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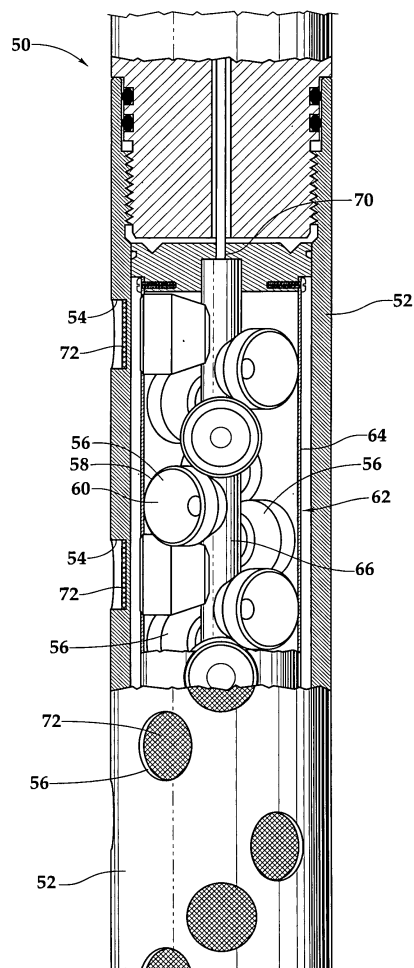
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(54) **Perforating apparatus for enhanced performance in high pressure wellbores**

(57) A perforating apparatus (50) includes a carrier gun body (52) having a plurality of radially reduced sections (54). The radially reduced sections (54) have a nanocomposite outer layer (72). A charge holder (62) is positioned within the carrier gun body (52). A plurality of shaped charges (56) are supported by the charge holder (62). The shaped charges (56) each have an initiation end and a discharge end. The discharge ends of the shaped charges (56) are disposed proximate the radially reduced sections (54) of the carrier gun body (52) such that the jets formed upon detonation of the shaped charges (56) travel through the radially reduced sections (54). The nanocomposite outer layers (72) of the radially reduced sections (54) enable enhanced performance of the perforating apparatus (50) in high pressure and high temperature wellbores.

FIG.2



Description

[0001] This invention relates, in general, to an apparatus for perforating subterranean wellbores using shaped charges and, in particular, to a perforating apparatus for enhanced performance in high pressure and high temperature wellbores.

[0002] Without limiting the scope of the present invention, its background will be described with reference to perforating a hydrocarbon bearing subterranean formation with a shaped charge perforating apparatus, as an example.

[0003] After drilling the section of a subterranean wellbore that traverses a hydrocarbon bearing subterranean formation, individual lengths of metal tubulars are typically secured together to form a casing string that is positioned within the wellbore. This casing string increases the integrity of the wellbore and provides a path through which fluids from the formation may be produced to the surface. Conventionally, the casing string is cemented within the wellbore. To produce fluids into the casing string, hydraulic openings or perforations must be made through the casing string, the cement and a distance into the formation.

[0004] Typically, these perforations are created by detonating a series of shaped charges located within one or more perforating guns that are deployed within the casing string to a position adjacent to the desired formation. Conventionally, the perforating guns are formed from a closed, fluid-tight hollow carrier gun body adapted to be lowered on a wire line or tubing conveyed into the wellbore. Disposed within the hollow carrier gun body is a charge holder that supports and positions the shaped charges in a selected spatial distribution. The shaped charges have conically constrained explosive material therein. A detonating cord that is used to detonate the shaped charges is positioned adjacent to the rear of the shaped charges. The detonating cord can be activated electronically or mechanically when the perforating gun has been positioned in the wellbore.

[0005] In such closed, fluid-tight type gun bodies, the explosive jets produced upon detonation of the shaped charges penetrate the hollow carrier gun body before penetrating the casing wall of the wellbore and the adjacent formation. To reduce the resistance produced by the hollow carrier gun body and increase the depth of perforation penetration into the formation, the perforating gun body may be provided with scallops or other radially reduced sections such as bands that leave relatively thin wall portions through which the explosive jets pass. The scallops in the hollow carrier gun body must be positioned in a spatial distribution that corresponds to the spatial distribution of the shaped charges held within the gun body by the charge holder.

[0006] It has been found, however, that the reduction in thickness of the carrier gun body at and near the scallops, limits the strength of the perforating guns. Thus, to perforate in certain high pressure and high temperature

wellbores, perforating guns of a given outer diameter must have increased wall thickness and/or reduced scallop depth. In either case, the performance of such perforating guns is diminished. Specifically, use of a carrier gun body with increased wall thickness reduces the available volume within the carrier gun body which necessitates the use of smaller shaped charges. Likewise, use of a carrier gun body with reduced scallop depth limits the penetration depth of the perforations into the formation.

[0007] A need has therefore arisen for a perforating apparatus that is operable for use in high pressure and high temperature wellbores that does not require a carrier gun body with increased wall thickness. A need has also arisen for such a perforating apparatus that is operable for use in high pressure and high temperature wellbores that does not require a carrier gun body with reduced scallop depth. Further, a need has arisen for such a perforating apparatus that is operable to achieve enhanced perforating performance in high pressure and high temperature wellbores.

[0008] The present invention disclosed herein comprises a perforating apparatus for enhancing perforating performance in high pressure and high temperature wellbores. The perforating apparatus of the present invention is operable for use in high pressure and high temperature wellbores without requiring a carrier gun body with increased wall thickness. In addition, the perforating apparatus of the present invention is operable for use in high pressure and high temperature wellbores without requiring a carrier gun body with reduced scallop depth.

[0009] In one aspect, the present invention is directed to a perforating apparatus for high pressure and high temperature applications. The perforating apparatus includes a carrier gun body having a plurality of radially reduced sections that have a nanocomposite outer layer. A charge holder is positioned within the carrier gun body. A plurality of shaped charges are supported by the charge holder. The shaped charges each have an initiation end and a discharge end and are positioned such that the discharge ends are disposed proximate the radially reduced sections of the carrier gun body.

[0010] In one embodiment, the radially reduced sections of the carrier gun body are recesses. In another embodiment, the radially reduced sections of the carrier gun body are bands. In certain embodiments, the use of a nanocomposite outer layer is not limited to the radially reduced sections of the carrier gun body. For example, a portion of the carrier gun body proximate the radially reduced sections may have a nanocomposite outer layer. Likewise, the entire carrier gun body may have a nanocomposite outer layer. Alternatively or additionally, the carrier gun body may have a nanocomposite inner layer or may be formed entirely from a nanocomposite material.

[0011] In one embodiment, the nanocomposite material that forms all or part of the carrier gun body may be a nanostructured alloy such as a nanostructured iron

based alloy. In this embodiment, the iron based alloy may be derived from metallic glass. Also, in this embodiment, the alloying constituents of the iron based alloy may be selected from the group consisting of boron, carbon, chromium, iron, manganese, molybdenum, nickel, niobium, silicon, tungsten and vanadium.

[0012] In one embodiment, the nanocomposite layers may be applied to the carrier gun body by a thermal spraying process. In another embodiment, the nanocomposite layers may be applied to the carrier gun body by a welding process. The nanocomposite layers may be so applied (i.e. by thermal spraying or welding) to the radially reduced sections. In additional embodiments, the nanocomposite layers may be integral with the carrier gun body material.

[0013] In another aspect, the present invention is directed to a perforating apparatus for high pressure and high temperature applications. The perforating apparatus includes a carrier gun body having an outer surface that is at least partially formed from a nanocomposite material. A charge holder is positioned within the carrier and a plurality of shaped charges are supported by the charge holder.

[0014] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0015] Figure 1 is a schematic illustration of an offshore oil and gas platform operating a perforating apparatus according to an embodiment of the present invention;

[0016] Figure 2 is partial cut away view of a perforating apparatus according to an embodiment of the present invention;

[0017] Figure 3 is partial cut away view of a perforating apparatus according to an embodiment of the present invention;

[0018] Figure 4 is a cross sectional view of a carrier gun body of a perforating apparatus according to an embodiment of the present invention;

[0019] Figure 5 is a cross sectional view of a carrier gun body of a perforating apparatus according to an embodiment of the present invention;

[0020] Figure 6 is a cross sectional view of a carrier gun body of a perforating apparatus according to an embodiment of the present invention;

[0021] Figure 7 is a cross sectional view of a carrier gun body of a perforating apparatus according to an embodiment of the present invention;

[0022] Figure 8 is a cross sectional view of a carrier gun body of a perforating apparatus according to an embodiment of the present invention; and

[0023] Figure 9 is a cross sectional view of a carrier gun body of a perforating apparatus according to an embodiment of the present invention.

[0024] While the making and using of various embodiments of the present invention are discussed in detail

below, it should be appreciated that the present invention provides many applicable inventive concepts which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention, and do not delimit the scope of the present invention.

[0025] Referring initially to Figure 1, a perforating apparatus of the present invention is operating from an offshore oil and gas platform is schematically illustrated and generally designated 10. A semi-submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. A subsea conduit 18 extends from deck 20 of platform 12 to wellhead installation 22 including blowout preventers 24. Platform 12 has a hoisting apparatus 26 and a derrick 28 for raising and lowering pipe strings such as work string 30.

[0026] A wellbore 32 extends through the various earth strata including formation 14. A casing 34 is cemented within wellbore 32 by cement 36. Work string 30 includes various tools including shaped charge perforating apparatus 38 that is operable to enhance perforating performance in high pressure and high temperature wellbores. When it is desired to perforate formation 14, work string 30 is lowered through casing 34 until shaped charge perforating apparatus 38 is positioned adjacent to formation 14. Thereafter, shaped charge perforating apparatus 38 is fired by detonating the shaped charges that are disposed within carrier gun body 40 and aligned with recesses 42 formed in the outer surface of carrier gun body 40. In the present invention, at least the outer surface of each recess 42 includes a nanocomposite layer that increases the strength of carrier gun body 40 at the location of each recess 42. Use of the nanocomposite outer layer allows carrier gun body 40 to have a relatively thin wall at the location of each recess 42, thereby enhancing perforating performance in high pressure and high temperature wellbores. As such, upon detonation, the liners of the shaped charges form jets that pass through recesses 42 and form a spaced series of perforations extending outwardly through casing 34, cement 36 and a desired depth into formation 14.

[0027] Even though figure 1 depicts a vertical well, it should be understood by those skilled in the art that the shaped charge perforating apparatus of the present invention is equally well-suited for use in wells having other configurations including deviated wells, inclined wells, horizontal wells, multilateral wells and the like. Accordingly, use of directional terms such as "above", "below", "upper", "lower" and the like are used for convenience in referring to the illustrations. Also, even though figure 1 depicts an offshore operation, it should be understood by those skilled in the art that the shaped charge perforating apparatus of the present invention is equally well-suited for use in onshore operations.

[0028] Referring now to figure 2, therein is depicted a shaped charge perforating apparatus of the present invention that is generally designated 50. Perforating apparatus 50 includes a carrier gun body 52 made of a

cylindrical sleeve having a plurality of radially reduced areas depicted as scallops or recesses 54. Radially aligned with each of the recesses 54 is a respective one of a plurality of shaped charges 56. Each of the shaped charges 56 includes an outer housing, such as housing 58, and a liner, such as liner 60. Disposed between each housing and liner is a quantity of high explosive.

[0029] The shaped charges 56 are retained within carrier gun body 52 by a charge holder 62 which includes an outer charge holder sleeve 64, an inner charge holder sleeve 66. In this configuration, outer tube 64 supports the discharge ends of shaped charges 56, while inner tube 66 supports the initiation ends of shaped charges 56. Disposed within inner tube 66 is a detonator cord 70, such as a Primacord, which is used to detonate shaped charges 56. In the illustrated embodiment, the initiation ends of shaped charges 56 extend across the central longitudinal axis of perforating apparatus 50 allowing detonator cord 70 to connect to the high explosive within shaped charges 56 through an aperture defined at the apex of the housings of shaped charges 56.

[0030] Each of the shaped charges 56 is longitudinally and radially aligned with one of the recesses 54 in carrier gun body 52 when perforating apparatus 50 is fully assembled. In the illustrated embodiment, shaped charges 56 are arranged in a spiral pattern such that each shaped charge 56 is disposed on its own level or height and is to be individually detonated so that only one shaped charge is fired at a time. It should be understood by those skilled in the art, however, that alternate arrangements of shaped charges may be used, including cluster type designs wherein more than one shaped charge is at the same level and is detonated at the same time, without departing from the principles of the present invention. As discussed below, each of the recesses 54 of perforating apparatus 50 has a nanocomposite outer layer 72 that increases the strength of carrier gun body 52, thereby enabling perforating apparatus 50 to be operable in high pressure and high temperature wellbores.

[0031] Referring now to figure 3, therein is depicted a shaped charge perforating apparatus of the present invention that is generally designated 100. Perforating apparatus 100 includes a plurality of shaped charges 102 of which three are pictured. Shaped charges 102 are mounted within a charge holder 104 that is positioned within a carrier gun body 106. In the illustrated embodiment, charge holder 104 may include one or more longitudinal sections, each of which are rotatably supported in carrier gun body 106 by a pair of supports 108, only one such support 108 being visible in figure 2. Each of the supports 108 includes rolling elements or bearings 110 contacting the interior of carrier gun body 106. In addition, optional thrust bearings 112 may be positioned between supports 108 at each end of carrier gun body 106 and devices 114 attached at each end of carrier gun body 106. Devices 114 may be tandems used to couple two guns to each other, a bull plug used to terminate a gun string, a firing head or any other type of device which

may be attached to a carrier gun body 106 in a gun string. In this configuration, charges 102 are permitted to rotate within carrier gun body 106.

[0032] In the illustrated embodiment, gravity is used to rotate charges 102 within carrier gun body 106 to the desired orientation. Specifically, by laterally offsetting the center of gravity of a rotating assembly 118 that includes charge holder 104, shaped charges 102 and weights 120, assembly 118 is biased by gravity to rotate to a specific position in which the center of gravity is located directly below the rotational axis.

[0033] Carrier gun body 106 is provided with radially reduced portions depicted as bands 122. Bands 122 extend circumferentially about carrier gun body 106 outwardly overlying each of the charges 102. Thus, as each of the shaped charges 102 rotates within carrier gun body 106, they remain directed to shoot through one of the bands 122. As with recesses 54 of perforating apparatus 50 discussed above, bands 122 have a nanocomposite outer layer 124 that increases the strength of carrier gun body 106, thereby enabling perforating apparatus 100 to be operable in high pressure and high temperature wellbores.

[0034] Referring now to figure 4, therein is depicted, in cross section, a portion of a carrier gun body of a perforating apparatus of the present invention that is generally designated 150. Carrier gun body 150 includes a plurality of radially reduced areas 152 which may represent scallops, recesses or bands such as those discussed above or other configurations in which the wall of carrier gun body 150 has certain thin wall portions. Each radially reduced area 152 has a nanocomposite outer layer 154 that increases the strength of carrier gun body 150, thereby enabling a perforating apparatus including carrier gun body 150 to be operable in high pressure and high temperature wellbores.

[0035] Nanocomposite outer layers 154 have a strength that is greater than the strength of the metal forming the remainder of carrier gun body 150. For example, the carrier gun body 150 may be formed from conventional steel while nanocomposite outer layers 154 are formed from a nanostructured material having nano-sized features such as nanograined iron alloys including nanograined steels. As used herein, a nanostructured material will include materials having features from 1 to 500 nanometers and more preferably materials having features from 1 to 100 nanometers.

[0036] Nanocomposite outer layers 154 may be formed from an iron based alloy having alloying constituents selected from the group consisting of boron, carbon, chromium, iron, manganese, molybdenum, nickel, niobium, silicon, tungsten and vanadium. In one example, the weight percents of the alloying constituents are between about 0% and 4% boron, between about 0.1% and 8% carbon, between about 0.5% and 21% chromium, between about 55% and 95% iron, between about 0% and 3% manganese, between about 0.5% and 8% molybdenum, between about 0% and 5% nickel, between

about 0% and 4% niobium, between about 0% and 2% silicon, between about 0% and 7% tungsten and between about 0% and 4% vanadium.

[0037] The material of nanocomposite outer layers 154 may be formed using a self-assembling phenomenon in solid state transformations involving decomposition of single phase supersaturated solid solutions into multiphase nanoscale microstructures. The self-assembled solid state nanostructures can be prepared using a variety of techniques including spinodal decomposition, eutectoid transformations, glass devitrification and the like. Alternatively, the material of nanocomposite outer layers 154 may be formed by using mechanical alloying of powdered metals. Preferably, the material of nanocomposite outer layers 154 is formed using a glass devitrification process wherein the alloying constituents of the iron based system are heat treated in a metallic glass state then devitrified into a material having the desired multiphase nanoscale grain structure.

[0038] Nanocomposite outer layers 154 may be applied to or formed on carrier gun body 150 using a variety of processing techniques including thermal spraying processes, welding processes or other suitable techniques or may be integrally formed with carrier gun body 150. For example, nanocomposite outer layers 154 may be applied to the carrier gun body 150 using a high velocity oxy fuel (HVOF) thermal spraying process that utilizes a combination of oxygen and one or more combustion gases such as hydrogen, propane, propylene, kerosene and the like to spray on the nanocomposite layer. Likewise, a twin wire arc spraying (TWAS) process may be used wherein two electrically opposed charged metal wires are fed together to produce a controlled arc at their intersection to form a molten metal which is atomized and propelled onto the carrier gun body 150 by jets of compressed air or gas to form the nanocomposite layer.

[0039] Alternatively, nanocomposite outer layers 154 may be applied to or formed on carrier gun body 150 using a variety of welding processes. For example, a plasma transfer arc welding (PTAW) process utilizes plasma to melt feedstock powder and form a fully dense and metallurgically bonded weld layer of the nanocomposite material on the carrier gun body 150. Likewise, a gas metal arc welding (GMAW) process utilizes a continuous consumable wire electrode and a shielding gas which are fed through a welding torch such that an electric arc is transferred between the wire electrode and the surface of the carrier gun body 150 and melts the wire to form the nanocomposite layer. Similarly, an open arc welding (OAW) process utilizes a continuous consumable wire electrode that is fed through a welding torch while an electric arc transferred between the wire electrode and the carrier gun body 150 melts the wire to form the nanocomposite layer.

[0040] Use of nanocomposite outer layers 154 in the radially reduced areas 152 of carrier gun body 150 enables enhanced perforating performance in high pressure and high temperature wellbores by increasing the

strength of carrier gun body 150 at the radially reduced areas 152. In addition, nanocomposite outer layers 154 increase the survivability of carrier gun body 150 following the perforation event by minimizing swelling, cracking, catastrophic rupturing or splitting of carrier gun body 150.

[0041] Referring now to figure 5, therein is depicted, in cross section, a portion of a carrier gun body of a perforating apparatus of the present invention that is generally designated 160. Carrier gun body 160 includes a plurality of radially reduced areas 162 which may represent scallops, recesses or bands such as those discussed above or other configurations in which the wall of carrier gun body 160 has certain thin wall portions. Each radially reduced area 162 as well as the area proximate each radially reduced area 162 has a nanocomposite outer layer 164 that increases the strength of carrier gun body 160, thereby enabling a perforating apparatus including carrier gun body 160 to be operable in high pressure and high temperature wellbores.

[0042] As with nanocomposite outer layers 154 discussed above, nanocomposite outer layers 164 have a strength that is greater than the strength of the metal forming the remainder of carrier gun body 160 and may be formed from a nanostructured material having nano-sized features such as the nanograined iron alloys discussed above. Nanocomposite outer layers 164 may be applied to or formed on carrier gun body 160 using a variety of processes such as those discussed above including thermal spraying and welding processes or may be integrally formed with carrier gun body 160.

[0043] Use of nanocomposite outer layers 164 in and around radially reduced areas 162 of carrier gun body 160 enables enhanced perforating performance in high pressure and high temperature wellbores by increasing the strength of carrier gun body 160. In addition, nanocomposite outer layers 164 increase the survivability of carrier gun body 160 following the perforation event by minimizing swelling, cracking, catastrophic rupturing or splitting of carrier gun body 160.

[0044] Referring now to figure 6, therein is depicted, in cross section, a portion of a carrier gun body of a perforating apparatus of the present invention that is generally designated 170. Carrier gun body 170 includes a plurality of radially reduced areas 172 which may represent scallops, recesses or bands such as those discussed above or other configurations in which the wall of carrier gun body 170 has certain thin wall portions. The outer surface of carrier gun body 170 has a nanocomposite outer layer 174 that increases the strength of carrier gun body 170, thereby enabling a perforating apparatus including carrier gun body 170 to be operable in high pressure and high temperature wellbores.

[0045] As with nanocomposite outer layers 154, 164 discussed above, nanocomposite outer layer 174 has a strength that is greater than the strength of the metal forming the remainder of carrier gun body 170 and may be formed from a nanostructured material having nano-

sized features such as the nanograined iron alloys discussed above. Nanocomposite outer layer 174 may be applied to or formed on carrier gun body 170 using a variety of processes such as those discussed above including thermal spraying and welding processes or may be integrally formed with carrier gun body 170.

[0046] Use of nanocomposite outer layer 174 of carrier gun body 170 enables enhanced perforating performance in high pressure and high temperature wellbores by increasing the strength of carrier gun body 170. In addition, nanocomposite outer layer 174 increases the survivability of carrier gun body 170 following the perforation event by minimizing swelling, cracking, catastrophic rupturing or splitting of carrier gun body 170.

[0047] Referring now to figure 7, therein is depicted, in cross section, a portion of a carrier gun body of a perforating apparatus of the present invention that is generally designated 180. Carrier gun body 180 includes a plurality of radially reduced areas 182 which may represent scallops, recesses or bands such as those discussed above or other configurations in which the wall of carrier gun body 180 has certain thin wall portions. The inner surface of carrier gun body 180 has a nanocomposite layer 184 that increases the strength of carrier gun body 180, thereby enabling a perforating apparatus including carrier gun body 180 to be operable in high pressure and high temperature wellbores.

[0048] As with nanocomposite outer layers 154, 164, 174 discussed above, nanocomposite inner layer 184 has a strength that is greater than the strength of the metal forming the remainder of carrier gun body 180 and may be formed from a nanostructured material having nanosized features such as the nanograined iron alloys discussed above. Nanocomposite inner layer 184 may be applied to or formed on carrier gun body 180 using a variety of processes such as those discussed above including thermal spraying and welding processes or may be integrally formed with carrier gun body 180.

[0049] Use of nanocomposite inner layer 184 of carrier gun body 180 enables enhanced perforating performance in high pressure and high temperature wellbores by increasing the strength of carrier gun body 180. In addition, nanocomposite inner layer 184 increases the survivability of carrier gun body 180 following the perforation event by minimizing swelling, cracking, catastrophic rupturing or splitting of carrier gun body 180.

[0050] Referring now to figure 8, therein is depicted, in cross section, a portion of a carrier gun body of a perforating apparatus of the present invention that is generally designated 190. Carrier gun body 190 includes a plurality of radially reduced areas 192 which may represent scallops, recesses or bands such as those discussed above or other configurations in which the wall of carrier gun body 190 has certain thin wall portions. Each radially reduced area 192 has a nanocomposite outer layer 194 and the inner surface of carrier gun body 190 has a nanocomposite layer 196 that increase the strength of carrier gun body 190, thereby enabling a per-

forating apparatus including carrier gun body 190 to be operable in high pressure and high temperature wellbores.

[0051] As with the nanocomposite outer layers discussed above, nanocomposite layers 194, 196 have a strength that is greater than the strength of the metal forming the remainder of carrier gun body 190 and may be formed from a nanostructured material having nanosized features such as the nanograined iron alloys discussed above. Nanocomposite layers 194, 196 may be applied to or formed on carrier gun body 190 using a variety of processes such as those discussed above including thermal spraying and welding processes or may be integrally formed with carrier gun body 190.

[0052] Use of nanocomposite layers 194, 196 of carrier gun body 190 enables enhanced perforating performance in high pressure and high temperature wellbores by increasing the strength of carrier gun body 190. In addition, nanocomposite layers 194, 196 increase the survivability of carrier gun body 190 following the perforation event by minimizing swelling, cracking, catastrophic rupturing or splitting of carrier gun body 190.

[0053] Referring now to figure 9, therein is depicted, in cross section, a portion of a carrier gun body of a perforating apparatus of the present invention that is generally designated 200. Carrier gun body 200 is formed from a nanocomposite material 202 that has a strength greater than a similarly dimensioned carrier gun body formed from conventional materials, thereby enabling a perforating apparatus including carrier gun body 200 to be operable in high pressure and high temperature wellbores. As with the nanocomposite layers discussed above, nanocomposite material 202 may be formed from a nanostructured material having nanosized features such as the nanograined iron alloys discussed above. In addition to enhancing perforating performance, carrier gun body 200 formed from nanocomposite material 202 increases the survivability of carrier gun body 200 following the perforation event by minimizing swelling, cracking, catastrophic rupturing or splitting of carrier gun body 200.

[0054] While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

Claims

1. A perforating apparatus comprising:

a carrier gun body having a plurality of radially reduced sections, the radially reduced sections

- having a nanocomposite outer layer;
 a charge holder positioned within the carrier gun body; and
 a plurality of shaped charges supported by the charge holder, the shaped charges each having an initiation end and a discharge end, the discharge ends being disposed proximate the radially reduced sections of the carrier gun body. 5
2. A perforating apparatus as claimed in claim 1, wherein the radially reduced sections further comprise recesses or bands. 10
3. A perforating apparatus as claimed in claim 1 or 2, wherein at least a portion of the carrier gun body proximate the radially reduced sections further comprises a nanocomposite outer layer. 15
4. A perforating apparatus as claimed in any of the preceding claims, wherein the carrier gun body further comprises a nanocomposite outer layer. 20
5. A perforating apparatus as claimed in any of the preceding claims, wherein the carrier gun body further comprises a nanocomposite inner layer. 25
6. A perforating apparatus comprising:
- a carrier gun body having a surface, the surface at least partially formed from a nanocomposite material; 30
 a charge holder positioned within the carrier; and
 a plurality of shaped charges supported by the charge holder. 35
7. A perforating apparatus as claimed in claim 6, wherein the carrier gun body has a plurality of radially reduced sections and wherein the nanocomposite material forms an outer surface of the radially reduced sections of the carrier gun body. 40
8. A perforating apparatus as claimed in claim 6 or 7, wherein the nanocomposite material forms an outer surface of at least a portion of the carrier gun body proximate the radially reduced sections. 45
9. A perforating apparatus as claimed in any of claims 6 to 8, wherein the surface of the carrier gun body further comprises an outer surface and/or an inner surface. 50
10. A perforating apparatus as claimed in any of claims 6 to 9, wherein the carrier gun body is entirely formed from nanocomposite material. 55
11. A perforating apparatus as claimed in any of the preceding claims, wherein the nanocomposite material further comprises a nanostructured alloy.
12. A perforating apparatus as claimed in any of claims 1 to 11, wherein the nanocomposite material further comprises an iron based alloy, and preferably wherein the iron based alloy is derived from a metallic glass, and/or preferably wherein alloying constituents of the iron based alloy are selected from the group consisting of boron, carbon, chromium, iron, manganese, molybdenum, nickel, niobium, silicon, tungsten and vanadium.
13. A perforating apparatus as claimed in any of the preceding claims, wherein the nanocomposite is applied to the carrier gun body by a thermal spraying process.
14. A perforating apparatus as claimed in any of claims 1 to 12, wherein the nanocomposite is applied to the carrier gun body by a welding process.
15. A perforating apparatus as claimed in any of claims 1 to 12, wherein the nanocomposite is integral with the carrier gun body material.

FIG. 1

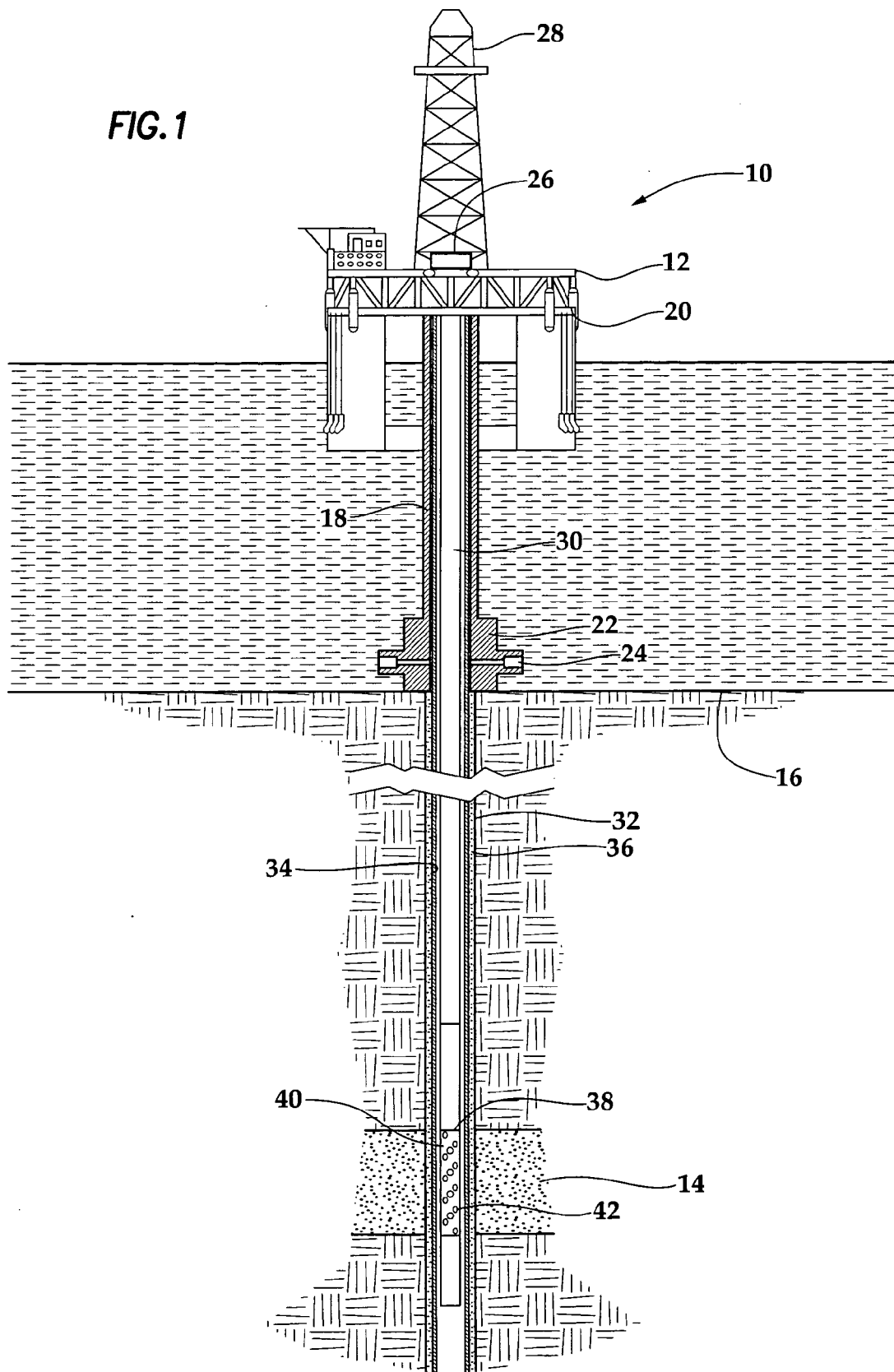


FIG.2

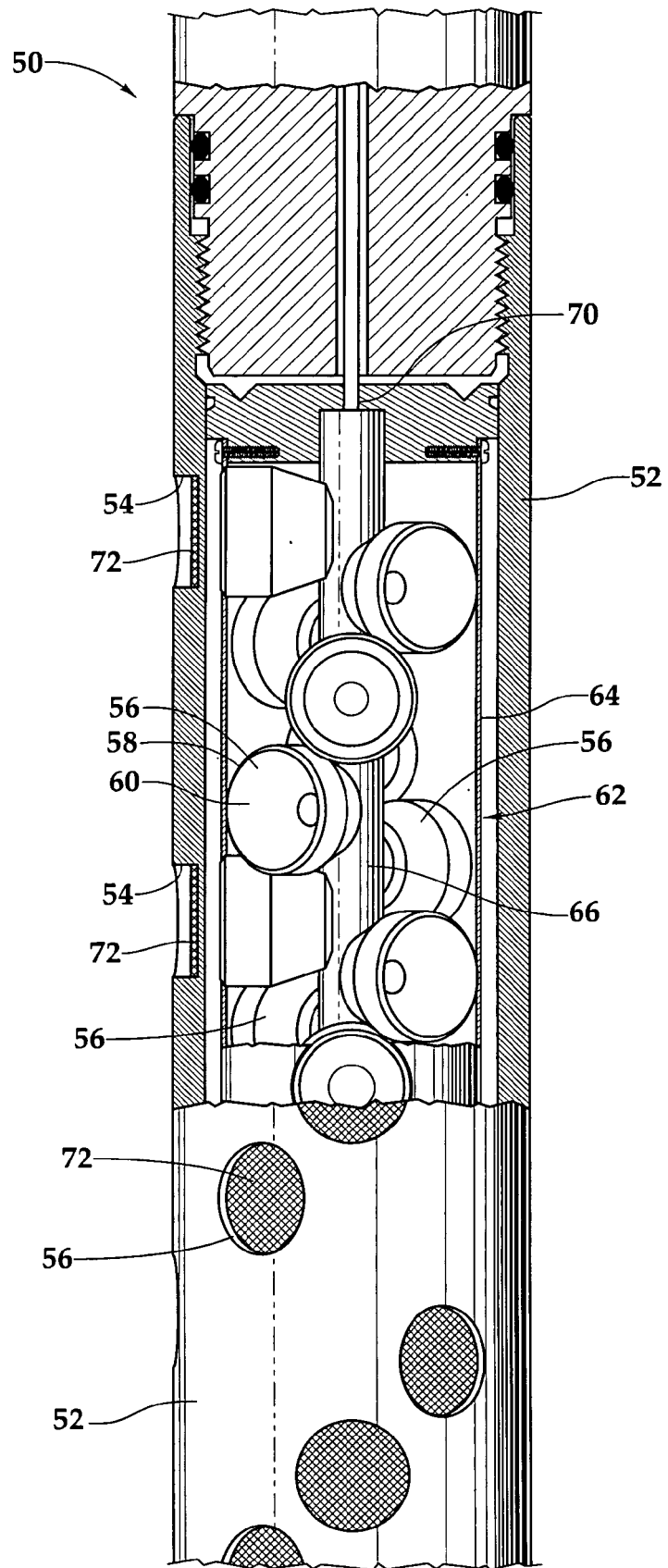
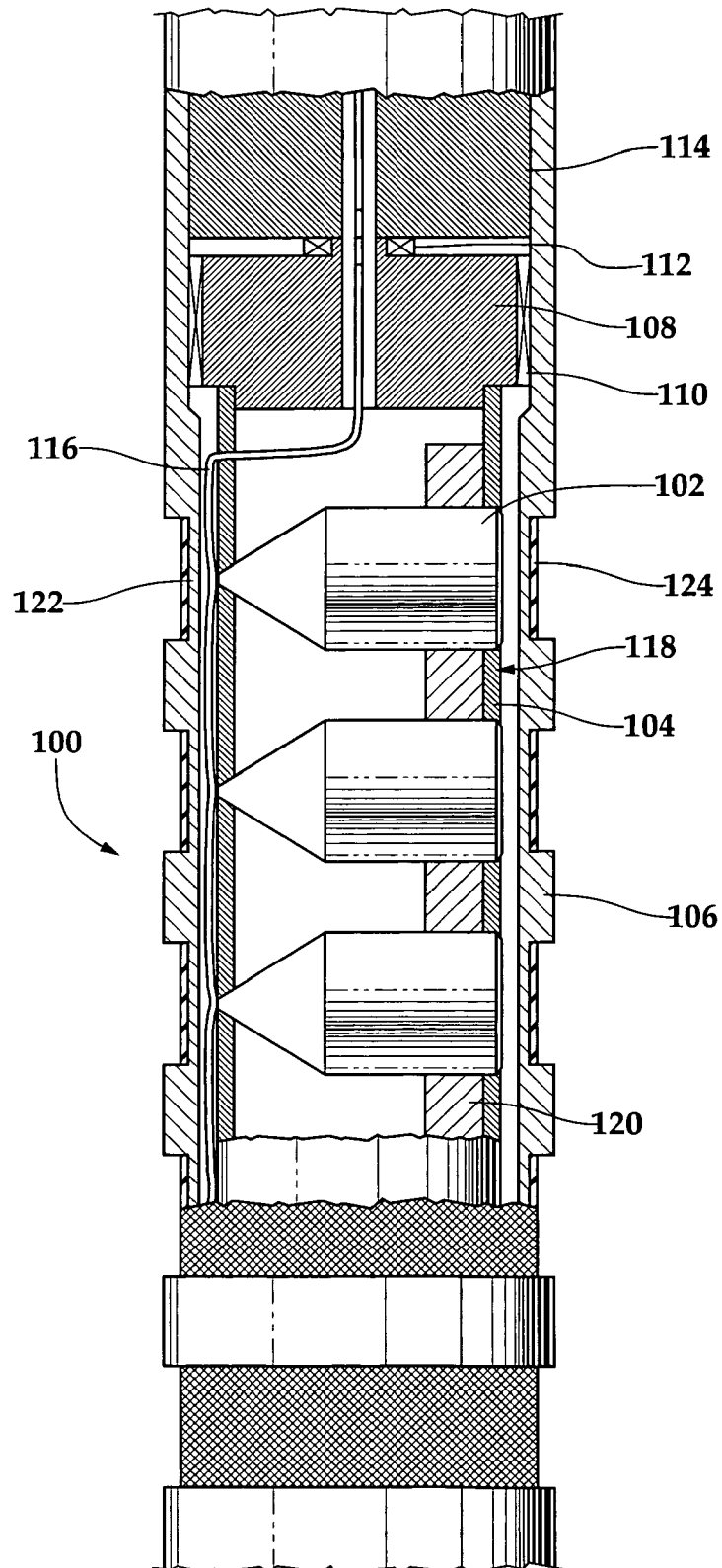


FIG.3



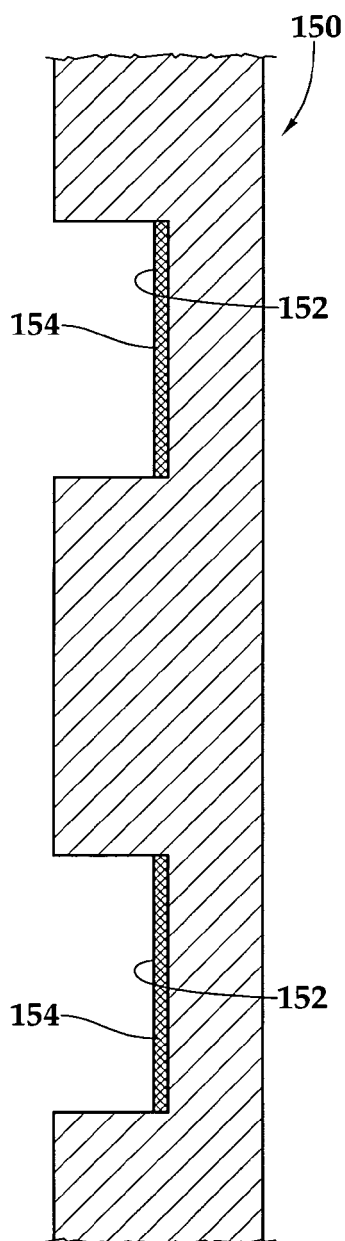


FIG. 4

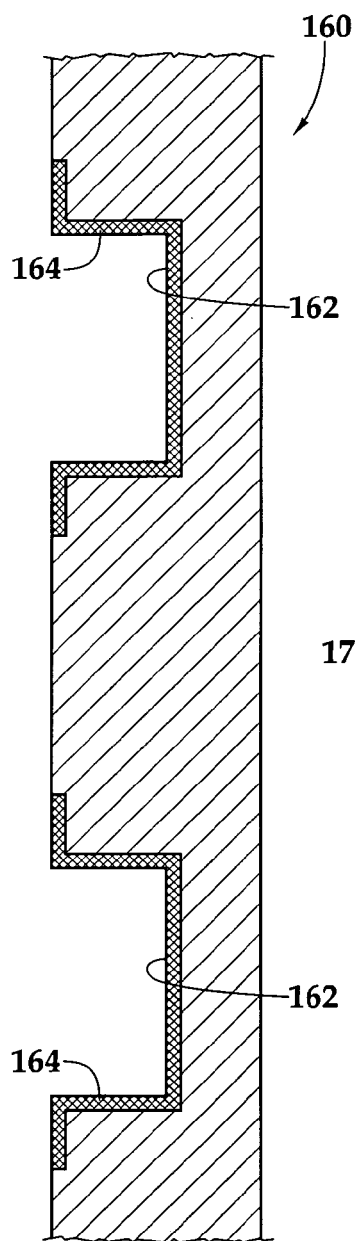


FIG. 5

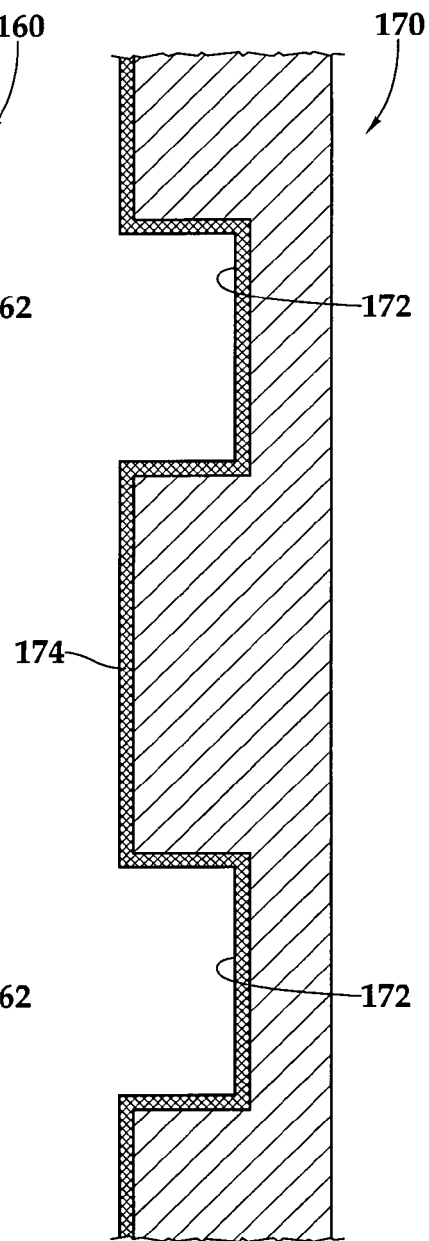


FIG. 6

