FLUID END WITH PROTECTED FLOW PASSAGES AND KIT FOR SAME

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ABSTRACT
This application describes systems for protecting steel fluid end body flow passages from direct impingement by high pressure fracking fluid. These fluid end body flow passages are protected by components in the form of cartridges and sleeves. This disclosure also describes kits and methods which utilize these systems to provide enhanced erosion and corrosion resistance as well as improved fatigue properties and extended service life to these fluid ends.
FLUID END WITH PROTECTED FLOW PASSAGES AND KIT FOR SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from U.S. Provisional Patent Application Ser. No. 61/800,852, filed Mar. 15, 2013, the disclosure of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention generally relates to hydraulic fracturing pump systems and, more particularly, to the fluid ends of multiplex reciprocating fracturing pumps.


[0004] Multiplex reciprocating pumps are generally used to pump high pressure fracturing fluids into wells for recovery of oil and gas trapped in shale formations and the like. Typically, these pumps have two sections, a power end which is coupled to a diesel engine and transmission that drives the pump and plungers in the fluid ends in which a mix of water, sand and chemicals are pressurized up to 15,000 psi or more.

[0005] These multiplex reciprocating pumps are commonly in the form of triplex pumps having three fluid cylinders and quintuplex pumps that have five cylinders. It will be appreciated, however, that the present disclosure has application to pumps which can utilize the features thereof in forms other than the triplex and quintuplex pumps. The fluid ends of these pumps typically comprise a single block having cylinders bored therein and are commonly referred to as monoblock fluid ends or an assembly of individual bodies with cylinders, referred to as modular fluid ends.

[0006] The pumping cycle of a fluid end is composed of two stages, a suction cycle during which a piston moves outward in a bore, thereby lowering the fluid pressure in the inlet to a fluid end and a discharge cycle during which the plunger moves forward in the plunger bore, thereby progressively increasing the fluid pressure to a predetermined level for discharge through a discharge pipe to a well site.

[0007] Fluid ends used in well site applications for oil and gas exploration have limited service life due to fatigue crack failures. These failures are a result of operating pressures, mechanical stresses, erosion and corrosion of the internal passages which have been addressed in prior art efforts with limited success.

[0008] 2. Discussion of the Prior Art

[0009] International Application No. PCT/IB2011/002771 (International Publication No. WO 2012 052842 A2 entitled “Fluid End Reinforced With Abrasive Resistant Insert, Coating or Linering”) describes the use of inserts in wear prone areas only and, as such, does not provide erosion, corrosion and fatigue crack protection throughout the entire flow passages in the fluid end.

[0010] U.S. Patent Publication 2008/0080994 A1, “Fluid End Reinforced With a Composite Material,” is directed to a fluid end of a reciprocating pump wherein carbon steel thin base material is formed into three tubes which are welded and then hydroformed to give a cross-like configuration. That structure is reinforced with a composite that provides some additional stress resistance and reduced weight, however, it does not utilize the inherent benefits of the originally designed high strength steel in the fluid block.

[0011] U.S. Pat. No. 3,786,729 is directed to a liner seal for the plunger bore and does not address the protection of high stress areas such as those associated with intersecting bores.

SUMMARY OF THE INVENTION

[0012] This disclosure is generally directed to a system for substantially protecting the portions of the fluid end body flow passages from impingement by high pressure fracturing fluid passing therethrough to provide enhanced erosion and corrosion resistance as well as improved fatigue properties and extended service life.

[0013] A first aspect of this disclosure is directed to a sleeve and cartridge components which cooperate to protect fluid end body portions surrounding the outer surface thereof from direct impingement thereon by high pressure fracturing fluid passing through said fluid end.

[0014] A second aspect of this disclosure is directed to a sleeve that is received in a plunger bore of a fluid end body which sleeve includes a pair of apertures that are connected to, and in flow communication with, the outlet of the suction bore and the inlet of the discharge bore.

[0015] In accordance with another aspect of the disclosure, a kit which includes one or two sleeves, a cartridge, and a plug is provided for installation in a conventional fluid end steel body which, when installed therein, cooperate to protect the fluid end body portions surrounding the outer surfaces thereof from impingement by high pressure fracturing fluid passing through said fluid end.

[0016] A further aspect of the present invention is directed to a method of installing one or more components in the flow passages of a fluid end body of a reciprocating pump used in the recovery of oil and gas for the purpose of extending the service life thereof and to minimize the effects of erosion, corrosion and fatigue, such components being configured and located within one or more bores in said fluid end body to protect the portions of said fluid body surrounding those components including portions associated with high stress areas such as the corners of intersecting bores.

[0017] It is to be understood that the foregoing general description and the following detailed description are exemplary and provided for purposes of explanation only and are not restrictive of the subject matter claimed. Further features and objects of the present disclosure will become apparent in the following description of the example embodiments and from the appended claims.

DESCRIPTION OF THE DRAWINGS

[0018] In describing the preferred embodiments, reference is made to the accompanying drawing figures or in like parts have like reference numerals and wherein:

[0019] FIG. 1 is a schematic illustration of a power end and fluid end of a reciprocating pump used in the recovery of oil and natural gas;

[0020] FIG. 2 is a perspective view of the block component of the fluid end shown in FIG. 1;

[0021] FIG. 3 is a side elevational view as seen from the mounting flange surface of the fluid end block shown in FIGS. 2 and 3;

[0022] FIG. 4 is a top plan view of the fluid end block shown in FIG. 2;

[0023] FIG. 5 is a sectional view of the fluid end block shown in FIG. 3 taken along the sectional line 5-5 of FIG. 3
which has been modified to accept the components of the first embodiment described herein, but prior to the installation of such components;

[0024] FIG. 6 is a perspective view of a sleeve component suitable for use in accordance with the first embodiment of the present disclosure;

[0025] FIG. 7 is an end view of the sleeve shown in FIG. 6;

[0026] FIG. 8 is a side elevational view of the sleeve shown in FIGS. 6 and 7;

[0027] FIG. 9 is a sectional view of the sleeve shown in FIGS. 6-8 taken along the section line 9-9 of FIG. 7;

[0028] FIG. 10 is a perspective view of a cartridge component suitable for use in the first embodiment of this disclosure;

[0029] FIG. 11 is a front elevational view of the cartridge shown in FIG. 10;

[0030] FIG. 12 is an end view of the cartridge component shown in FIGS. 10-11;

[0031] FIG. 13 is a side elevational view of the cartridge shown in FIGS. 10-12;

[0032] FIG. 14 is a sectional view of the cartridge shown in FIGS. 10-13 taken along the line 14-14 of FIG. 11;

[0033] FIG. 15 is a perspective view of an end plug suitable for use in the first embodiment of this disclosure;

[0034] FIG. 16 is a top plan view of the plug shown in FIG. 15;

[0035] FIG. 17 is a side elevational view of the plug shown in FIGS. 15 and 16;

[0036] FIG. 18 is a bottom plan view of the plug shown in FIGS. 15-17;

[0037] FIG. 19 is a sectional view of the plug shown in FIGS. 15-18 taken along the section line 19-19 of FIG. 16;

[0038] FIG. 20 is a schematic sectional view illustrating a procedure of installing the sleeve component shown in FIGS. 6-7 in a fluid end in accordance with the first embodiment of the present disclosure;

[0039] FIG. 21 is a schematic view illustrating a procedure for installing the cartridge of FIGS. 10-14 in a fluid end block in accordance with the first embodiment of the present disclosure;

[0040] FIG. 22 is a schematic view, partially in section, illustrating the assembly of the components of the first embodiment of the present disclosure;

[0041] FIG. 23 is an assembly drawing, partially in section, illustrating another embodiment of the present disclosure which utilizes a single sleeve component;

[0042] FIG. 24 is a perspective view of a sleeve which can be used in accordance with the embodiment of FIG. 23; and

[0043] FIG. 25 is a perspective view of a retainer nut suitable for use with the embodiment shown in FIG. 23.

**DETAILED DESCRIPTION OF THE INVENTION**

[0044] In accordance with an important aspect of the present disclosure, the subject invention is particularly suited for use in existing fluid end designs, however, it is not restricted to those designs and can be utilized in other high pressure pumping applications where operating pressures, mechanical stresses, erosion and corrosion of internal passages are a concern. For the purpose of illustration, however, it will be described in conjunction with a conventional tripleplex fluid end such as is generally shown in FIGS. 1-5.

[0045] Referring to FIG. 1, a tripleplex reciprocating pump system is generally designated by the reference numeral 10 and includes a power end 11, typically driven by a diesel engine and transmission, which is coupled to a pump body or fluid end 12 that is supplied with water and other ingredients for the fracturing fluid via an inlet 13. It is pressurized in the fluid end and discharged through a high pressure outlet 14 therein. Fluid end 12 includes a mounting surface 16 which can be used to directly secure the fluid end to the power end by plurality of bolts 17.

[0046] As best shown in FIGS. 2-5, the fluid end 12 includes a block 12a formed from a high strength steel forging, which is machined to provide a first or plunger bore 18, a second or suction bore 19, center chamber 20 for pressurization of the fracturing fluid and a third bore or high pressure discharge bore 21. Each of the high pressure discharge bores 21 shown in FIG. 5 feeds into a common internal high pressure discharge passage 22 which directly communicates with the high pressure discharge outlet 14.

[0047] The components of this first disclosed embodiment include a sleeve component, the details of which are shown in FIGS. 6-9, a cartridge component, the details of which are shown in FIGS. 10-14, a combination retainer/positioning plug, the details of which are shown in FIGS. 15-19 and the assembly of these components with conventional internal valves, seals, etc. are shown in FIG. 22.

[0048] In FIGS. 6-9, the cylindrical sleeve component of the first disclosed embodiment is designated by the reference numeral 25 and can be composed of stainless steel, Inconel® and Incoloy® and other metal and alloys exhibiting suitable corrosion and erosion resistance and strength. If desired, coatings and surface treatments may be applied to the surfaces of the sleeves to improve the corrosion and erosion characteristics thereof. As shown, sleeve component 25 includes a first sleeve portion 25a, a second sleeve portion 25b which are coupled to each other by integral interconnecting bridge portion 25c and 25d. The outer surfaces of the first and second sleeve portions 25a and 25b are configured to be respectively received in direct contact with a first portion of the first bore, the plunger bore, and a second portion of the first bore that can also be referred to as an access bore.

[0049] Sleeve 25 also includes a pair of flow passage apertures 26 and 27 defined by inner edges of bridge portions 25c and 25d which are configured to be in alignment with the second or suction bore 19 and third or high pressure discharge bore 21 when the sleeve is installed in a fluid cylinder of the fluid end 12.

[0050] If desired, first tubular sleeve portion 25a and second tubular sleeve portion 25b may be in the form of two separate sleeves (without the interconnecting bridge portions) which are respectively received in the first and second portions of the first bore, namely the plunger and access bores.

[0051] In FIGS. 10-14, the cylindrical cartridge component of the first disclosed embodiment is designated by the reference numeral 30. As shown, cartridge component includes a first portion 30a which is configured to be received in the second or suction bore 19, a pair of apertures 30b and 30c, an upper portion 23d are configured to be received in the third or high pressure discharge bore 30d and a bottom edge 30e that engages a removable plug which will be more fully described below. As with sleeve 25, the cartridge 30 can be composed of stainless steel, Inconel®, Incoloy® as well as other metals and alloys. Correspondingly, coatings and surface treatments may be applied to the surfaces of the cartridge to improve the corrosion and erosion characteristics thereof. Apertures 30b and 30c are positioned to be in alignment with the first and
second portions of the first bore and the center chamber 20 for accommodating the reciprocal movement of a plunger 31 (FIG. 23).

[0052] As will be described more fully later in conjunction with FIG. 22, the perimeter of each aperture 30a and 30b includes a full perimeter groove in which a gasket is received. These gaskets can be formed from a suitable material which can withstand the high pressures, chemicals and other conditions associated with machining operations and can include elastomers and synthetic fluorocarbon polymers which exhibit these properties.

[0053] In accordance with an important aspect of this disclosure, the sleeves and cartridges can be machined and/or surface treated prior to their assembly into the block. This feature provides greater flexibility in shaping the internal cylinder contours, resulting in improved performance and durability of the fluid end.

[0054] In some applications, it may be preferred to machine the mating fluid end bore surfaces and the outside surfaces of the sleeves and cartridge inserts to standard dimensions while machining the internal surfaces to address the required configurations. If desired, stress in the fluid end block may be reduced by increasing the thickness of the sleeve and cartridge cylinder to optimize the contours of the interfacing surfaces of the fluid end block. For example, by having a larger radius between intersecting bores of the block.

[0055] The plug component of this disclosed embodiment is separately shown in FIGS. 15-19 and designated by the reference numeral 32 which includes top end face having an annular rim 32a configured for direct contact with cartridge bottom edge 30(c) and a threaded annular sidewall 32b that is mattingly received in the threaded lower end of the second or suction bore 19 of fluid end 20. Plug 32 is sized to secure cartridge 30 in a fixed operating position in the second and third bores with the apertures 30b and 30c in alignment with the first or plunger bore 18. As shown, wrench-receiving recesses 33-36 can be provided in the bottom end face 32c of plug 32 to facilitate its installation and removal in and to the fluid end 12.

[0056] Installation of the sleeve 25 into the first or plunger bore can be made from either end. For example, in the sleeve installation step shown in FIG. 20 of the illustrated embodiment, since the diameters of first bore 18 and sleeve 25 are larger than the diameter of the open end of the bore opposite the mounting flange, access to the bore can be made through the mounting flange surface 16 (FIGS. 2-4). It will be appreciated, however, that if the relative dimensions of bore 18 and sleeve 25 are appropriate, access to the interior of the bore and insertion of the sleeve could be done by removal of the retainer nut 53 (FIG. 22) covering that open end.

[0057] The surface of the bore 18 and sleeve 25 are machined to provide a smooth surrounding surface and to an equally smooth outer surface of the sleeve. In order to insure intimate surface-to-surface direct contact between the bore and sleeve, the sleeve can, if desired, have a slightly larger outer diameter than the bore. A differential temperature between the two is created to provide the necessary clearance during insertion and an interference fit when the temperature of both are normalized.

[0058] As schematically depicted in FIG. 21, after the sleeve 25 is installed, the cartridge is also machined to have outer diameter which is again slightly larger than the machined diameters of the second and third bores. A differential temperature between the cartridge and these bores is then created to provide the assembly clearance during this insertion and, when allowed to normalize, to provide a tight, interference fit between the cartridge and the second and third bores.

[0059] FIG. 22 illustrates a fluid cylinder assembly 40 in which the sleeve, cartridge and plug components have been incorporated along with the internal working elements (e.g., plunger, suction valve, high pressure discharge valve, etc.). As shown, plunger 31 is received in the first bore 18 and reciprocates to effect pressurization in the chamber 20 to draw fracturing fluid therein, at low pressure from the second or suction bore 19 containing a suction valve 41 and associated intake mechanism 42. Correspondingly, the third high pressure discharge bore 21 receives pressurized fracturing fluid from chamber 20 and discharges the same into the internal high pressure passage 22 via discharge valve 43 and associated discharge mechanism 44.

[0060] Plunger packing assembly 49 and associated O ring seals in seal carriers 46 and 47 function to prevent or at least minimize passage of fracturing fluid to the fluid body portions which surround the sleeve 25 and cartridge 30 components. As shown in FIG. 22, corrosion resistant material strips and beads 48 composed of a titanium-reinforced epoxy putty such as Devcon® (ITW Devon, Danvers, Mass.) can be utilized to minimize or eliminate seepage of fracturing fluid into the portions of the fluid end body portions surrounding the sleeve 25 and cartridge 30.

[0061] As schematically depicted in FIG. 22, during operation, the regions designated by reference numeral 51 represent the highest stress location in the assembled sleeve and cartridge. Correspondingly, the region designated by the reference numeral 52 represents the highest stress location in the block which is lower than the stress at region 51. Since the sleeve and cartridge components by reason of their composition (e.g., high strength stainless steel, Inconel®, Incolon®, etc.) provide greater resistance to erosion and corrosion as well as mechanical stresses and fatigue than is provided by the forged steel block, it follows the greater service life results.

[0062] Correspondingly, because the stress at the 52 location is less than that at the 51 location it follows that the overall stress on the block is reduced.

[0063] As previously noted, each of apertures 30b and 30c in the cartridge 30 has a perimeter groove in which a gasket is received. Those gaskets provide an effective seal between the outer surface of the cartridge and the edges of apertures 26 and 27 of the sleeve 25 which withstand the high pressure of the fracturing fluid in the flow passages.

[0064] As shown, an access opening 18a at one end of bore 18 receives a removable retaining nut 53 to provide selective access to the interior of the first bore, when desired.

[0065] FIGS. 23-25 depict a further embodiment of the present invention where like parts have like reference numerals. This embodiment is designated by the reference numeral 60 and includes a modified block 61 formed from a high strength steel forging, a modified first plunger bore 62 and a modified sleeve 63, composed of high strength stainless steel, Inconel®, Incolon® and equivalent metals and alloys. It does not require a cartridge like the cartridge 30 of the first embodiment.

[0066] As shown in FIG. 23, the modified bore includes a first section 62a with an enlarged diameter and a second co-axially aligned reduced diameter section 62b. The sleeve 63 includes a first portion 63a which is sized to be tightly
received in the bore section 62a and a second portion 63b sized to be received in bore section 62b with an interference fit between surfaces of bore sections 62a and 62b and the corresponding cylindrical surface of sleeve portions 63a and 63b.

[0067] A seal carrier plate 64 has a lip 64a which contacts an outer end face of sleeve portion 63a. As shown, an annular shoulder 62c in the bore 62 between bore section 62a and 62b is in direct contact with an annular back face 63c. Lip 64a of seal carrier 64 and the shoulder 62c serve to maintain the sleeve 63 in a fixed position during tracking operations.

[0068] In accordance with an important feature of this disclosure, sleeve 63 has a pair of apertures 63c and 63d, each of which is defined by a full perimeter groove in which a gasket is received. As with cartridge 30 of the first embodiment, the gaskets are formed from a suitable material which can withstand the high pressures and chemical erosion associated with tracking operations and can include elastomers and synthetic fluorocarbon polymers that exhibit these properties which are known to those skilled in the art.

[0069] As shown in FIGS. 23 and 24, the sleeve apertures 63c and 63d can be located in the outer surface of bore 62b at locations designated by reference numeral 65 and 66 and provide an effective seal between the sleeve and fluid end body portions in contact therewith.

[0070] The reference numerals 67 and 68 identify high stress locations in the sleeve interior portions in the area adjacent the sleeve apertures 63c and 63d and pressurization chamber 20. As such, these areas are in locations wherein the resistance to erosion, corrosion, high stress and fatigue provided by high-strength stainless steel, Inconel®, Incoloy® and equivalents as contemplated by this disclosure is important.

[0071] As shown, an access opening 70 is enclosed by a removable retaining nut 69.

[0072] While the subject invention has been disclosed and described with illustrative examples, it will be appreciated that modifications and/or changes may be made to those examples by those skilled in the art without departing from the spirit and scope of this invention as defined by the appended claims.

1. In a fluid end of a reciprocating pump for delivery of fracturing fluid at high pressure into a well for recovery of oil and natural gas trapped in shale rock formations, said fluid end having at least one fluid cylinder assembly; a body having a first bore which includes a reciprocating plunger; a second bore which includes a suction valve; and a third bore which includes a discharge valve, said first bore being generally perpendicular to both said second and third bores which are in flow communication with each other, an outlet of said second bore and an inlet of said third bore defining a chamber with said first bore that receives a reciprocating plunger for drawing fracturing fluid into said chamber at low pressure and discharging said fracturing fluid at high pressure.

2. The improvement comprising:
   at least one tubular sleeve in said first bore, the outer surface of said tubular sleeve configured to be in direct contact with the surface of said first bore that surrounds said at least one tubular sleeve;
   at least one tubular cartridge in a fluid passage defined by said second and third bores, the outer surface of said at least one tubular cartridge configured to be in direct contact with the surface of said second and third bores that surrounds said at least one tubular cartridge;
   a fluid-tight seal between contacting surfaces of said at least one sleeve and said at least one cartridge;
   said at least one sleeve and said at least one cartridge, when installed in said fluid end cylinder assembly, cooperating to overlie the fluid end body portions that surround each of them and to protect them from direct impingement thereon by high pressure fracturing fluid passing through said fluid end cylinder assembly providing said fluid end with enhanced erosion and corrosion resistance as well as improved fatigue properties and extended service life.

3. The improvement of claim 1 wherein said second and third bores respectively contain first and second tubular cartridges.

4. The improvement of claim 1 in which an outer cylindrical surface on one of said at least one tubular sleeve and said at least one tubular cartridge is in sealing contact with an annular, interior-facing edge surface of the other of said at least one tubular sleeve and at least one tubular cartridge.

5. The improvement of claim 1 wherein said at least one cartridge and said at least one sleeve is composed of a material with enhanced erosion and corrosion resistance was well as improved fatigue resistant properties.

6. The improvement of claim 5 wherein said material is a metal selected from the group consisting of stainless steel, Inconel®, Incoloy® and other metals and alloys exhibiting suitable corrosion resistance, erosion resistance and strength.

7. The improvement of claim 1 wherein said at least one tubular sleeve and said at least one tubular cartridge has a protective coating or surface treatment applied to enhance the erosion and corrosion resistance and fatigue properties thereof.

8. A fluid end of a reciprocating pump for delivery of fracturing fluid at high pressure into a well to extract and recover oil and natural gas trapped in shale rock formations, said fluid end having at least one fluid cylinder assembly comprising:
   a chamber formed therein;
   a first bore in communication with said chamber, said first bore including a reciprocating plunger for effecting pressurization in said chamber to draw fracturing fluid therein at low pressure and to discharge said fracturing fluid at high pressure;
   a second bore formed in said fluid and in communication with said chamber, said second bore including a section valve for receiving fracturing fluid at low pressure into said chamber;
   a third bore formed in said fluid end in communication with said chamber, said third bore including a discharge valve for release of high pressure fracturing fluid through an outlet in said fluid end;
   said second and third bores defining a fluid passage in said fluid end cylinder assembly;
   at least one tubular sleeve in direct contact with said first bore, the outer surface of said tubular sleeve configured to be in an interference fit with the surface of said first bore that surrounds said at least one tubular sleeve; at least one tubular cartridge in said fluid passageway, the outer surface of said at least one tubular sleeve config-
ured to be an interference fit with the surface of said passageway surrounding said at least one tubular cartridge;
a fluid tight seal between contacting surfaces of said at least one sleeve and said at least one cartridge;
said at least one sleeve and said at least one cartridge cooperating to overlie the fluid end body portions sur-
rounding each of them and to protect said underlying fluid body portions from direct impingement thereon by
high pressure fracking fluid passing through said fluid end and providing said fluid end with enhanced erosion
and corrosion resistance as well as improved fatigue properties and extended service life.
9. The fluid end of claim 8 wherein said second and third bores respectively contain first and second tubular cartridges.
10. The fluid end of claim 8 in which an outer cylindrical surface on one of said at least one tubular sleeve and said at
least one tubular cartridge is in fluid tight sealing contact with an annular interior-facing edge surface of the other of said
at least one tubular sleeve and said at least one tubular cartridge.
11. The fluid end of claim 8 edge surface wherein said at least one cartridge and said at least one sleeve is composed of
a material with enhanced erosion and corrosion resistance as well as improved fatigue resistant properties.
12. The fluid end of claim 11 wherein said material is a metal selected from the group consisting of stainless steel,
Inconel®, Incoloy® and other metals and alloys exhibiting suitable corrosion resistance, erosion resistance and strength.
13. The fluid end of claim 12 wherein said at least one tubular sleeve and said at least one tubular cartridge has a
protective coating or surface treatment applied to enhance the erosion and corrosion resistance and fatigue properties
thereof.
14. A kit for enhancing the service life of a fluid end of a reciprocating pump used in the recovery of oil and natural
gas trapped in shale rock formations, said fluid end with at least one fluid cylinder including: a body having a first bore which
includes a suction valve; and a third bore which includes a discharge valve, said first bore being generally perpendicular
to both said second and third bores which are in flow communication with each other, an outlet of said second bore and
an inlet of said third bore defining a chamber in alignment with said first bore that receives said reciprocating plunger for
drawing fracking fluid into said chamber at low pressure and discharging said fracking fluid at high pressure,
said kit comprising:
at least one tubular sleeve adapted to be received in said first bore, the outer surface of said first tubular sleeve
configured to be in direct contact with the surface of said first bore that surrounds said at least one tubular
sleeve;
at least one tubular cartridge adapted to be received in said second bore, the outer surface of said at least one
tubular cartridge being configured to be in direct contact with the inner surface of said second bore;
said at least one sleeve and said at least one cartridge when installed in said fluid body cooperating to protect the
fluid end body portions surrounding the outer surfaces of said at least one sleeve and said at least one cartridge
from impingement by high pressure fracking fluid passing through said fluid end to provide said fluid end with
enhanced erosion and corrosion resistance as well as improved fatigue properties and with extended service
life.
15. The kit of claim 14 wherein each of said at least one tubular sleeve and said at least one tubular cartridge is com-
posed of a material with enhanced erosion and corrosion resistance and fatigue properties.
16. The kit of claim 14 wherein each of said at least one tubular sleeve and said at least one tubular cartridge has a
protective coating or surface treatment applied to enhance it prior to being installed in said fluid body applied to enhance
the erosion and corrosion resistance and fatigue properties.

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