the debris removal system **200** may be integrally formed with or otherwise configured to be permanently coupled to a power tool.

The debris removal system **200** is configured to remove (and optionally collect) cutting debris generated adjacent to the workpiece during the operation of the rotary cutting tool **100**. The debris removal system **200** removes debris by generating an area of lower pressure (i.e., a vacuum) adjacent to the workpiece thereby causing air and at least a portion of the



debris to be drawn away from the workpiece. While the debris removal system **200** is shown as an attachment (e.g., adapter, module, add-on feature, etc.) intended to be selectively added and detached from the rotary cutting tool **100**, those skilled in the art who review this disclosure will readily appreciate that the debris removal system **200** may be integrated with the rotary cutting tool **100** in a manner such that the debris removal system **200** will be permanently coupled to the rotary cutting tool **100**.

Referring to FIGS. **4** and **5**, the debris removal system **200** generally includes a pressure differential generating element (shown as a fan assembly **202**), a drive element (shown as an output shaft extension **220**) adapted to transfer rotational movement of the output shaft of the power tool to the pressure differential generating element, a cover element (shown as a housing **240**) disposed at least partially about the pressure differential generating element, a coupling element (shown as a mounting assembly **270**) for securing the debris removal system **200** to the rotary power tool **100**, a sealing element (shown as a sealing system **300**) adapted to reduce the amount of debris drawn into the motor housing of the rotary cutting tool **100**, and a debris collection element (shown as a debris receptacle or canister **320**) suitable for collecting at least some of the debris removed by the pressure differential generating element.

Referring to FIG. **6**, the fan assembly **202** is shown as generally comprising a first impeller **204**, an annular hub **206**, and a substantially planar portion **208**. Rotation of first impeller **204** functions as a pump creating an area of lower pressure adjacent to the workpiece. This negative pressure differential created by rotation of the first impeller **204** causes air to be drawn from around the workpiece into the housing **240** (e.g., as shown in FIG. **5**). At least a portion of the debris is carried away by the air that is drawn by the first impeller **204** thereby facilitating its removal from the workpiece and/or the rotary cutting tool **100**.

The first impeller **204** is shown as having a plurality of fan blades **210** extending outwardly in a radial direction from the annular hub **206** and in the axial direction from the substantially planar portion **208**. The fan blades **210** have a radius that is shown as changing from a relatively larger radius near the annular hub **206** to a relatively smaller radius near the substantially planar portion **208**. The fan blades **210** are further shown as bending or curving as they extend outwardly in a radial direction from the annular hub **206**. The configuration of the fan blades **210** is intended to assist in drawing air from around the workpiece into the housing **240**. The fan blades **210** may be generally perpendicular to the substantially planar portion **208**, or alternatively, the fan blades **210** may be tilted and provided at an angle relative to the substantially planar portion **208**. According to various other exemplary embodiments, the fan blades **210** may have any of a number of configurations suitable for drawing air from around the workpiece.

The annular hub **206** is shown in the form of a sleeve having an inner surface **212** defining a bore **214** (e.g., as shown in FIG. **5**). The bore **214** has a diameter sufficiently sized to be disposed about the output shaft extension **220** and facilitate in coupling the fan assembly **202** to the output shaft extension **220**. Thus, the fan assembly **202** is generally concentrically aligned with the central longitudinal axis of the rotary cutting tool **100**. Coupling the fan assembly **202** to the output shaft extension **220** enables the debris removal system **200** to be driven (i.e., powered) by the rotary cutting tool **100**. More specifically, coupling the fan assembly **202** to the output shaft extension **220** allows the fan assembly **202** to rotate in response to the rotation of the output shaft extension **220** (and

to that of the output shaft). As such, the output shaft extension **220** and the fan assembly **202** will operate at substantially the same speed. As mentioned above, the output shaft of the rotary cutting tool **100** (and thus the output shaft extension **220** and the fan assembly **202**) may operate at speeds up to 30,000 rpm.

The fan assembly **202** may be coupled to the output shaft extension **220** using any of a variety of suitable techniques. For example, the inner surface **212** of the hub **206** may frictionally engage (e.g., press-fit, snap-fit, axially interfering fit, etc.) the output shaft extension **220** as the output shaft extension **220** is inserted into the bore **214**. Alternatively, the fan assembly **202** may be coupled to the output shaft extension **220** using one or more mechanical fasteners (e.g., set screws, locking pins, etc.), a welding process (e.g., ultrasonic welding, etc.), an adhesive, or any other suitable technique. According to a further alternative embodiment, the fan assembly **202** may be integrally formed with the output shaft extension **220** to provide a unitary one-piece member.

The substantially planar portion **208** may provide support for the fan blades **210** and/or may assist in guiding debris that is drawn into the debris removal system **200**. The substantially planar portion **208** is shown as being relatively flat and extending in a substantially radial direction (relative to the output shaft extension **220**), but according to the various alternative embodiments, the substantially planar portion **208** may have one or more portions that extend linearly or curvilinearly in both an axial and/or radial direction. According to the embodiment illustrated, a projection or raised lip **211** is provided about the inner periphery of the substantially planar portion **208**. The raised lip **211** may provide additional rigidity to the fan assembly **202** by reducing deflection of the substantially planar portion during rotation of the first impeller **204**, and/or may further assist in guiding debris that is drawn into the debris removal system **200**.

Referring to FIG. **4**, to transfer the rotational movement of the output shaft of the rotary cutting tool **100** to the fan assembly **202** and/or the sealing system **300**, the output shaft extension **220** is provided. The output shaft extension **220** is shown as a cylindrical member extending between a first end **222** and a second end **224**. The length of the output shaft extension **220** may vary depending on the other components of the debris removal system **200**. Threads **226** are provided on an inner surface of the first end **222** for coupling the output shaft extension **220** to the threaded end of the output shaft of the rotary cutting tool **100**. For such an embodiment, the collet nut **152** is removed from the threaded end of the output shaft and replaced with the output shaft extension **220**. According to various alternative embodiments, the first end **222** may have a structure other than the threads **226** which cooperate with a corresponding structure on the output shaft of the rotary cutting tool **100** for securing the motor shaft extension **220** to the output shaft of the rotary cutting tool **100**. According to a further alternative embodiment, the first end **222** may have a structure configured to be coupled to the collet nut **152**.

The second end **224** of the output shaft extension **220** is configured to receive a device or mechanism **228** capable of securing a cutting accessory to the output shaft extension **220**. According to the embodiment illustrated, the mechanism **228** includes a collet **230** and a collet nut **232**. The collet nut **232** may be the same collet nut **152** shown in FIG. **1**, or alternatively, may be particularly adapted to couple to the second end **224** of the output shaft extension **220**.

To assist in maintaining the pressure differential generated by the rotation of the fan assembly **202** and/or to assist in defining the flow path or passage for debris drawn away from

the workpiece, the housing **240** is provided (e.g., as shown in FIG. 4). The housing **240** includes a cylindrical portion **242** defining a cavity or chamber **244** configured to receive the fan assembly **202**. The housing **240** extends between a first end **246** and a second end **248** and is preferably coaxially aligned with the central axis of the rotary cutting tool **100**. Threads **250** are provided on an indented outer surface of the first end **246**. The threads **250** are provided to detachably secure the housing **240** to the mounting system **270**. According to various other exemplary embodiments, the housing **240** may be coupled to the mounting system **270** using any of a variety of suitable techniques. For example, cylindrical portion **242** may include an inner detent or a raised ring to allow it to be snap-fit to a corresponding structure on the mounting system **270**. According to a further alternative embodiment, the housing **240** may be coupled directly to the housing **110** of the rotary cutting tool **100**.

The second end **248** of the housing **240** includes an indented cylindrical portion providing a surface to which a tool accessory may be coupled. For example, the second end **248** may be configured to receive a depth guide (e.g., the depth guide **160** shown in FIG. 5, the depth guide **1600** shown in FIGS. 14-15, etc.). According to various alternative embodiments, the second end **248** may include a structure (e.g. threads, a groove, a rib, etc.) for assisting in coupling a tool accessory to the housing **240**.

The housing **240** may be made of any of a variety of suitable materials, such as hard plastic similar to that used for the housing **110** of the rotary cutting tool **100**. The housing **240** may be formed of such a material in two or more complementary members (e.g., first and second clamshells halves, etc.) by a suitable molding process. The two or more members are then joined together to form the complete housing **240**. The two or more members may be coupled together in any suitable technique, for example, using a welding process or an adhesive. The two or more members are preferably coupled together, using screws or another type of mechanical fastener. For this purpose, screw holes **252** may be formed in the housing **240**. According to various alternative embodiments, the housing **240** may be formed as a one-piece member.

Referring further to FIG. 4, the chamber **244** defined by the housing **240** is sufficiently sized to receive the fan assembly **202** so that the first impeller **204** of the fan assembly **202** can rotate in a generally unobstructed manner therein. While the first impeller **204** requires a certain amount of clearance between the cylindrical portion **242** and the fan blades **210**, according to the embodiment illustrated, any space or gap between the fan blades **210** and the cylindrical portion **242** is minimized to assist in maintaining the pressure differential generated by the fan assembly **202**, and/or to reduce the overall size of the debris removal system **200**. By way of example, a gap ranging between approximately 1 millimeter and approximately 2.5 millimeters may be provided between the first impeller **204** and the cylindrical portion **242**. According to various other exemplary embodiments, a portion of the first impeller **204** may be configured to engage (e.g., brush against, etc.) the cylindrical portion **242** as the first impeller **204** rotates. For example, a bearing surface may be provided between the first impeller **204** and the cylindrical portion **242**.

The chamber **244** is in fluid communication with at least one exhaust port or conduit (shown as an exhaust duct **254**). The exhaust duct **254** provides an opening through which debris may exit the housing **240** after being drawn by the rotation of the fan assembly **202**. According to the embodiment illustrated, a single exhaust duct **254** is provided. The

exhaust duct **254** is preferably sized large enough to prevent or minimize the exhaust duct **254** from becoming clogged with debris.

The debris removal system **200** is shown as including the canister **320** which is configured to collect debris drawn by the fan assembly **202** and passed through the exhaust duct **254**. The canister **320**, shown as being supported at an open end of the exhaust duct **254**, may be detachably or fixedly coupled at the exhaust duct **254**. The canister **320** may be coupled at the exhaust duct **254** by a friction fit, interference fit, mechanical fastener (e.g., clip, screw, rivet, etc.), adhesive, welding or any other known or otherwise suitable technique. Detachably coupling the canister **320** at the exhaust duct **254** may allow the entire canister **320** to be selectively removed from the debris removal system **200** and/or the rotary cutting tool **100**. Being able to selectively remove the canister **320** may allow a user to more easily empty debris collected in the canister **320** and/or may provide a user with a tool having increased flexibility. For example, if a user is operating a power tool in a limited space, it may be desirable to use the debris removal system **200** without the canister **320**.

Preferably, the canister **320** will have sufficient capacity to collect debris generated during several cutting operations. Referring again to FIG. 5, the canister **320** is shown as being in the form of a relatively rigid housing having an inlet **322** configured to be in communication with the exhaust duct **254** and one or more exhaust vents **324** for allowing air to pass through the system. Preferably, a filter (e.g., a pad, bag, screen, etc.) is provided within the canister **320** to trap debris while allowing air to pass through the exhaust vents **324**. Those skilled in the art will appreciate that the canister **320** may be replaced with any suitable mechanism for collecting debris (e.g., a fine mesh bag, etc.). Further, the debris collection element may be substantially near the rotary cutting tool **100** (as shown), or alternatively, may be provided at a distance from the tool and coupled thereto via a suitable conduit (e.g., hose, tube, pipe, etc.). According to a further alternative embodiment, an external or stand-alone vacuum (not shown) may be coupled to the exhaust duct **254** for collecting debris and/or to assist in the removal of the cutting debris from the workpiece and/or the rotary cutting tool **100**.

Optionally, a seal (not shown) may be employed to seal the interface or joint between the canister **320** and the exhaust duct **254** of the housing **240**. According to an exemplary embodiment, the seal may be a gasket formed of a resilient material, such as rubber, and designed to be compressed between the canister **320** and the exhaust duct **254**. According to various alternative embodiments, the seal may be provided by any known or otherwise suitable technique for providing a seal. Providing a seal between the exhaust duct **254** and the canister **320** may reduce the likelihood that an opening (e.g., a gap, etc.) will exist between the exhaust duct **254** and the canister **320**. Such an opening, if present, may cause an undesired change of pressure within the system (e.g., a hose of the vacuum, etc.) and/or provide an unintended escape path for debris.

According to an alternative embodiment, the debris removal system **200** may be configured without a debris collection element. For example, for certain power tools and/or certain applications a user may not be concerned about airborne debris and may only be interested in removing debris from around the workpiece. For such an embodiment, the exhaust duct **254** may be provided at an angle for directing debris away from the user and/or the rotary cutting tool **100**.

Referring to FIGS. 5-9, the debris removal system **200** is coupled to the rotary cutting tool **100** by the mounting assembly **270**. Preferably, the mounting assembly **270** is configured

11

to detachably couple the debris removal system **200** to the rotary cutting tool **100** so that a user can selectively add or remove the debris removal system **200** depending on the particular application. The mounting system **270** is shown as including a first member or a mounting ring **272** and second member or a compression ring **274**. The mounting ring **272** and the compression ring **274** cooperate to facilitate the securement of the debris removal system **200** to the operating end **170** of the rotary cutting tool **100**.

The mounting ring **272** includes a cylindrical portion **276** extending between a first end **278** configured to be coupled to the operating end **170** of the rotating cutting tool **100** (e.g., a tool neck **171**, etc.) and a second end **280** configured to be coupled to the housing **240** of the debris removal system **200**. The first end **278** defines an aperture having a diameter corresponding to the diameter of the tool neck **171**. According to various alternative embodiments, the first end **278** of the mounting ring **272** may have other configurations than that shown to match the particular power tool for which the debris removal system is to be used with. According to further alternative embodiments, the first end **278** of the mounting ring **272** may include an adjustable member (e.g., a clamp, etc.) for allowing the debris removal system **200** to be used with power tools differing in size and/or shape.

Referring to FIG. 9, the first end **278** is shown as including an upwardly extending annular projection **284** configured to snap over the tool neck **171**. A lip or rib **285** is provided adjacent an end of the projection **284** for engaging a corresponding structure (shown as a groove **173**) on the tool neck **171**. Engagement of the rib **285** into the groove **173** assists in securing the mounting ring **272** to the tool neck **171**. Preferably, the projection **284** is a resilient member configured to flex when a radial force is exerted thereto.

The first end **278** of the mounting ring **272** is also shown as forming a seal with the tool neck **171**. In particular, the seal is provided between a shoulder portion **175** of the tool neck **171** and an end surface of the first end **278**. The shoulder portion **175** of the tool neck **171** is shown as being a substantially radial surface (relative to the output shaft), but alternatively may be an angled or sloped surface. According to an exemplary embodiment, the end surface of the first end **278** is formed of a resilient material configured to form a compression seal when the rib **285** engages the groove **173**. The resilient member may be integrally molded with the mounting ring **272**, or alternatively may be provided as a separate component that is attached to the mounting ring **272** and/or the tool neck **171**.

According to an exemplary embodiment, threads **282** are provided on an inner surface of the second end **280** of the mounting ring **272** for detachably coupling the mounting assembly **270** to the threads **250** of the housing **240** (e.g., as shown in FIG. 4). According to various alternative embodiments, the second end **280** may include any of a number of mechanisms for coupling the mounting assembly **270** to the housing **240**.

The mounting assembly **270** further includes the compression ring **274**. The compression ring **274** is an annular member having a substantially planar portion **286**, a first annular projection **288** extending outwardly from a first surface of the substantially planar portion **286**, and one or more annular sealing projections **290** (shown as a pair of sealing projections **290**) extending outwardly from a second surface of the substantially planar portion **286**. The compression ring **274** is concentrically aligned with the mounting ring **272** with the first annular projection **288** being disposed outside of the projection **284** of the mounting ring **272** (i.e., provided on a side opposite the tool neck **171**). A first or free end of the first

12

annular projection **288** is shown as having an inclined surface configured to engage a corresponding surface on the projection **284**. When the housing **240** is threaded onto the mounting ring **272**, the housing **240** will exert a force on the compression ring **274** which will in turn cause the compression ring **274** to exert a force on the projection **284** thereby urging the rib **285** into the groove **173**.

According to various other exemplary embodiments, any number of suitable mounting assemblies may be employed to couple the housing **240** to the rotary cutting tool **100**. For example, the mounting ring **272** and the compression ring **274** may be integrally formed as a single, one-piece unitary body. According to a further alternative embodiment, the mounting assembly may be configured to permanently couple the debris removal system **200** to the rotary cutting tool **100**.

Referring now to FIG. 6, an exemplary embodiment of the sealing system **300** is shown. The sealing system **300** is provided in an effort to prevent debris from being drawn into the housing **110** of the rotary cutting tool **100** and/or to reduce the amount of debris realized by a front bearing (not shown) of the rotary cutting tool **100**. Reducing the amount of debris drawn into the housing **110** may prolong the operating life of the rotary cutting tool **100** by reducing the amount of build-up that may occur on the motor from debris entering the housing **110**. Similarly, reducing the amount of debris reaching the front bearing may allow the output shaft to continue to rotate at a consistent speed. The sealing system **300** provides a seal between the output shaft of the rotary cutting tool **100** and the debris removal system **200**. To accommodate the dynamic nature of the sealing location between the output shaft and the debris removal system **200** (e.g., the output shaft of the rotary cutting tool **100** can operate in excess of 30,000 rpm), the sealing system **300** is preferably in the form of a non-contact seal (i.e., a seal that does not physically contact the rotating output shaft).

According to the embodiment illustrated, the sealing system **300** comprises a first seal **302** and a second seal **304**. The first seal **302** is configured to generate an air stream or flow for pushing or deflecting at least a portion of the debris away from the tool **100**, while the second seal **304** is configured to deter debris from reaching the front bearing and/or the housing **110** by providing a labyrinth seal comprising at least one barrier for restricting (e.g., selectively altering, etc.) a passage leading to the interface or joint between the output shaft and the output shaft extension **220**. According to various other exemplary embodiments, the debris removal system **200** may include only one seal (e.g., the first seal **302** or the second seal **304**, etc.), or may include any number of seals greater than two.

The first seal **302** (e.g., a deflection seal, etc.) is shown as a fan assembly generally comprising a second impeller **306** and a substantially planar portion **308**. The second impeller **306** is shown as having a plurality of fan blades **310** outwardly extending in a radial direction from an annular hub **312** and in axial direction from the substantially planar portion **308**. The fan blades **310** are shown as being generally perpendicular to the substantially planar portion **308**. The substantially planar portion **308** divides the first impeller **204** from the second impeller **306** and may assist in preventing debris drawn into the housing **240** from reaching the operating end **170** of the rotary cutting tool **100**.

The second seal **304** provides additional sealing protection by functioning as a back-up seal for debris getting past the first seal **302**. The second seal **304** is in the form of a labyrinth seal having one or more barriers (e.g., projections, etc.). According to the embodiment illustrated, the second seal **304** comprises one or more annular projections **314** (e.g. barriers,

etc.) extending from the second impeller **306** which cooperate with the sealing projections **290** extending from the compression ring **274** to form the labyrinth seal. As shown, the annular projection **314** is concentrically aligned between the sealing projections **290**. When assembled, a gap is provided between a free end of the annular projection **314** and the substantially planar portion **286** of the compression ring **274**. Similarly, gaps are provided between free ends of the sealing projections **290** and the substantially planar portion **308** of the second impeller **306**. The size of such gaps are minimized. These gaps define a passage (such as, e.g., represented by arrow **301** in FIG. **6**) through which debris would have to follow in order to reach the operating end **170** of the rotary cutting tool **100**. According to various other exemplary embodiments, the second seal **304** may include any number of barriers, aligned at any of a variety of orientations, for restricting the passage leading to the joint between the output shaft and the output shaft extension **220**.

It should be noted that, the first impeller **204** may be integrally formed with the second impeller **306** or may be provided as a separate component. According to the embodiment illustrated, the first impeller **204** and the second impeller **306** are separate components configured to be coupled together in a manner such that the rotation of the first impeller **204** coincides with the rotation of the second impeller **306**.

In some applications, a user may wish to detach the debris removal system **200** from the rotary cutting tool **100**. For example, when making cuts in close quarters or obstructed areas, the added length and/or width of the debris removal system **200** may become an obstruction, and actually interfere with the making of accurate cuts. Further, when repeatedly making overhead cuts, the added weight of the debris removal system **200** may be undesirable to a user. Thus, it is desirable to provide for both securely coupling the debris removal system **200** to the rotary cutting tool **100** and for easily detaching the debris removal system **200** from the rotary cutting tool **100**.

With reference to FIGS. **7** through **12**, the following methods may be employed to add or remove the debris removal system **200** relative to the rotary cutting tool **100**. To add the debris removal system **200** to the rotary cutting tool **100**, a depth guide (if being employed) is selectively removed from the operating end **170** of the rotary cutting tool **100**, and the collet nut **152** is removed from the output shaft. The mounting ring **272** of the mounting assembly **270** can then be disposed over (e.g. snapped over, etc.) the operating end **170** such that the rib **285** of the projection **284** extending from the mounting ring **272** is substantially aligned with and engages the groove **173** formed in the tool neck **171**. The compression ring **274** can then be disposed about the tool neck **171** such that the first annular projection **288** is provided on the outside of the projection **284** of the mounting ring **272**. Alternatively, the mounting ring **272** and the compression ring **274** may be coupled together and installed on the rotary cutting tool as a single unit.

The output shaft extension **220** may then be coupled to the output shaft by rotating the output shaft extension **220** about the threads of the output shaft. The second impeller **306** and the first impeller **204** can then be disposed about the output shaft extension **220**. Alternatively, the second impeller **306**, the first impeller **204**, and the output shaft extension **220** may be coupled together and installed on the rotary cutting tool **100** as a single unit.

The housing **240** may then be threaded into the mounting ring **272**. As the housing **240** is threaded into the mounting ring **272**, the compression ring **274** forces the mounting ring **272** into engagement with the tool neck **171**. At this point, the

mechanism **228** may be coupled to the second end **224** of the output shaft extension **220**, and/or the depth guide **160** may be added. To remove the debris removal system **200**, the above-described steps may be reversed.

Referring to FIG. **13**, another exemplary embodiment of a debris removal system **1200** is shown. For brevity, the description of the debris removal system **1200** will be generally limited to its differences relative to the debris removal system **200** described above. For convenience, elements of the debris removal system **1200** that are substantially similar to corresponding elements of the debris removal system **200** will be identified by the same reference numerals but preceded by a "1."

The debris removal system **1200** differs from the debris removal system **200** in that the sealing system **1300** does not make use of the second impeller **306**. Without the second impeller **306**, the sealing system **1300** does not employ a deflection seal or a labyrinth seal. Rather, the sealing system **1300** comprises a bearing **500** disposed about the output shaft extension **1220**. The bearing **500** is shown as being disposed about the output shaft extension **1220** near the interface with the output shaft. According to other embodiments, the bearing **500** may be disposed about the output shaft extension **1220** in a different location.

As indicated earlier, it may be desirable to provide an attachment that a user may use to set the depth of the cut to be made by the rotary cutting tool **100** (i.e., a depth guide). However, it has been discovered that in certain applications use of a depth guide in combination with the debris removal system **200** reduces the pressure differential (i.e., suction) generated by the debris removal system **200** around the workpiece thereby reducing the effectiveness and/or efficiency of the debris removal system **200**. The reduction of suction is caused at least in part by the general openness of the depth guide. For example, the depth guide **160** illustrated in FIG. **1** intentionally includes a generally open structure so that visibility by a user around the operating head of the power tool is increased.

With reference to FIGS. **14** and **15**, another exemplary embodiment of a depth guide suitable for use with a power tool utilizing a vacuum or debris removal system, such as the debris removal system **200**, is provided. The depth guide, shown as depth guide **1600**, is capable of maintaining a pressure differential created by the debris removal system **200** so that cutting debris can be effectively removed from around the tool bit when a depth guide is being used. According to an exemplary embodiment, the depth guide **1600** is selectively attachable to the debris removal system **200** and/or the housing **110** of the rotary cutting tool **100**.

It should be noted that while the depth guide **1600** is described as being coupled to the debris removal system **200**, the depth guide **1600** may also be coupled directly to the rotary cutting tool **100** in the event that a debris removal system is not used.

The depth guide **1600** generally includes an outer portion (e.g., body, etc.), shown as a base **1602** and an inner portion, shown as an insert **1604**. The insert **1604** is shown as being a separate member that is coupled relative to the base **1602**, but alternatively the base **1602** and the insert **1604** may be provided as an integrally formed one-piece unitary body. The base **1602** and the insert **1604** cooperate to define a substantially enclosed passage or chamber between the workpiece and the debris removal system **200**.

The base **1602** is shown as a generally cylindrical member having a top end **1605** (shown in FIG. **15**) and a bottom end **1606** (shown in FIG. **14**). When the depth guide **1600** is coupled to the debris removal system **200**, the top end **1605** is

## 15

configured to be adjacent to the debris removal system **200**, while the bottom end **1606** is configured to be placed adjacent to the workpiece during a cutting operation performed by the rotary cutting tool.

According to the embodiment illustrated, threads **1608** are provided on an inner surface of the base **1602** for coupling the depth guide **1600** to the outside of the debris removal system **200**. For such an embodiment, complementary threads are disposed on an outer surface of the debris removal system **200** (e.g., at second end **248** of housing **240**, etc.) to engage the threads **1608**. For example, complementary threads may be disposed on an outer surface of the second end **248** of the housing **240** (shown in FIG. 5). The threads **1608** preferably begin at the top end **1605** of the base **1602** and extend downward a substantial length of the base **1602**.

With the engagement of the threads **1608** and the corresponding threads on the debris removal system **200**, the depth of the cut of the rotary cutting tool **100** may be set by rotating the base **1602** relative to the debris removal system **200**. Depending on the direction of rotation, rotation of the base **1602** will cause the base **1602** to move upward or downward in an axial direction relative to the debris removal system **200** thereby setting the depth of cut. For such an embodiment, the accuracy of the depth guide **1600** is dictated, at least in part, by the size of the threads **1608**. For example, a user is likely to have more control over the positioning of the depth guide **1600** in the axial direction if the thread size of the threads **1608** is a relatively fine thread rather than a relatively coarse thread.

To assist a user in rotating the base **1602**, an outer surface of the base **1602** includes a configuration intended to promote gripping of the base **1602** either by a hand of the user or by a suitable tool (e.g., wrench, clamp, etc.). According to an exemplary embodiment, the outer surface of the base **1602** includes one or more raised projections intended to simplify the rotation of the base **1602**. According to the embodiment illustrated, the base **1602** includes a series of spaced-apart projections **1610** extending in a substantially axial direction around the periphery of the outer surface of the base **1602**. The projections **1610** are shown as being substantially rectangular in shape, but alternatively may be provided in any of a variety of suitable shapes (e.g., spherical, etc.).

Attachment of the depth guide **1600** to the debris removal system **200** is not limited to a threaded connection. According to various alternative embodiments, the depth guide **1600** may be attached to the debris removal system **200** in any suitable manner. For example, the base **1602** of the depth guide **1600** may be formed to have a split collar structure and a cam closing mechanism (e.g., an over-center latch) which is operated to close the collar tight around the end of the debris removal system **200**, and which may be operated to loosen the collar to remove the depth guide **1600** from the debris removal system **200**.

Referring to FIG. 14 in particular, the bottom end **1606** of the base **1602** includes one or more apertures (e.g., cutouts, notches, windows, etc.), shown as openings **1614**. The openings **1614** allow air to enter when a negative pressure differential is created by the debris removal system **200** and provide visibility around the rotary cutting tool **100** for a user. According to an exemplary embodiment, the openings **1614** are sized large enough to provide sufficient visibility around the rotary cutting tool **100** for the user. According to the embodiment illustrated, the base **1602** is provided with two openings **1614**, spaced equidistant from each other at approximately 180 degrees.

Still referring to FIG. 14, the insert **1604** is provided, at least in part, to limit the amount of air passing through the

## 16

openings **1614** in the base **1602** so that the negative pressure differential created by the debris removal system **200** is substantially maintained. The insert **1604** is shown as a generally cylindrical member that is coupled to the base **1602**. According to an exemplary embodiment, the insert **1604** is coupled to the base **1602** via an interference fit (e.g., snap-fit, etc.). According to various alternative embodiments, the insert **1604** may be coupled to the base **1602** using a mechanical fastener, friction fit, adhesive, welding, or any other known or suitable technique.

The insert **1604** includes a member (e.g., panel, shield, etc.), shown as deflector **1616**, corresponding to each of the openings **1614**. The deflectors **1616** are aligned with the openings **1614** and offset radially inward therefrom. Each deflector **1616** includes one or more apertures (e.g., cutouts, notches, windows, etc.), shown as an opening **1618**. The size of the opening **1618** is smaller than the size of the opening **1614** from which the deflector **1616** is positioned behind. Utilizing the inwardly offset deflectors **1616** in combination with the openings **1614** may improve visibility around the cutting tool since the openings **1614** can be sized larger than if no deflector **1616** was provided. According to various alternative embodiments, use of the insert **1604** and/or the deflectors **1616** may be eliminated and the openings **1614** in the base **1602** may be optimized so that a user is provided with sufficient visibility without substantially diminishing the suction created by the debris removal system **200**.

A locking mechanism may be used to lock the base **1602** in a fixed position relative to the debris removal system **200** to securely fix the depth guide **1600** in place. According to an exemplary embodiment, the locking mechanism is a biasing element (e.g., a spring arm, etc.) supported at the debris removal system **200** and configured to releasably engage the insert **1604** for securing the base **1602** in a fixed position.

Referring to FIG. 15, the insert **1604** is shown as including a plurality of spaced-apart indentations **1612** with openings facing the inner surface of the base **1602**. According to the embodiment illustrated, the insert **1604** includes four indentations **1612**, each one being spaced-apart approximately 90 degrees from an adjacent indentation **1612**. The biasing element on the debris removal system **200** is configured to releasably engage one or more of the indentations **1612** to lock or otherwise secure the depth guide **1600** at every 90 degrees of rotation. Use of the biasing element, in combination with the indentations **1612**, is intended to reduce the likelihood that the locking mechanism will loosen or otherwise fail due to the vibration of the rotary cutting tool **100** during operation. According to various alternative embodiments, the locking mechanism may be implemented as a cam lever, as a threaded nut or a screw, or as any other suitable type of device or mechanism.

The debris removal systems **200** and **1200** detailed above advantageously provide debris removal systems that are not required to be connected to a standalone vacuum system. The debris removal systems **200** and **1200** also advantageously provide debris removal systems that are detachable and which may be securely coupled to a power tool in a relatively simple and efficient manner. The debris removal systems **200** and **1200** further advantageously provide debris removal systems configured to reduce the amount of debris entering the motor housing of the power tool. The debris removal systems **200** and **1200** further advantageously provide debris removal systems that are driven by an already existing output shaft of the power tool.

It is important to note that the construction and arrangement of the power tool and debris removal system as shown in the various exemplary embodiments is illustrative only.

17

Although only a few embodiments of the present inventions have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. For example, elements shown as integrally formed may be constructed of multiple parts or elements, elements shown as multiple parts may be integrally formed, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present invention as defined in the appended claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present inventions as expressed in the appended claims.

What is claimed is:

1. A method of using a hand-held power tool having a debris removal attachment, the method comprising:
  - providing a hand-held power tool having a tool neck and an output shaft;
  - providing a debris removal attachment comprising:
    - an extension shaft having a first end and a second end, the first end configured to couple to the output shaft of the hand-held power tool, and the second end configured to couple to a tool bit;
    - a first impeller coupled to the extension shaft; and
    - a housing adjacent the first impeller;
  - wherein the debris removal attachment is configured to be coupled to the tool neck;
  - selectively coupling the extension shaft to the output shaft; and
  - rotating the first impeller to generate a pressure differential sufficient to draw debris into the housing.
2. The method of claim 1, further comprising providing a second impeller coupled to the extension shaft, the rotation of which is configured to push debris away from an interface between the extension shaft and the hand-held power tool.
3. The method of claim 1, further comprising coupling the attachment to a tool neck of the hand-held power tool.
4. The method of claim 3, wherein coupling the attachment to a tool neck comprises slidably engaging the attachment and the tool neck of the hand-held power tool.
5. The method of claim 1, further comprising providing a labyrinth seal in a pathway between an exterior of the housing and an interface of the extension shaft and the hand-held power tool, the labyrinth seal having a plurality of spaced apart annular projections provided for disrupting the pathway.
6. The method of claim 1, further comprising sealing an interface between the extension shaft and the hand-held power tool with at least one bearing disposed about the extension shaft.
7. A method of using a hand-held power tool having a debris removal attachment, the method comprising:
  - providing a hand-held power tool comprising:
    - a motor disposed in a motor housing;
    - an output shaft coupled to the motor; and
  - providing a debris removal attachment comprising:

18

- an extension shaft having a first end and a second end, the second end configured to couple to a tool bit;
  - a first impeller coupled to the extension shaft, the rotation of which is configured to generate a pressure differential sufficient to draw debris into the debris removal attachment;
  - a housing substantially disposed about the first impeller;
  - a second impeller coupled to the extension shaft; and
  - a substantially planar member separating the first impeller and the second impeller; and
  - detachably coupling the first end of the extension shaft to the output shaft.
8. The method of claim 7, further comprising rotating the second impeller to push debris away from an interface between the extension shaft and the hand-held power tool.
  9. The method of claim 7, wherein the debris removal attachment further comprises a labyrinth seal having a plurality of spaced apart annular projections provided for disrupting a pathway between an exterior of the housing and an interface of the extension shaft and the hand-held power tool.
  10. The method of claim 7, further comprising sealing an interface between the extension shaft and the hand-held power tool with at least one bearing disposed about the extension shaft.
  11. The method of claim 7, further comprising coupling the attachment to a tool neck of the hand-held power tool.
  12. The method of claim 11, wherein coupling the attachment to a tool neck comprises slidably engaging the attachment and the tool neck of the hand-held power tool.
  13. The method of claim 7, further comprising powering the hand-held power tool with a battery.
  14. The method of claim 7, wherein the housing defines an exhaust port through which debris drawn into the housing is designed to exit the housing; and
    - further comprising coupling a receptacle to the exhaust port, the receptacle configured for collecting debris exiting the exhaust port.
  15. The method of claim 7, further comprising selectively coupling a depth guide to the debris removal attachment.
  16. A method of using a debris removal attachment for a hand-held power tool having an output shaft, the method comprising:
    - providing an extension shaft, the extension shaft having a first impeller coupled to the extension shaft, a first end, and a second end, the first end configured to couple to the output shaft, and the second end configured to couple to a tool bit;
    - providing a housing adjacent the first impeller;
    - providing a labyrinth seal in a pathway between an exterior of the housing and an interface of the extension shaft and the output shaft, the labyrinth seal having a plurality of spaced apart annular projections provided for disrupting the pathway;
    - selectively coupling the first end of the extension shaft to the output shaft such that operation of the hand-held power tool causes rotation of the extension shaft; and
    - operating the hand-held power tool to cause rotation of the first impeller to generate a pressure differential sufficient to draw debris into the housing.
  17. The method of claim 16, further comprising providing a second impeller coupled to the extension shaft, the rotation of which is configured to push debris away from the interface between the extension shaft and the output shaft.
  18. The method of claim 17, further comprising providing a substantially planar member that separates the first impeller and the second impeller.

**19**

**20**

**19.** The method of claim **17**, wherein the first impeller to the second impeller are permanently coupled.

**20.** The method of claim **19**, wherein the extension shaft is permanently coupled to the first impeller and the second impeller.

5

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