



(12) PATENT

(11) 347600

(13) B1

(19) NO

NORWAY

(51) Int Cl.

E21B 43/116 (2006.01)

E21B 43/117 (2006.01)

Norwegian Industrial Property Office

(21)	Application nr.	20180507	(86)	International Filing Date and Application Number	2014.07.16 PCT/CA2014/050673
(22)	Date of Filing	2018.04.13	(85)	Date of Entry into National Phase	2018.04.13
(24)	Date of Effect	2014.07.16	(30)	Priority	2013.07.18, CA, 2821506
(41)	Publicly Available	2016.01.06			
(45)	Granted	2024.01.29			
(62)	Divisional application	20171759, 2017.11.07			
(73)	Proprietor	DynaEnergetics Europe GmbH, Kaiserstrasse 3, 53840 TROISDORF, Tyskland			
(72)	Inventor	Frank Haron Preiss, An der Arndtrude 20, 53175 BONN, Tyskland Liam McNelis, Gallusstrasse 72, 53227 BONN, Tyskland Eric Mulhern, 2936-41 Avenue NW, ABT6T1K5 EDMONTON, Canada Thilo Scharf, Derora Churchhill, LETTERKENNY CO., DONEGAL, Ireland David C Parks, 12 Crestmont Way SW, ABT3B5Z6 CALGARY, Canada			
(74)	Agent or Attorney	NERDERIKET AS, Kvibakken 93B, 4034 STAVANGER, Norge			

(54) Title **Perforation gun system**

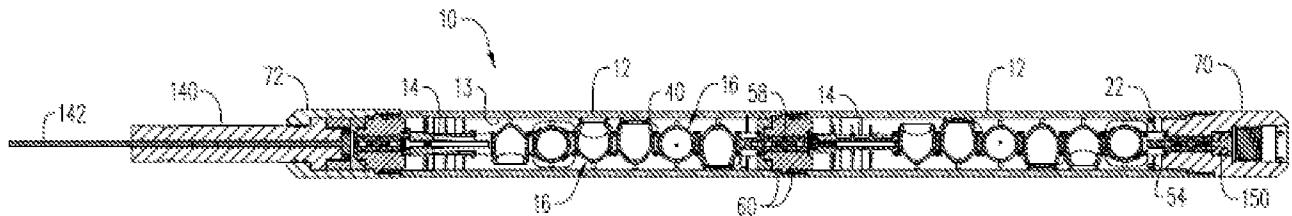
(56) References

US 2008/0149338 A1, US 4598775 A

(57) Cited:

(57) Abstract

A perforation gun system based on combinations of basic components including a top connector, a self-centralizing charge holder system and a bottom connector that can double as a spacer. Any number of spacers can be used with any number of holders for any desired specific metric or imperial shot density, phase and length gun system. A perforation gun system kit as well as a method of assembling a perforation gun system is also disclosed.



FIELD

[0001] A perforation gun system is generally described. More particularly, various perforation gun components that can be modularly assembled into a perforation gun system, the assembled perforated gun system itself, a perforation gun system kit, and a method for 5 assembling a perforation gun system are generally described.

BACKGROUND

[0002] Perforation gun systems are used in well bore perforating in the oil and natural gas industries to tie a bore hole with a storage horizon within which a storage reservoir of oil or 10 natural gas is located.

[0003] A typical perforation gun system consists of an outer gun carrier, arranged in the interior of which there are perforators – usually hollow or projectile charges – that shoot radially outwards through the gun carrier after detonation. Penetration holes remain in the gun carrier after the shot.

15 [0004] In order to initiate the perforators, there is a detonating cord leading through the gun carrier that is coupled to a detonator.

[0005] Different perforating scenarios often require different phasing and density of charges or gun lengths. Moreover, it is sometimes desirable that the perforators shooting radially outwards from the gun carrier be oriented in different directions along the length of the barrel.

20 Therefore, phasing may be required between different guns along the length.

[0006] Onsite assembly of perforation gun systems may also be problematic under certain conditions as there are certain safety hazards inherent to the assembly of perforation guns due to the explosive nature of certain of its sub-components, including the detonator and the detonating cord.

25 [0007] There is thus a need for a perforation gun system, which by virtue of its design and components would be able to address at least one of the above-mentioned needs, or overcome or at least minimize at least one of the above-mentioned drawbacks. Patent publications US 2008/0149338 A1 and US 4598775 A show examples of prior art perforation gun systems.

US 2008/0149338 A1 discloses a perforation gun apparatus and a process for assembling a 30 loading tube for the perforation gun at a first location different from the location at which perforating operations will be conducted. Whereas patent publication US 4598775 A discloses a perforating gun device which has multiple shaped charges supported in aligned relationship

within a housing. The charges are arranged so that they do not interfere with one another when detonated.

SUMMARY

5 [0008] According to an embodiment, an object is to provide perforation gun systems, according to the independent claim 1, that addresses at least one of the above- mentioned needs.

[0009] According to an embodiment, there is provided a perforation gun system having an outer gun carrier and comprising:

- a top connector;

10 - at least one stackable charge holder for centralizing a single shaped charge within the gun carrier;

- a detonation cord connected to the top connector and to each stackable charge holder;
- at least one bottom connector for terminating the detonation cord in the gun system; and
- a detonator energetically coupled to the detonation cord,

15 wherein each of the top connector, at least one stackable charge holder and at least one bottom connector comprise a rotation coupling for providing a selectable clocking rotation between each of the top connector, at least one stackable charge holder and at least one bottom connector.

[0010] In some embodiments, the bottom connector may double as a spacer for spacing a plurality of stackable charge holders, and may either act as a metric dimensioned spacer or as an 20 imperial dimensioned spacer for any specific metric or imperial shot density, phase and length gun system.

[0011] According to another aspect, there is also provided a perforation gun system kit having component parts capable of being assembled within an outer gun carrier, the kit comprising a combination of:

25 - a top connector;

- at least one stackable charge holder for centralizing a single shaped charge within the gun carrier;
- a detonation cord connectable to the top connector and to each stackable charge holder;
- at least one bottom connector adapted for terminating the detonation cord in the gun system; and

30 - a detonator energetically couplable to the detonation cord,

wherein each of the top connector, at least one stackable charge holder and at least one bottom connector comprise a coupling having a plurality of rotational degrees of freedom for providing a

selectable rotation between each of the top connector, at least one stackable charge holder and at least one bottom connector.

[0012] According to another aspect, there is also provided a method for assembling a perforation gun system, comprising the steps of:

- 5 providing a perforation gun system kit having component parts capable of being assembled within an outer gun carrier, the kit comprising a combination of:
 - a top connector;
 - at least one stackable charge holder for centralizing a single shaped charge within the gun carrier;
- 10 - a detonation cord connectable to the top connector and to each stackable charge holder;
 - at least one bottom connector adapted for terminating the detonation cord in the gun system and adapted for doubling as a spacer for spacing a plurality of stackable charge holders; and
 - a detonator energetically couplable to the detonation cord,wherein each of the top connector, at least one stackable charge holder and at least one bottom
- 15 connector comprise a coupling having a plurality of rotational degrees of freedom for providing a selectable rotation between each of the top connector, at least one stackable charge holder and at least one bottom connector;
- assembling a plurality of the stackable charge holders in a predetermined phase to form a first gun assembly;
- 20 running the detonation cord into a bottommost bottom connector;
- assembling the bottommost bottom connector onto the assembled plurality of stackable charge holders;
- running a through wire between the bottommost bottom connector and the top connector, so that the wire goes from the top connector to the bottom connector;
- 25 clicking the detonation cord into recessed formed in capturing projections, the captured projections being provided in each of the charge holders;
- running the detonation cord into the top connector;
- cutting the detonator cord; and
- installing charges into each of the charge holders.

30 [0013] A number of optional steps that are detailed below may be added to the above-described steps of the method.

[0014] According to another aspect, there is also provided a top connector for a perforation

gun system comprising:

- a coupler for providing energetic coupling between a detonator and a detonating cord;
- at least one directional locking fin for locking the top connector within a gun carrier;
- a rotation coupling for providing a selectable clocking rotation between the top connector, and a charge holder

wherein the top connector is configured to receive electrical connections therethrough.

[0015] According to another aspect, there is also provided a stackable charge holder for a perforation gun system having an outer gun carrier, the charge holder comprising:

- a charge receiving structure for receiving a single shaped charge;
- a plurality of projections for centralizing the shaped charge within the gun carrier; and
- at least one rotation coupling for providing a selectable clocking rotation between the charge holder and an adjacent component in the perforation gun system;

wherein a pair of the plurality of projections is configured for capturing a detonation cord traversing the charge holder.

[0016] According to another aspect, there is also provided a bottom connector for a perforation gun system comprising:

- a terminating structure arranged for terminating a detonation cord in the gun system;
- a plurality of wings for axially locking the bottom connector to a snap ring fixed in the carrier;
- a rotation coupling for providing a selectable clocking rotation between the bottom connector and a charge holder;

wherein the rotation coupling is arranged such that bottom connector doubles as a spacer for spacing a plurality of stackable charge holders.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other objects and advantages will become apparent upon reading the detailed description and upon referring to specific embodiments thereof that are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments and are not therefore to be considered to be limiting of its scope, exemplary embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0018] FIG. 1 is a side cut view of a perforation gun system according to an embodiment;

[0019] FIG. 2 is a side view of a top connector, bottom connector and stackable charge

holders of a perforation gun system in accordance with another embodiment;

[0020] FIG. 3 is a side view of a top connector, bottom connector and stackable charge holders of a perforation gun system in accordance with another embodiment;

[0021] FIG. 4 is a front perspective view of a bottom connector in accordance with an embodiment;

[0022] FIG. 5 is a rear perspective view of the bottom connector shown in FIG. 4;

[0023] FIG. 6 is a front view of a stackable charge holder in accordance with an embodiment;

[0024] FIG. 7 is a front perspective view of the stackable charge holder shown in FIG. 6;

10 [0025] FIG. 8 is a rear perspective view of the stackable charge holder shown in FIG. 6;

[0026] FIG. 9 is a bottom view of the stackable charge holder shown in FIG. 6;

[0027] FIG. 10 is a top view of the stackable charge holder shown in FIG. 6;

[0028] FIG. 11 is a bottom view of a half-portion of a top connector in accordance with an embodiment;

15 [0029] FIG. 12 is a side view of the half-portion of the top connector shown in FIG. 11;

[0030] FIG. 13 is a top perspective view of the half-portion of the top connector shown in FIG. 11;

[0031] FIG. 14 is a bottom perspective view of the half-portion of the top connector shown in FIG. 11;

20 [0032] FIG. 15 is a perspective view of a top connector in accordance with an embodiment;

[0033] FIG. 16 is a front end view of the top connector shown in FIG. 15;

[0034] FIG. 17 is a rear end view of the top connector shown in FIG. 15;

[0035] FIG. 18 is a rear perspective view of the top connector shown in FIG. 15;

25 [0036] FIG. 19 is an enlarged detailed side cut view of a portion of the perforation gun system including a bulkhead and stackable charge holders shown in FIG. 1;

[0037] FIG. 20 is a perspective view of a bottom sub of a gun system in accordance with an embodiment;

[0038] FIG. 21 is a side view of a gun carrier of a gun system in accordance with an embodiment;

[0039] FIG. 22 is a side cut view of the gun carrier shown in FIG. 21;

[0040] FIG. 23 is a side view of a top sub of a gun system in accordance with an embodiment;

[0041] FIG. 24 is a side cut view of the top sub shown in FIG. 23;

[0042] FIG. 25 is a side view of a tandem seal adapter of a gun system in accordance with an embodiment;

[0043] FIG. 26 is a perspective view of the tandem seal adapter shown in FIG. 25;

[0044] FIG. 27 is a perspective view of a detonator in accordance with an embodiment;

[0045] FIG. 28 is a detailed perspective view of the detonator shown in FIG. 27;

[0046] FIG. 29 is another detailed perspective view of the detonator shown in FIG. 27;

[0047] FIG. 30 is another detailed perspective view of the detonator shown in FIG. 27;

[0048] FIG. 31 is another detailed perspective view of the detonator shown in FIG. 27, with a crimp sleeve;

[0049] FIG. 32 is a detailed side view of a tandem seal adapter and detonator in accordance with another embodiment;

[0050] FIG. 33 is a side cut view of a portion of a perforation gun system illustrating the configuration of the top sub in accordance with another embodiment;

[0051] FIG. 34 is a side cut view of a portion of a perforation gun system illustrating the configuration of the bottom sub in accordance with another embodiment; and

[0052] FIGS. 35A and 35B are electrical schematic views of a detonator and of wiring within a perforated gun system in accordance with another embodiment.

[0053] In the following description and accompanying FIGS., the same numerical references refer to similar elements throughout the FIGS. and text. Furthermore, for the sake of simplicity and clarity, namely so as not to unduly burden the FIGS. with several reference numbers, only certain FIGS. have been provided with reference numbers, and components and

features of the embodiments illustrated in other FIGS. can be easily inferred therefrom. The embodiments, geometrical configurations, and/or dimensions shown in the FIGS. are for exemplification purposes only. Various features, aspects and advantages of the embodiments will become more apparent from the following detailed description.

5 [0054] Moreover, although some of the embodiments were primarily designed for well bore perforating, for example, they may also be used in other perforating scenarios or in other fields, as apparent to a person skilled in the art. For this reason, expressions such as "gun system", etc., as used herein should not be taken as to be limiting, and includes all other kinds of materials, objects and/or purposes with which the various embodiments could be used and may
10 be useful. Each example or embodiment are provided by way of explanation, and is not meant as a limitation and does not constitute a definition of all possible embodiments.

[0055] In addition, although some of the embodiments are illustrated in the accompanying drawings comprise various components and although the embodiment of the adjustment system as shown consists of certain geometrical configurations as explained and illustrated herein, not
15 all of these components and geometries are essential and thus should not be taken in their restrictive sense, i.e. should not be taken as to limit the scope. It is to be understood, as also apparent to a person skilled in the art, that other suitable components and cooperations thereinbetween, as well as other suitable geometrical configurations may be used for the adjustment systems, and corresponding parts, according to various embodiments, as briefly
20 explained and as can easily be inferred herefrom by a person skilled in the art, without departing from the scope.

[0056] Referring to FIGS. 1 to 3, an object is to provide a perforation gun system 10 having an outer gun carrier 12. The gun system 10 includes a top connector 14. At least one stackable charge holder 16 is provided for centralizing a single shaped charge 18 within the gun
25 carrier 12. A detonation cord 20 is connected to the top connector 14 and to each stackable charge holder 16.

[0057] The gun system 10 includes at least one bottom connector 22 for terminating the detonation cord 20 in the gun system. As better shown in FIG. 2, it is also possible that the bottom connector 22 double as or serve the function of a spacer 24 for spacing a plurality of
30 stackable charge holders 16.

[0058] In an embodiment, the gun system also includes a detonator 26 energetically coupled to the detonation cord 20.

[0059] As better shown in FIGS. 4 to 18, each of the top connector 14, stackable charge

holder 16 and bottom connector 22 includes a rotation coupling 30 for providing a selectable clocking rotation between each of the above-mentioned components. As seen, for instance, in Fig. 8, the rotation coupling 30 includes a first rotation coupling 30a and a second rotation coupling 30b.

5 [0060] Hence, a user can build multiple configurations of gun systems using various combinations of basic components. A first of these basic components includes a top connector. Another basic component is a single charge holder that centralizes a single shaped charge. The holder is adapted to be stacked and configured into 0, 30, 60, up to 360 degrees or any other combination of these phases for any specified length. Another basic component is a bottom
10 connector that terminates the detonation cord in the gun. The bottom connector may carry as well an electrical connection therethrough. The bottom connector may also double as an imperial measurement stackable spacer to provide any gun shot density up to, for example, 6 shots per foot. Alternately, another bottom connector may be provided or configured to double as a metric measurement stackable spacer to provide any gun shot density up to, for example, 20 shots per
15 meter. Another basic component includes a push-in detonator that does not use wires to make necessary connections. The push-in detonator may use spring-loaded connectors, thus replacing any required wires and crimping.

20 [0061] Therefore, within the self-centralizing charge holder system, any number of spacers can be used with any number of holders for any specific metric or imperial shot density, phase and length gun system.

[0062] In an embodiment, only two pipe wrenches are required for assembly on site of the gun system, as no other tools are required.

[0063] In an embodiment, the top connector 14 provides energetic coupling between the detonator and detonating cord.

25 [0064] In an embodiment, each of the top connector 14, stackable charge holder 16 and bottom connector 22 are configured to receive electrical connections therethrough.

[0065] In an embodiment, all connections are made by connectors, such as spring-loaded connectors, instead of wires, with the exception of the through wire that goes from the top connector 14 to the bottom connector 22, whose ends are connectors.

30 [0066] In an embodiment, components of the assembly may include molded parts, which may also be manufactured to house the wiring integrally, through, for instance, overmolding, to encase the wiring and all connectors within an injection molded part. For example, the charge

holder 16 could be overmolded to include the through wire.

[0067] In an embodiment, and as shown in FIGS. 4 and 5, each bottom connector 22 includes a plurality of fins 32 for axially locking each bottom connector against a snap ring 54, or an equivalent retainment mechanism to keep the charge holder 16 from sliding out of the bottom of carrier 12 as it is handled, (shown on FIG. 1). According to an aspect, and as illustrated in FIG. 19, the bottom connector 22 may be recessed into the tandem seal adapter 48. The bottom connector 22 from a first gun assembly can accommodate or house an electrical connection through a bulkhead assembly 58 to the top connector 14 of a second or subsequent gun assembly, as seen for instance in FIG. 19. The top and bottom connector, as well as the spacer, in an embodiment, are made of 15% glass fiber reinforced, injection molding PA6 grade material, commercially available from BASF under its ULTRAMID® brand, and can provide a positive snap connection for any configuration or reconfiguration. As better shown in FIG. 5, a terminating means structure 34 is provided to facilitate terminating of the detonation cord. The snap ring 54 is preinstalled on the bottom of the carrier 12. The assembly can thus shoulder up to the snap ring 54 via the bottom connector fins 32.

[0068] In an embodiment and as shown in FIGS. 6 to 10, each stackable charge holder 16 has a plurality of projections 40 resting against an inner surface 13 or diameter of the gun carrier 12 (as shown in FIG. 1) and thereby centralizing the shaped charge therewithin. A pair of the plurality of projections 42 may also be configured for capturing the detonation cord (not shown) traversing each stackable charge holder 16. The pair of the plurality of projections 42 are also used for centralizing the shaped charge within an inner surface of the gun carrier.

[0069] In an embodiment, as shown in FIGS. 11 to 18, the top connector 14 includes at least one directional locking fin 46. Although the use of directional locking fins is described, other methods of directional locking may be used, in order to eliminate a top snap ring that would otherwise be used to lock the assembly. As better shown in FIG. 19, the locking fins 46 are engageable with corresponding complementarily-shaped structures 47 housed within the carrier 12, upon a rotation of the top connector 14, to lock the position of the top connector along the length of the carrier 12.

[0070] In an embodiment, as better shown in FIG. 19, the bottom connector 22 on one end and the top connector 14 on the other end abuts/connects to the bulkhead assembly 58. The tandem seal adapter 48 is configured to seal the inner components within the carrier 12 from the outside environment, using sealing means 60 (shown herein as o-rings). Thus, the tandem seal adapter 48 seals the gun assemblies from each other along with the bulkhead 58, and transmits a

ground wire to the carrier 12. Hence, the top connector 14 and bulkhead 58 accommodate electrical and ballistic transfer to the charges of the next gun assembly for as many gun assembly units as required, each gun assembly unit having all the components of a gun assembly.

[0071] In an embodiment, the tandem seal adapter 48 is a two-part tandem seal adapter (not shown) that fully contains the bulkhead assembly 58 (comprised of multiple small parts as shown, for instance, in FIG. 19) and that is reversible such that it has no direction of installation.

[0072] In an embodiment and as better shown in FIGS. 27-31 and 35A, the detonator assembly 26 includes a detonator head 100, a detonator body 102 and a plurality of detonator wires 104, including a through wire 106, a signal-in wire 108 and a ground wire 110. The through wire 106 traverses from the top to the bottom of the perforating gun system 10, making a connection at each charge holder 16. The detonator head 100 further includes a through wire connector element 112 connected to the through wire 106 (not shown), a ground contact element 114 for connecting the ground wire 110 to the tandem seal adapter (also not shown), through ground springs 116, and a bulkhead connector element 118 for connecting the signal-in wire 108 to the bulkhead assembly 58 (also not shown). Different insulating elements 120A, 120B are also provided in the detonator head 100 for the purpose of insulating the detonator head 100 and detonator wires 104 from surrounding components. As better shown in FIG. 31, a crimp sleeve 122 can be provided to cover the detonator head 100 and body 102, thus resulting in a more robust assembly. The above configuration allows the detonator to be installed with minimal tooling and wire connections.

[0073] In an embodiment as shown in FIGS. 32, 33 and 35B illustrate a connection of the above-described detonator assembly 26 to the tandem seal adapter 48 and a pressure bulkhead 124. The bulkhead 124 includes spring connector end interfaces comprising contact pins 126A, 126B, linked to coil springs 128A, 128B. This dual spring pin connector assembly including the bulkhead 124 and coil springs 128A, 128B is positioned within the tandem seal adapter 48 extending from a conductor slug 130 to the bulkhead connector element. The dual spring pin connector assembly is connected to the through wire 106 of the detonator assembly 26.

[0074] In an embodiment and as better shown in FIGS. 11 to 18, the top connector 14 may have a split design to simplify manufacturing and aid in assembly. By “split design” what is meant is that the top connector 14 can be formed of two halves - a top half 15A and a bottom half 15B. As better shown in FIGS. 15 or 18, the top connector 14 may also include a blind hole 47 to contain or house the detonation cord, thus eliminating the need for crimping the detonation cord during assembly.

[0075] In an embodiment and as shown for example in FIGS. 4 to 18, the rotation coupling 30 may either include a plurality of pins 50 (FIG. 5) symmetrically arranged about a central axis of the rotation coupling 30, or a plurality of sockets 52 (FIG. 4) symmetrically arranged about the central axis of the rotation coupling 30 and configured to engage the plurality of pins 50 of an adjacent rotation coupling 30.

[0076] In another embodiment, the rotation coupling 30 may either include a polygon-shaped protrusion, or a polygon-shaped recess configured to engage the polygon-shaped protrusion of an adjacent rotation coupling. The polygon can be 12-sided for example for 30 degree increments.

10 [0077] In another embodiment, the top and bottom subs work with off the shelf running/setting tools as would be understood by one of ordinary skill in the art.

15 [0078] In one embodiment and as shown in FIG. 33, the top sub 72 facilitates use of an off the shelf quick change assembly 140 to enable electrical signals from the surface, as well as to adapt perforating gun system to mechanically run with conventional downhole equipment. The quick change assembly 140 may include a threaded adapter 143 to set an offset distance between an electrical connector 142 and the contact pin 126B extending from the bulkhead assembly 58.

20 [0079] In one embodiment and as shown in FIG. 34, the bottom sub 70 may be configured as a sealing plug shoot adapter (SPSA) to be used specifically with this embodiment. The SPSA may receive an off the shelf quick change assembly 140 (not shown) and insulator 150 that communicates with a firing head threaded below it (not shown). A setting tool (not shown) may run on the bottom side of the perforating gun.

[0080] In an embodiment, final assembly of the tool string requires only two pipe wrenches. No tools are required to install the detonator or any electrical connections.

25 [0081] An object is to also provide a perforation gun system kit having the basic component parts described above and capable of being assembled within an outer gun carrier.

[0082] In an embodiment, a method for assembling a perforation gun system is provided, to which a certain number of optional steps may be provided. The steps for assembling the gun system for transport include the steps of:

30 providing a perforation gun system kit having component parts capable of being assembled within an outer gun carrier (element 12 in FIGS. 1, 21 and 22), the kit comprising a combination of:

- a top connector;

- at least one stackable charge holder for centralizing a single shaped charge within the gun carrier;
- a detonation cord connectable to the top connector and to each stackable charge holder;
- at least one bottom connector adapted for terminating the detonation cord in the gun system and adapted for doubling as a spacer for spacing a plurality of stackable charge holders; and
- a detonator energetically couplable to the detonation cord,

wherein each of the top connector, at least one stackable charge holder and at least one bottom connector comprise a coupling having a plurality of rotational degrees of freedom for providing a selectable rotation between each of the top connector, at least one stackable charge holder and at least one bottom connector;

10 assembling a plurality of the stackable charge holders in a predetermined phase to form a first gun assembly;

running the detonation cord into a bottommost bottom connector;

assembling the bottommost bottom connector onto the assembled plurality of stackable charge 15 holders;

running a through wire between the bottommost bottom connector and the top connector, so that the through wire goes from the top connector to the bottom connector;

clicking the detonation cord into recessed formed in capturing projections, the capturing projections being provided in each of the charge holders;

20 running the detonation cord into the top connector;

cutting the detonator cord, if the detonator cord is not pre-cut a predetermined length; and installing charges into each of the charge holders.

[0083] In an embodiment, the method further includes, prior to transport, the steps of: pushing assembled components together to engage all pin connections therebetween; and

25 carrying out a continuity test to ensure complete connectivity of the detonating chord.

[0084] In an embodiment, on location, to complete the assembly, the method further comprises the steps of

threading on the previously assembled components a bottom sub (element 70 on FIGS. 1 and 20);

installing and connecting the detonator;

30 pushing in a tandem seal adapter with o-rings onto the first gun assembly;

pushing in a bulkhead (element 58 in FIG. 19) onto the tandem seal adapter, if the bulkhead and the tandem seal adapter are not pre-assembled;

threading a subsequent gun assembly onto the first gun assembly or threading a top sub (element

72 in FIGS. 1, 23 and 24) onto a topmost assembled gun assembly, for connection to a quick change assembly.

[0085] Of course, the scope of the perforation gun system, various perforation gun components, the perforation gun system kit, and the method for assembling a perforation gun system should not be limited by the various embodiments set forth herein, but should be given the broadest interpretation consistent with the description as a whole. The components and methods described and illustrated are not limited to the specific embodiments described herein, but rather, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. Further, steps described in the method may 10 be utilized independently and separately from other steps described herein. Numerous modifications and variations could be made to the above-described embodiments without departing from the scope of the FIGS. and claims, as apparent to a person skilled in the art.

[0086] In this specification and the claims that follow, reference will be made to a number of terms that have the following meanings. The singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Further, reference to "top," "bottom," "front," "rear," and the like are made merely to differentiate parts and are not necessarily determinative of direction. Similarly, terms such as "first," "second," etc. are used to identify one element from another, and unless otherwise specified are not meant to refer to a particular order 15 or number of elements.

[0087] As used herein, the terms "may" and "may be" indicate a possibility of an occurrence within a set of circumstances; a possession of a specified property, characteristic or function; and/or qualify another verb by expressing one or more of an ability, capability, or possibility associated with the qualified verb. Accordingly, usage of "may" and "may be" indicates that a modified term is apparently appropriate, capable, or suitable for an indicated 20 capacity, function, or usage, while taking into account that in some circumstances the modified term may sometimes not be appropriate, capable, or suitable. For example, in some circumstances an event or capacity can be expected, while in other circumstances the event or capacity cannot occur. This distinction is captured by the terms "may" and "may be".

[0088] As used in the claims, the word "comprises" and its grammatical variants logically 30 also subtend and include phrases of varying and differing extent such as for example, but not limited thereto, "consisting essentially of" and "consisting of".

[0089] Advances in science and technology may make equivalents and substitutions

possible that are not now contemplated by reason of the imprecision of language; these variations should be covered by the appended claims. This written description uses examples to disclose the perforation gun system, various perforation gun components, the perforation gun system kit, and the method for assembling a perforation gun system, including the best mode, and also to enable any person of ordinary skill in the art to practice same, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the perforation gun system, various perforation gun components, the perforation gun system kit, and the method for assembling a perforation gun system is defined by the claims, and may include other examples that occur to those of ordinary skill in the art.

CLAIMS

1. A perforation gun system (10) comprising an outer gun carrier (12), comprising:
 - a top connector (14);
 - a stackable charge holder (16), wherein the stackable charge holder (16) positions a single shaped charge (18) within the charge holder (16);
 - a detonating cord (20) connected to the stackable charge holder (16); and
 - at least one bottom connector (22),
characterized in that:
 - a wireless push-in detonator (26) is energetically coupled to the detonating cord (20); and
 - each of the top connector (14), the stackable charge holder (16) and the at least one bottom connector (22) comprise a rotation coupling (30) providing a selectable clocking rotation between each of the top connector (14), the stackable charge holder (16) and the bottom connector (22).
2. The perforation gun system (10) of claim 1, wherein the detonator (26) comprises:
 - a detonator head (100);
 - a detonator body (102); and
 - a plurality of detonator wires (104) between the detonator head (100) and the detonator body (102), wherein the detonator wires (104) comprise a through wire (106), a signal-in wire (108) and a ground wire (110).
3. The perforation gun system (10) of claim 2, wherein the detonator head (100) comprises:
 - a through wire connector element (112) connected to the through wire (106);
 - a ground contact element (114) configured to connect the ground wire to a tandem seal adapter through ground springs (116); and
 - a bulkhead connector element (118) for connecting the signal-in wire to a bulkhead assembly (58).

4. The perforation gun system (10) of claim 1, wherein the stackable charge holder (16) is one of a plurality of stackable charge holders (16), the plurality of stackable charge holders (16) comprising a bottommost stackable charge holder, and the detonating cord (20) is terminated at the bottommost stackable charge holder.
5. The perforation gun system (10) of claim 4, wherein a bottom connector (22) of the at least one bottom connector doubles as a spacer for spacing the plurality of stackable charge holders (16).
6. The perforation gun system (10) of claim 2, wherein the through wire (106) traverses from the top connector (14) to the at least one bottom connector (22) of the perforation gun system (10), making a connection at the stackable charge holder (16).
7. The perforation gun system (10) of claim 1, wherein the rotation coupling (30) comprises at least one of a plurality of pins (50) and a plurality of sockets (52), wherein the plurality of pins (50) and the plurality of sockets (52) are symmetrically arranged about a central axis of the rotation coupling (30), and the plurality of pins (50) and the plurality of sockets (52) are configured to engage the plurality of sockets (52) or the plurality of pins (50) of an adjacent rotation coupling (30).
8. The perforation gun system (10) of Claim 7, wherein the at least one bottom connector (22) comprises:
a cylindrical body comprising a first base and a second base, wherein the plurality of pins (50) outwardly extend from the first base, each pin (50) being spaced apart from an adjacent pin (50), and the plurality of sockets (52) at least partially extend into the second base, each socket (52) being spaced apart from an adjacent socket (52).

9. The perforation gun system (10) of Claim 8, wherein the cylindrical body comprises:
a plurality of alternating v-shaped channels and v-shaped walls, the v-shaped channels partially extending from the first base towards the second base, and the v-shaped walls extend from the second base to the first base,
wherein at least one of the pins (50) extend from one of the v-shaped walls.
10. The perforation gun system (10) of Claim 9, wherein the at least one bottom connector comprises a plurality of wings (32) radially extending from the body, adjacent the first base, the wings (52) being configured to axially lock the at least one bottom connector (22) against a snap ring arranged in the perforation gun system (10).
11. The perforation gun system (10) of Claim 9, wherein each of the pins comprise:
a first end; and
a second end opposite the first end,
wherein the first end extends from one of the v-shaped walls and the second end is wider than the first end.
12. The perforation gun system (10) of Claim 7, wherein
the stackable charge holder (16) comprises corresponding rotation couplings (30),
and
the rotation coupling (30) is engageable with the corresponding rotation couplings (30) to facilitate orientation of the charge holder (16) at a predetermined phase.
13. The perforation gun system (10) of claim 1, wherein
the stackable charge holder comprises a charge receiving structure configured for receiving a shaped charge, and a plurality of projections (40) extending from the charge receiving structure.

14. The perforation gun system (10) of Claim 7, wherein the stackable charge holder (16) comprises:
 - a first base; and
 - a second base spaced apart from the first base, wherein
 - a pair of arms extend between the first and second bases,
 - the plurality of pins (50) outwardly extend from the first base, each pin (50) being spaced apart from an adjacent pin (50), and
 - the plurality of sockets (52) at least partially extend into the second base, each socket (52) being spaced apart from an adjacent socket (52).
15. The perforation gun system (10) of Claim 14, wherein the rotation coupling (30) comprises:
 - a first rotation coupling (30a); and
 - a second rotation coupling (30b), wherein
 - the first rotation coupling (30a) is integrated with the first base and the second rotation coupling (30b) is integrated with the second base, and
 - each of the first rotation coupling (30a) and the second rotation coupling (30b) comprises at least a plurality of pins and/or a plurality of sockets arranged about the central axis.

PATENTKRAV

1. Perforeringskanonsystem (10) omfattende en utvendig kanonbærer (12),
omfattende:
en toppkonnektor (14);
5 en stabelbar ladningsholder (16), hvori den stabelbare ladningsholderen (16) plasserer en enkelt rettet ladning (18) i ladningsholderen (16);
en lunte (20) festet til den stabelbare ladningsholderen (16); og
minst én bunnkonnektor (22),
karakterisert ved at:
10 en trådløs, innstikkbar detonator (26) er energetisk koplet til lunten (20); og
hver av toppkonnektoren (14), den stabelbare ladningsholderen (16) og den minst
ene bunnkonnektoren (22) omfatter en rotasjonskopling (30) som tilveiebringer en
valgbar taktrotasjon mellom minst én av toppkonnektoren (14), den stabelbare
ladningsholderen (16) og bunnkonnektoren (22).
- 15 2. Perforeringskanonsystem (10) ifølge krav 1, hvori detonatoren (26) omfatter:
et detonatorhode (100);
et detonatorlegeme (102); og
en flerhet av detonatorledninger (104) mellom detonatorhodet (100) og
detonatorlegemet (102), hvori detonatorledningene (104) omfatter en
20 gjennomgående ledning (106), en signal-inn-ledning (108) og en jordledning
(110).
- 25 3. Perforeringskanonsystem (10) ifølge krav 2, hvori detonatorhodet (100) omfatter:
et kopplingselement (112) for gjennomgående ledning koplet til den
gjennomgående ledningen (106);
et jordkontaktelement (114) konfigurert til å kople jordledningen til en
tandemtetningsadapter gjennom jordingsfjærer (116); og
et skottkopplingselement (118) for å kople signal-inn-ledningen til en
skottsammenstilling (58).
- 30 4. Perforeringskanonsystem (10) ifølge krav 1, hvori den stabelbare
ladningsholderen (16) er én av en flerhet stabelbare ladningsholdere (16),
flerheten av stabelbare ladningsholdere (16) omfatter en nederste stabelbar

ladningsholder, og lunten (20) avsluttes ved den nederste stabelbare ladningsholderen.

5. Perforeringskanonsystem (10) ifølge krav 4, hvori en bunnkonnektor (22) av den minst én bunnkonnektoren fungerer som et avstandsstykke for å skape avstand mellom flerheten av stabelbare ladningsholdere (16).
6. Perforeringskanonsystem (10) ifølge krav 2, hvori den gjennomgående ledningen (106) går fra toppkonnektoren (14) til perforeringskanonsystemets (10) minst én bunnkonnektor (22) og danner en kopling ved den stabelbare ladningsholderen (16).
- 10 7. Perforeringskanonsystem (10) ifølge krav 1, hvori rotasjonskoplingen (30) omfatter minst én av en flerhet av pinner (50) og en flerhet av kontakter (52), hvori flerheten av pinner (50) og flerheten av kontakter (52) er symmetrisk anordnet omkring en sentralakse av rotasjonskoplingen (30), og flerheten av pinner (50) og flerheten av kontakter (52) er konfigurert til å gå i inngrep med flerheten av kontakter (52) eller flerheten av pinner (50) tilhørende en naborotasjonskopling (30).
8. Perforeringskanonsystem (10) ifølge krav 7, hvori den minst én bunnkonnektoren (22) omfatter:
20 et sylinderisk legeme omfattende en første grunnflate og en andre grunnflate, hvori flerheten av pinner (50) har utstrekning utover fra den første grunnflaten, hver pinne (50) er i avstand fra en nabopinne (50), og flerheten av kontakter (52) strekker seg i det minste delvis inn i den andre grunnflaten, hver kontakt (52) er i avstand fra en nabokontakt (52).
- 25 9. Perforeringskanonsystem (10) ifølge krav 8, hvori det sylinderiske legemet omfatter:
en flerhet av alternerende v-formede kanaler og v-formede veggene, de v-formede kanalene strekker seg delvis fra den første grunnflaten mot den andre grunnflaten, og de v-formede veggene strekker seg fra den andre grunnflaten til den første

grunnflaten,
hvor minst én av pinnene (50) strekker seg fraén av de v-formede veggene.

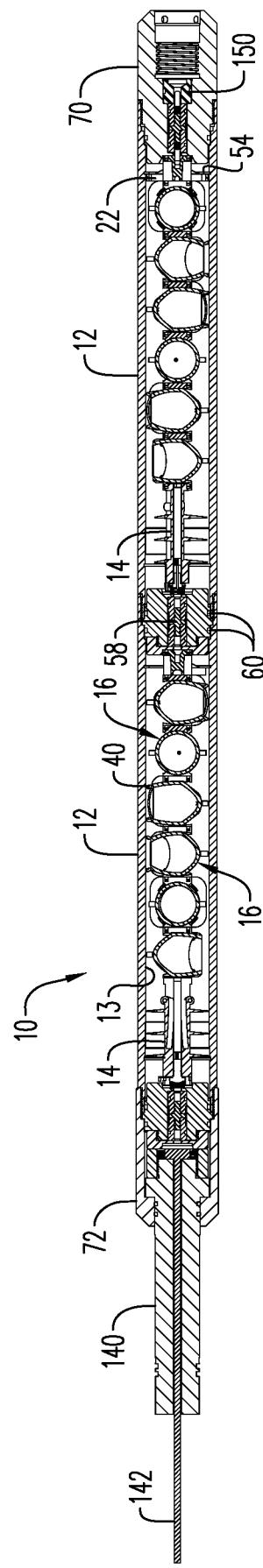
10. Perforeringskanonsystem (10) ifølge krav 9, hvor den minst én bunnkonnekturen omfatter en flerhet av vinger (32) som strekker seg radielt fra legemet, tilstøtende den første grunnflaten, vingene (52) er konfigurert til å låse den minst én bunnkonnekturen (22) aksielt mot en låsering anordnet i perforeringskanonsystemet (10).
11. Perforeringskanonsystem (10) ifølge krav 9, hvor hver av pinnene omfatter: en første ende; og
en andre ende motstående til den første enden,
hvor den første enden strekker seg fra én av de v-formede veggene og den andre enden er bredere enn den første enden.
12. Perforeringskanonsystem (10) ifølge krav 7, hvor den stabelbare ladningsholderen (16) omfatter korresponderende rotasjonskoplinger (30), og
rotasjonskoplingen (30) kan gripe inn med de korresponderende rotasjonskoplingene (30) for å lette orienteringen av ladningsholderen (16) ved en forhåndsbestemt fase.
13. Perforeringskanonsystem (10) ifølge krav 1, hvor den stabelbare ladningsholderen omfatter en ladningsmottakerkonstruksjon konfigurert for å motta en formet ladning, og en flerhet av fremspring (40) som strekker seg ut fra ladningsmottakerkonstruksjonen.
14. Perforeringskanonsystem (10) ifølge krav 7, hvor den stabelbare ladningsholderen (16) omfatter:
en første grunnflate; og
en andre grunnflate i avstand fra den første grunnflaten, hvor et par armer strekker seg mellom den første og den andre grunnflaten, en flerhet av pinner (50) som strekker seg utover fra den første grunnflaten, hver pinne (50) er i avstand fra en nabopinne (50), og

en flerhet av kontakter (52) som i det minste delvis strekker seg inn i den andre grunnflaten, hver kontakt (52) er i avstand fra en nabokontakt (52).

15. Perforeringskanonsystem (10) ifølge krav 14, hvori rotasjonskoplingen (30) omfatter:

5 en første rotasjonskopling (30a); og
en andre rotasjonskopling (30b), hvori
den første rotasjonskoplingen (30a) er integrert i den første grunnflaten og den
andre rotasjonskoplingen (30b) er integrert i den andre grunnflaten, og
hver av den første rotasjonskoplingen (30a) og den andre rotasjonskoplingen
10 (30b) omfatter i det minste en flerhet av pinner og/eller en flerhet av kontakter
anordnet omkring sentralaksen.

1/18

**FIG. 1**

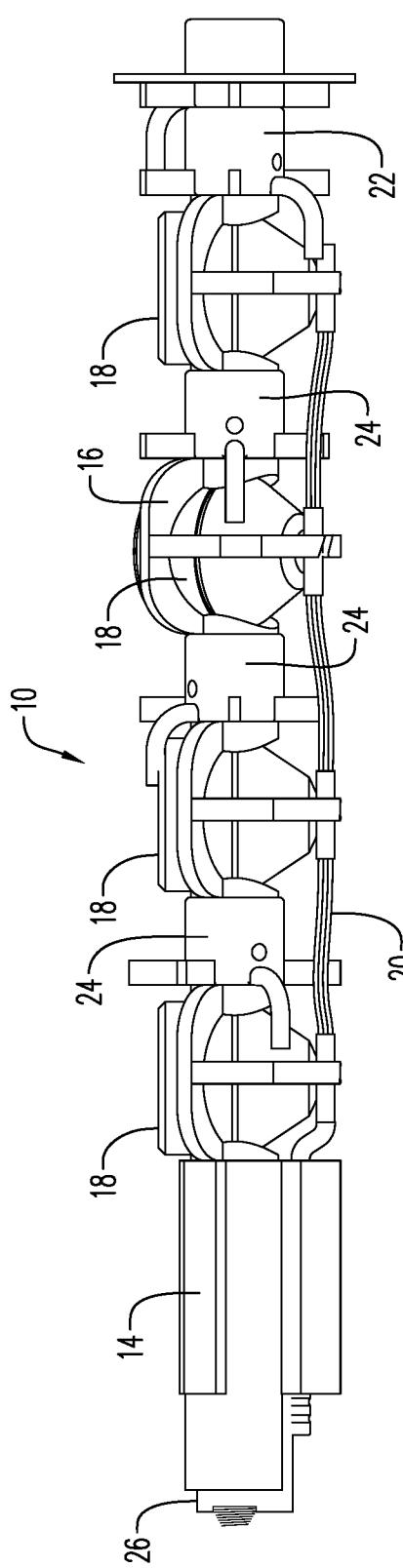


FIG. 2

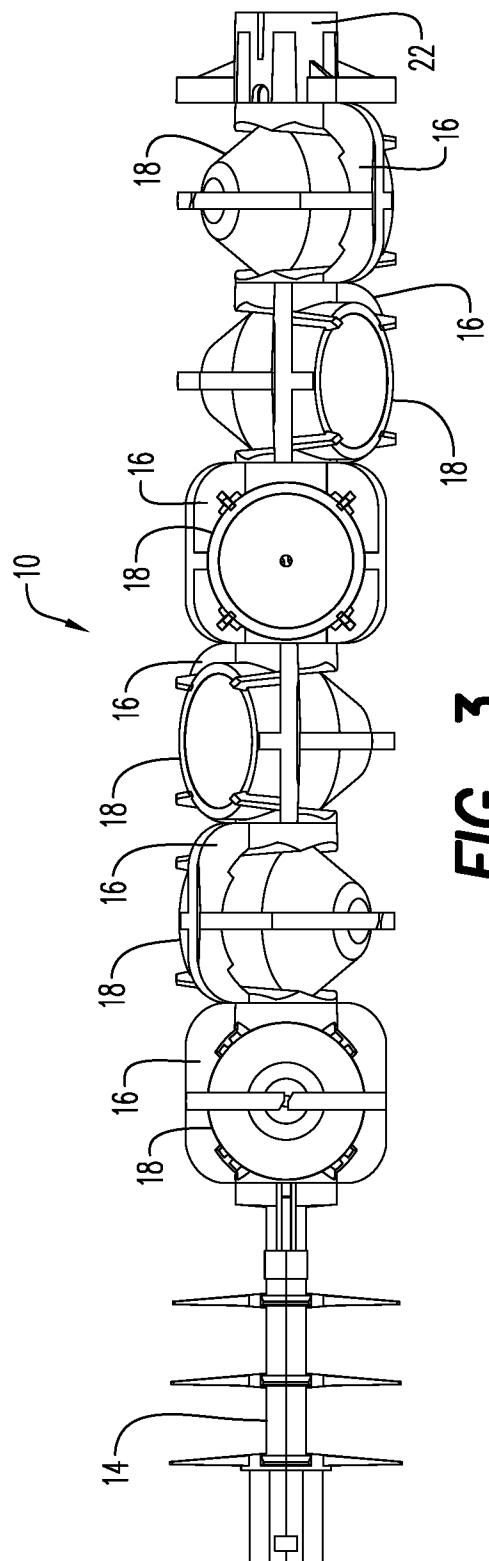
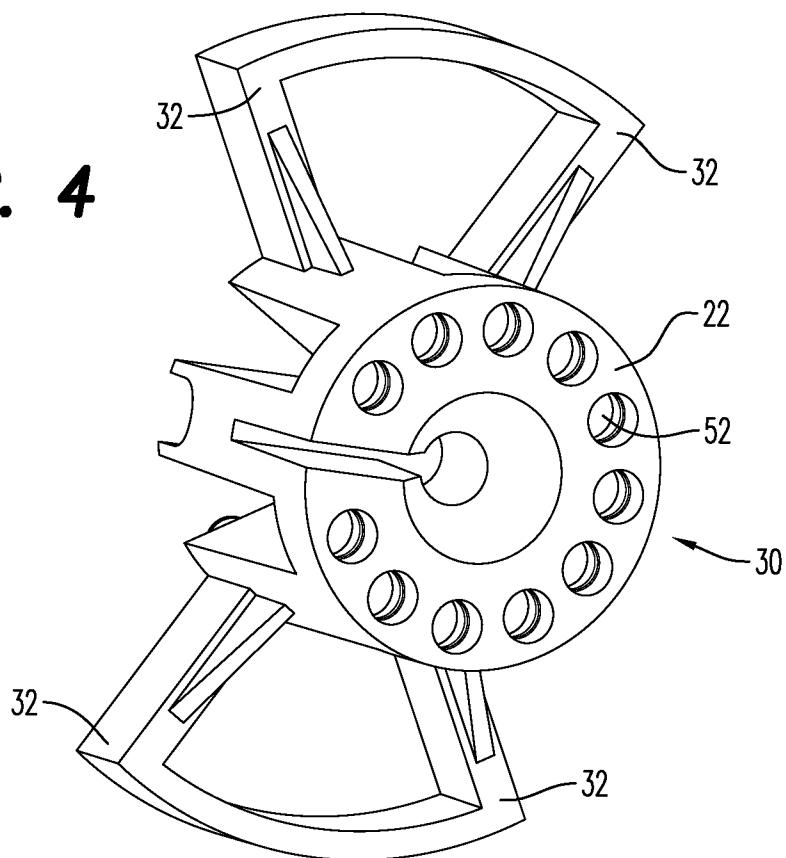
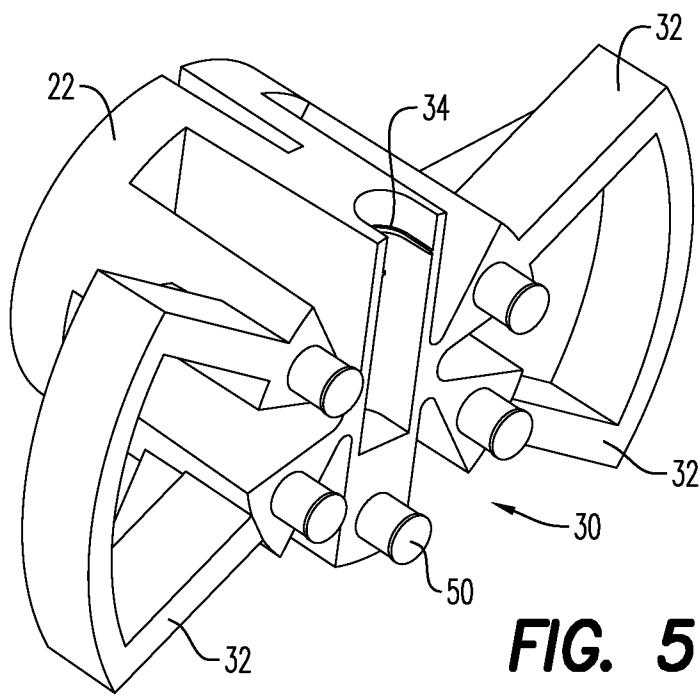
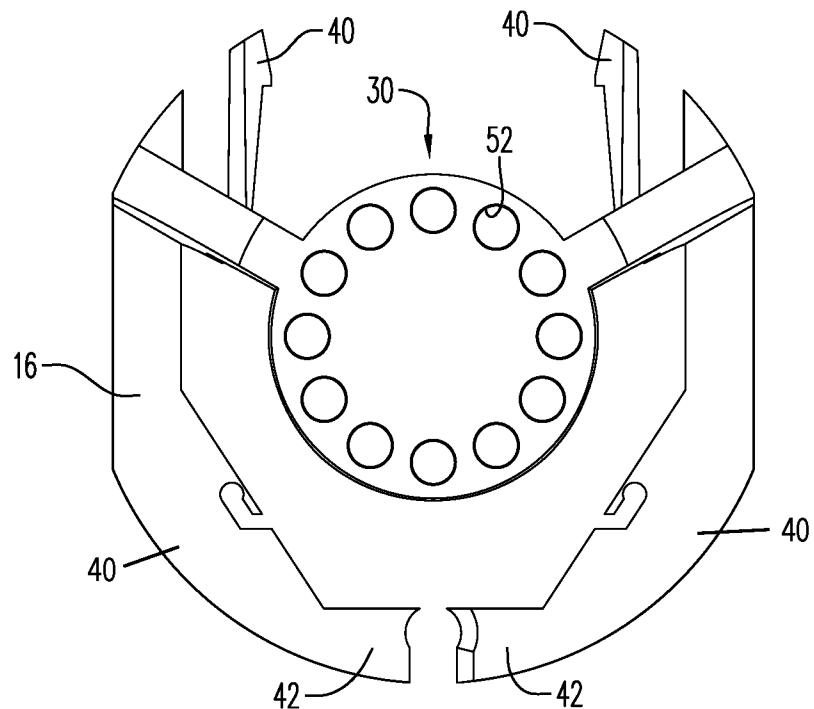
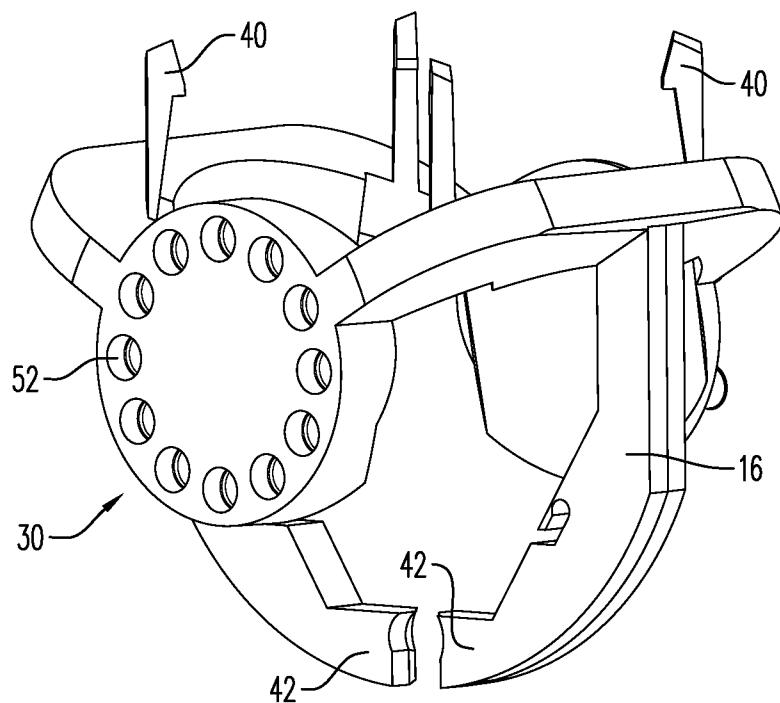


FIG. 3

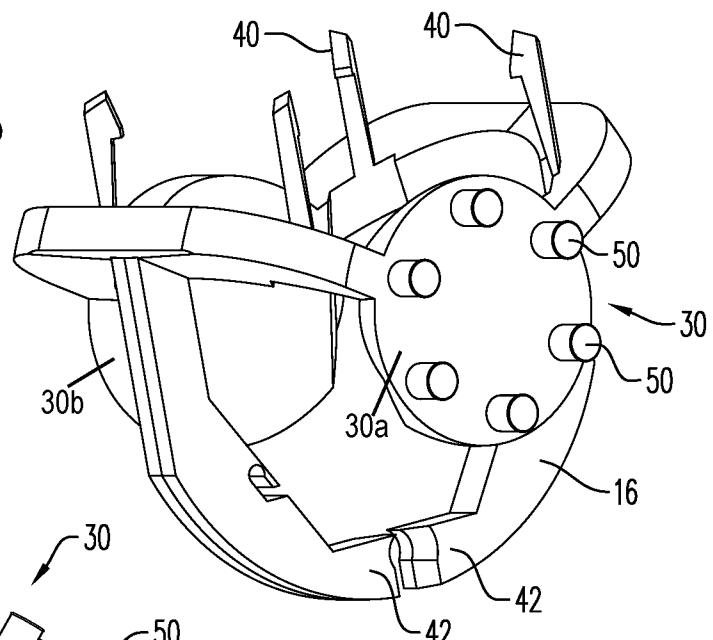
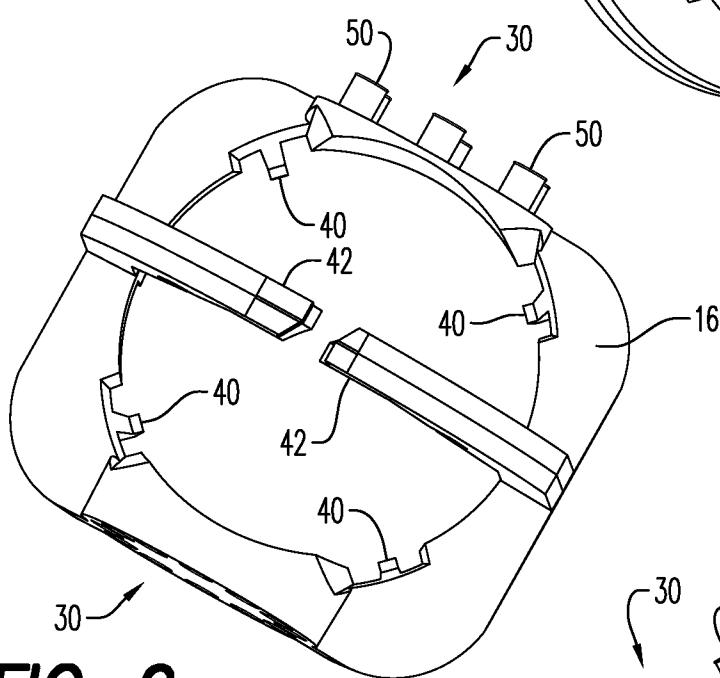
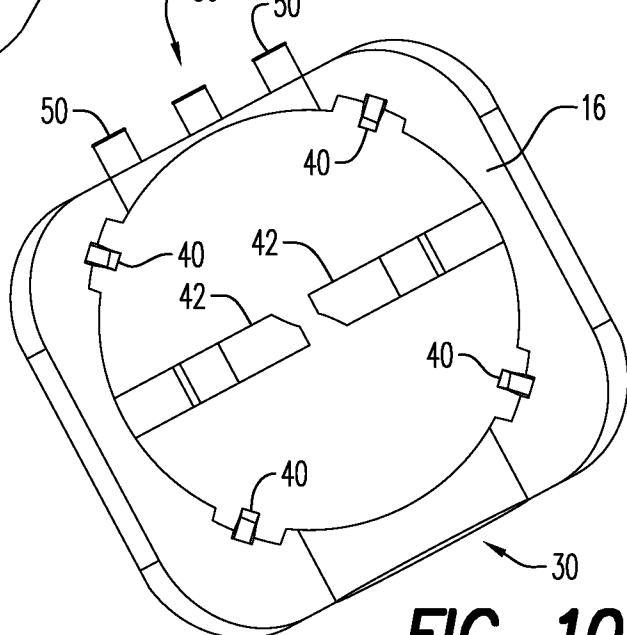
3/18

FIG. 4**FIG. 5**

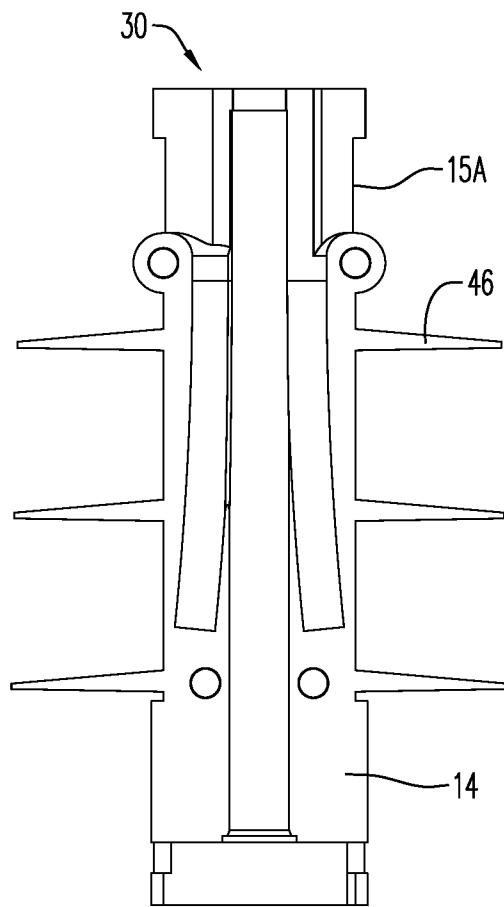
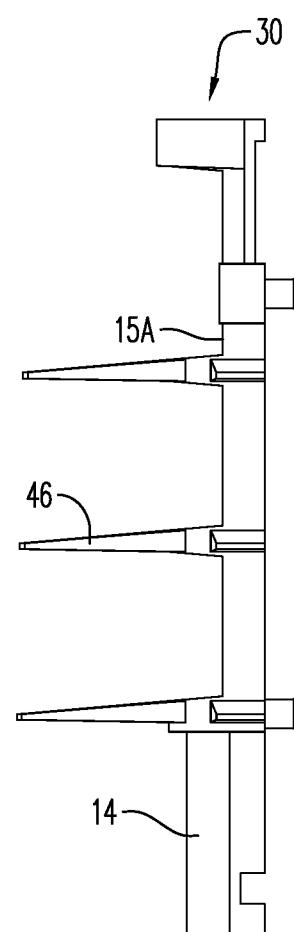
4/18

**FIG. 6****FIG. 7**

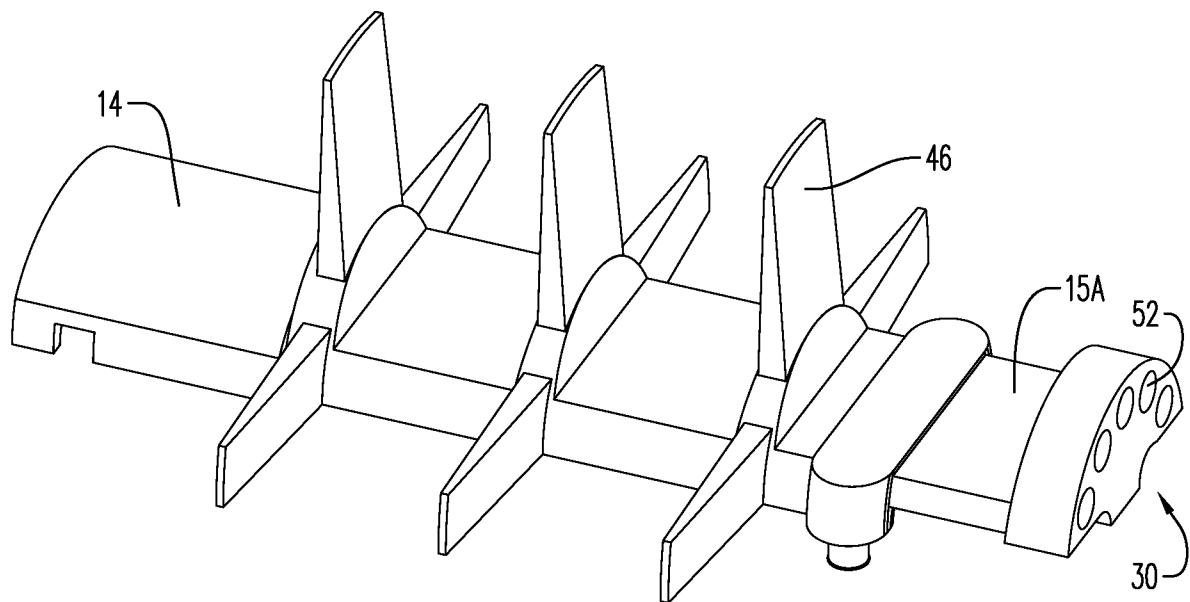
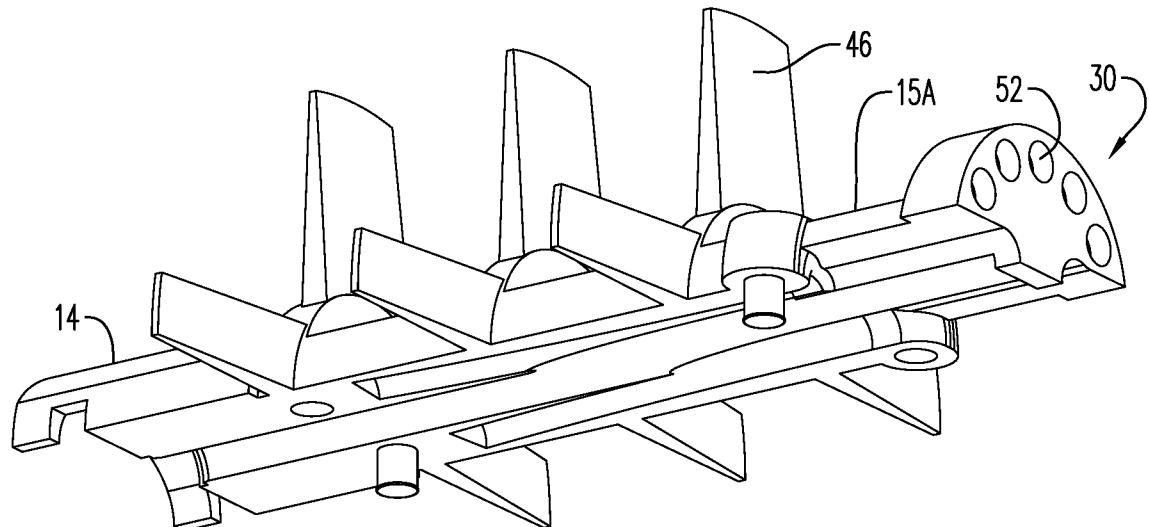
5/18

FIG. 8**FIG. 9****FIG. 10**

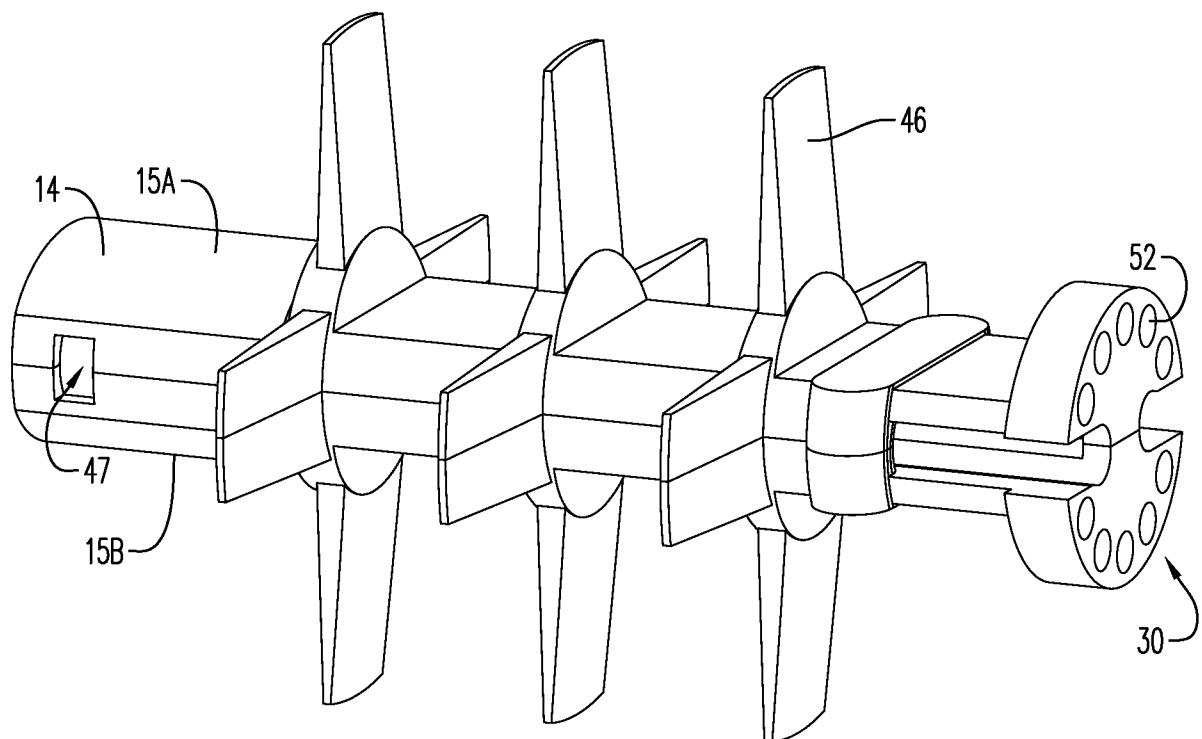
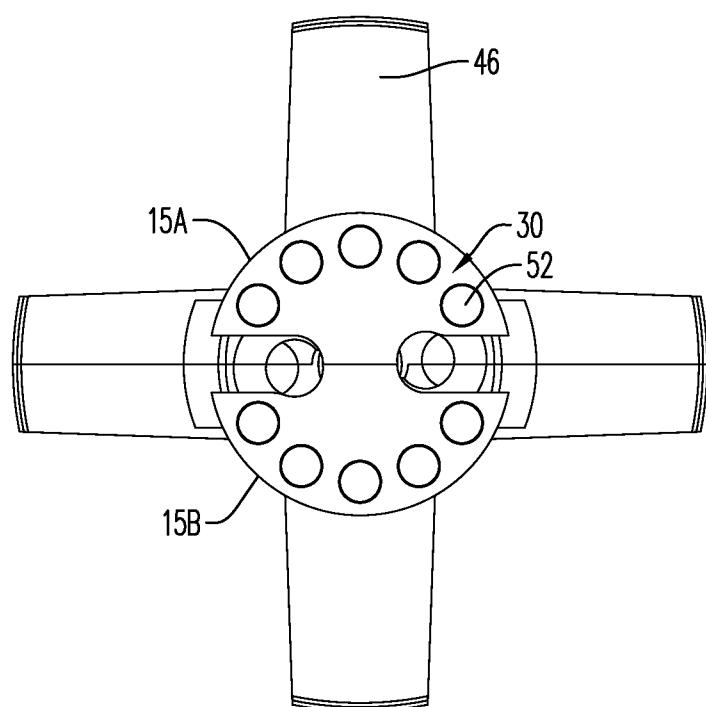
6/18

**FIG. 11****FIG. 12**

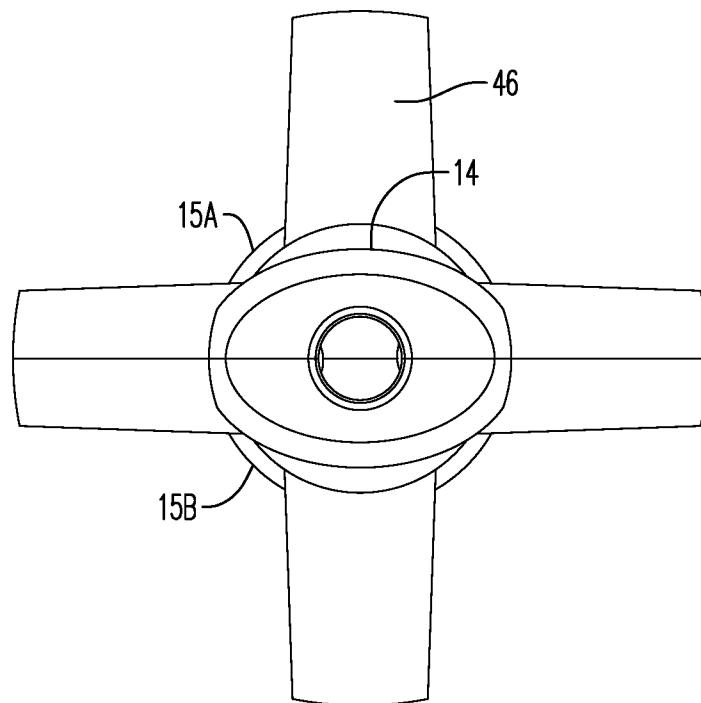
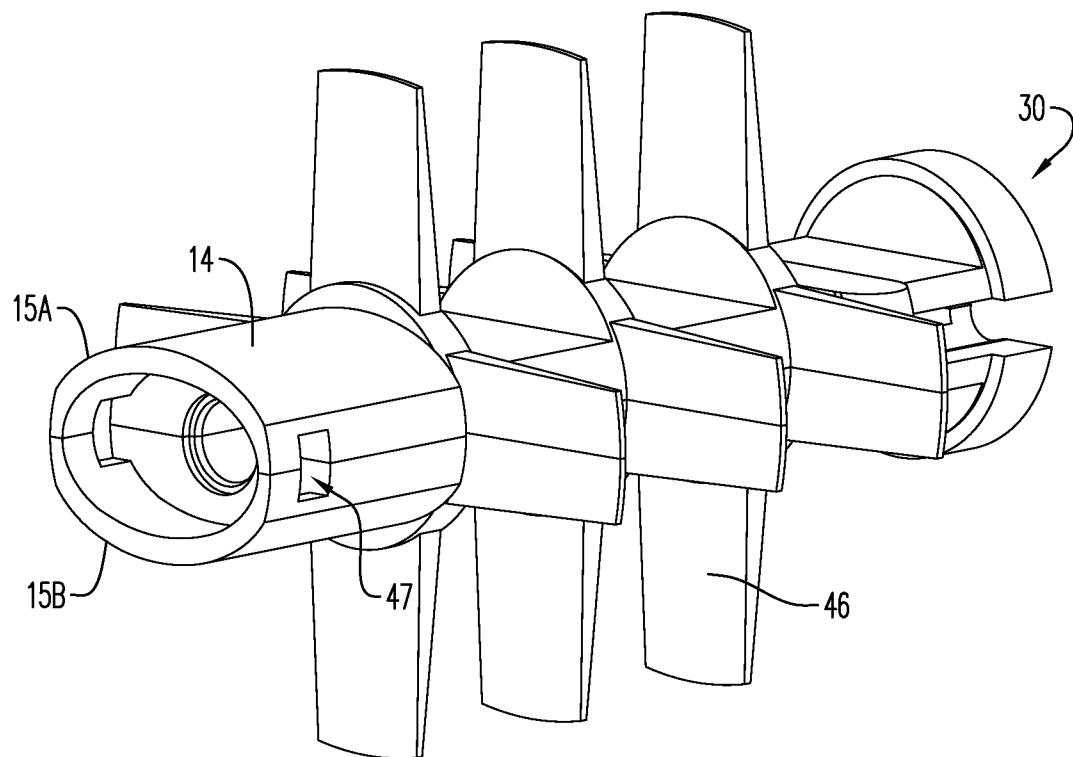
7/18

**FIG. 13****FIG. 14**

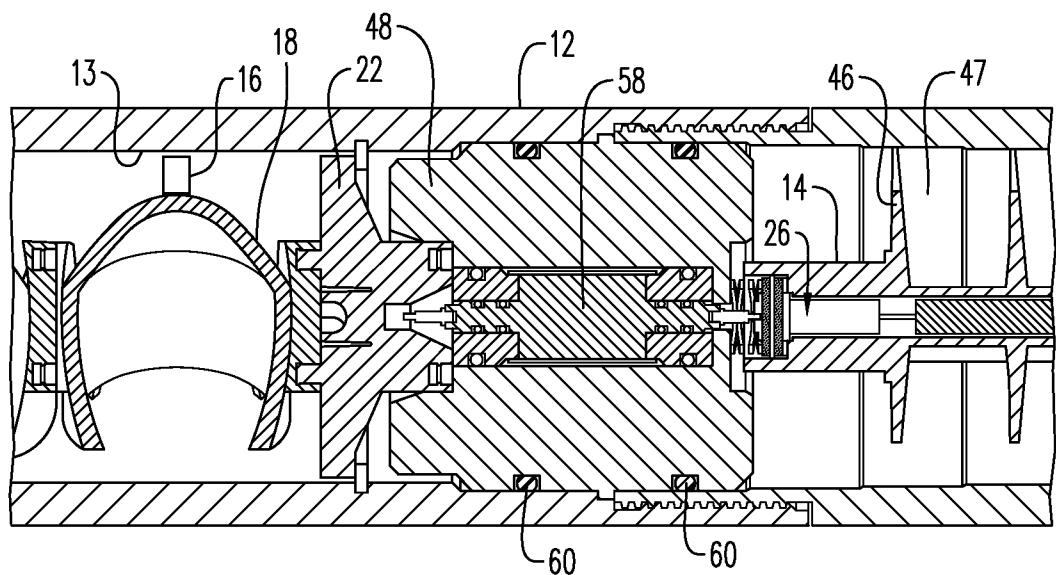
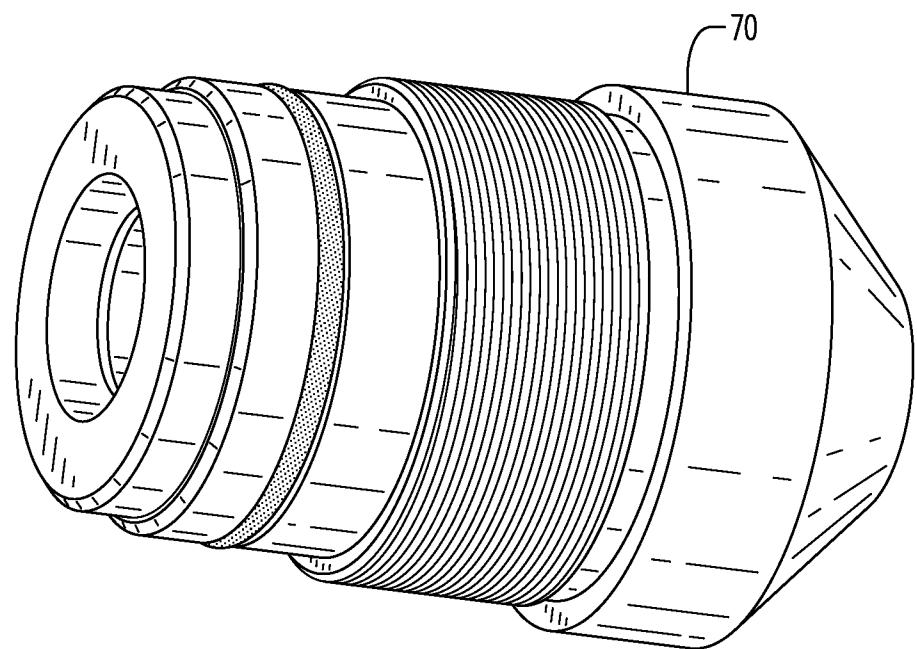
8/18

**FIG. 15****FIG. 16**

9/18

**FIG. 17****FIG. 18**

10/18

**FIG. 19****FIG. 20**

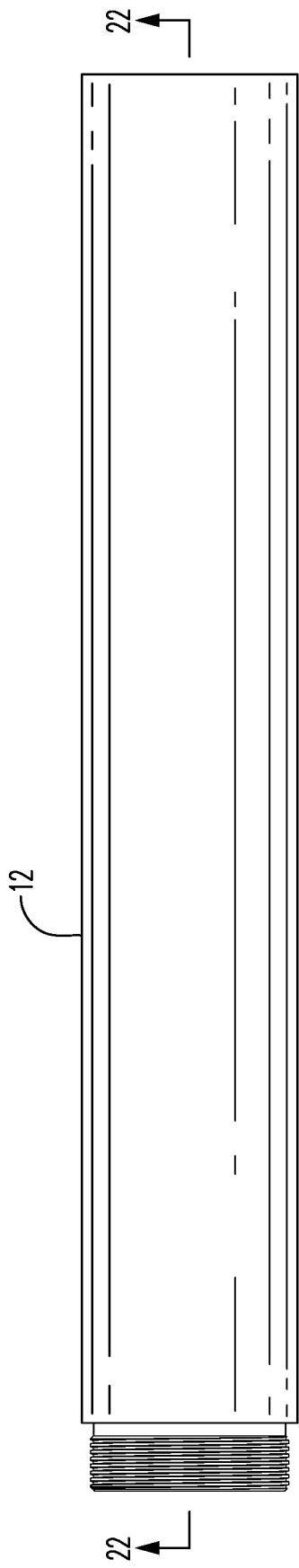


FIG. 21

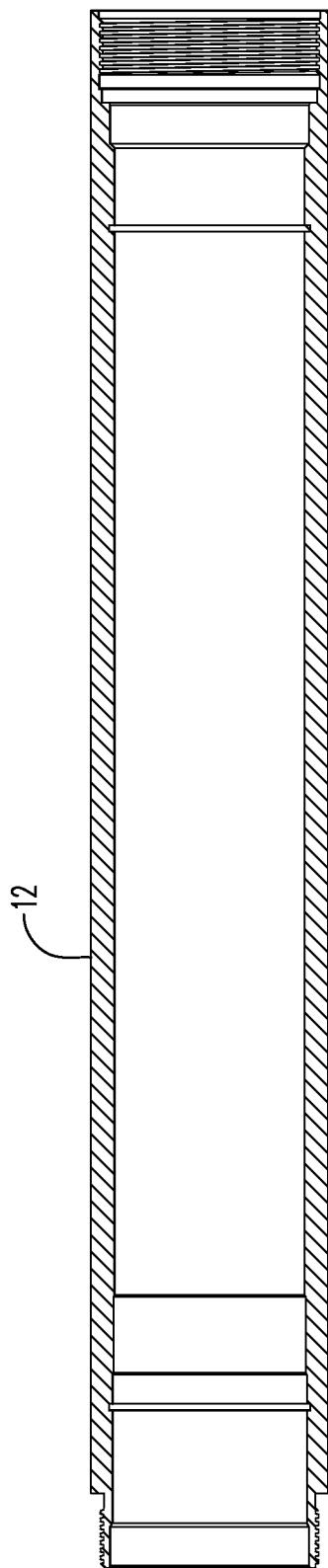
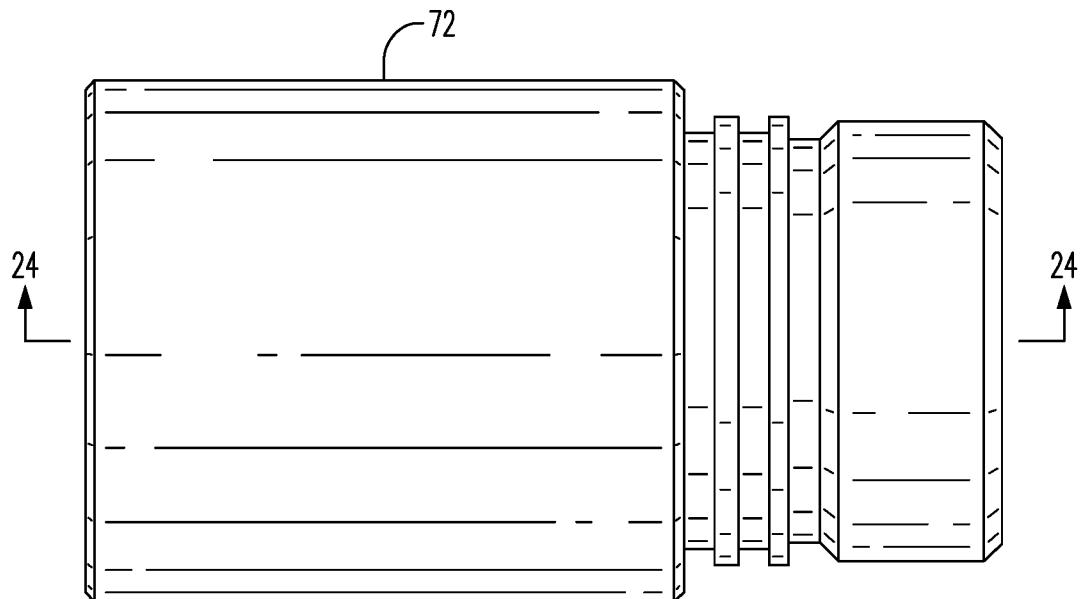
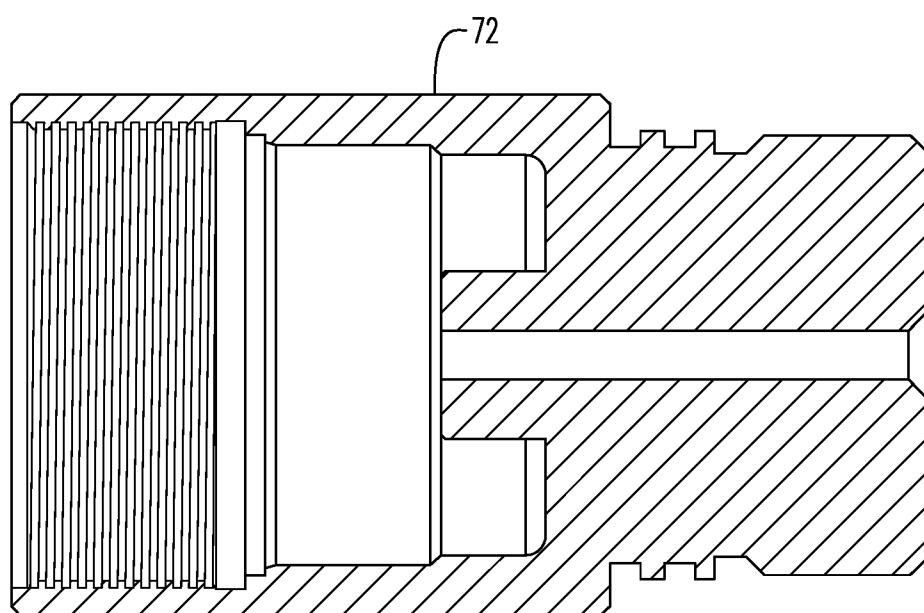
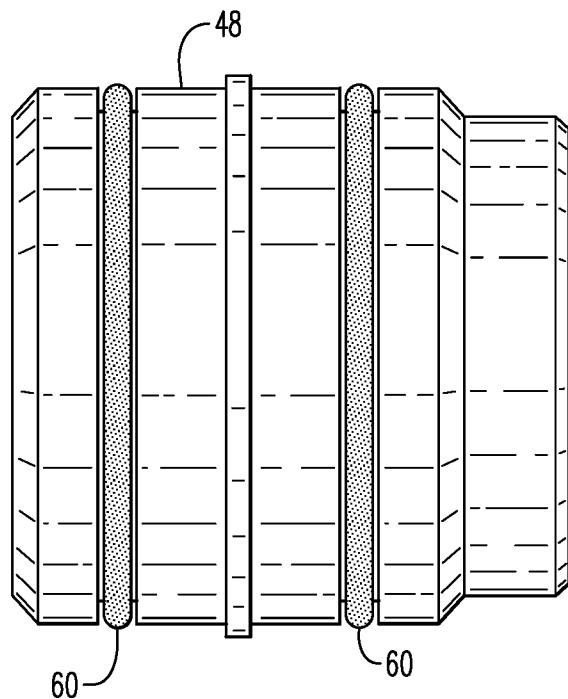
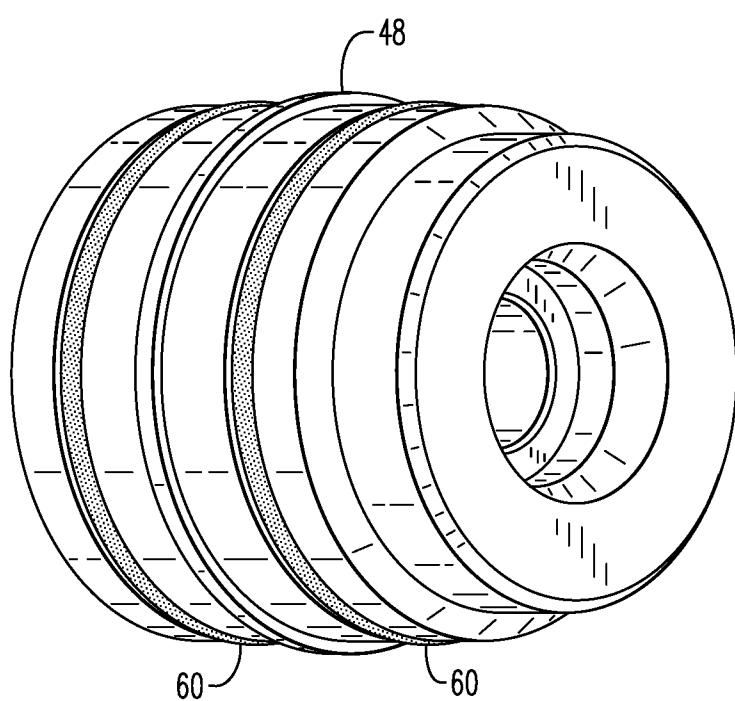


FIG. 22

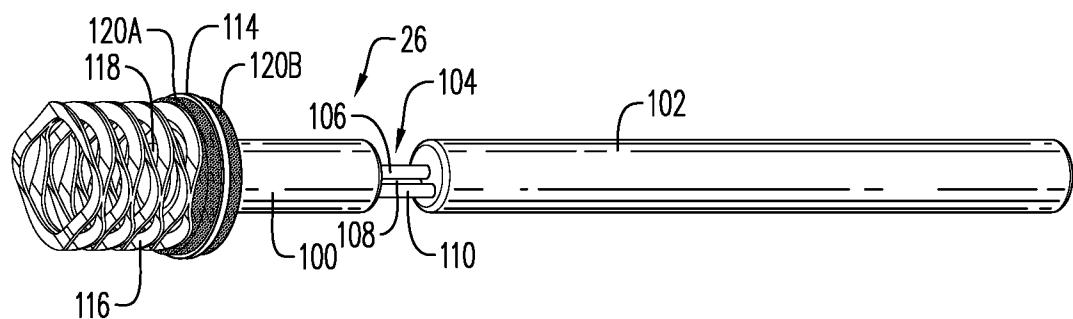
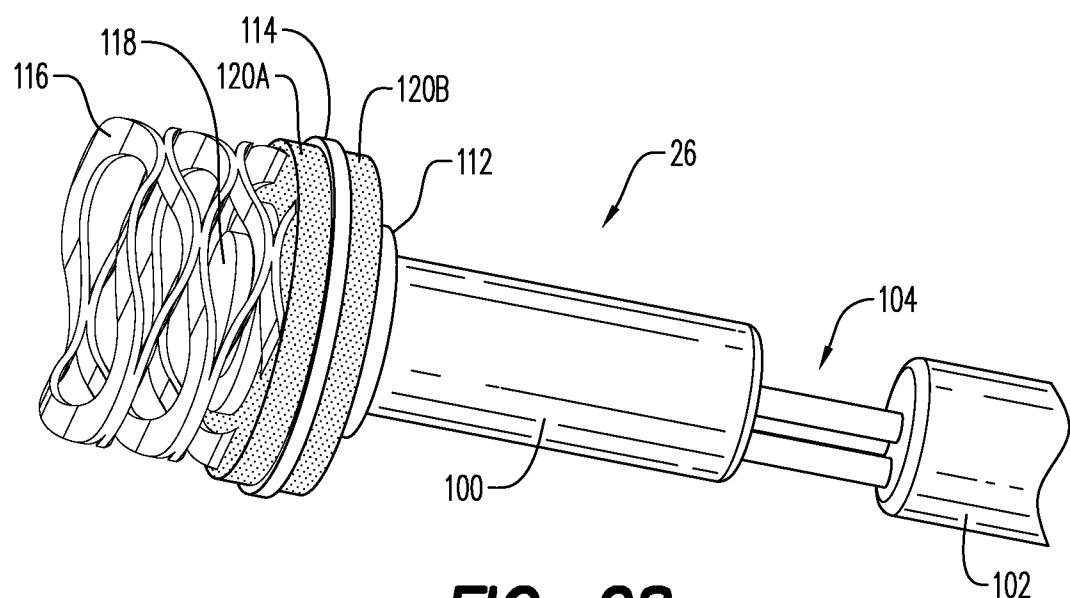
12/18

**FIG. 23****FIG. 24**

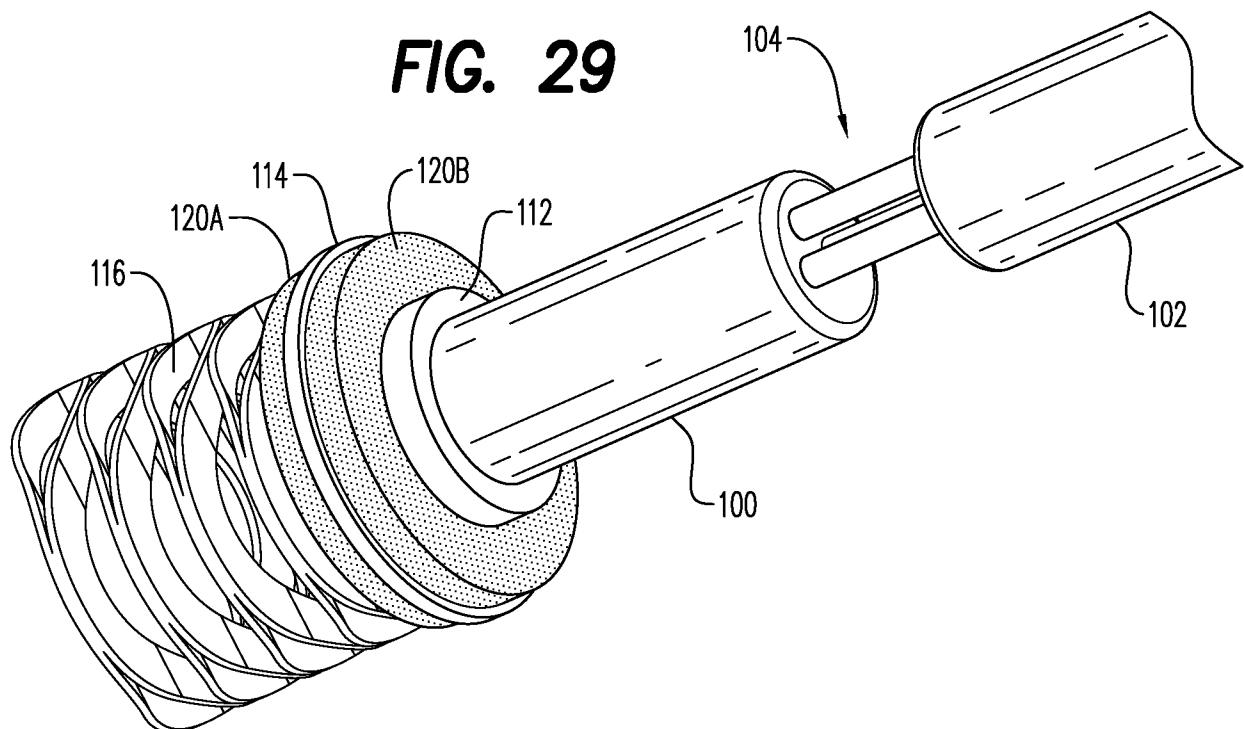
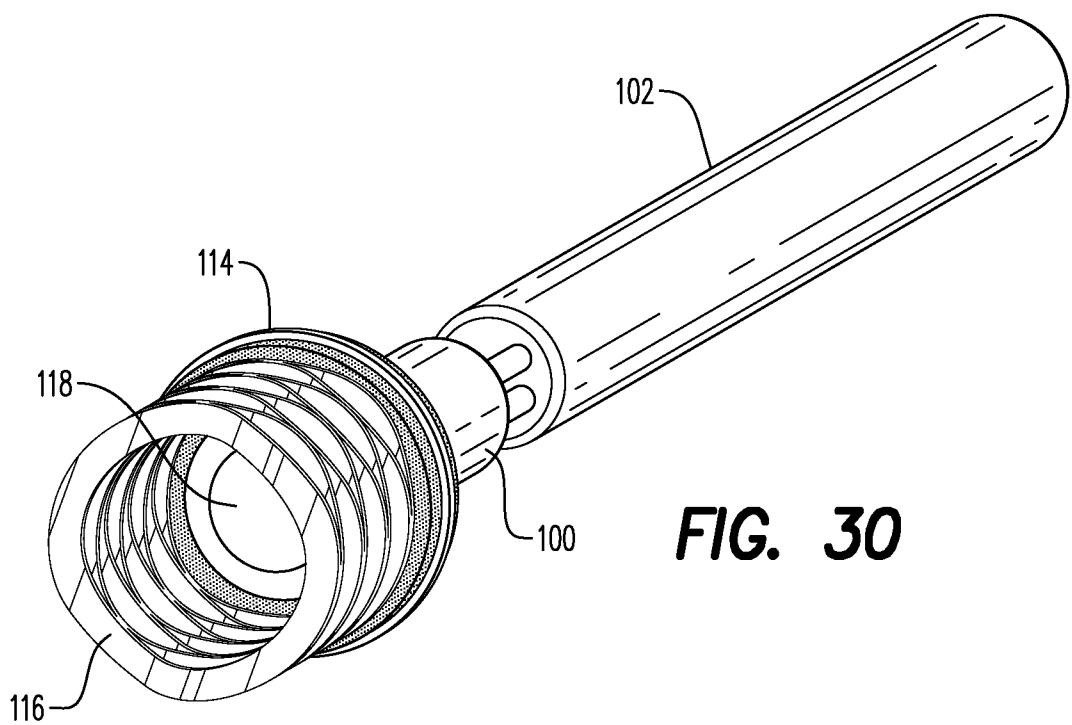
13/18

**FIG. 25****FIG. 26**

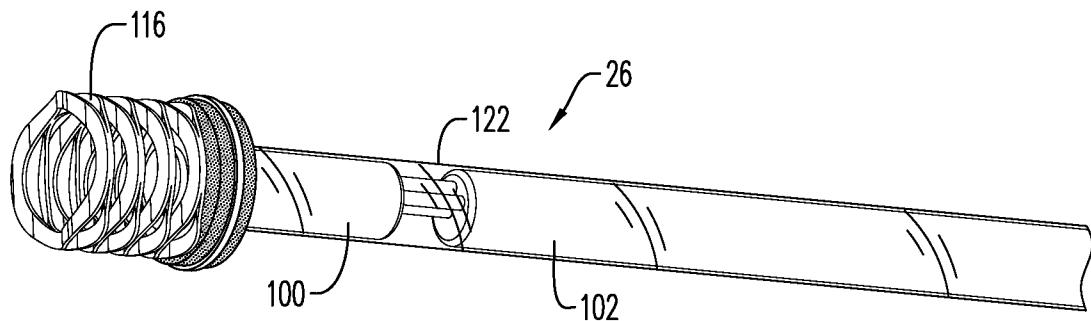
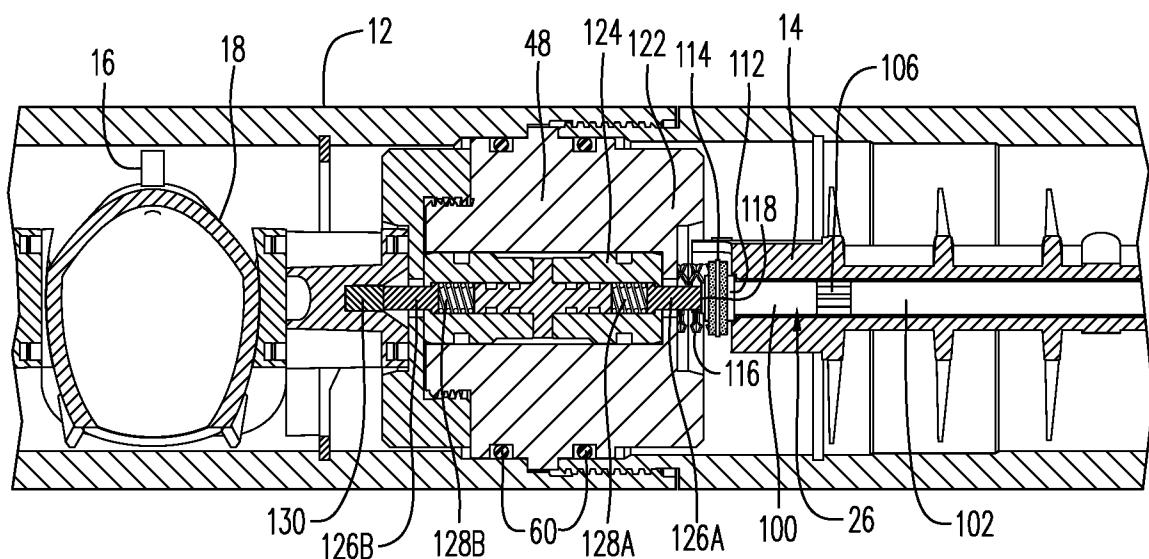
14/18

**FIG. 27****FIG. 28**

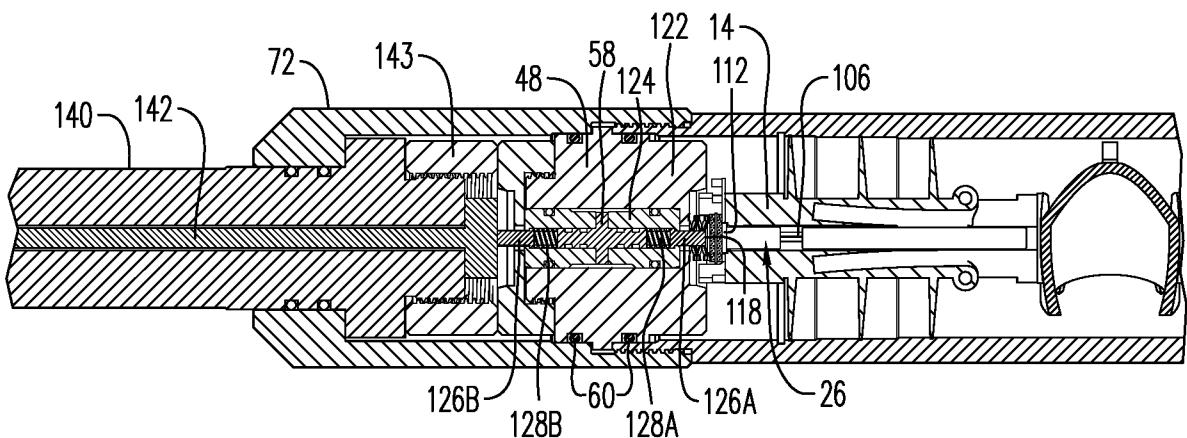
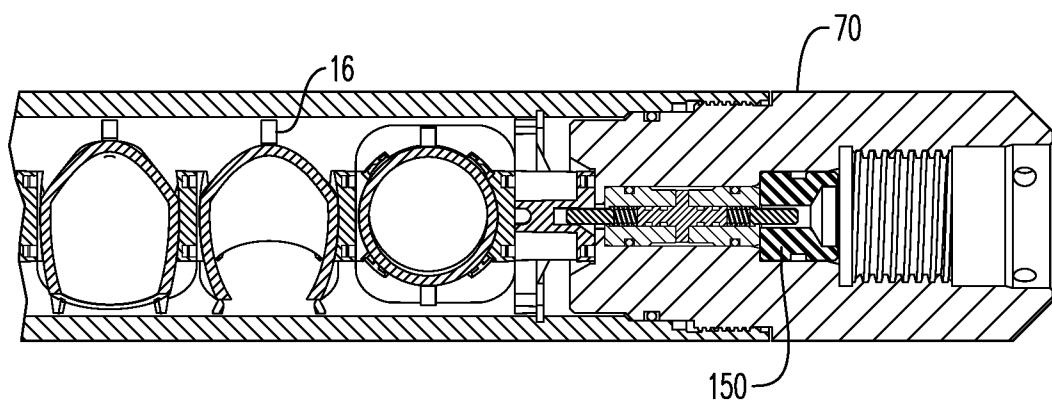
15/18

FIG. 29**FIG. 30**

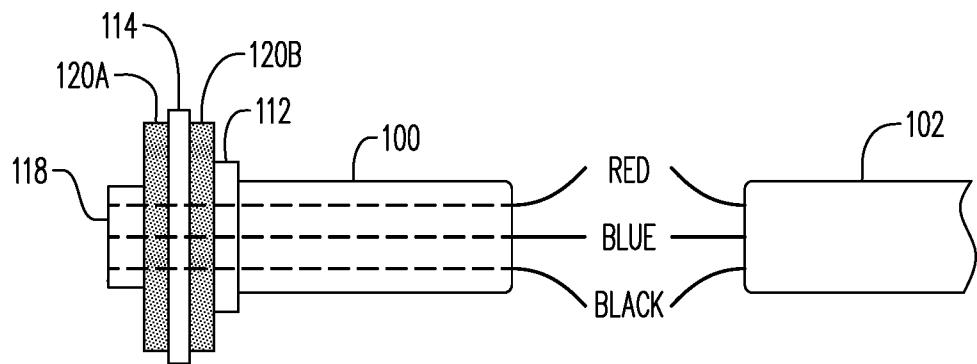
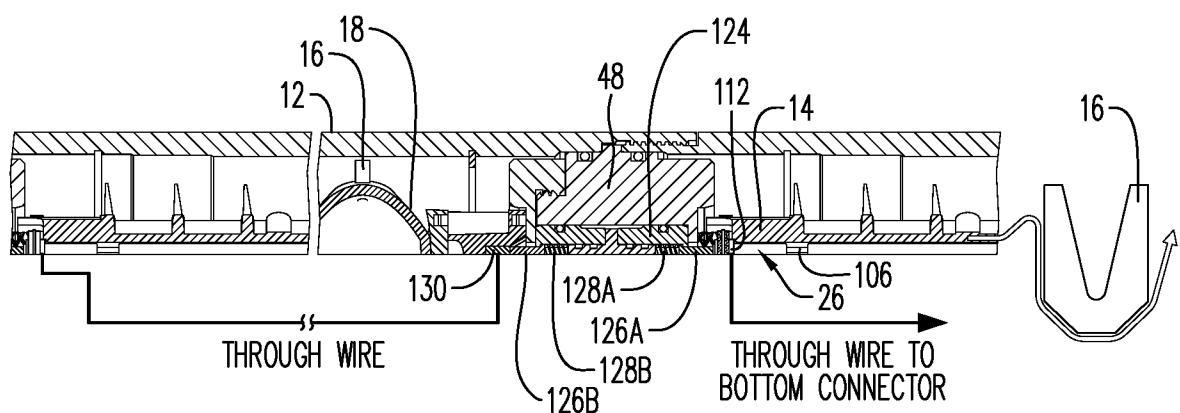
16/18

**FIG. 31****FIG. 32**

17/18

**FIG. 33****FIG. 34**

18/18

**FIG. 35A****FIG. 35B**