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(54) **Wear resistant crossover**

(57) A wear resistant crossover comprising a generally tubular element having an axial passage therethrough, and at least one exit port located through an axial wall of said crossover, wherein said crossover is made of a material including a ceramic.

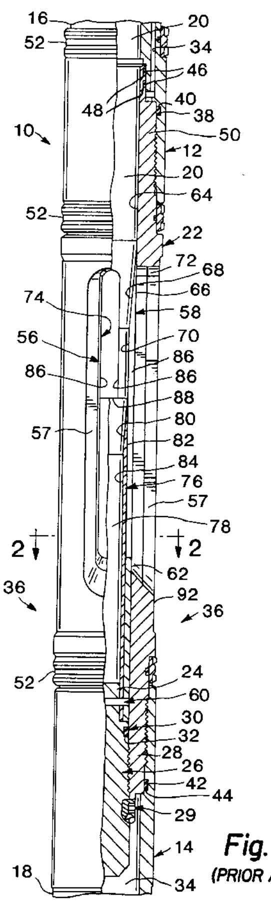

Fig. I
(PRIOR ART)

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Description

[0001] The present invention relates generally to tools used in subterranean wells and, specifically relates to a wear resistant crossover tool used in the delivery of highpressure abrasive slurry in formation fracturing operations.

[0002] Many potentially productive geological formations beneath the earth's surface contain a sufficient volume of valuable fluids, such as hydrocarbons, but production of the fluids is hampered by the low permeability of the formation. "Permeability" is a term used to describe that quality of a geological formation that enables fluids to move about in the formation. All potentially productive formations have pores, a quality described using the term "porosity", within which the valuable fluids are contained. If, however, the pores are not interconnected, the fluids cannot move about and, thus, cannot be brought to the earth's surface.

[0003] When production of a formation having very low permeability, but a sufficient quantity of valuable fluids in its pores is desired, it becomes necessary to artificially increase the formation's permeability. This is typically accomplished by "fracturing" the formation. Fracturing is achieved by applying sufficient pressure to the formation to cause the formation to crack or fracture. The desired result being that the cracks interconnect the formation's pores and allow the valuable fluids to be brought out of the formation and to the surface.

[0004] A conventional method of fracturing a formation begins with drilling a subterranean well into the formation and cementing a protective tubular casing within the well. The casing is then perforated to provide fluid communication between the formation and the interior of the casing that extends to the surface. A packer is set in the casing to isolate the formation from the rest of the wellbore, and hydraulic pressure is applied to the formation via tubing that extends from the packer to pumps on the surface.

[0005] The pumps apply the hydraulic pressure by pumping fracturing fluid down the tubing, through the packer, into the wellbore below the packer, through the perforations, and finally, into the formation. The pressure is increased until the desired quality and quantity of cracks is achieved and maintained. Much research has gone into discerning the precise amount and rate of fracturing fluid and hydraulic pressure to apply to the formation to achieve the desired quality and quantity of cracks.

[0006] Modern fracturing fluids may include sophisticated manmade proppants suspended in gels. "Proppant" is the term used to describe material in the fracturing fluid which enters the formation cracks once formed and while the hydraulic pressure is still being applied (that is, while the cracks are still being held open by the hydraulic pressure), and acts to prop the cracks open. When the hydraulic pressure is removed, the proppant keeps the cracks from closing completely. The proppant thus helps to maintain the artificial permeability of the formation after the fracturing job is over. Fracturing fluid containing suspended proppant is also called slurry.

[0007] A proppant may be nothing more than very fine sand, or it may be a material specifically engineered for the job of holding formation cracks open. Whatever its composition, the proppant must be very hard and strong to withstand the forces trying to close the formation cracks. These qualities also make the proppant a very good abrasive. It is not uncommon for holes to be formed in the protective casing, tubing, pumps, and any other equipment through which slurry is pumped.

[0008] Particularly susceptible to abrasion wear from pumped slurry is any piece of equipment in which the slurry must make a sudden or significant change in direction. Due to its inertia, the slurry tends to maintain its velocity and direction of flow, and resists any change thereof. An object in the flowpath of the slurry that tends to change the velocity or direction of the slurry's flow will soon be worn away as the proppant in the slurry incessantly impinges upon the object. Of particular concern in this regard is the piece of equipment attached to the tubing extending below the packer which takes the slurry as it is pumped down the tubing and redirects it radially outward so that it exits the tubing and enters the formation through the perforations. That piece of equipment is called a Acrossover. Assuming, for purposes of convenience, that the tubing extends vertically through the wellbore, and that the formation is generally horizontal, the crossover must change the direction of the slurry by ninety degrees. Because of this change of direction, the crossover must withstand significant potential abrasive wear.

[0009] One attempt to minimize the wear on the crossover is the use of wear-resistant insert. For example, U. S. Patent No. 5,636,691 discloses the use of a sacrificial tubular insert. Reference is made to Figures 1, 2 and 3 of the present application, which show an abrasive slurry delivery apparatus 10 similar to that disclosed in the US Patent No. 5,636,691 patent. Apparatus 10 is specially adapted for use within a tool string which is suspended from tubing extending to the earth's surface, the tubing being longitudinally disposed within protective casing 2 in a subterranean wellbore. The service tool string is typically inserted through a packer 4 during a fracturing job. Pressurized, abrasive slurry is then pumped through the service tool string. Tubular upper connector 12 and lower connector 14 permit interconnection of the apparatus 10 into the service-tool string. Accordingly, upper portion 16 of upper connector 12 is connected to the service tool string above the apparatus 10, and lower portion 18 of lower connector 14 is connected to the remainder of the service tool string extending below the apparatus.

[0010] An axial flow passage 20 extends axially downward from the upper portion 16 of upper connector 12, axially through the upper connector, and into a generally tubular crossover 22. The axial flow passage 20 terminates at upper radially reduced portion 24 of generally cylindrical plug 26. Plug 26 is threadedly installed into lower portion 28 of crossover 22 and secured with a pair of set screws 29. Sealing engagement between the plug 26 and the lower portion 28 of crossover 22 is provided by seal 30 disposed in circumferential groove 32 externally formed on the plug.

[0011] Radially displaced, longitudinally extending, circulation flow passage 34 extends downwardly from upper portion 16, through the upper connector 12, longitudinally through the crossover 22, through the lower connector 14, and to lower portion 18. When operatively installed in a wellbore 36, the circulation flow passage 34 in the apparatus 10 is sealingly isolated from the wellbore external to the apparatus by seal 38 disposed in circumferential groove internally formed on the upper connector 12, and by seal 42 disposed in circumferential groove 44 internally formed on the lower connector 14. The circulation flow passage 34 is sealingly isolated from coaxial flow passage 20 in the apparatus 10 by seal 30, and by a pair of seals 46, each disposed in one of a pair of circumferential grooves 48 externally formed on an upper portion 50 of the crossover 22 which extends coaxially into the upper connector 12.

[0012] Annular antifriction seal rings 52 are disposed in longitudinally spaced apart external annular recesses 54 formed on upper portion 16 of upper connector 12, between upper connector 12 and crossover 22, and between crossover 22 and lower connector 14. The antifriction seal rings 52 ease insertion and movement of the apparatus 10 within the packer and other equipment into which the apparatus 10 may be longitudinally disposed, as well as providing an effective seal therebetween. Upper portion 50 of crossover 22 is threadedly attached to upper connector 12, and lower portion 28 of the crossover is threadedly attached to lower connector 14.

[0013] Four longitudinally extending circumferentially spaced apart slotted outlet openings or exit ports 56 (three of which are visible in Figure 1), having external radially extending and circumferentially sloping surfaces 57 formed thereon, provide fluid communication between the axial flow passage 20 and the wellbore 36. It is through these exit ports 56 that a slurry must pass in its transition from longitudinal flow in the axial flow passage 20 to radial flow into the wellbore 36. Because of the substantial change of direction from longitudinal flow to radial flow of the slurry through the exit ports 56, the exit ports are particularly susceptible to abrasion wear from proppant contained in the slurry.

[0014] In order to protect the exit ports 56 against abrasion wear, a tubular protective sleeve 58 is coaxially disposed within the crossover 22. The protective sleeve 58 is made of a suitably hard and tough abrasion resistant material, such as tungsten carbide, or is made of a material, such as alloy steel, which has been hardened. If made of an alloy steel, the protective sleeve 58 is preferably through-hardened by a process such as case carburizing or nitriding. Other materials and hardening methods may be employed for the protective sleeve 58 without deviating from the principles of the present invention. Tests performed by the applicants indicate that the protective sleeve 58 is preferably made of tungsten carbide.

[0015] The protective sleeve 58 is secured into the crossover 22 by drive pin 60 that extends laterally through the protective sleeve and the upper portion 24 of the plug 26. Outer diameter 62 of protective sleeve 58 is only slightly smaller than inner diameter 64 of crossover 22 to prevent the slurry from flowing between the protective sleeve and the crossover. Alternatively, the protective sleeve 58 outer diameter 62 may be slightly larger than the crossover 22 inner diameter 64 such that a press fit or shrink fit is obtained between them.

[0016] Upper portion 66 of protective sleeve 58 extends axially upward past the exit ports 56 in the crossover 22, thereby completely internally overlapping that portion of the crossover 22 in which the exit ports 56 are located. Internal longitudinally extending and radially sloping transition surface 68 formed in the upper portion 66 of protective sleeve 58 provides a smooth transition between the inner diameter 64 in the upper portion 50 of the crossover 22 and radially reduced inner diameter 70 of the protective sleeve 58. Note that transition surface 68 extends radially opposite and longitudinally across upper end surfaces 72 of exit ports 56.

[0017] Four longitudinally extending and circumferentially spaced slotted outlet openings or flow ports 74 formed in the protective sleeve 58 are circumferentially aligned with the exit ports 56 in the crossover 22. Flow ports 74 are each slightly smaller in length and width than exit ports 56. Thus, flow ports 74 do not permit direct impingement of the slurry on the crossover 22 as it flows radially from the axial flow passage 20 and into the wellbore 36.

[0018] Coaxially disposed within the protective sleeve 58 is a tubular sacrificial insert 76. The insert 76 is secured to the upper portion 24 of the plug 26 radially intermediate the plug and the protective sleeve 58. The insert 76 extends longitudinally upward from the plug 26 to a location somewhat downward from transition surface 68 of the protective sleeve 58. An upwardly opening interior hollow cylindrical volume within the insert 76 above the upper portion 24 of the plug 26 forms a slurry well 78. An internal longitudinally extending and radially sloped transition surface 80 formed in an upper portion 82 of the insert 76 smooths the transition between the inner diameter 70 of the protective sleeve 58 to inner diameter 84 of the insert. As the slurry flows longitudinally downward through the coaxial flow passage 20 into the crossover 22, the slurry will enter the well 78 through its upwardly facing open upper portion 82 and quickly fill the well. Thereafter, the downwardly flowing slurry will directly impinge on the portion of the slurry which has filled the well 78, effectively preventing the slurry from abrading any portion of the crossover 22, protective sleeve 58, or insert 76 due to direct longitudinal impingement by the slurry.

[0019] However, as the slurry flow changes direction from longitudinal to radial near the upper portion 82 of the insert 76, abrasion from the slurry flow will gradually wear away the insert. This wearing away of the insert 76 is intended, and the material of which the insert is made is selected to regulate the rate at which the insert wears away. For most applications, the insert 76 is preferably made of brass. The insert 76 may also be made of a more easily abraded material such as aluminum, or a less easily abraded material such as mild steel, to regulate its wear rate without deviating from the principles of the present invention. Preferably, the material of which the insert 76 is made should be selected such that the insert wears longitudinally downward, gradually exposing more of the protective sleeve 58 to the radially directed flow of the slurry, such that the flow ports 74 of the protective sleeve 58 are not permitted to wear circumferentially outward sufficiently far to expose the exit ports 56 of the crossover 22 to the radially directed flow of the slurry.

[0020] The flow ports 74 of the protective sleeve 58 wear at a greater rate at a portion of the flow ports 74 exposed to the radially directed slurry flow that is most longitudinally downward. Thus, portions 86 of the protective sleeve 58 will have the greatest rate of wear. This is because portions 86 are the portions of the protective sleeve 58 exposed to the radially directed slurry flow which are most longitudinally downward disposed.

[0021] With longitudinally extending and circumferentially spaced apart slotted ports such as the flow ports 74 in the protective sleeve 58, the high wear rate portions 86 extend longitudinally approximately 1.5 inches (38.1 mm). For this reason, upper edge 88 of the insert 76 is longitudinally spaced downward from the transition surface 68 on the protective sleeve 58 approximately 1.5 inches (38.1 mm), thereby preventing excessive wear of the transition surface 68 (where radial thickness of the protective sleeve 58 is minimal) and upper portion 66 of the protective sleeve. The longitudinal extent of high wear rate portions 86 may vary depending on factors such as slurry flow rate and flow port 74 width and number of flow ports. The longitudinal distance between the upper edge 88 of the insert 76 and the transitional surface 68 of the protective sleeve 58 may be varied without deviating from the principles of the present invention.

[0022] The insert 76 acts to effectively "spread" the circumferential wear of the flow ports 74 longitudinally downward as the insert 76 wears longitudinally downward within the protective sleeve 58. This is due to the fact that as the insert 76 wears longitudinally downward a gradually increasingly downward portion of the flow ports 74 is exposed to the radially directed slurry flow. In other words, high wear rate portions 86 gradually move longitudinally downward as insert 76 wears longitudinally downward. This unique interaction of the insert 76 with the protective sleeve 58 acts to prolong the useful life of the protective sleeve.

[0023] Turning now to Figure 2, a cross-sectional view may be seen of the apparatus 10 representatively illustrated in Figure 1. The cross-section is taken through line 2-2 of Figure 1 that extends laterally through the crossover 22. In this view, the manner in which circulation flow passage 34 extends longitudinally through the crossover 22 may be seen. Eight longitudinally extending and circumferentially spaced circulation ports 90 are disposed radially intermediate the inner diameter 64 of the crossover 22 and outer diameter 92 of the crossover. Two each of the circulation ports 90 are disposed in the crossover 22 circumferentially intermediate each pair of exit ports 56. Note that various quantities and locations may be chosen for the circulation ports 90 and the exit ports 56 in the crossover 22.

[0024] Figure 2 also illustrates the necessity for preventing abrasion wear of the crossover 22. If exit ports 56 are allowed to wear appreciably circumferentially outward, the exit ports 56 will eventually be in fluid communication with the circulation ports 90. It may also be clearly seen in Figure 2 that flow ports 74 in protective sleeve 58, being somewhat smaller in width than the exit ports 56, act to protect the exit ports 56 from abrasion wear due to radially outwardly directed flow of the slurry. Note that in this view protective sleeve 58 and insert 76 each completely internally overlap the inner diameter 64 of the crossover 22. Thus, the crossover 22 is not only protected against circumferentially outward wear of its exit ports 56, it is also protected against radially outward wear of its inner diameter 64.

[0025] Figure 3 illustrates the use of a blast joint 90 to protect casing 2. The radial flow from the crossover can damage the casing 2. Therefore, the blast joint 90 redirects the flow from the exit ports 56 of the crossover 10. The blast joint 90 acts as a shield and endures the full force of the abrasive slurry. Often, a sacrificial liner 92 is placed on the impact surface. The redirected slurry passes through ports 96 in the blast joint 90 and enters the well annulus 6. From there, the abrasive slurry can pass into the formation through perforations 8 in the casing 2. One problem observed with the use of blast joints is the exterior wear produced on the crossover. In other words, the radial flow of slurry from the crossover strikes the blast joint 90 and rebounds against the exterior surface of the crossover, below the ports 54.

[0026] It would be desirable to provide a crossover tool that can better withstand the abrasion from a high pressure slurry. Such a material should be suitable for use as a sacrificial insert in the exit ports, the interior surface, or the exterior surface of the crossover. Alternatively, a need exists for a material that can be used to form the entire crossover.

[0027] The present invention relates to a highly wear resistant crossover tool made of a ceramic material such as zirconia. Zirconia is a trade name for a material that is approximately 96% zirconium oxide and approximately 4% magnesium oxide. Zirconia has been found to have superior wear resistance. Further, zirconia can be machined into a variety of shapes. Zirconia has a melting point of approximately 5000°F (2760°C) and a specific gravity of between approximately 5.6 and 6.0. It is available from manufacturers such as Coors Ceramics Company of Golden, Colorado. Zirconia is chemically inert. In other words, there are no known conditions causing instability. It demonstrates a tensile strength of approximately 352 MPa and a hardness of between 11.8 and 12.7 GPa (as measured by the Knoop 1000g hardness test). These properties compare favorably to the steel used in existing crossovers. Other materials could include zinc oxide, tungsten carbide, various composites and other fired materials.

[0028] In another embodiment, a ceramic crossover is used with a metal outer sleeve. The sleeve can include the necessary threading to connect the crossover assembly to other tool string elements. In another embodiment, a steel crossover is shielded with ceramic wear elements. For example, the axial ports can include inserts that endure the abrasive force of the fracturing fluid. Inner and outer protective sleeves can also be used to protect the inner and outer surfaces of the crossover. In certain circumstances, the well casing is protected from the abrasive effects by a blast joint. The blast joint is suspended around the crossover and redirects the abrasive slurry to an entry point into the formation. When blast joints are used, the reflected slurry can abrade the outer surface of the crossover. Thus, an outer sleeve can lengthen the useful life of the crossover.

[0029] According to one aspect of the invention there is provided a wear resistant crossover comprising a generally tubular element having an axial passage therethrough, and at least one exit port located through an axial wall of said crossover, wherein said crossover is made of a material including a ceramic.

[0030] In an embodiment, the crossover further comprises a plug having a terminal surface across said axial passage.

[0031] In an embodiment, the or each exit port comprises a sloped surface.

[0032] In an embodiment, the or each exit port comprises an upper surface substantially perpendicular to the axial wall of the crossover.

[0033] Preferably, the ceramic includes zirconium oxide.

[0034] In an embodiment, the crossover further comprises at least one annularly located circulation port.

[0035] In an embodiment, the crossover further comprises an outer metal sleeve.

[0036] According to another aspect of the invention there is provided a wear resistant crossover comprising: a generally tubular mandrel having an axial passage therethrough, and inner surface and an outer surface; at least one exit port located through an axial wall of said crossover; and at least one sacrificial insert coupled to said crossover, wherein said sacrificial insert is composed of a wear resistant material including a ceramic.

[0037] In an embodiment, the or each sacrificial insert comprises an insert dimensioned to fit within the at least one exit port. The insert may comprise a solid member having a plurality of portals therethrough. The insert may comprise an upper and lower contact surface, and at least one of said contact surfaces may be sloped. The crossover insert portals may comprise a plurality of holes of increasing area.

[0038] In an embodiment, the or each sacrificial insert comprises an inner sleeve dimensioned to fit against an inner surface of the mandrel.

[0039] In an embodiment, the or each sacrificial insert comprises an outer sleeve dimensioned to fit against the outer surface of the mandrel.

[0040] In an embodiment, said mandrel further comprises at least one circulation flow passage.

[0041] According to another aspect of the invention there is provided a wear resistant insert for use with a crossover comprising a sacrificial member made of a ceramic.

[0042] The sacrificial member may be dimensioned to fit into an exit port of the crossover. The sacrificial member may be an inner sleeve or an outer sleeve.

[0043] Reference is now made to the accompanying drawings, in which:

Figure 1 is a partially cross-sectional view of a prior art slurry delivery apparatus having a crossover, a tubular protective sleeve, and a tubular sacrificial insert therein which can be made in accordance with the present invention;

Figure 2 is an enlarged scale cross-sectional view of the crossover of the slurry delivery apparatus, taken along line 2-2 of Figure 1 ;

Figure 3 is a sectional across a crossover and a surrounding blast joint;

Figure 4 is a cross-sectional view across the length of an embodiment of a crossover tool according to the present invention;

Figure 5 is a cross-sectional across the axis of the crossover tool shown in Figure 4;

Figure 6 illustrates a ceramic crossover having a metal outer sleeve; and

Figures 7, 8, 9, and 10 illustrate a crossover with ceramic wear elements in the axial ports, and along the inner and outer diameters.

[0044] Figures 4 and 5 illustrate a first embodiment of an all ceramic crossover 100 which embodies the present invention. The crossover 100 is connected to a tool string by its upper connector 102. The service tool string is typically inserted through a packer during a fracturing job. A pressurized, abrasive slurry is then pumped into the service tool string. Tubular upper connector 102 and lower connector 104 permit interconnection of the crossover 100 into the service tool string. Axial flow passage 106 extends downward through the crossover from the upper connector 102. The axial flow passage 106 terminates at the terminal surface 110. The terminal surface 110 can be any shape, but in one embodiment is a generally conical shape. The terminal surface 110 can be an integral part of the crossover or alternatively, can be part of a plug 111 coupled to the crossover. When the slurry is pumped through the axial passage 106, it impacts upon the termination surface 110, and is redirected through at least one exit port 108. In the embodiment illustrated, three exit ports 108 are used. The redirected slurry impacts against the walls of the formation to enhance its permeability and to deliver proppant to maintain the improved permeability.

[0045] To better understand the size of the invention, a typical crossover 100 could be between ten and eighteen inches (0.254 to 0.457 m) in length. The ports 108 could be between six and nine inches in length (0.152 to 0.229 m). A wall thickness of the crossover might be between one-half to two inches (12.7 to 50.8 mm). The exit ports 108 can be any suitable shape, but in a preferred embodiment, are generally oval. The ports 108 have both an upper surface 108a and a lower surface 108b. The upper surface 108a is generally perpendicular to the inner and outer axial walls 118 and 120 of the crossover. The lower surface 108b can have a downwardly angled slope as shown. The slope of surface 108b prevents direct impingement of the slurry against its surface.

[0046] After a formation is fractured, the valuable fluids therein flow into the annulus of the wellbore. The fluids then enter the relatively low pressure of the circulation flow passages 116 shown best in Figure 5. The reservoir's fluid must be brought back to the surface. The circulation flow passages 116 pass axially through the body of the crossover 100. Any number of circulation flow passages can be formed in the crossover. Three sets of three are shown in the illustrated embodiment.

[0047] The crossover 100 is preferably made of Azirconia, a material that can be between 85% to 100% zirconium oxide with the remainder being magnesium oxide. Zirconia has been found to have superior wear resistance. Further, zirconia can be machined into a variety of shapes. Zirconia has a melting point of approximately 5000°F (2760°C) and a specific gravity of between approximately 5.6 and 6.0. These properties compare favorably to the steel used in existing crossovers.

[0048] Figure 6 illustrates an alternative embodiment of the invention wherein the crossover is made of a wear resistant material such as described above. However, the crossover 100 is sheathed with a metal sleeve 122. In other ways, the configuration and function of the crossover 100 is the same. For example, the crossover will have at least one exit port 108. An abrasive slurry will be delivered through a axial flow passage until it reaches a terminal surface 1 10 which will redirect the slurry through the exit ports 108. The metal sleeve protects the crossover from damage during the installation of the crossover into the tool string. Threads on the metal sleeve 122 can be used to couple the crossover to upper and lower connectors 102, 104.

[0049] Figures 7, 8, 9, and 10 illustrate a crossover 200 also embodying the present invention. The crossover 200 uses a mandrel 202 that is shielded with a variety of wear resistant sacrificial elements made of a material like zirconia. For example, an insert 204 can be placed in the exit port 206 of the crossover. To ensure that the insert 204 remains in the exit ports, the upper and lower contact surfaces 210, 212 are outwardly declined. In other words, the area of the exit port 206 decreases from the inner surface of the crossover to its outer surface. The insert 204 is placed into the exit port and the pressure of the exiting slurry forces the contact surfaces together and prevents any movement by the insert 204. The insert 204 can include a number of flow distribution portals 208. These portals 208 can vary in order to create a more even pressure gradient across the exit port. For example, if there were only a single portal, the exit slurry pressure would be greater near the bottom of the portal. If two equal portals were used in the insert, the exit slurry pressure would be greater from the lower of the two. Therefore, it is preferable to have portals 208 of decreasing size from the top of the insert to its bottom. The insert 204 shown in Figure 8 illustrates the use of several portals, with lowest portal 208a being the smallest. Portals 208b and 208c are progressively larger.

[0050] Figures 9 and 10 illustrate the coaxial outer and inner sacrificial sleeves 214, 216, respectively. These sacrificial sleeves 214, 216 can be made of the same material as the insert 204. For example, the use of zirconia for theses sacrificial sleeves is an improvement over prior art sleeves made of brass as described in U.S. Patent No. 5,636,691 discussed above. The outer sacrificial sleeve 214 has a portal 218 that matches the external dimensions of the exit port 206 on mandrel 202. Likewise, the inner diameter of surface 220 matches the outer diameter of the mandrel 202. The inner sacrificial sleeve 216 has a portal 222 that substantially matches the internal dimensions of the exit port 206. Likewise, the outer diameter of surface 224 matches the inner diameter of the mandrel 202. In one embodiment, the wall thickness of either sleeve can be between 0.1 and 0.3 inches (2.54 to 7.62 mm) in thickness. Of course, the anticipated life is extended as the sleeve thickness is increased.

[0051] It will be appreciated that the invention described above may be modified.

Claims

1. A wear resistant crossover comprising a generally tubular element having an axial passage there-

through, and at least one exit port located through an axial wall of 5 said crossover, wherein said crossover is made of a material including a ceramic.

2. A crossover according to Claim 1, further comprising a plug having a terminal surface across said axial passage.

3. A crossover according to Claim 1 or 2, wherein the or each exit port comprises a sloped surface.

4. A crossover according to Claim 1 or 2, wherein the or each exit port comprises an upper surface substantially perpendicular to the axial wall of the crossover.

5. A wear resistant crossover comprising: a generally tubular mandrel having an axial passage therethrough, and an inner surface and an outer surface; at least one exit port located through an axial wall of said crossover; and at least one sacrificial insert coupled to said crossover, wherein said sacrificial insert is composed of a wear 20 resistant material including a ceramic.

6. A crossover according to Claim 5, wherein the or each sacrificial insert comprises an insert dimensioned to fit within the at least one exit port.

7. A crossover according to Claim 6, wherein the insert comprises a solid member having a plurality of portals therethrough.

8. A crossover according to Claim 6 or 7, wherein said insert comprises an upper and lower contact surface, wherein at least one of said contact surfaces is sloped.

9. A wear resistant insert for use with a crossover, comprising a sacrificial member made of a ceramic.

10. An insert according to Claim 9, wherein said ceramic includes a zirconium oxide.

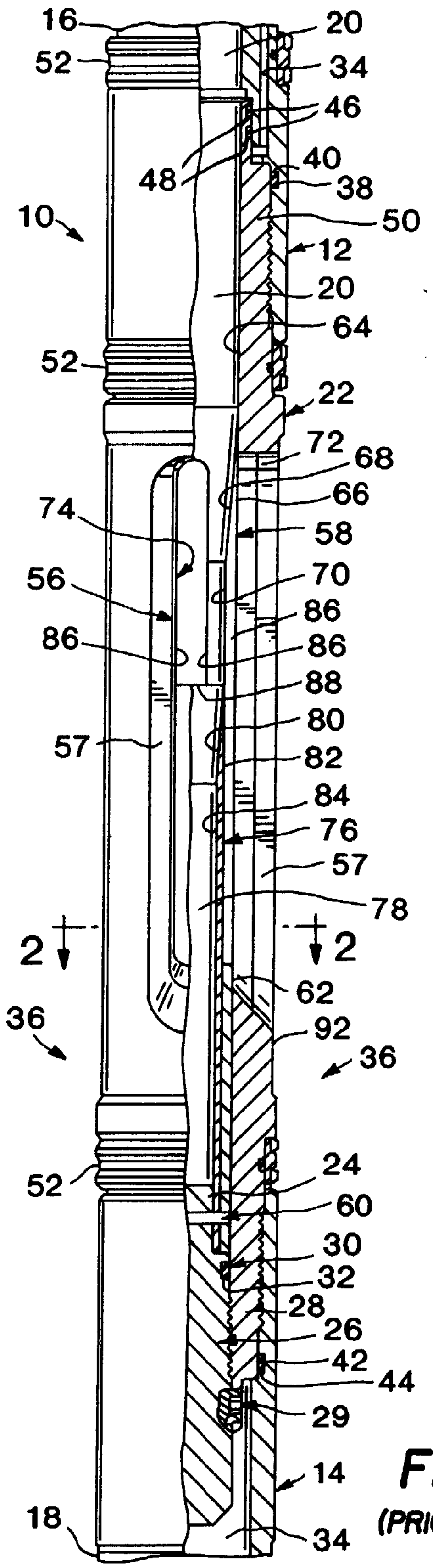

Fig. 1
(PRIOR ART)

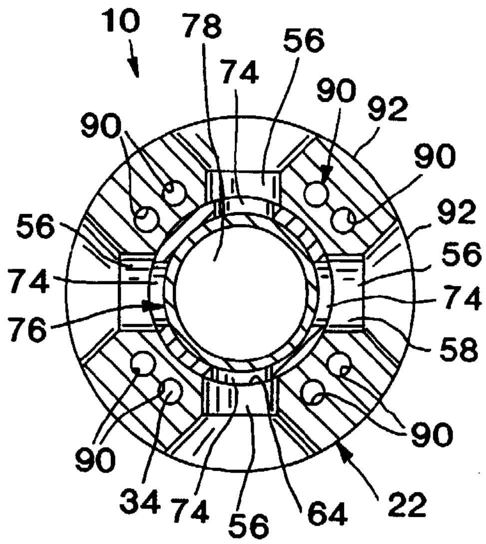

Fig. 2
(PRIOR ART)

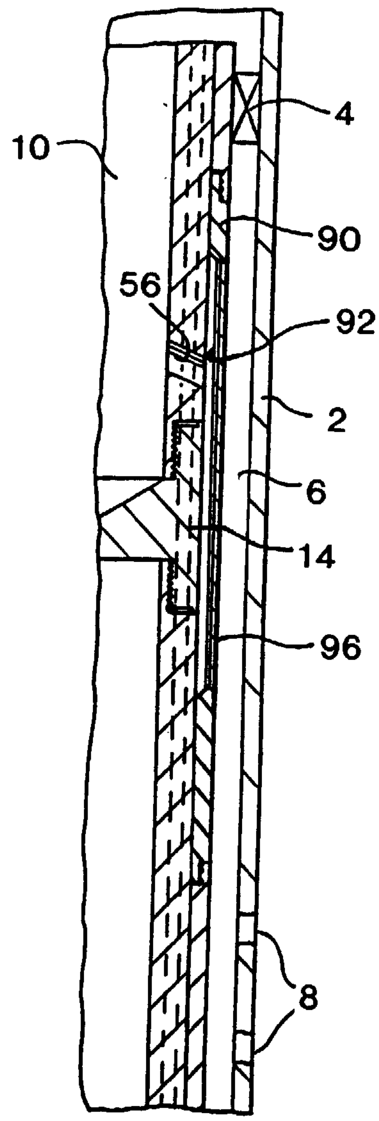

Fig. 3
(PRIOR ART)

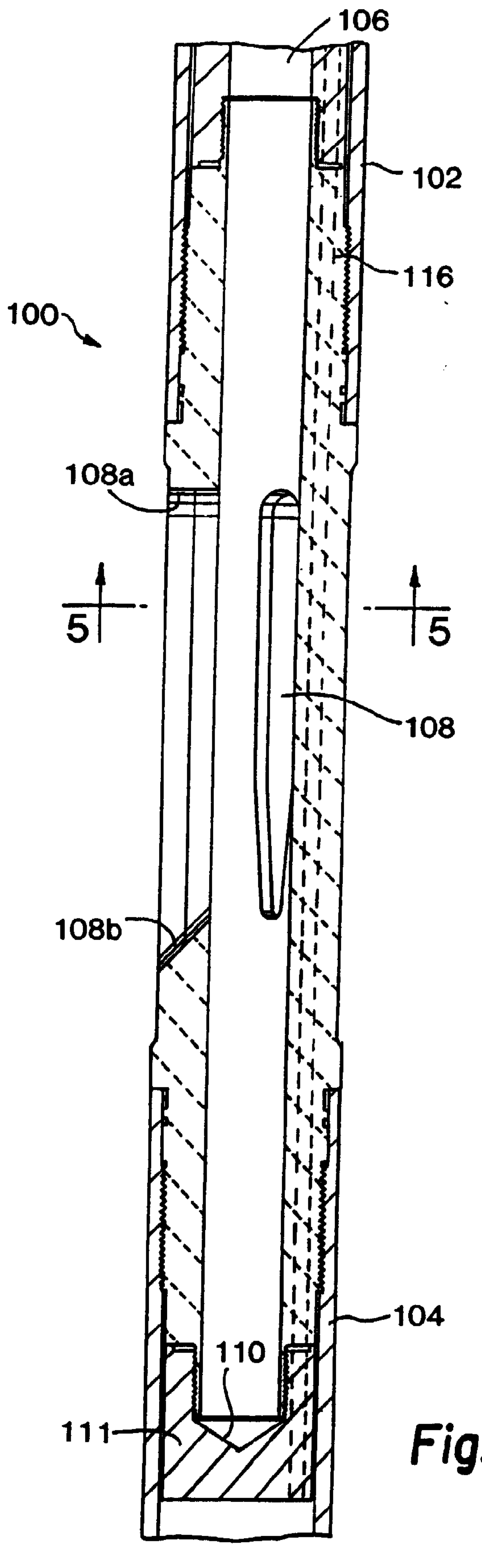

Fig. 4

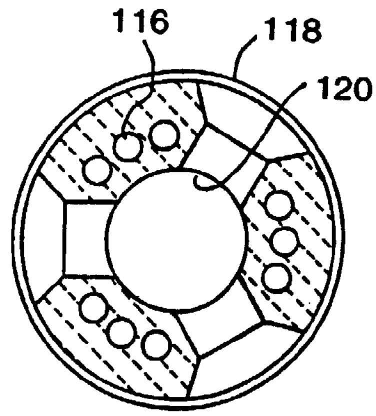

Fig. 5

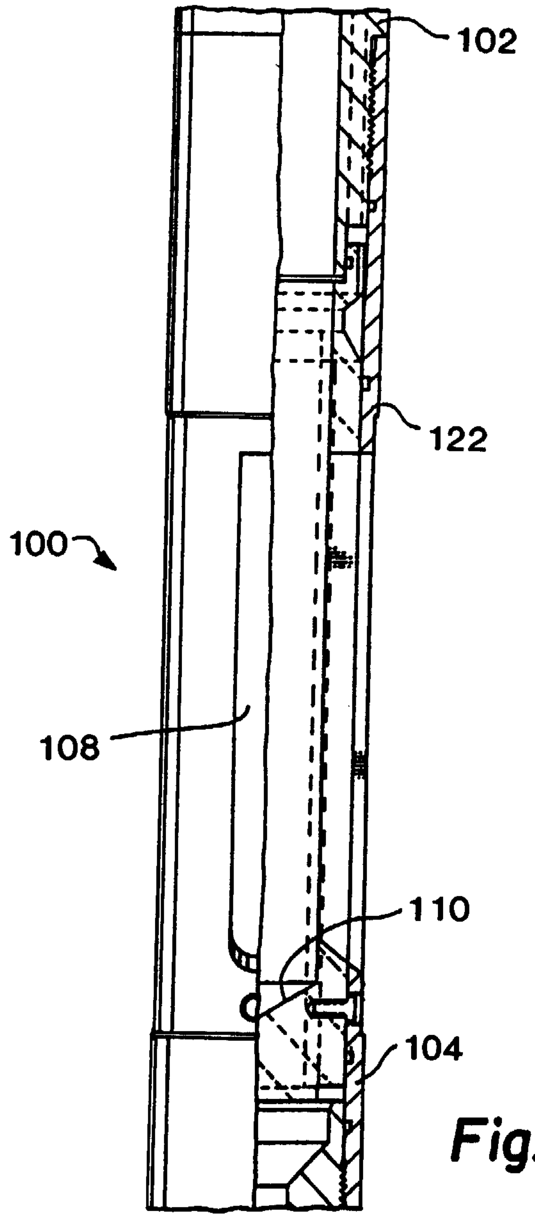

Fig. 6

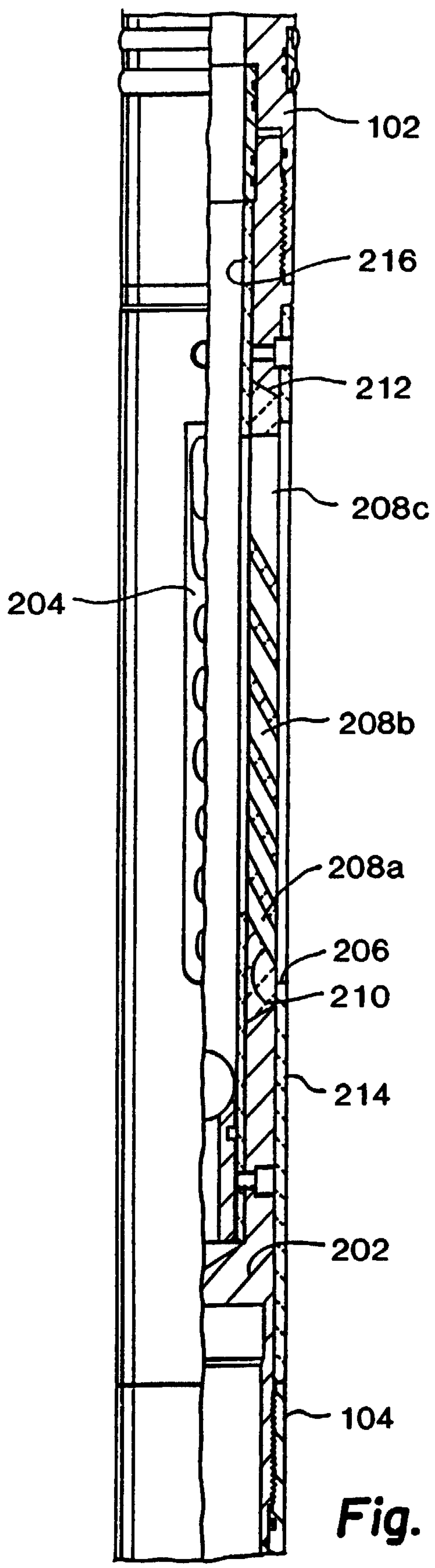
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Fig. 7

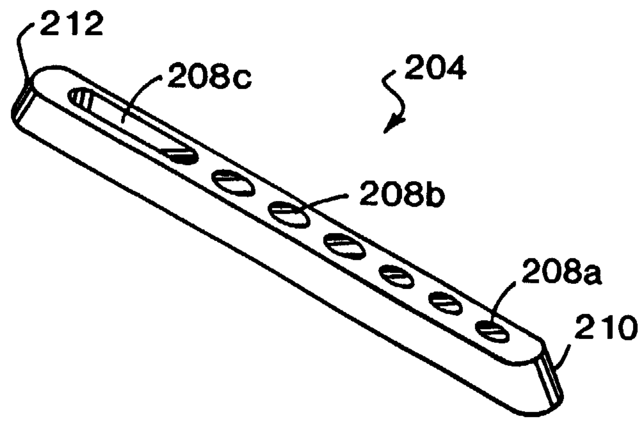
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Fig. 8

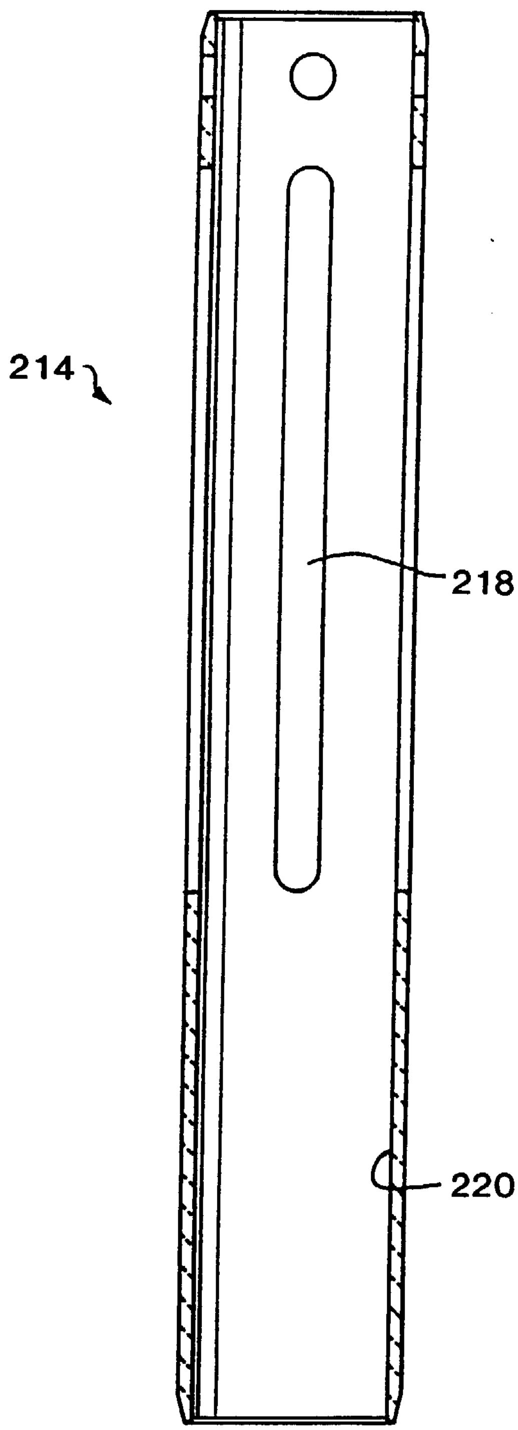

Fig. 9

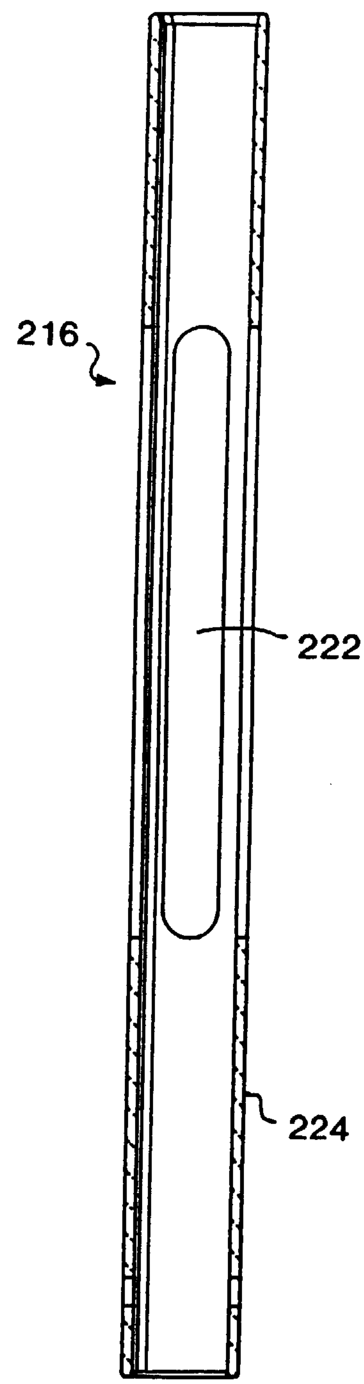

Fig. 10