US010392871B2

(12) **United States Patent**
Fenwick

(10) **Patent No.: US 10,392,871 B2**
(45) **Date of Patent: Aug. 27, 2019**

(54) **EARTH BORING SYSTEMS AND METHODS WITH INTEGRAL DEBRIS REMOVAL**

(71) Applicant: **American Piledriving Equipment, Inc.**, Kent, WA (US)

(72) Inventor: **Matthew E. Fenwick**, Kent, WA (US)

(73) Assignee: **American Piledriving Equipment, Inc.**, Kent, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 273 days.

(21) Appl. No.: **15/352,064**

(22) Filed: **Nov. 15, 2016**

(65) **Prior Publication Data**

US 2017/0138133 A1 May 18, 2017

Related U.S. Application Data

(60) Provisional application No. 62/256,996, filed on Nov. 18, 2015.

(51) **Int. Cl.**

E21B 17/046	(2006.01)
E21B 17/02	(2006.01)
E21B 21/01	(2006.01)
E21B 10/42	(2006.01)
E21B 10/60	(2006.01)
E21B 17/18	(2006.01)

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

CPC ***E21B 17/046*** (2013.01); ***E21B 10/42*** (2013.01); ***E21B 10/60*** (2013.01); ***E21B 17/18*** (2013.01)

(58) **Field of Classification Search**

CPC E21B 17/02; E21B 17/046; E21B 21/01

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

48,515	A	7/1865	Campbell et al.
500,780	A	7/1893	Simon
628,962	A	7/1899	Speer
910,421	A	1/1909	Schlueter

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2394894	A1	8/2003
CA	2942801	A1	10/2015

(Continued)

OTHER PUBLICATIONS

USPTO, "Final Office Action, U.S. Appl. No. 15/285,326,", dated Aug. 14, 2017, 10 pages.

(Continued)

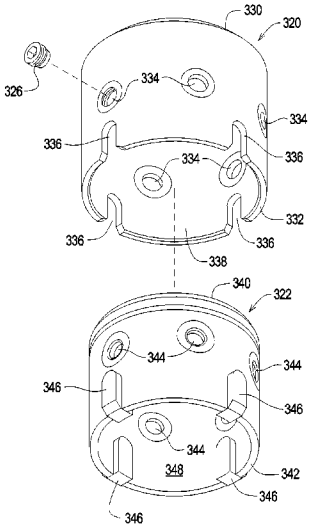
Primary Examiner — Catherine Loikith

(74) *Attorney, Agent, or Firm* — Michael R. Schacht; Schacht Law office, Inc.

(57) **ABSTRACT**

A drill string comprising a bit portion, a distal extension portion, a proximal extension portion, and a connecting portion. The bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define supply path and a return path. The supply path extends through the distal proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion. The return path extends from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion.

21 Claims, 9 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

999,334	A		8/1911	Pearson
1,288,989	A		12/1918	Rees
1,294,154	A		2/1919	Payne
1,322,470	A		11/1919	Schenk
1,464,231	A		8/1923	Yezek
1,654,093	A		12/1927	Reid
1,684,816	A		9/1928	Arden
1,787,000	A		12/1930	Hunt
1,903,555	A		4/1933	Robertson
2,101,285	A		12/1937	Stevens
2,128,428	A		8/1938	Murray, Jr.
2,232,845	A		2/1941	Fieroh
2,239,024	A		4/1941	Vance
2,350,921	A		6/1944	Pinazza
2,436,251	A		2/1948	Dobie et al.
2,439,219	A		4/1948	O'Connor
2,577,252	A		12/1951	Kjellman
2,760,747	A		8/1956	Mordarski
2,952,132	A		9/1960	Urban
2,975,846	A		3/1961	Bodine
3,004,389	A		10/1961	Muller
3,059,436	A		10/1962	Hermann, Jr.
3,106,258	A		10/1963	Muller
3,115,198	A		12/1963	Kuss
3,172,485	A		3/1965	Spannhake et al.
3,175,630	A		3/1965	Hein et al.
3,278,235	A		10/1966	Bergstrom
3,280,924	A		10/1966	Tatamikov
3,287,983	A		11/1966	Austin et al.
3,300,987	A		1/1967	Maeda
3,313,376	A		4/1967	Holland
3,371,727	A		3/1968	Belousov et al.
3,381,422	A		5/1968	Olson
3,391,435	A		7/1968	Lebelle
3,394,766	A		7/1968	Lebelle
3,396,805	A		8/1968	Muller
3,411,305	A		11/1968	Cella
3,412,813	A		11/1968	Johnson
3,460,637	A		8/1969	Schulin
3,513,587	A		5/1970	Artur
3,528,302	A		9/1970	Kinnan
3,530,947	A		9/1970	Gendron
3,577,645	A		5/1971	Zurawski
3,583,497	A		6/1971	Kossowski et al.
3,684,037	A		8/1972	Bodine
3,686,877	A		8/1972	Bodin
3,711,161	A		1/1973	Proctor et al.
3,786,874	A		1/1974	Demichelis et al.
3,786,878	A	*	1/1974	Chapman E21B 17/18 175/106
3,808,820	A		5/1974	Bodine
3,828,864	A		8/1974	Haverkamp et al.
3,865,501	A		2/1975	Kniep
3,871,617	A		3/1975	Majima
3,874,244	A		4/1975	Rasmussen et al.
3,891,186	A		6/1975	Thorsell
3,907,042	A		9/1975	Halwas et al.
3,909,149	A		9/1975	Century
3,952,796	A		4/1976	Larson
3,999,392	A		12/1976	Fukushima et al.
4,033,419	A		7/1977	Pennington
4,067,369	A		1/1978	Harmon
4,082,361	A		4/1978	Lanfermann
4,100,974	A		7/1978	Pepe
4,113,034	A		9/1978	Carlson
4,143,985	A		3/1979	Axelsson et al.
4,144,939	A		3/1979	Knothe
4,155,600	A		5/1979	Lanfermann et al.
4,166,508	A		9/1979	van den Berg
4,195,698	A		4/1980	Nakagawasai
4,274,761	A		6/1981	Boguth
4,285,405	A		8/1981	Weir
4,297,056	A		10/1981	Nottingham
4,312,413	A		1/1982	Loftis
4,351,624	A		9/1982	Barber
4,375,927	A		3/1983	Kniep
4,397,199	A		8/1983	Jahn
4,428,699	A		1/1984	Juhola
4,455,105	A		6/1984	Juhola
4,519,729	A		5/1985	Clarke et al.
4,522,304	A		6/1985	Walter
4,537,527	A		8/1985	Juhola et al.
4,547,110	A		10/1985	Davidson
4,553,443	A		11/1985	Rossfelder et al.
4,601,615	A		7/1986	Cavalli
4,603,748	A		8/1986	Rossfelder et al.
4,606,427	A		8/1986	Beer
4,616,716	A		10/1986	Bouplon
4,625,811	A		12/1986	Tuenkers
4,627,768	A		12/1986	Thomas et al.
4,632,602	A		12/1986	Hovnanian
4,637,475	A		1/1987	England et al.
4,645,017	A		2/1987	Bodine
4,650,008	A		3/1987	Simson
4,735,270	A		4/1988	Fenyvesi
4,755,080	A		7/1988	Cortlever et al.
4,768,900	A		9/1988	Burland
4,813,814	A		3/1989	Shibuta et al.
4,819,740	A		4/1989	Warrington
4,863,312	A		9/1989	Cavalli
4,915,180	A		4/1990	Schisler
5,004,055	A		4/1991	Porritt et al.
5,088,565	A		2/1992	Evarts
5,106,233	A		4/1992	Breaux
5,117,925	A		6/1992	White
5,213,449	A		5/1993	Morris
5,240,348	A		8/1993	Breaux
5,244,316	A		9/1993	Wright et al.
5,253,542	A		10/1993	Houze
RE34,460	E		11/1993	Ishiguro et al.
5,263,544	A		11/1993	White
5,281,775	A		1/1994	Gremillion
5,343,002	A		8/1994	Gremillion
5,355,964	A		10/1994	White
5,388,931	A		2/1995	Carlson
5,410,879	A		5/1995	Houze
5,439,326	A		8/1995	Goughnour et al.
5,529,132	A		6/1996	Evarts
5,540,295	A		7/1996	Serrette
5,544,979	A		8/1996	White
5,549,168	A		8/1996	Sadler et al.
5,549,170	A		8/1996	Barrow
5,562,169	A		10/1996	Barrow
5,609,380	A		3/1997	White
5,653,556	A		8/1997	White
5,658,091	A		8/1997	Goughnour et al.
5,794,716	A		8/1998	White
5,800,096	A		9/1998	Barrow
5,811,741	A		9/1998	Coast et al.
5,860,482	A		1/1999	Gremillion et al.
6,039,508	A		3/2000	White
6,129,159	A		10/2000	Scott et al.
6,179,527	B1		1/2001	Goughnour
6,234,260	B1		5/2001	Coast et al.
6,250,426	B1		6/2001	Lombard
6,360,829	B1		3/2002	Naber et al.
6,386,295	B1		5/2002	Suver
6,394,704	B1		5/2002	Saeki et al.
6,427,402	B1		8/2002	White
6,431,795	B2		8/2002	White
6,447,036	B1		9/2002	White
6,543,966	B2		4/2003	White
6,557,647	B2		5/2003	White
6,582,158	B1		6/2003	Van Stein
6,648,556	B1		11/2003	White
6,672,805	B1		1/2004	White
6,732,483	B1		5/2004	White
6,736,218	B1		5/2004	White
6,896,448	B1		5/2005	White
6,908,262	B1		6/2005	White
6,942,430	B1		9/2005	Suver
6,988,564	B2		1/2006	White
7,080,958	B1		7/2006	Morris
7,168,890	B1		1/2007	Evarts

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,392,855	B1	7/2008	White
7,694,747	B1	4/2010	White
7,708,499	B1	5/2010	Evarts
7,824,132	B1	11/2010	White
7,854,571	B1	12/2010	Evarts
7,914,236	B2	3/2011	Neville
7,950,877	B2	5/2011	Evarts
8,070,391	B2	12/2011	White
8,181,713	B2	5/2012	White
8,186,452	B1	5/2012	White et al.
8,434,969	B2	5/2013	White
8,496,072	B2	7/2013	White
8,763,719	B2	7/2014	White
9,249,551	B1	2/2016	White
9,255,375	B2	2/2016	Yingling et al.
9,957,684	B2	5/2018	Suver et al.
2001/0002230	A1	5/2001	White
2005/0039952	A1	2/2005	Hill et al.
2006/0198706	A1	9/2006	Neville
2010/0266344	A1	10/2010	Plotkin et al.
2010/0303552	A1	12/2010	Yingling et al.
2011/0162859	A1	7/2011	White
2012/0292062	A1	11/2012	White
2013/0149040	A1	6/2013	Evarts
2014/0056652	A1	2/2014	Suver
2014/0377011	A1	12/2014	Yingling et al.
2015/0016893	A1	1/2015	Suver et al.
2016/0356294	A1	12/2016	Fenwick et al.
2017/0101759	A1	4/2017	Suver
2017/0138133	A1	5/2017	Fenwick
2017/0167102	A1	6/2017	Suver et al.

FOREIGN PATENT DOCUMENTS

CN	102296608	B	7/2015
DE	4010357	A1	10/1990
EP	0172960	A1	3/1986
EP	362158		4/1990
EP	526743		10/1993
FR	838717		3/1939
FR	2560247		8/1985
GB	2003769		3/1979
GB	2023496		1/1980
GB	2028902		3/1980
GB	2043755		10/1980
GB	2060742		5/1981
GB	2069659	A	8/1981
JP	5494703		7/1979
JP	355098526		7/1980
JP	356034828		4/1981
JP	57169130		10/1982
JP	59228529	A	12/1984
JP	61221416		10/1986
JP	0258627		2/1990
JP	497015	A	3/1992
JP	473035		6/1992
JP	6136751		5/1994
JP	2005256500	A	9/2005
JP	2005315050	A	11/2005
JP	2006089933	A	4/2006
JP	2006177125	A	7/2006
JP	2006312825	A	11/2006
JP	2009138487	A	6/2009
NL	42349		1/1938
NL	65252		2/1950
NL	7710385		3/1978
NL	7707303		1/1979
NL	7805153		11/1979
NO	46428		4/1929
RU	2109881	C1	4/1998
SU	1027357		7/1983
WO	WO8707673		12/1987
WO	WO8805843		8/1988
WO	2012031108	A1	3/2012

OTHER PUBLICATIONS

USPTO, "Non-Final Office Action, U.S. Appl. No. 15/372,196," dated Oct. 4, 2017, 23 pages.
USPTO, "Final Office Action, U.S. Appl. No. 15/285,326,", dated Apr. 25, 2018, 9 pages.
"Castle Board Drain Method", Japanese brochure, Reference Nos. APE00857 through APE00863, Aug. 1976.
"Kony Drain Board," undated, 1 page.
"The 1.sup.st Report on the Treatment of Soft Foundation of Juck Hyun Industrial Site", Ref. Nos. APE00854 through APE00856, Mar. 1976.
A report identifying systems for driving mandrels carrying wick drain material into the earth, identified by Ref. Nos. APE0510 through APE0536, (undated).
A series of photographs identified by reference Nos. APE01147 through APE01159. 1990-1993.
International Construction Equipment, Inc "Hydraulic Vibratory Driver/Extractors for Piling and Caisson Work," 10 pages.
International Construction Equipment, Inc "Hydraulic Vibratory Driver/Extractors for Piling and Caisson Work," Ref. No. V7-0890-51, 1974, 3 pages.
Korean document, Ref. Nos. APE00864 through APE00891, 1982-1997.
Schematic drawings identified by Ref. Nos. APE01038, APE01039, and APE0339, (undated).
USPTO, "Non-Final Office Action, U.S. Appl. No. 15/285,326,", dated Apr. 25, 2017, 10 pages.

* cited by examiner

FIG. 1

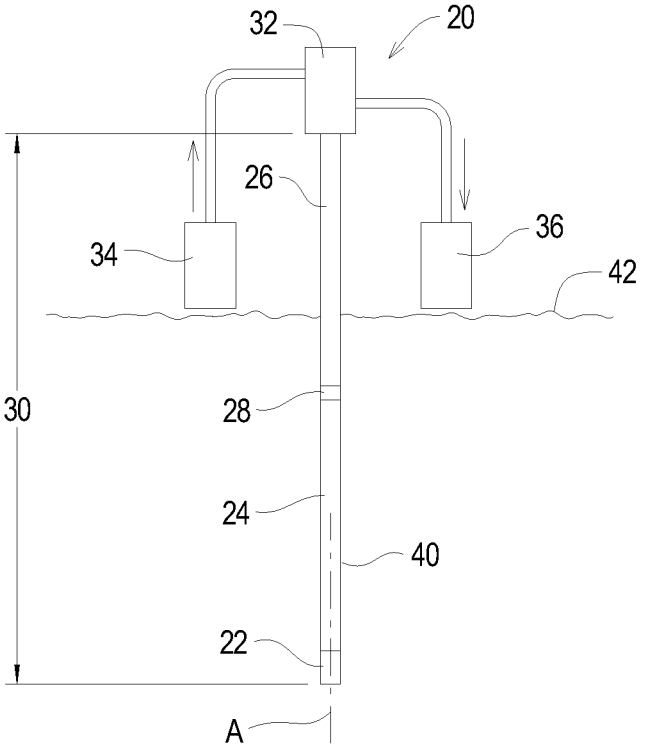


FIG. 2

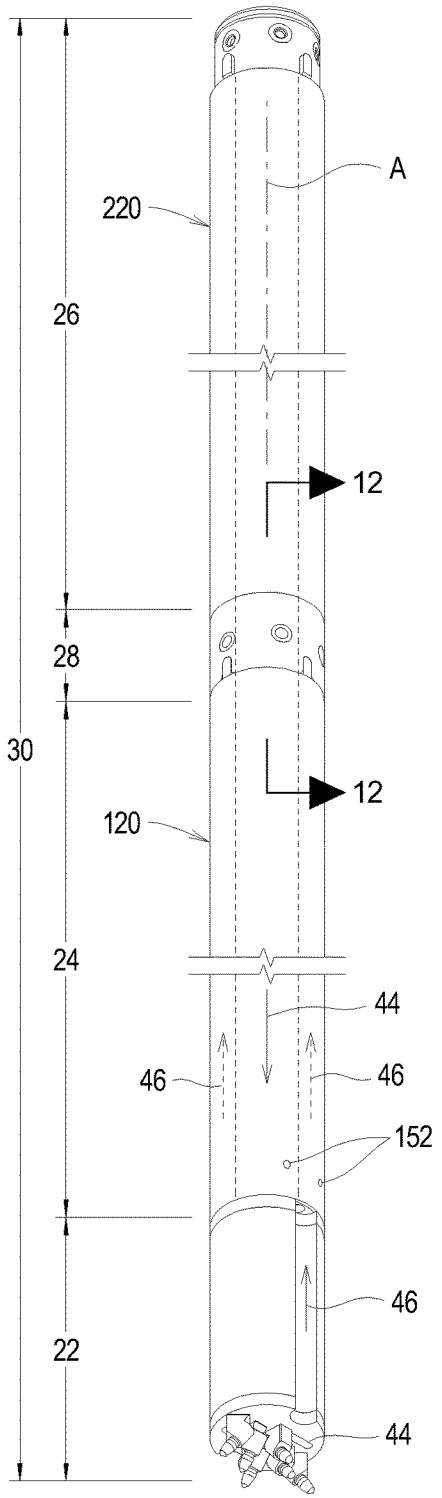

A
220
26
12
28
30
12
120
24
44
46
46
152
46
22
44

FIG. 3

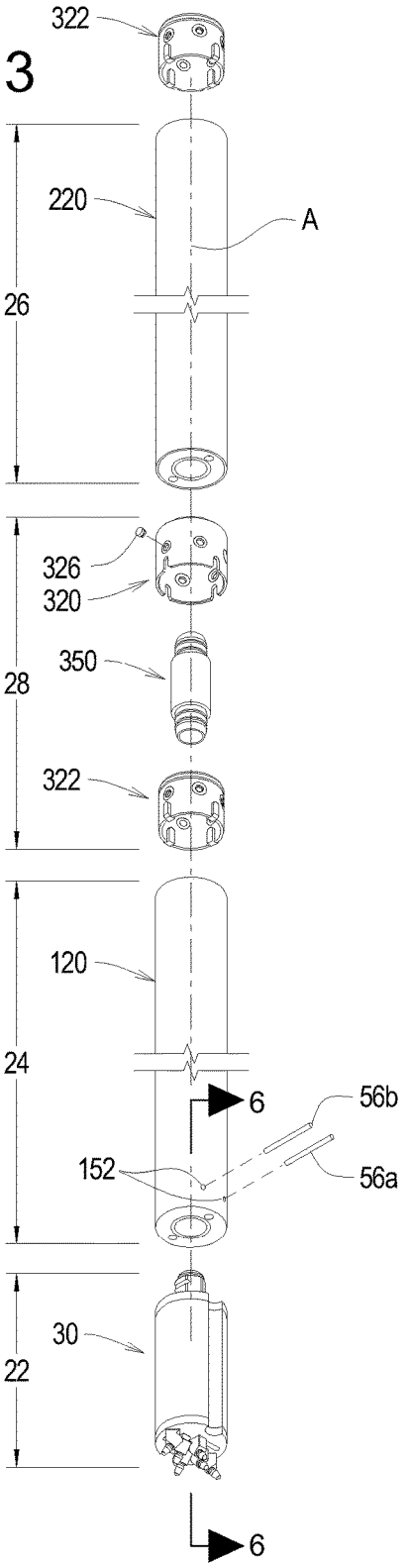

322
220
A
26
326
320
350
28
322
120
24
6
56b
152
56a
30
22
6

FIG. 4

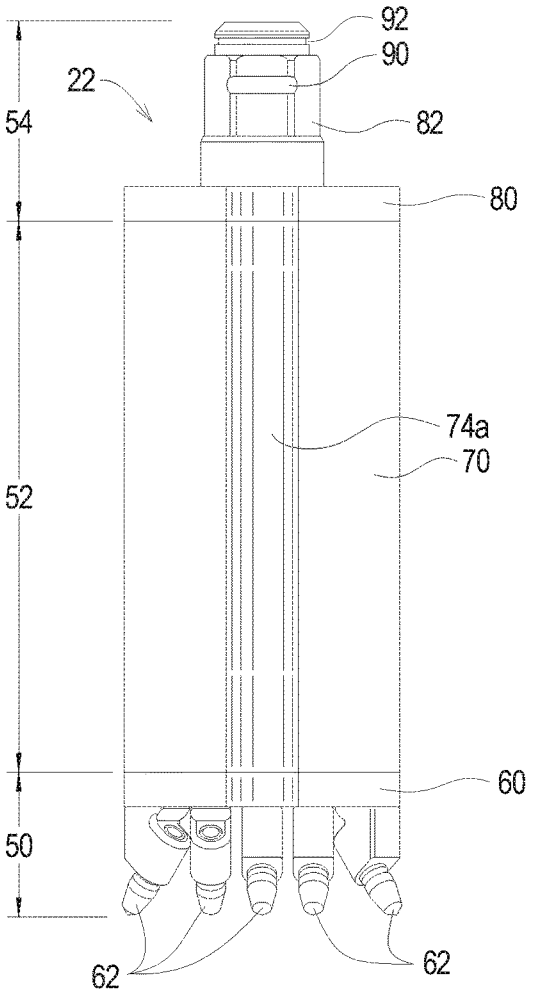


FIG. 5

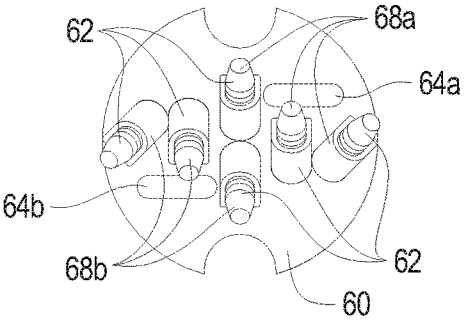


FIG. 6

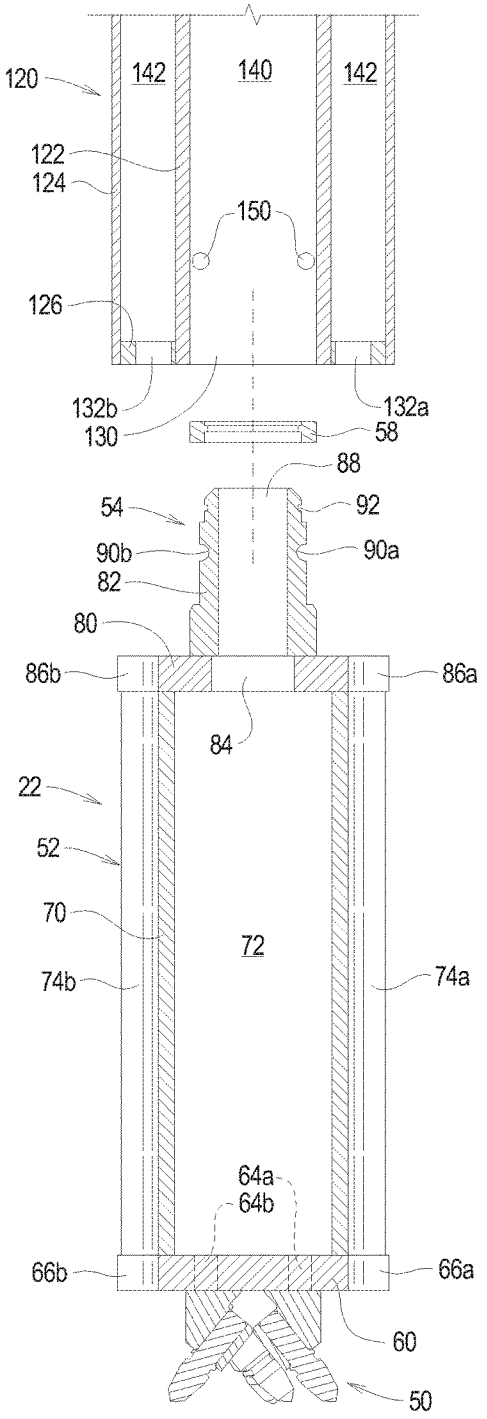

120
142
140
142
122
124
150
126
132b
130
132a
58
88
54
92
90b
90a
82
80
86b
86a
84
22
52
70
72
74b
74a
64a
64b
66b
66a
60
50

FIG. 7

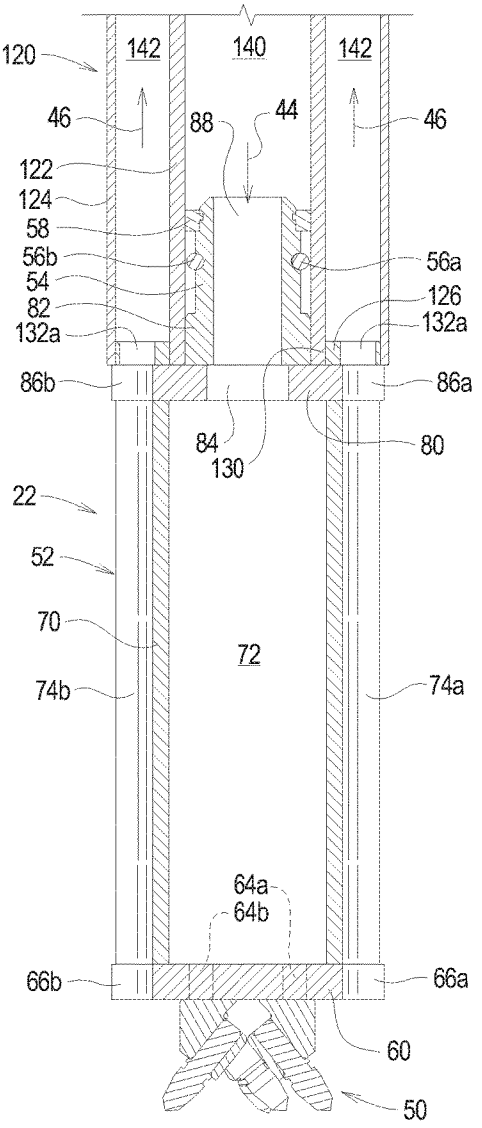

120
142
140
142
46
88
44
46
122
124
58
56b
54
82
132a
56a
126
132a
86b
86a
84
130
80
22
52
70
72
74b
74a
64a
64b
66b
66a
60
50

FIG. 8

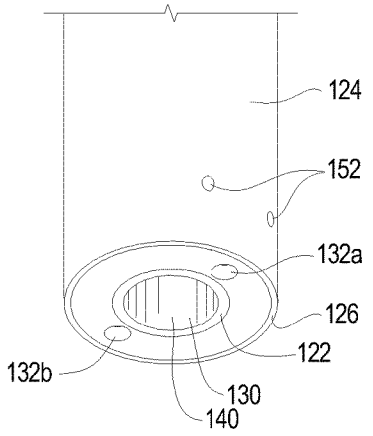


FIG. 9

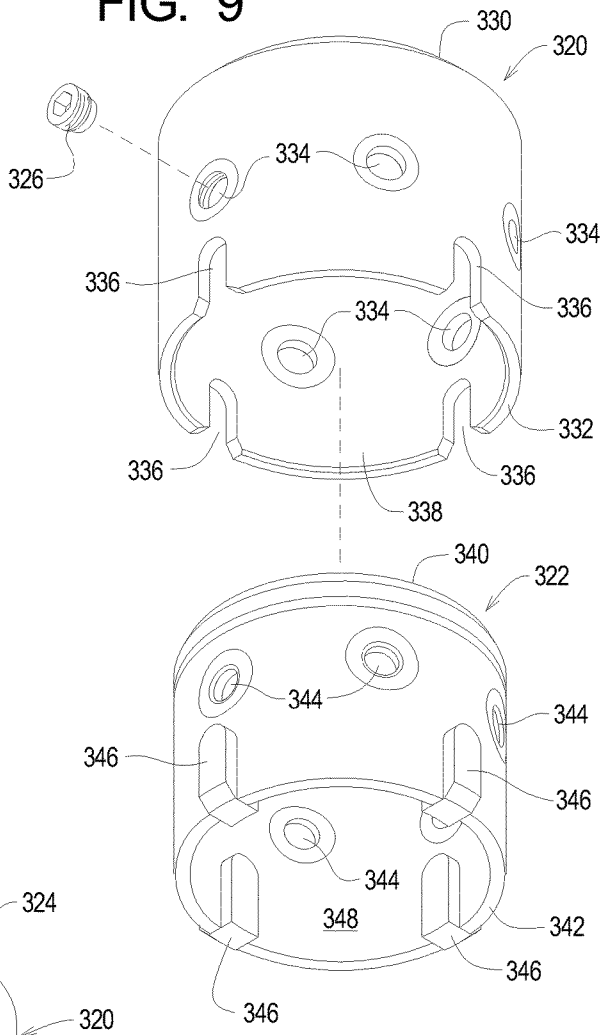


FIG. 10

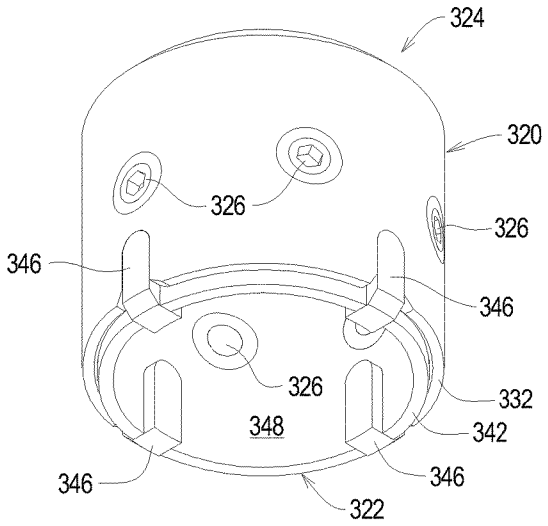


FIG. 11

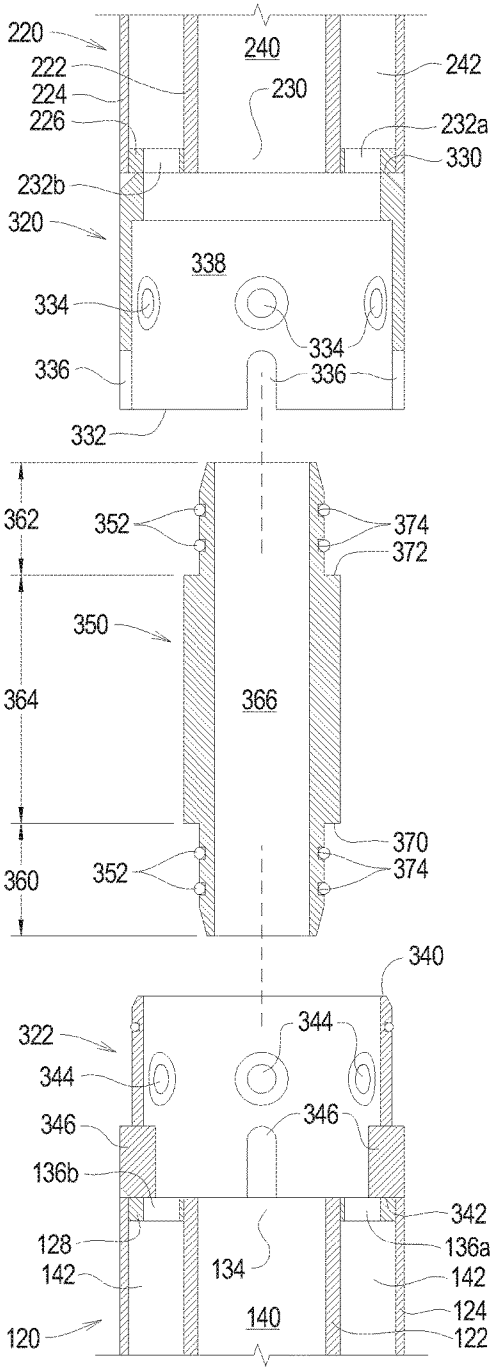

220
222
224
226
240
230
242
232a
330
232b
320
338
334
334
336
336
332
362
352
374
372
350
364
366
370
360
352
374
340
322
344
344
346
346
136b
342
128
136a
142
134
142
140
124
120
122

FIG. 12

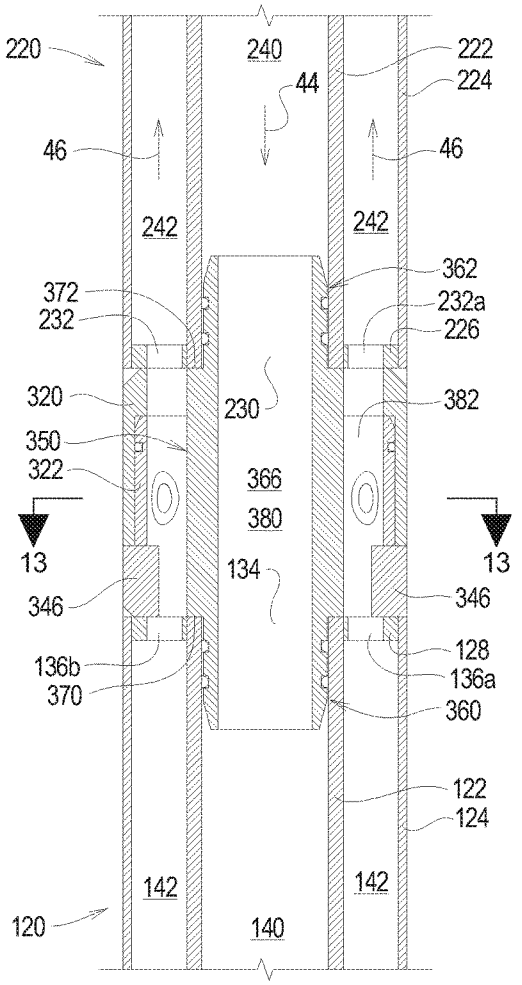

220
240
222
44
224
46
46
242
242
362
372
232a
232
226
320
230
382
350
322
366
380
13
13
134
346
346
128
136b
136a
370
360
122
124
142
142
120
140

FIG. 13

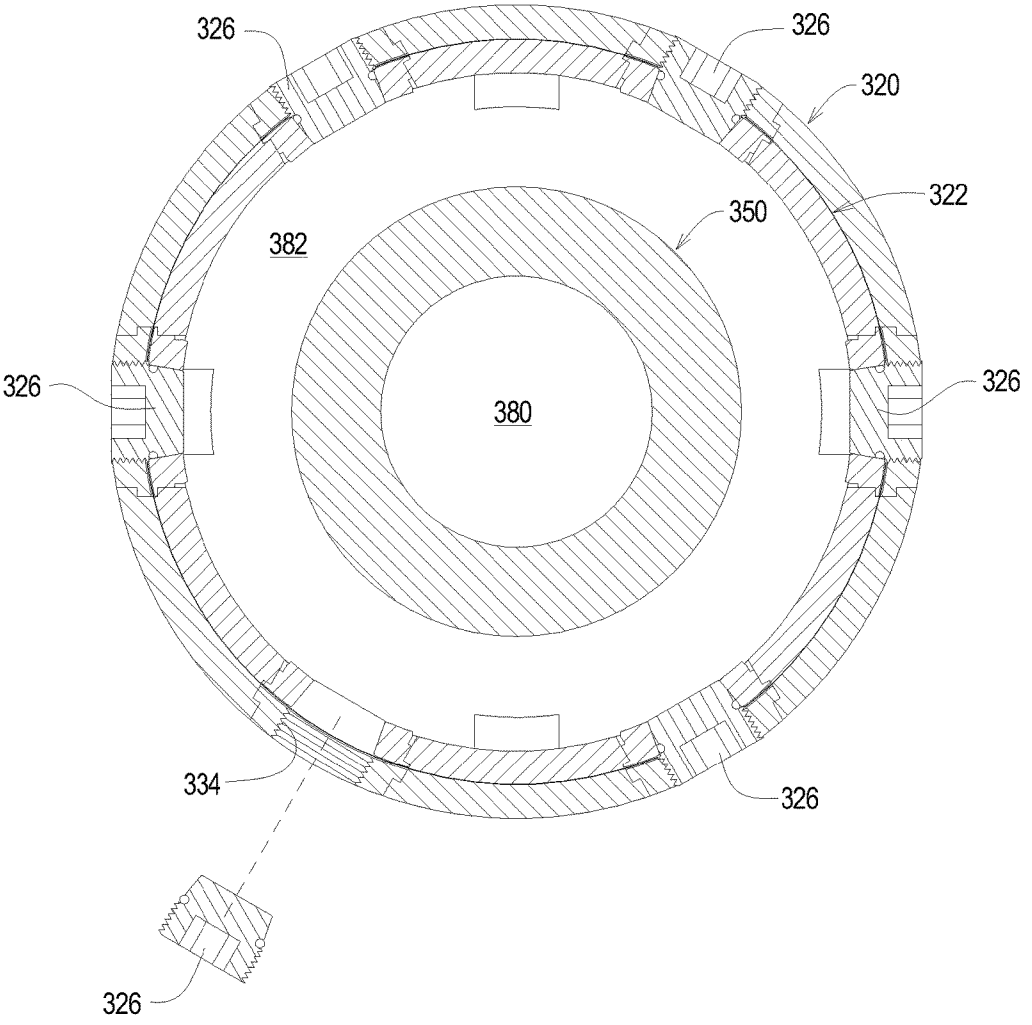


FIG. 14

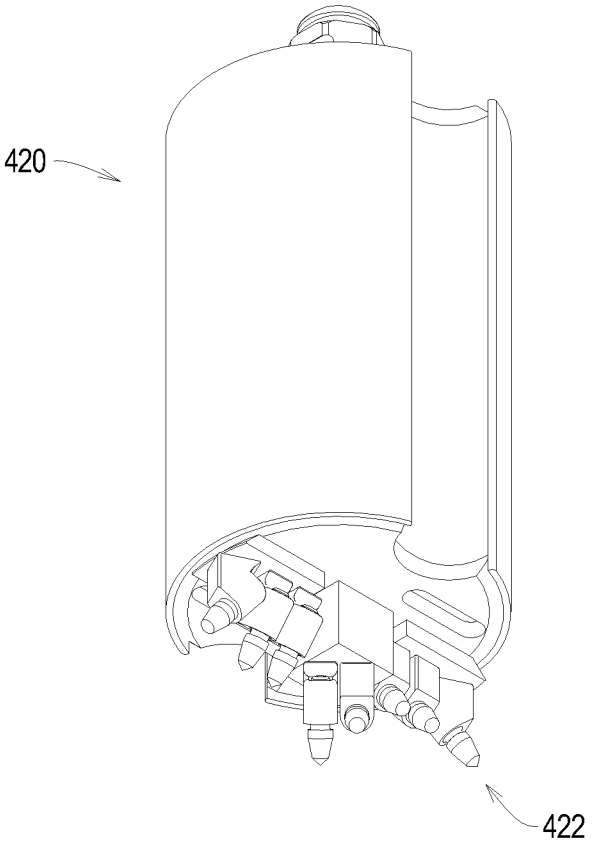


FIG. 15

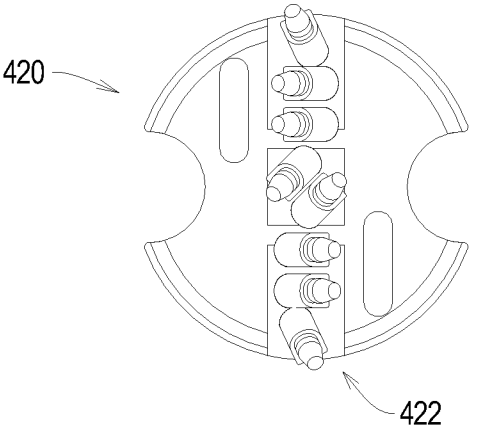


FIG. 16

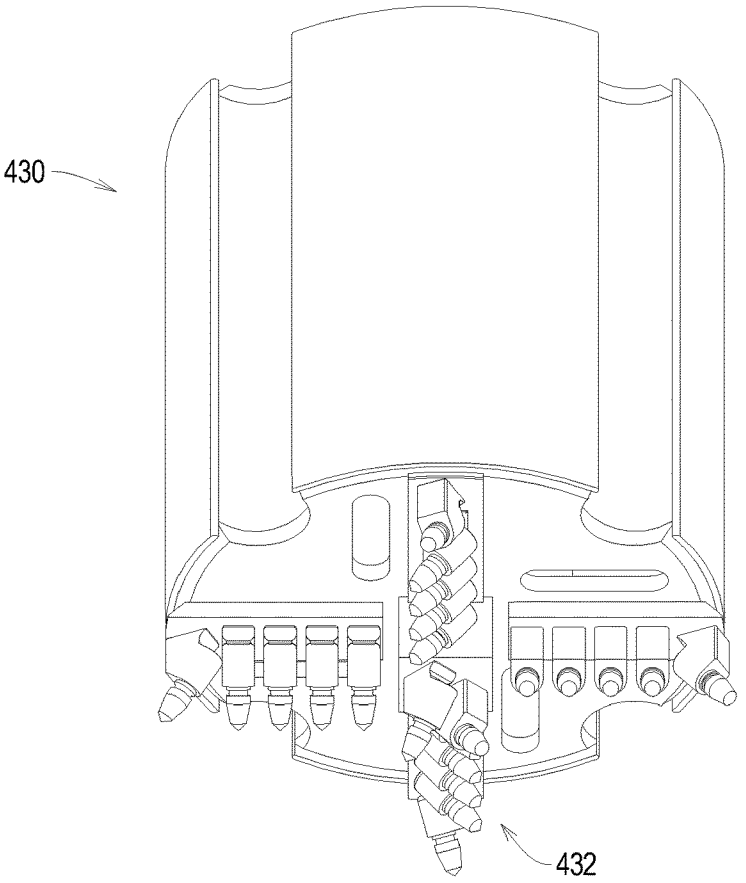
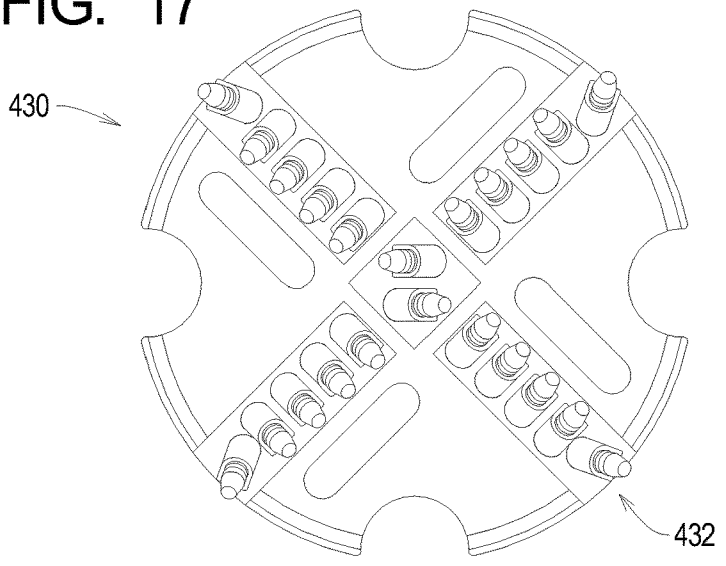


FIG. 17



EARTH BORING SYSTEMS AND METHODS WITH INTEGRAL DEBRIS REMOVAL

RELATED APPLICATIONS

This application, U.S. patent application Ser. No. 15/352,064 filed Nov. 15, 2016 claims benefit of U.S. Provisional Application Ser. No. 62/256,996 filed Nov. 18, 2015, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to earth boring systems and methods and, in particular, to earth boring systems and methods configured remove debris as the hole is being bored.

BACKGROUND

The present invention relates to system and methods for forming a hole in the earth and, in particular, to systems and methods that use drill fluid to remove drill cuttings as the hole is formed in the earth.

SUMMARY

The present invention may be embodied as a drill string comprising a bit portion, a distal extension portion, a proximal extension portion, and a connecting portion. The bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define a supply path and a return path. The supply path extends through the distal proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion. The return path extends from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion.

The present invention may also be embodied as a method of forming a hole in the earth comprising the following steps. A bit portion is operatively connected to a distal extension portion. The distal extension portion is operatively connected to a proximal extension portion to define a supply path and a return path. The supply path extends through the distal proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion. The return path extends from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion. The bit portion is engaged with the earth. The proximal portion is rotated to cause rotation of the bit portion through the distal extension portion. Drill fluid is forced through the supply path and to the cutter region. The drill fluid in the cutter region is collected through the return path.

The present invention may also be embodied as an earth boring system for forming a hole in the earth comprising a drill string, a drive system, a drill fluid supply, and a drill debris collector. The drill string comprises a bit portion, a distal extension portion, a proximal extension portion, and a connecting portion. The bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define a supply path and a return path. The supply path extends through the distal proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion. The return path extends from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion. The drill fluid supply forces drill fluid through the supply path such that the drill fluid mixes with the cuttings in the cutter region to form drill debris and the drill debris flows back up through the return path. The drill debris collector collects the drill debris.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a somewhat schematic, side elevation view of a first example earth boring system of the present invention depicting a drill string comprising a bit portion, a distal extension portion, a proximal extension portion, and a connector portion;

FIG. **2** is a perspective view of the drill string of the first example earth boring system of the present invention;

FIG. **3** is an exploded, perspective view of the drill string of the first example earth boring system;

FIG. **4** is a side elevation view of a first example bit portion of the first example earth boring system;

FIG. **5** is a bottom plan view of the first example bit portion;

FIG. **6** is a side elevation, cutaway view taken along lines **6-6** in FIG. **3** depicting details of the process of connecting distal extension portion with the first example bit portion;

FIG. **7** is a side elevation, cutaway view taken along lines **6-6** in FIG. **3** depicting the distal extension portion connected with the first example bit portion;

FIG. **8** is a perspective view of a distal end of the distal extension portion;

FIG. **9** is a perspective view illustrating details of the connector portion in an unconnected configuration;

FIG. **10** is a perspective view illustrating details of the connector portion in a connected configuration;

FIG. **11** is a side elevation, cutaway view depicting details of the process of connecting distal extension portion with the proximal extension portion;

FIG. **12** is a side elevation, cutaway view taken along lines **12-12** in FIG. **2** depicting the distal extension portion connected with the proximal extension portion;

FIG. **13** is a section view taken along lines **13-13** in FIG. **12** depicting details of the process of connecting distal extension portion with the proximal extension portion;

FIG. **14** is a perspective view of a second example bit portion that may be used to form a second example earth boring system of the present invention;

FIG. **15** is a bottom plan view of the second example bit portion;

FIG. **16** is a perspective view of a third example bit portion that may be used to form a third example earth boring system of the present invention; and

FIG. **17** is a bottom plan view of the third example bit portion.

DETAILED DESCRIPTION

Referring initially to FIGS. **1-3** of the drawing, depicted therein is a first example earth boring system **20** of the present invention. The first example earth boring system **20** comprises a bit portion **22**, a distal extension portion **24**, a proximal extension portion **26**, and a connector portion **28**.

The distal extension portion **24** is connected to the bit portion **22** and the connector portion **28** connects the distal extension portion **24** to the proximal extension portion **26** to

form a drill string **30** defining a string axis A. FIG. **1** further illustrates that earth boring system **20** comprises, in addition to the drill string **30**, a drive system **32**, a drill fluid supply **34**, and a drill debris collector **36**. In this discussion, the terms "distal" and "proximal" are used with respect to the drive system **32**.

The drive system **32** is configured to rotate the drill string **30** axially about the string axis A, to transfer drill fluid from the drill fluid supply **34** to the drill string **30**, and to transfer drill debris from the drill string **30** to the drill debris collector **36**. In particular, FIG. **1** further illustrates that the earth boring system **20** is adapted to form a hole **40** in the earth **42**. Only two extension portions are employed in the first example earth boring system **20**, but only one connector portion or more than two connector portions may be used as necessary to create a drill string that allows the earth boring system **20** to bore the hole **40** in the earth **42** to a desired depth.

During use, the drill string **30** is supported a desired angle at a desired point on the earth, and the drive system **32** is operatively connected to the drill string **30**. Operation of the drill system **32** to cause axial rotation of the drill string **30** causes the bit portion **22** to bore the hole **40**. At the same time, the drill fluid supply **34** forces drill fluid along a supply path **44** (FIG. **2**) formed by the drill string **30** to the bit portion **22**. Cuttings formed as the bit portion **22** engages the earth **42** are carried by the drill fluid back up the drill string **30** along a return path **46** (FIG. **2**) and are deposited in the drill debris collector **36**.

With the foregoing general understanding of the construction and operation of the first example earth boring system **20** in mind, the details of the example drill string **30** will now be described in detail. In the following example, letter appendices to reference characters are employed to indicate a specific example a part or feature but are not intended to be separate or distinguishable from the generic form of that part or feature.

Referring now to FIGS. **4-7**, the first example bit portion **22** will now be described in further detail. As perhaps best shown in FIG. **6**, the example bit portion **22** comprises a cutter assembly **50**, a bit housing **52**, a bit coupler **54**, at least one coupler pin **56**, and at least one seal member **58**.

The cutter assembly **50** comprises a cutter plate **60** and a plurality of cutter heads **62**. The cutter plate **60** defines at least one cutter plate slot **64** and at least one cutter plate notch **66**. FIG. **5** illustrates that the example cutter heads **62** are arranged in at least one cutter head group **68** and that one cutter plate slot **64** and one cutter plate notch **66** are associated with each cutter head group **68**. In the example bit portion **22**, first and second cutter head groups **68***a* and **68***b* are employed, and first and second cutter plate slots **64***a* and **64***b* and first and second cutter plate notches **66***a* and **66***b* are associated with the first and second cutter head groups **68***a* and **68***b*, respectively.

FIGS. **6** and **7** illustrate that the example bit housing **52** comprises a bit housing member **70** defining a bit housing chamber **72** and at least one bit housing groove **74**. One bit housing groove **74** is associated with each of the cutter plate notches **66**, so first and second housing grooves **74***a* and **74***b* are associated with the first and second cutter plate notches **66***a* and **66***b*, respectively.

FIGS. **6** and **7** further illustrate that the example bit coupler **54** comprises a coupler plate **80** and a coupler member **82**. The example coupler plate **80** defines a first coupler plate opening **84** and at least one coupler plate notch **86**. The example coupler member **82** defines a coupler member passageway **88**. The coupler member **82** is secured to the coupler plate **80** such that the coupler member passageway **88** is aligned with the coupler plate opening **84**. In the example bit portion **22** comprising first and second housing grooves **74***a* and **74***b*, first and second coupler plate notches **86***a* and **86***b* are provided.

At least one pin groove **90** is formed in the coupler member **82**. In the example drill string **30**, first and second coupler pins **56***a* and **56***b* and first and second pin grooves **90***a* and **90***b* are provided. In addition, a seal groove **92** (FIG. **6**) is formed on the coupler member **82** such that the coupler pin grooves **90** are arranged between the seal groove **92** and the coupler plate **80**.

The example bit portion **22** is formed by securing the cutter heads **62** to the cutter head plate **60** in the first and second cutter head groups **68***a* and **68***b*. The cutter head plate **60** is secured to the bit housing member **70** to define one end of the bit housing chamber **72** with first and second coupler plate slots **64***a* and **64***b* in communication with the bit housing chamber **72** and the first and second coupler plate notches **86***a* and **86***b* in communication with the first and second bit housing grooves **74***a* and **74***b*. The coupler plate **80** is secured to the bit housing member **70** to define another end of the bit housing chamber **72** and such that the first coupler plate opening **84** is in communication with the bit housing chamber **72** and the first and second coupler plate notches **86***a* and **86***b* are aligned with the first and second bit housing grooves **74***a* and **74***b*.

Turning now to FIGS. **6-12**, the example proximal and distal extension portions **24** and **26** will now be described in detail. The example distal extension portion **24** comprises an extension housing assembly **120** comprising first and second extension housing members **122** and **124**, a distal end plate **126** (FIGS. **6-8**), and a proximal end plate **128** (FIGS. **11** and **12**). The distal end plate **126** defines at least one supply distal end plate opening **130** and at least one removal distal end plate opening **132**, while the proximal end plate **128** defines at least one supply proximal end plate opening **134** and at least one removal proximal end plate opening **136**. The example end distal plate **126** define first and second removal end plate openings **132***a* and **132***b*; the example proximal end plate **128** defines first and second removal end plate openings **136***a* and **136***b*.

As shown in FIGS. **6-8**, **11** and **12**, the distal and proximal end plates **126** and **128** are rigidly connected to the first and second extension housing members **122** and **124** such that the supply end plate openings **130** and **134** are in fluid communication with a supply extension chamber **140** defined by the first extension housing member **122** and the removal end plate openings **132** and **136** are in fluid communication with a removal extension chamber **142** defined by the second extension housing member **124**.

At least one first coupler pin opening **150** is further formed in the first extension housing member **122**, and at least one second coupler pin opening **152** is formed in the second extension housing member **124**. In the example drill string **30**, at least one pair of the first coupler pin openings **150** and at least one pair of second coupler pin openings **152** are provided. Further, each coupler pin opening **150** and **152** may further comprise a complementary coupler pin opening (not visible in the drawing) formed in the housing members **122** and **124**. The coupler pin openings **150** and **152** are sized, dimensioned, and located adjacent to the distal end plate **126** as will be described in further detail below.

FIGS. **11** and **12** illustrate that, like the distal extension portion **24**, the example proximal extension portion **26** comprises an extension housing assembly **220** comprising first and second extension housing members **222** and **224**, a

distal end plate **226**, and a proximal end plate **228** (not visible). The distal end plate **226** defines at least one supply distal end plate opening **230** and at least one removal distal end plate opening **232**, while the proximal end plate **228** defines at least one supply proximal end plate opening (not visible) and at least one removal proximal end plate opening (not visible). The example end distal plate **226** defines first and second removal end plate openings **232***a* and **232***b*; the example proximal end plate **228** similarly defines first and second removal end plate openings (not visible).

As shown in FIGS. **11** and **12**, the distal and proximal end plates **226** and **228** are rigidly connected to the first and second extension housing members **222** and **224** such that the supply end plate openings **230** and **234** are in fluid communication with a supply extension chamber **240** defined by the first extension housing member **222** and the removal end plate openings **232** and **236** are in fluid communication with a removal extension chamber **242** defined by the second extension housing member **224**.

Desirably, but not necessarily, the distal and proximal extension portions **24** and **26** are, for the most part, the same. If additional extension portions are used to form a longer drill string than the example drill string **30**, these additional extension portions will desirably, but again not necessarily, the same as the proximal end portion **26**. The example proximal end portion **26** and any additional end portions need not employ pin openings such as the pin openings **150** and **152** formed in the distal end portion **24** for reasons that will become apparent below. If pin openings are formed in the proximal end portion **24** and any additional extension portions, such pin openings will not be used and may be plugged. The standardization of distal, proximal, and any additional extension portions can simplify the logistics of designing and fabricating a drill string as desired for a particular set of operating conditions at the desired location of the hole **40** to be bored into the earth **42**.

FIGS. **9-13** illustrate that the example connector portion **28** comprises a first connector housing **320** and a second connector housing **322**. The first and second connector housings **320** and **322** are connected to form a connector assembly **324** by connector screws **326**.

The first connector housing **320** defines a first plate edge **330**, a key edge **332**, first screw openings **334**, key slots **336**, and a first connector housing passageway **338**. The second connector housing **322** defines a leading edge **340**, a second plate edge **342**, second screw openings **344**, key projections **338**, and a second connector housing passageway **348**.

The example connector portion **28** further comprises a connector member **350** and a plurality of seal members **352**. The example connector member **350** defines first and second connector end portions **360** and **362** and an intermediate portion **364** and defines a connector passageway **366**. The intermediate portion **364** defines first and second shoulder portions **370** and **372**, and at least one seal groove **374** is formed on each of the first and second connector end portions **360** and **362**.

The first plate edge **330** is secured to the distal end plate **226** of the proximal extension housing assembly **220**, and the second plate edge **342** is secured to the proximal end plate **128** of the distal end plate housing assembly **120**.

The example drill string **30** is fabricated as follows. Initially, the bit portion **22** is secured to the distal extension portion **24** as follows. The seal member **58** is arranged in the seal groove **92** on the coupler member **82**, and the coupler member **82** is inserted into the supply extension chamber **140** such that the seal **58** engages an inner wall of the first extension housing member **122**. The coupler pins **56***a* and **56***b* are inserted through the coupler pin openings **150***a* and **152***b* such that the coupler pins **56***a* and **56***b* are at least partly arranged within the coupler pin grooves **90***a* and **90***b*. So arranged, the coupler pins **56** prevent relative movement of the bit portion **22** and the distal end portion **24** along the string axis A. The coupler pins **56** also translate axial rotation of the extension housing assembly **120** to the bit housing **52** such that axial rotation of the drill string **30** rotates the cutter heads **62** such that the cutter heads **62** engage the earth **42** to form the hole **40** in a conventional manner.

The example connector portion **28** is then used to connect the distal and extension portion **24** to the proximal end portion **26** as follows. The seal members **352** are arranged in the seal grooves **374**. The connector member **350** is arranged such that the first shoulder portion **370** engages the first extension housing member **122** of the distal extension housing assembly **120** with the seal members **352** against an inner surface of the first extension housing member **122**. The leading edge **340** of the second connector housing **322** is inserted into the first connector housing passageway **338** such that: the second shoulder portion **372** of the connector portion **28** engages the first extension housing member **222** of the proximal extension housing assembly **220** with the seal members **352** against an inner surface of the first extension housing member **222**; the key slots **336** receive the key projections **346**; and the first and second screw openings **334** and **344** are aligned. The connector screws **326** are then inserted through the aligned screw openings **334** and **344**. At least one of the screw openings **334** and **344** may be threaded to engage threads on the connector screws **326** to secure the connector screws **326** in place as shown in FIG. **13**. At this point, a supply connector chamber **380** is formed within the connector bore **366**, and a removal connector chamber **382** is formed within the first connector housing bore **338** and outside of the connector member **350**.

The key projections **346** engage the key slots **336** to transfer axial rotation of the proximal extension housing assembly **220** to the distal extension housing assembly **120**. The connector screws **326** prevent relative movement of the distal and proximal extension housing assemblies **120** and **220** relative to each other during normal operation of the drill string **30**. The connector screws **326** will also transfer axial rotation of the proximal extension housing assembly **220** to the distal extension housing assembly **120**.

In addition, the arrangement described above and depicted, for example, in FIGS. **7** and **12** creates the supply path **44** and return path **46** described above. In particular, the supply path **44** extends through the supply extension chamber **240** of the proximal extension housing assembly **220**, through the connector member bore **366**, through the supply extension chamber **140** of the distal extension housing assembly **120**, through the supply connector chamber **380**, through the bit housing chamber **72**, out of the cutter plate slots **64**, and into an active cutting region surrounding the cutter assembly **50**. The return path **46** extends from the active cutting region surrounding the cutter assembly **50** up along the bit housing grooves **74** (contained by the inner wall of the hole **40**), through the second coupler plate opening(s) **86**, through the removal extension chamber **142** defined by the distal extension housing assembly **120**, through the removal connector chamber **382** defined by the connector portion **28**, and through the removal extension chamber **242** formed by the proximal extension housing assembly **220**.

In use, the drill fluid supply **34** forces the drill fluid through the drive system **32** and along the supply path **44**

such that the drill fluid mixes with cuttings or tailings generated by the cutter assembly **50** in the active cutting region surrounding the cutter assembly **50**. Pressure on the drill fluid forces the mixture of drill fluid and cuttings or tailings out of the active cutting region and back up along the return path **46** and out of the drive system **32**, where the mixture of drill fluid and cuttings or tailings is collected in the drill debris collector **36**.

Although the various components of a drill string forming a part of an earth boring system of the present invention may be fabricated in many shapes, the use of parts that are generally symmetrical about a plane extending through the string axis A is desirable for a number of reasons. The bit housing **52**, coupler member **82**, extension housing members **122**, **124**, **222**, and **224**, first and second connector housings **320** and **322**, and connector member **350** are all substantially cylindrical or have at least a portion that is cylindrical. The example supply path **44** is thus generally cylindrical. The example return path **46** is generally annular and surrounds the supply path **44**.

Depicted in FIGS. **14** and **15** is a second example bit portion **420** with different dimensions and a different cutter assembly **422** than the example bit portion **22** and cutter assembly **50** described above. The second example bit portion **420** may be used as part of a drill string like the example drill string **30** with appropriate sizing of the other parts of the drill string.

FIGS. **16** and **17** depict a third example bit portion **430** with different dimensions and a different cutter assembly **432** than the example bit portions **22** and **420** and cutter assemblies **50** and **422** described above. The cutter assembly **432** comprises four groups of cutter heads radially extending from a center group of cutter heads and defines four cutter plate slots, with one cutter plate slot arranged between each pair of cutter head groups. The third example bit portion **430** may be used as part of a drill string like the example drill string **30** with appropriate sizing of the other parts of the drill string.

What is claimed is:

1. A drill string comprising:
- a bit portion;
- a distal extension portion;
- a proximal extension portion; and
- a connecting portion; whereby
- the bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define
  - a supply path extending through the proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion; and
  - a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion;
- a portion of the return path defined by the distal extension portion surrounds the supply path; and
- the bit portion defines at least one housing groove, where the return path extends at least partly through the at least one housing groove.

2. A drill string as recited in claim **1**, in which the connecting portion comprises:
- a first connector housing secured to the proximal extension portion;
- a second connector housing secured to the distal extension portion; and
- a connector member defining a connector passageway; wherein
- the first and second housings are secured to each other to transfer rotational forces from the proximal extension portion to the distal extension portion; and
- the connector member engages the proximal extension portion and the distal extension portion such that
  - a portion of the supply path extends through the connector passageway, and
  - a portion of the return path extends between the connector member and at least one of the first and second connector housings.

3. A drill string as recited in claim **2**, in which the connecting portion further comprises at least one seal member arranged between the connector member and at least one of the first and second connector housings to inhibit the flow of material between the supply path and the return path.

4. A drill string as recited in claim **1**, in which:
- the distal extension portion defines first and second distal extension housing members arranged to define distal supply and removal extension chambers;
- the proximal extension portion defines first and second proximal housing members arranged to define proximal supply and removal extension chambers; and
- the connecting portion comprises
  - a first connector housing secured to the proximal extension portion;
  - a second connector housing secured to the distal extension portion; and
  - a connector member defining a connector passageway; wherein
  - the first and second housings are secured to each other to transfer rotational forces from the proximal extension portion to the distal extension portion; and
  - the connector member engages the first distal extension housing member and the first proximal extension housing member such that
    - a portion of the supply path extends through the proximal supply extension chamber, the connector passageway, and the distal supply extension chamber, and
    - a portion of the return path extends through the distal removal extension chamber, between the connector member and at least one of the first and second connector housings, and through the proximal removal extension chamber.

5. A drill string as recited in claim **4**, in which the connecting portion further comprises:
- at least one key projection; and
- at least one key slot; wherein
- the at least one key projection engages the at least one key slot to transfer rotational forces from the proximal extension portion to the distal extension portion.

6. A drill string as recited in claim **1**, in which the connecting portion comprises:
- a first connector housing secured to the proximal extension portion;
- a second connector housing secured to the distal extension portion;
- at least one key projection; and
- at least one key slot; wherein
- the at least one key projection engages the at least one key slot to transfer rotational forces from the proximal extension portion to the distal extension portion.

7. A drill string as recited in claim **6**, in which the connecting portion further comprises:

at least one first opening formed in the first connector housing;

at least one second opening formed in the second connector housing; and

at least one connector screw adapted to engage the at least one first opening and the at least one second opening to secure the proximal extension portion to the distal extension portion.

8. A drill string as recited in claim **1**, in which the connecting portion further comprises at least one seal member arranged to inhibit the flow of material between the supply path and the return path.

9. A drill string as recited in claim **1**, in which the bit portion comprises:

a bit;

a bit coupler;

a bit housing for supporting the bit and the bit coupler; and

at least one coupler pin; wherein

the at least one coupler pin engages the bit housing and the distal extension portion to secure the bit portion to the distal extension portion to transfer rotation of the distal extension portion to the bit.

10. A drill string as recited in claim **9**, further comprising at least one seal member arranged between the bit coupler and the distal extension portion to inhibit the flow of material between the supply path and the return path.

11. A drill string as recited in claim **1**, in which:

the distal extension portion defines first and second distal extension housing members arranged to define distal supply and removal extension chambers, where the first distal extension housing member defines at least one first coupler pin opening;

the proximal extension portion defines first and second proximal housing members arranged to define proximal supply and removal extension chambers, where the second distal extension housing member defines at least one second coupler pin opening; and

the bit portion comprises:

a bit;

a bit coupler defining at least one coupler pin groove;

a bit housing for supporting the bit and the bit coupler; and

at least one coupler pin; wherein

the at least one coupler pin extends through the at least one second coupler pin opening and the at least one first coupler pin opening and is arranged at least partly within the at least one coupler pin groove to secure the bit portion to the distal extension portion to transfer rotation of the distal extension portion to the bit.

12. A method of forming a hole in the earth comprising the steps of:

providing a bit portion defining at least one housing groove;

the bit portion is operatively connected to a distal extension portion;

operatively connecting the distal extension portion to a proximal extension portion to define

a supply path extending through the proximal extension portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion;

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion, where the return path extends at least partly through the at least one housing groove; and

a portion of the return path defined by the distal extension portion surrounds the supply path;

engaging the bit portion with the earth;

rotating the proximal portion to cause rotation of the bit portion through the distal extension portion;

forcing drill fluid through the supply path and to the cutter region; and

collecting drill fluid in the cutter region through the return path.

13. A method as recited in claim **12**, in which the step of operatively connecting the distal extension portion to the proximal extension portion comprises the steps of:

securing a first connector housing to the proximal extension portion;

securing a second connector housing to the distal extension portion; and

securing the first and second housings to each other to transfer rotational forces from the proximal extension portion to the distal extension portion; and

arranging a connector member to engage the proximal extension portion and the distal extension portion such that

a portion of the supply path extends through the connector passageway,

a portion of the return path extends between the connector member and at least one of the first and second connector housings.

14. An earth boring system for forming a hole in the earth, comprising:

a drill string comprising

a bit portion defining at least one housing groove;

a distal extension portion;

a proximal extension portion; and

a connecting portion;

a drive system;

a drill fluid supply; and

a drill debris collector; whereby

the bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define

a supply path extending through the proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion;

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion; and

a portion of the return path defined by the distal extension portion surrounds the supply path;

the drill fluid supply forces drill fluid through the supply path such that

the drill fluid mixes with cuttings in the cutter region to form drill debris,

the drill debris flows back up through the return path; and

the drill debris collector collects the drill debris; and

the return path extends at least partly through the at least one housing groove.

15. An earth boring system as recited in claim **14**, in which the connecting portion comprises:

a first connector housing secured to the proximal extension portion;

a second connector housing secured to the distal extension portion; and

a connector member defining a connector passageway; wherein

the first and second housings are secured to each other to transfer rotational forces from the proximal extension portion to the distal extension portion; and

the connector member engages the proximal extension portion and the distal extension portion such that

a portion of the supply path extends through the connector passageway, and

a portion of the return path extends between the connector member and at least one of the first and second connector housings.

16. An earth boring system as recited in claim **14**, in which:

the distal extension portion defines first and second distal extension housing members arranged to define distal supply and removal extension chambers;

the proximal extension portion defines first and second proximal housing members arranged to define proximal supply and removal extension chambers; and

the connecting portion comprises

a first connector housing secured to the proximal extension portion;

a second connector housing secured to the distal extension portion; and

a connector member defining a connector passageway; wherein

the first and second housings are secured to each other to transfer rotational forces from the proximal extension portion to the distal extension portion; and

the connector member engages the first distal extension housing member and the first proximal extension housing member such that

a portion of the supply path extends through proximal supply extension chamber, the connector passageway, and the distal supply extension chamber, and

a portion of the return path extends through the distal removal extension chamber, between the connector member and at least one of the first and second connector housings, and through the proximal removal extension chamber.

17. A drill string comprising:

a bit portion;

a distal extension portion;

a proximal extension portion; and

a connecting portion; whereby

the bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define

a supply path extending through the proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion; and

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion; and

the bit portion defines at least one housing groove, where the return path extends at least partly through the at least one housing groove.

18. A drill string comprising:

a bit portion comprising

a bit,

a bit coupler,

a bit housing for supporting the bit and the bit coupler, where the bit housing defines at least one housing groove, and

at least one coupler pin;

a distal extension portion;

a proximal extension portion; and

a connecting portion; whereby

the at least one coupler pin engages the bit housing and the distal extension portion to secure the bit portion to the distal extension portion to transfer rotation of the distal extension portion to the bit;

the bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define

a supply path extending through the proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion; and

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion; and

the return path extends at least partly through the at least one housing groove.

19. A method of forming a hole in the earth comprising the steps of:

providing a bit portion defining at least one housing groove;

the bit portion is operatively connected to a distal extension portion;

operatively connecting the distal extension portion to a proximal extension portion to define

a supply path extending through the proximal extension portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion,

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion, and

the return path extends at least partly through the at least one housing groove; and

engaging the bit portion with the earth;

rotating the proximal portion to cause rotation of the bit portion through the distal extension portion;

forcing drill fluid through the supply path and to the cutter region; and

collecting drill fluid in the cutter region through the return path.

20. An earth boring system for forming a hole in the earth, comprising:

a drill string comprising

a bit portion, where the bit portion defines at least one housing groove,

a distal extension portion,

a proximal extension portion, and

a connecting portion;

a drive system;

a drill fluid supply; and

a drill debris collector; whereby

the bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define

a supply path extending through the proximal extension portion, the connecting portion, the distal extension

portion, and the bit portion to a cutter region associated with the bit portion,

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion, and

the return path extends at least partly through the at least one housing groove;

the drill fluid supply forces drill fluid through the supply path such that

the drill fluid mixes with cuttings in the cutter region to form drill debris, and

the drill debris flows back up through the return path; and

the drill debris collector collects the drill debris.

21. A drill string comprising:

a bit portion comprising

a bit;

a bit coupler;

a bit housing for supporting the bit and the bit coupler; and

at least one coupler pin;

a distal extension portion;

a proximal extension portion; and

a connecting portion; whereby

the bit portion is operatively connected to the distal extension portion and the connecting portion operatively connects the distal extension portion to the proximal extension portion to define

a supply path extending through the proximal extension portion, the connecting portion, the distal extension portion, and the bit portion to a cutter region associated with the bit portion; and

a return path extending from the cutter region through the bit portion, the distal extension portion, the connector portion, and the proximal extension portion;

the at least one coupler pin engages the bit housing and the distal extension portion to secure the bit portion to the distal extension portion to transfer rotation of the distal extension portion to the bit;

a portion of the return path defined by the distal extension portion surrounds the supply path; and

the bit housing defines at least one housing groove, where the return path extends at least partly through the at least one housing groove.

* * * * *