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(54) PRESSURE ACTIVATED COMPLETION TOOLS AND METHODS OF USE

(71) Applicant: **Rapid Design Group Inc.**, Leduc (CA)

(72) Inventors: **Serhiy Arabsky**, Beaumont (CA); **Vitaliy Arabsky**, Beaumont (CA)

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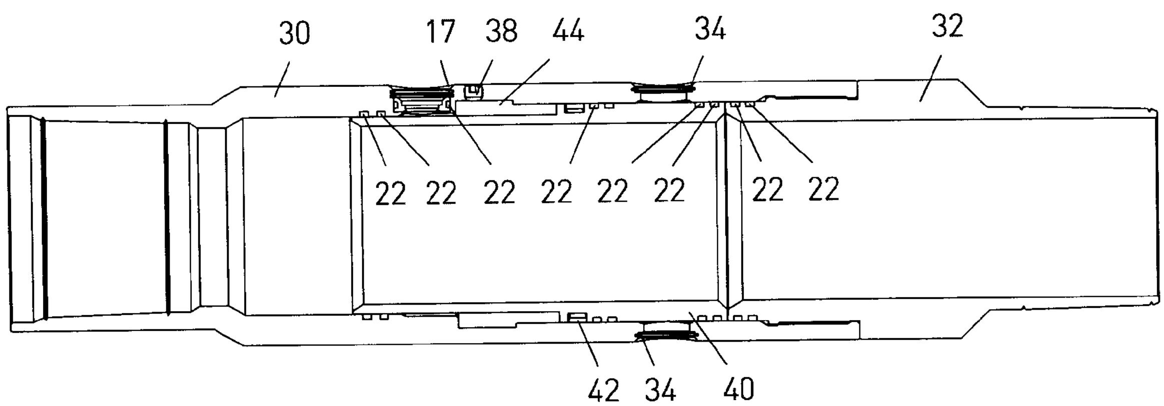
(57) **ABSTRACT**

Methods and apparatus of pressure activated completion tools for hydraulic fracturing and related processes are provided. In some embodiments, the hydraulic fracturing apparatuses for accessing a subterranean formations can include a tubular body to be fluidly connected in-line with a completion string, the tubular body having at least one burst port configured to receive burst inserts (burst plugs), and a movable inner sleeve that can slide along the inside of the tubular body when exposed to hydraulic pressure from a first position to a second position. The tubular body can also have flow-port(s) that are blocked when the movable inner sleeve is in the first position and opened when the movable inner sleeve slides to the second position.



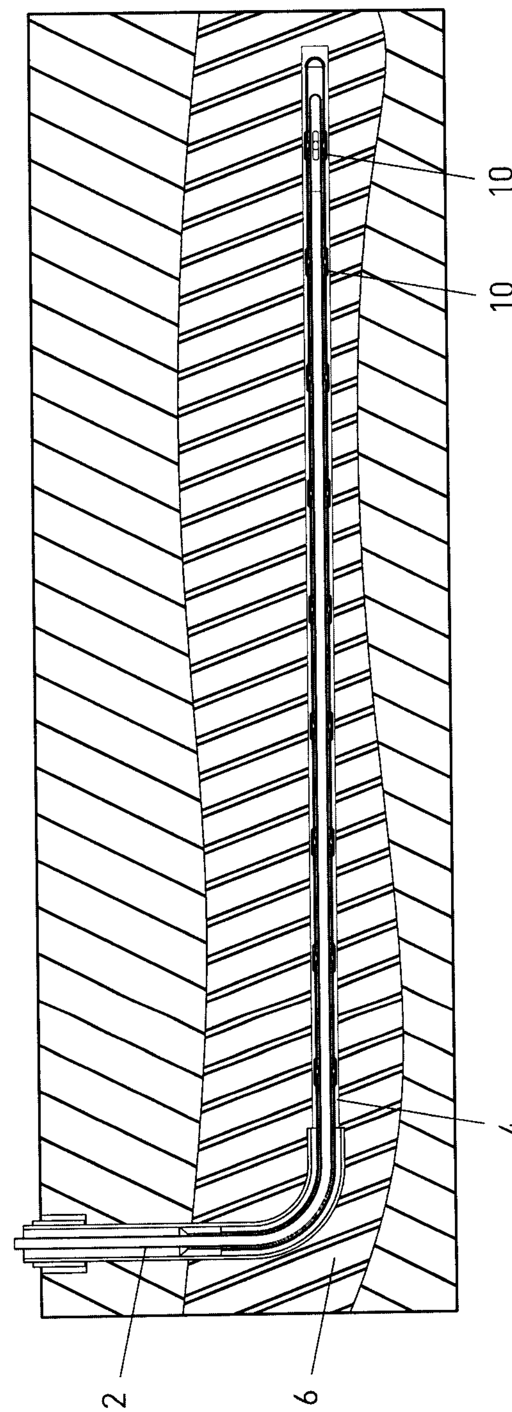


Figure 1

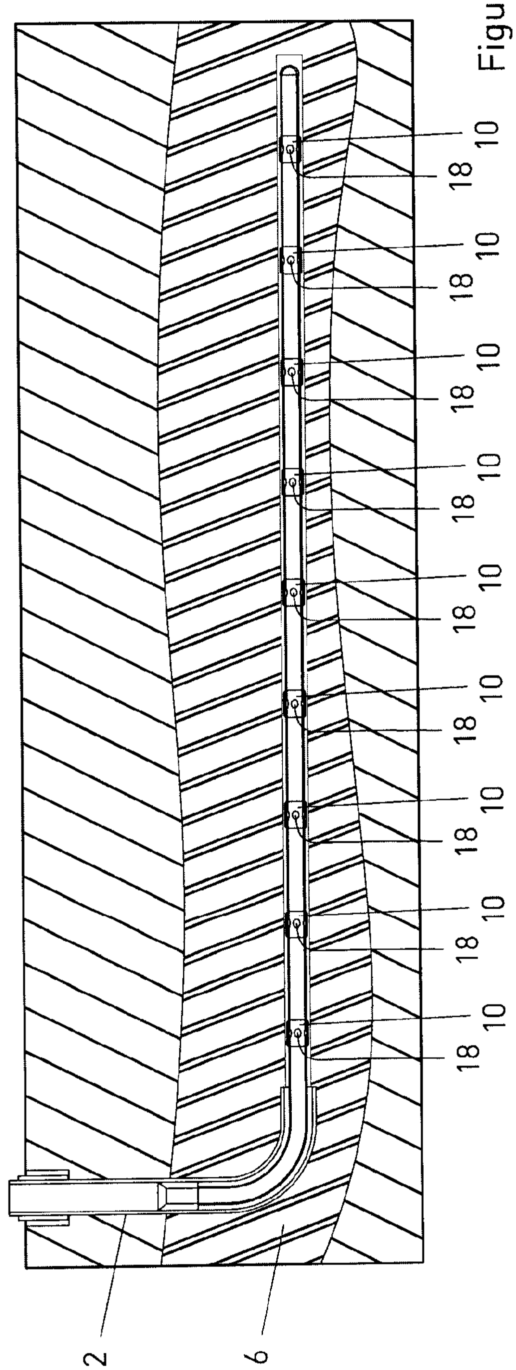


Figure 2A

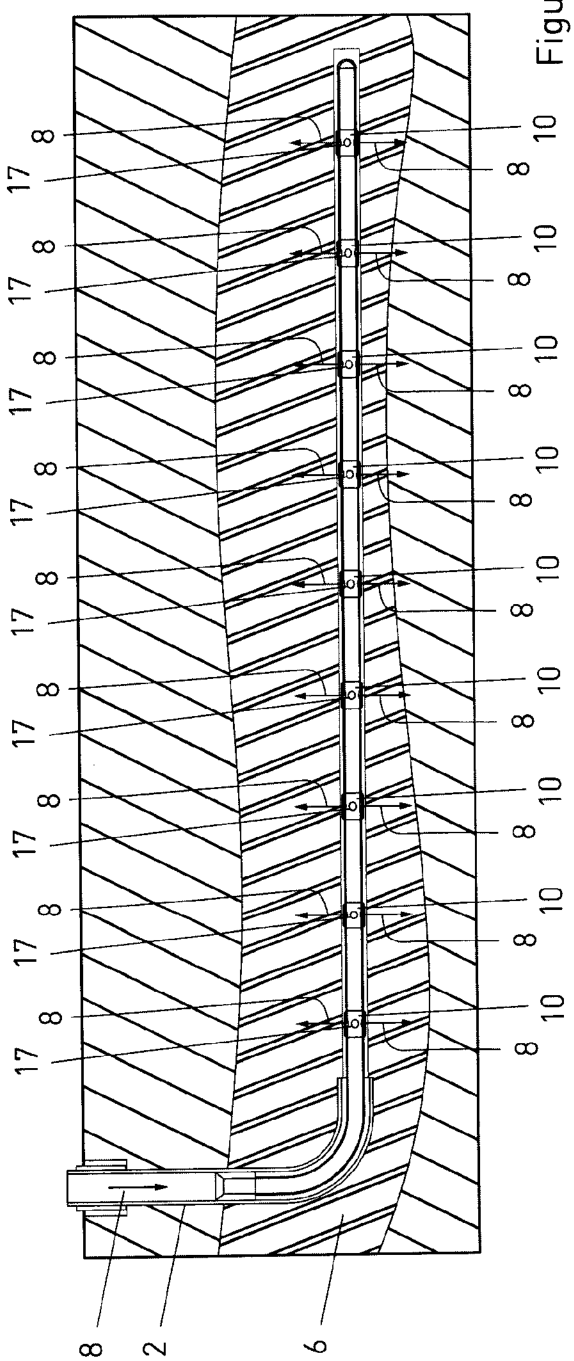


Figure 2B

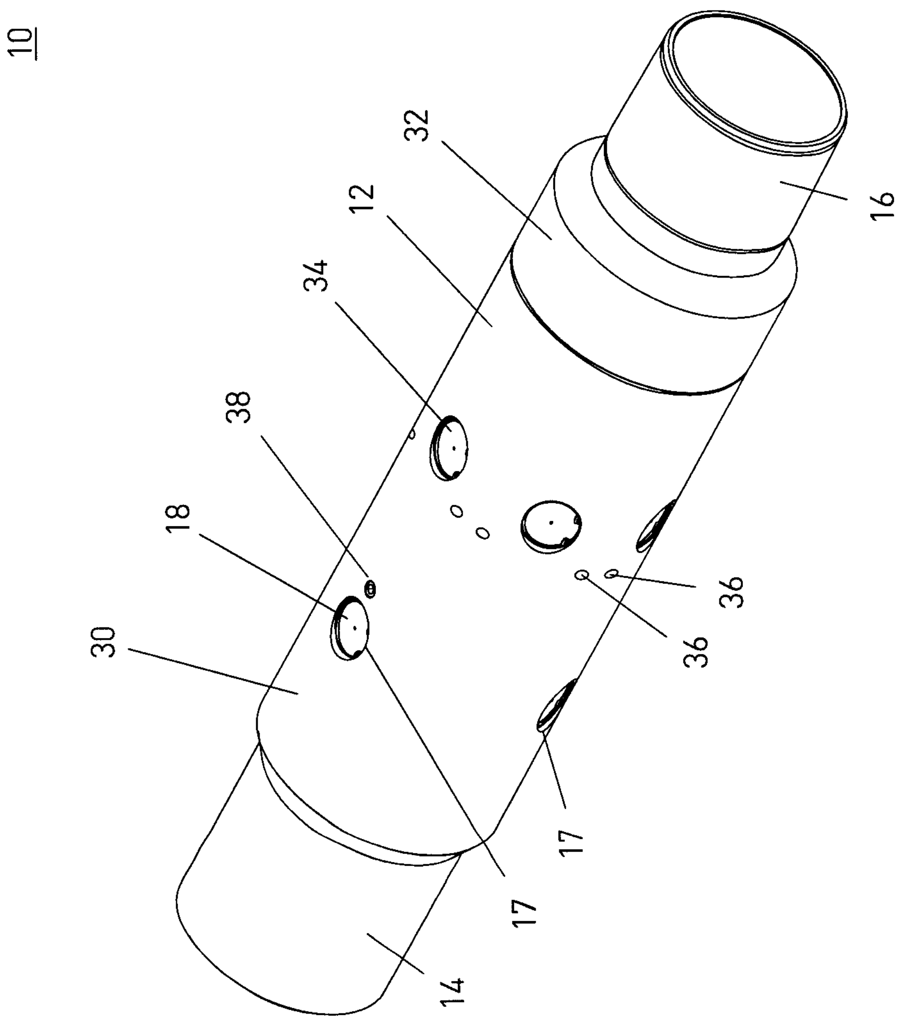


Figure 3

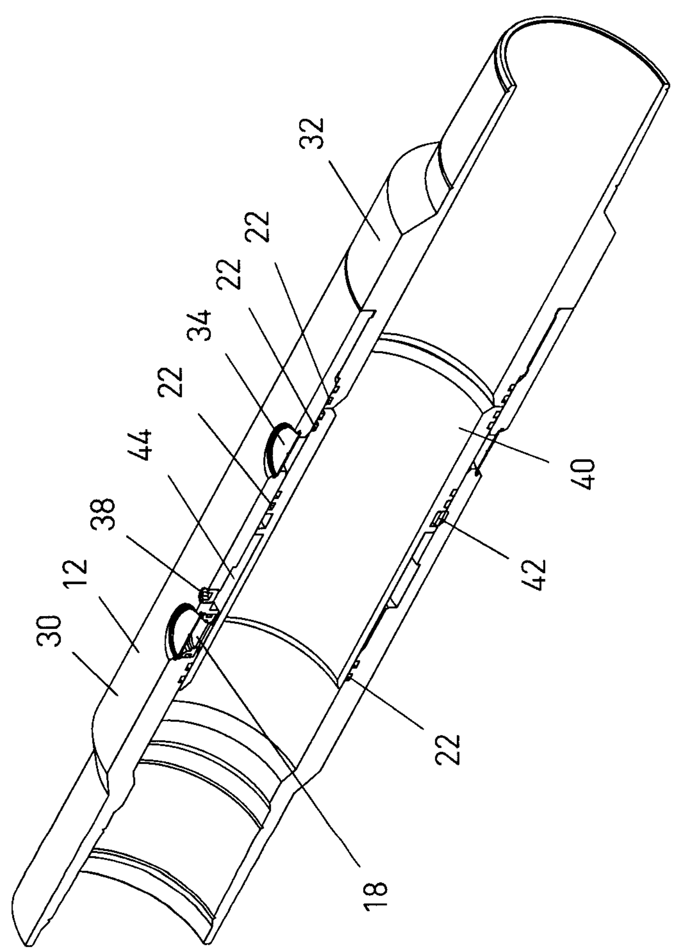


Figure 4

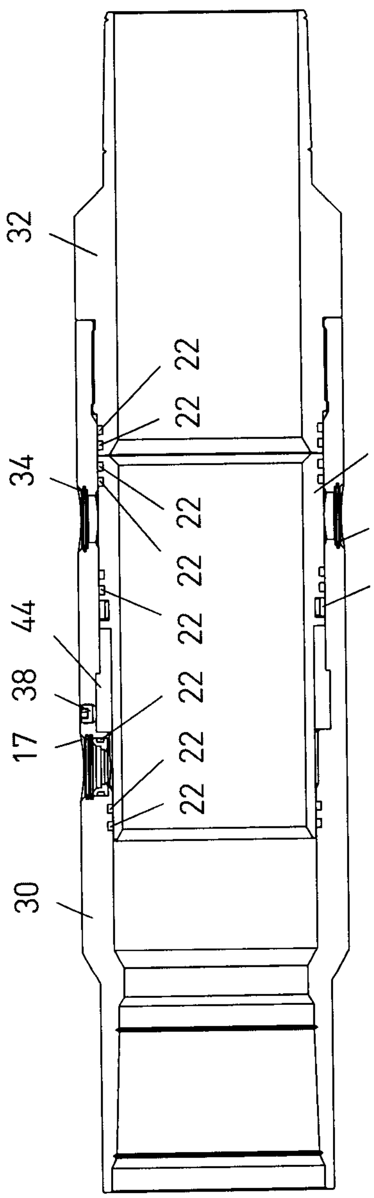


Figure 5A

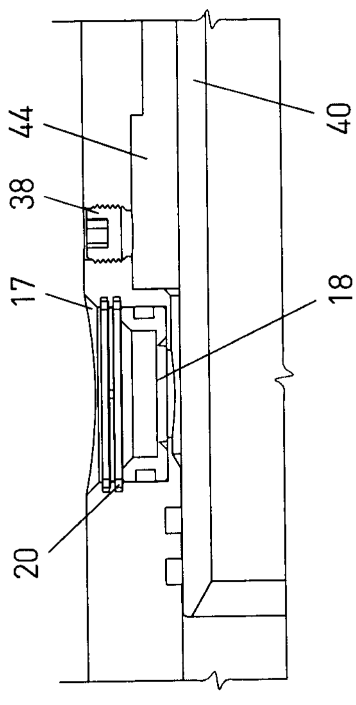


Figure 5B

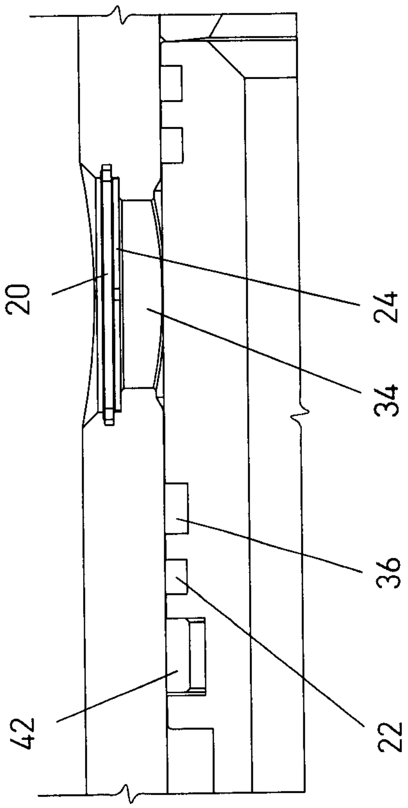


Figure 5C

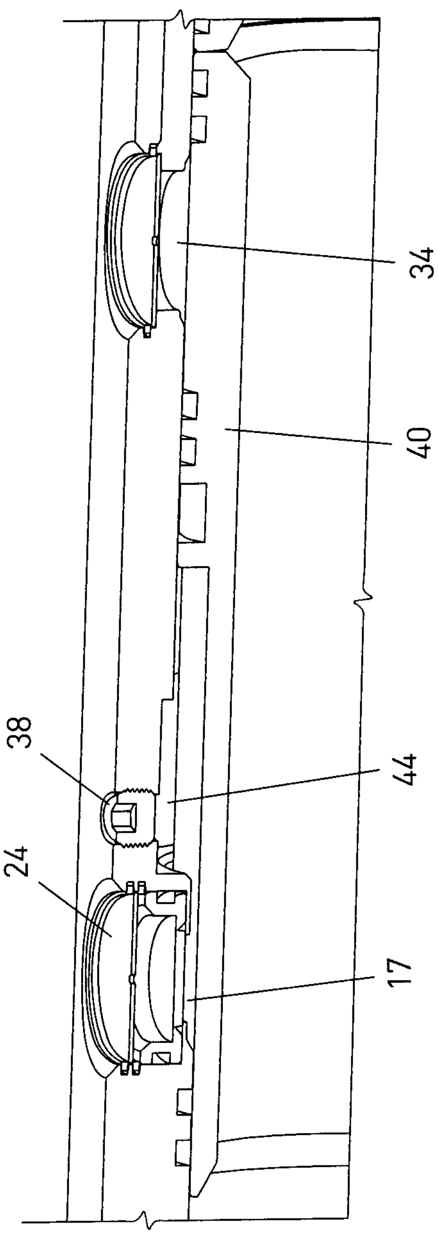


Figure 5D

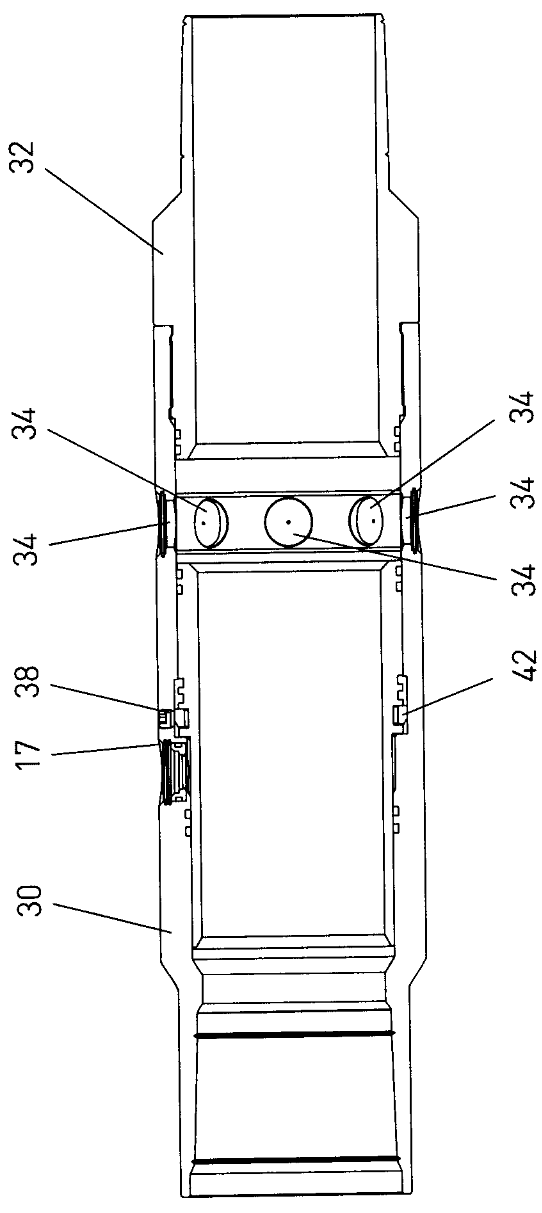


Figure 5E

PRESSURE ACTIVATED COMPLETION TOOLS AND METHODS OF USE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/935,723, filed Feb. 4, 2014, which is herein incorporated by reference.

TECHNICAL FIELD

[0002] The present disclosure is related to the field of methods and apparatus of completion tools, in particular, methods and apparatus of pressure activated completion tools for hydraulic fracturing.

BACKGROUND

[0003] The technique of hydraulic fracturing (commonly referred to as "fracing" or "fracking") is used to increase or restore the rate at which fluids, such as oil, gas or water, can be produced from a reservoir or formation, including unconventional reservoirs such as shale rock or coal beds. Fracing is a process that results in the creation of fractures in rocks. The most important industrial use is in stimulating oil and gas wells where the fracturing is done from a wellbore drilled into reservoir rock formations to increase the rate and ultimate recovery of oil and natural gas.

[0004] Hydraulic fractures may be created or extended by internal fluid pressure which opens the fracture and causes it to extend through the rock. Fluid-driven fractures are formed at depth in a borehole and can extend into targeted formations. The fracture height or width is typically maintained after the injection by introducing an additive or a proppant along with the injected fluid into the formation. The fracturing fluid has two major functions, to open and extend the fracture; and to transport the proppant along the length or height of the fracture.

[0005] Current fracing systems and methods, however, can be expensive and inefficient.

[0006] In many cases, it is desired to target the fracturing process at a specific location in a formation. Prior attempts to address this issue include the devices and methods disclosed in Canadian Patent Application 2,755,848 and Canadian Patent 2,692,377, both of which are hereby incorporated by reference in their entirety.

[0007] Both of these documents disclose a burst opening for fracing fluid to exit a completion/service string and access a formation. It is known that burst disks can work in a cemented environment, however, both of these tools are problematic to use in practice. When the fluid pressure is used to burst open these tools, only one out of multiple openings will burst. Pressure is lost at that point and the flow area is severely limited.

[0008] Attempts to address the issue of using hydraulic pressure to actuate various downhole components include those disclosed in Canadian Patent 2,637,519, Canadian Patent Application CA 2,719,561, and Canadian Patent Application 2,776,560, all of which are hereby incorporated by reference in their entirety. These methods and apparatuses, however, have their shortcomings. A problem with the exposed vent holes of these devices is that they can be prone to being plugged, restricted, or blocked by debris, especially during cementing operations.

[0009] Safer, more reliable, and cost-effective fracing methods and systems are quickly becoming sought after technology by oil and natural gas companies. It is, therefore, desirable to provide an apparatus and method for hydraulic fracturing that can overcome the shortcomings of the prior art and provide a greater degree of reliability.

SUMMARY

[0010] Methods and apparatus of pressure activated completion tools for hydraulic fracturing and related processes are provided. In some embodiments, the hydraulic fracturing apparatuses for accessing a subterranean formations can include a tubular body to be fluidly connected in-line with a completion string, the tubular body having at least one burst port configured to receive burst inserts (burst plugs), and a movable inner sleeve that can slide along the inside of the tubular body when exposed to hydraulic pressure from a first position to a second position. The tubular body can also have flow-port(s) that are blocked when the movable inner sleeve is in the first position and opened when the movable inner sleeve slides to the second position.

[0011] In some embodiments, the pressure activated tools can be used in a well bore to allow for multistage completions to be performed reliably with the use of cement or packers for zonal isolation. The tools can allow for large flow areas without restriction during stimulation treatment via straddle packer or liner.

[0012] Broadly stated, in some embodiments, a hydraulic fracturing apparatus is provided for perforating a subterranean formation, the apparatus comprising: a tubular body configured to be fluidly connected in-line with a completion string having an upstream and a downstream, the tubular body having at least one burst port, the at least one burst port configured to receive a burst plug; a movable inner sleeve within the tubular body that can slide along the inside of the tubular body from a first position to a second position when exposed to hydraulic pressure, and at least one flow-port in the tubular body that is blocked when the movable inner sleeve is in the first position and opened when the movable inner sleeve slides to the second position.

[0013] In some embodiments, the apparatus can further comprise a burst plug disposed within the at least one burst port, the burst plug configured to burst at a predetermined pressure threshold. In some embodiments, the at least one flow port is spaced away from the at least one burst port. In some embodiments, the apparatus can further comprise a fluid compartment in fluid communication with the at least one burst port, the fluid compartment configured to receive an incompressible fluid. In some embodiments, the movable inner sleeve abuts the fluid compartment. In some embodiments, the burst plug disposed within the at least one burst port is configured to burst open in response to pressure transferred from the movable inner sleeve through the incompressible fluid to the burst plug. In some embodiments, the movable inner sleeve is configured to move to its second position in response to pressure. In some embodiments, the incompressible fluid is oil. In some embodiments, the apparatus can further comprise a locking means to lock the movable inner sleeve at a predetermined position within the tubular body. In some embodiments, the predetermined position of the movable inner sleeve is the second position. In some embodiments, the locking means comprises a C snap ring and a corresponding groove. In some embodiments, the at least one burst port is configured to receive a shield. In some embodiments, the at least one flow-port is configured to receive a shield. In some embodiments, the at least one flow-port is larger in diameter than the at least one burst port. In some embodiments, the at least one flow-port is approximately twice as large in diameter than the at least one burst port. In some embodiments, the at least one flow-port has a diameter that is choked in order to limit fluid flow out of the flow-port or to create a jetting effect.

[0014] Broadly stated, in some embodiments, a method is provided for hydraulic fracturing a formation in a well, the method comprising the steps of: providing an apparatus as described herein; supplying pressurized fracture fluid to the apparatus; sliding the movable inner sleeve into the second position; opening the at least one flow-port; allowing the pressurized fracture fluid to flow through the flow-port to contact the formation; and fracturing the formation in the well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a diagram of a side elevation view of a well depicting an embodiment of an apparatus for hydraulic fracing where formation and well head are visible.

[0016] FIGS. **2**A and **2**B are diagrams of a side elevation view of a well depicting embodiments of an apparatus for hydraulic fracing along a completion string.

[0017] FIG. **3** is a perspective view of an embodiment of an apparatus for hydraulic fracing.

[0018] FIG. **4** is a perspective, cross-sectional view of the embodiment of FIG. **3**.

[0019] FIGS. **5**A to **5**D are cross-sectional and close-up views of the embodiment of FIG. **3**.

[0020] FIG. **5**E is a cross-sectional view of the embodiment of FIG. **3** in an open position.

DETAILED DESCRIPTION OF EMBODIMENTS

[0021] An apparatus and method for hydraulic fracturing are provided herein.

[0022] Referring to FIG. **1** and FIG. **2**, a well **2** is shown from a side elevation view where service/completion string **4** is downhole and proximate formation **6**. Fracing fluid **8** can be pumped downhole through service/completion string **4** to fracing apparatus **10**. Apparatus **10** can then release pressurised fracing fluid **8** to fracture formation **6** as shown in FIG. **2**B.

[0023] Referring now to FIG. **3**, apparatus **10** is shown comprising a main body **12** with a top connector **14** and a bottom connector **16**. Top and bottom as used herein are relative term and it would be understood by one skilled in the art that the orientation could be inverted without detracting from the function of apparatus. Similarly, top and bottom can be interchanged with terms such as left and right, or upstream and downstream, as required by the context of apparatus **10**. The main body **12** can be tubular as to allow a fluid connection with a service/completion sting **4** and allow fracing (or other fluid) to pass through body **12**.

[0024] Main body **12** can include one or more burst ports **17** which can be configured to receive a burst plug **18** and burst plug **18** can be disposed within burst ports **17** to initially block fluid flow through burst ports **17**. It would be understood that burst plug **18** could also be called a burst disk or a burst insert. In some embodiments, burst plug **18** can be positioned towards the interior of, and blocking the opening of burst port **17**. Retention means, such as a burst plug retainer **20** (such as a snap ring as shown in FIG. **5**B) and/or a seal **22** can be used to hold burst plug **18** in place.

[0025] An additional shield **24** can also be used to cover burst port **17**. In some embodiments, shield **24** can be a thin aluminum shield, although it would be understood that other suitable materials could be used. In some embodiments, shield **24** can be positioned towards the exterior of the opening of burst port **17**. In some embodiments, a void can be defined therewithin, for example the void can be defined between the shield **24** and burst plug **18**. Like burst plug **18**, shield **24** can provide additional blocking function to prevent debris and other substances from blocking burst port **17**. In some cases, shield **24** can block cement and other debris from entering burst port **17**. In some embodiments, shield **24** can be vented to provide a means of equalizing pressure between the void and an annulus formed between the tubular member and the wellbore. In some embodiments, the void can be filed with a substance (such as a gel or grease) for resisting entry of a wellbore fluid (such as cement) thereinto through the hole. Shield **24** can prevent the gel or grease in that void from escaping.

[0026] In some embodiments, burst plug **18** can be burst plugs as described in U.S. 61/921,254, incorporated by reference herein in its entirety. In these embodiments, burst plug **18** does not require an atmospheric chamber or a core that disengages. It would also be appreciated that other burst plug types and designs as known in the art could be used without detracting from function of apparatus **10**.

[0027] Referring back to FIG. **3**, in some embodiments, apparatus **10** can comprise and upper housing **30** and a lower housing **32**. Apparatus **10** can also comprise flow-ports **34** downstream of burst ports **17**. In some embodiments, flow-ports **34** can be larger in diameter than burst ports **17**, in some cases being approximately twice as large. In some embodiments, the diameter of flow-ports **34** can be choked in order to limit fluid flow out of the flow-port or to create a jetting effect.

[0028] In some embodiments, the void in flow-ports **34** can be filled with grease and shield **24** can be placed there (loosely fitting) to prevent the grease from leaking out. At least one fluid fill plug **38** can also be included in apparatus **10**. In some embodiments, apparatus **10** can also include shear pins **36** and a groove on shift sleeve **40** to receive shear pin **36**.

[0029] FIG. **4** depicts a movable inner shift sleeve **40** disposed within upper housing **30**. Seals **22** can be used around sleeve **40**. Sleeve **40** can be slidable between at least two positions, a first position where flow ports **34** are blocked and a second position where flow ports **34** are opened/exposed to allow fluid communication (for the flow of pressurised frac fluid **8**, as an example) between the inside of the tubular apparatus **10** and the external of apparatus **10**. In some embodiments, a "C" snap ring **42** can also be used as a means for locking sleeve **40** in a predetermined position.

[0030] A fluid compartment **44** can also be positioned between sleeve **40** and upper housing **30**. Prior to operation, fluid compartment **44** can be filled with a fluid through fluid fill plug **38**. In some embodiments, fluid compartment **44** can be filled with an incompressible fluid, such as oil although it would be understood that other fluids could accomplish the same function. The incompressible fluid in compartment **44** can be configured to act as a media to transfer uphole pressure, applied by pressurised fracing fluid

8 to inner sleeve **40**, to the burst plug **18**. Burst plug **18** can be configured to be a releasing mechanism that can burst open at a threshold pressure level, for example approximately 3000-3500 psi. The incompressible fluid is then allowed to exit through opened burst port **17** leaving an empty compartment **44**, and in turn, allow the inner sleeve to shift into the second position to expose flow-ports **34**.

[0031] In operation, and referring to FIGS. **5**A to **5**D, apparatus **10** can use sleeve **40** to cover otherwise unblocked flow-ports **34** and to shift sleeve **40** and expose multiple flow-ports **34** simultaneously. When fluid pressure is increased inside of apparatus **10**, sleeve **40** tries to shift upstream due to a pressure differential that can be created by the seals positioned at different diameters. In some embodiments, shift sleeve **40** can have a larger diameter, for example an approximately 4.875" diameter, at the point where shift sleeve **40** is proximate flow ports **34**, and shift sleeve **40** can have a smaller diameter, for example an approximately 4.375" diameter where the shift sleeve **40** is proximate seals **22** and burst ports **17**. As would be understood, Pressure=Force/Area or F=Pressure*Area; thus a larger area can result is a greater force that can push the sleeve **40** uphole/upstream.

[0032] In turn, such an uphole/upstream shift can thereby put pressure on fluid compartment **44**; which in turn can put pressure on burst plug **18**. Once a predetermined threshold pressure, for example approximately 3000-3500 psi is reached, burst plug **18** can burst allowing the escape of the incompressible fluid (for example, oil). Upstream movement of the shift sleeve **40** can then be allowed, exposing flow-ports **34** and allowing pressurized fracing fluid **8** to exit apparatus **10** to fracture formation **6**. See FIG. **5**E for example.

[0033] In embodiments using shear pins **36**, once a predetermined threshold pressure, for example approximately 3000-3500 psi is reached, shear pins **36** can shear and burst plug **18** can burst allowing the escape of the incompressible fluid (for example, oil). In some embodiments, the predetermined threshold pressure, for example approximately 3000-3500 psi, can be set by a combination of both of the threshold pressures of shear pins **36** and burst plug **18**.

[0034] The volume of incompressible fluid can be very small, allowing for burst plug **18** to be a debris barrier to prevent anything from getting into fluid compartment **44** and preventing the shifting of sleeve **40**.

[0035] Prior art sleeve systems have not been greatly successful because a "differential" chamber with a vent hole was required in order to make the sleeve shift due to pressure. A problem with vent holes is that they are prone to being obstructed by debris, especially during cementing operations. As such, the apparatus and methods of the present disclosure still burst the tool open, but instead of actually releasing frac fluid and fracing through the burst ports **17**, burst ports **17** can be used as an activation feature to open/expose the flow ports **34**.

[0036] As such, burst plug **18** can be used in burst ports **17** for at least two reasons. The first, in a closed, un-burst configuration, is to act as a barrier and to prevent the debris from entering the compartment **44** and preventing proper function of apparatus **10**. Secondly, burst plug **18** can be configured during manufacture or otherwise to be burst in response to a predetermined pressure. This predetermined pressure can therefore be the threshold activation value of apparatus **10** as when burst plug **18** bursts into an open configuration, the oil is allowed to escape compartment **44** and sleeve **40** is able to shift upstream to expose flow ports **34**. Pressurized fracture fluid is then able to flow through the opened flow-port to contact the formation in order to fracture the formation in the well.

[0037] Although a few embodiments have been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention. The terms and expressions used in the preceding specification have been used herein as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding equivalents of the features shown and described or portions thereof, it being recognized that the invention is defined and limited only by the claims that follow.

1. A hydraulic fracturing apparatus for perforating a subterranean formation, the apparatus comprising:

a tubular body configured to be fluidly connected in-line with a completion string having an upstream and a downstream, the tubular body having at least one burst port, the at least one burst port configured to receive a burst plug;

a movable inner sleeve within the tubular body that can slide along the inside of the tubular body from a first position to a second position when exposed to hydraulic pressure, and

at least one flow-port in the tubular body that is blocked when the movable inner sleeve is in the first position and opened when the movable inner sleeve slides to the second position.

2. The apparatus of claim **1**, further comprising a burst plug disposed within the at least one burst port, the burst plug configured to burst at a predetermined pressure threshold.

3. The apparatus of claim **1**, wherein the at least one flow port is spaced away from the at least one burst port.

4. The apparatus of claim **1**, further comprising a fluid compartment in fluid communication with the at least one burst port, the fluid compartment configured to receive an incompressible fluid.

5. The apparatus of claim **4**, wherein the movable inner sleeve abuts the fluid compartment.

6. The apparatus of claim **5**, wherein the burst plug disposed within the at least one burst port is configured to burst open in response to pressure transferred from the movable inner sleeve through the incompressible fluid to the burst plug.

7. The apparatus of claim **6**, wherein the movable inner sleeve is configured to move to its second position in response to pressure.

8. The apparatus of claim **4**, wherein the incompressible fluid is oil.

9. The apparatus of claim **1**, further comprising a locking means to lock the movable inner sleeve at a predetermined position within the tubular body.

10. The apparatus of claim **9**, wherein the predetermined position of the movable inner sleeve is the second position.

11. The apparatus of claim **9** wherein the locking means comprises a C snap ring and a corresponding groove.

12. The apparatus of claim **1**, wherein the at least one burst port is configured to receive a shield.

13. The apparatus of claim **1**, wherein the at least one flow-port is configured to receive a shield.

14. The apparatus of claim **1**, wherein the at least one flow-port is larger in diameter than the at least one burst port.

15. The apparatus of claim **14**, wherein the at least one flow-port is approximately twice as large in diameter than the at least one burst port.

16. The apparatus of claim **1**, wherein the at least one flow-port has a diameter that is choked in order to limit fluid flow out of the flow-port or to create a jetting effect.

17. A method of hydraulic fracturing a formation in a well, the method comprising the steps of:

providing the apparatus of claim **1**;

supplying pressurized fracture fluid to the apparatus;

sliding the movable inner sleeve into the second position;

opening the at least one flow-port;

allowing the pressurized fracture fluid to flow through the flow-port to contact the formation; and

fracturing the formation in the well.

* * * * *