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(54) Title: SCREEN FLOW EQUALIZATION SYSTEM

(57) Abstract: An assembly of inflow control devices on a string along with isolation devices can be delivered into an existing or newly delivered screen assembly that requires inflow control for balanced flow from the formation. In newly delivered screen assemblies, any gravel packing that needs to be done can be accomplished without the presence of the inflow devices for faster circulation and improved gravel deposition. External annular barriers can also be delivered with an original screen assembly in a new well installation. The inflow devices and barriers can be of a variety of designs and the internal string can be removable if the barriers are retrievable to facilitate further drilling or completion below the screen assembly.



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APPLICATION FOR PATENT

Title: Screen Flow Equalization System

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FIELD OF THE INVENTION

[0001] The field of the invention is control of flow through screen sections either newly run or retrofit in existing wells by using internal flow control devices on an inner string separated by barriers within the screen and optionally for new installations additional external annular barriers.

BACKGROUND OF THE INVENTION

[0002] Formations with long production intervals frequently provide an of imbalance of the incoming flow along the interval that leads to problems with water coning or other water production challenges, and also production of other undesirable fluids. Prior solutions have included balancing the flow along a long production interval with a plurality of inflow control devices, which may be designed, tuned, or manipulated to segment and distribute the inflow across the production interval to improve the inflow characteristics. Typically these devices have been integrated into an assembly including sand screen systems.

[0003] Inflow control devices in the past were incorporated within sand screen systems which included a blank non-perforated base pipe with a screen mounted to it and sealed at opposed ends to define an annular space between the base pipe and the screen surrounding it with an inflow control device provided in fluid communication with both the main bore of the production tubing and this annular space to control the fluid inflow profile of fluids produced through that screen section, into the annular space, and into the production tubing. The produced fluid would flow along the base pipe and inside the screen to an inflow control device (ICD) which in the case of the Equalizer® inflow control device sold by Baker Oil Tools included a spiral flow path whose resistance to a given flow rate could be designed to be higher in one location along the production interval or lower in another. Thus, any number of ICDs could be provided along a long production interval with zonal isolation between the segments including an ICD to segment and isolate the flow characteristics as desired to balance the production of fluid and prevent undesired production complications such as water coning or the like. The operation of an ICD in this manner is well understood throughout the oil & gas completions

industry, and for a given screen section, the flow would travel through the ICD and enter another annular space with a hole or holes in the base pipe and from there all flows from a collection of isolated screen sections would enter the base pipe and be conducted to the surface through a tubing string. Some examples of screen assembly flow control and balancing systems are illustrated in the following patents:

- 7,413,022 Expandable flow control device;
- 7,409,999 Downhole inflow control device with shut-off feature;
- 7,290,606 Inflow control device with passive shut-off feature;
- 6,192,983 Coiled tubing strings and installation methods;
- 6,112,817 Flow control apparatus and methods;
- 6,082,454 Spooled coiled tubing strings for use in wellbores; and
- 5,896,928 Flow restriction device for use in producing wells.

[0004] There are limitations to the integrated designs of screens with inflow control devices described above. One limitation is the ICDs limit the ability to circulate gravel packing slurries when trying to do a gravel pack on an assembly of screen sections. Another limitation is that for existing installations that have an assembly of screen sections, there is no way to use the above described integrated screen with ICD to retrofit an existing screened well without running in a second screen assembly inside the existing assembly, assuming space permits. Doing so would greatly reduce flow altogether and create a new problem when trying to solve the problem of maldistribution. Still further, the close tolerances in the screen annulus between the screen and base pipe of conventional systems limits applicability of ICD usage for highly viscous or heavy oil production.

[0005] The present invention is directed at the limitations described above and focuses on decoupling the integration of the ICD from the primary sand screen assembly and separating the ICDs from that screen assembly so that, for example, a retrofit of an existing screen assembly can be done to provide flow balancing to a screen assembly already in the hole; or so that the annular space along which axial flow occurs can be spaced as desired limited only by the

isolation capabilities of a particular zonal isolation device between isolated sections. This is accomplished by locating a plurality of ICDs on a separate inner string separated from one another by zonal isolation devices. The ICDs and the isolation devices can be of a variety of types. The isolation devices are preferably but not necessarily interventionless and allowed to set themselves downhole, and the zones of interest can be adjacent or separated by blank pipe. In that manner, an existing screen assembly without ICDs can be retrofitted for balanced flow to eliminate the issues relating to flow imbalance described above.

[0006] In new installations, ordinary screens with optional external annulus barriers can be run in first and if needed, gravel packed without limits to circulation normally posed by the presence of screens integrated with ICDs and the lack of perforated base pipe along the production interval for taking circulation returns. After gravel packing, if required, the internal string is run in with the ICDs the same as if the installation were a retrofit operation described above. The internal zonal isolation barriers straddle the ICDs to define discrete zones within the screen sections. The zonal isolation barriers outside the screen can be self actuating packers such as swelling packers. Alternatively, either the outer string with the sand screen or the inner string with the ICDs (or both) can have ball seats and spaced seals around a port that communicated to the external seals to set them. The internal barriers can be retrievable to allow the string with the ICDs to be pulled from inside the screens to facilitate drilling or workover further downhole or to permit replacement of ICDs as production profiles change during the life of a well. These and other advantages of the present invention will be more apparent to those skilled in the art from a review of the description of the preferred embodiment and the associated drawings below while understanding that the full scope of the invention is to be determined from the claims appended below.

SUMMARY OF THE INVENTION

[0007] A tubing conveyed assembly of retrievable or non-retrievable inflow control devices on a tubing string along with isolation devices can be delivered into an existing or newly delivered screen assembly that requires inflow control for balanced flow from the formation. In newly delivered screen assemblies, any gravel packing that needs to be done can be accomplished without the presence of the inflow devices and with conventionally perforated base pipe for faster circulation and improved gravel deposition. External annular barriers can also be

delivered with an original screen assembly in a new well installation. The inflow devices and barriers can be of a variety of designs and the internal string can be removable if the barriers are retrievable to facilitate further drilling or completion below the screen assembly.

[0008] In one aspect, an embodiment of the invention can include a wellbore completion system, comprising an outer string including a plurality of perforated base pipe joints. A plurality of such joints may be perforated and open to flow of reservoir fluid from an annulus between the screen joints and a production zone of a reservoir; an inner inflow control string may be provided within the screen joints. The inner string may include at least a plurality of zonal isolation devices disposed along a string of non-perforated base pipe to control the flow of fluid along the inner string within an annulus between the inner and outer strings; and at least one inflow control device may be provided between at least two of the zonal isolation devices to control the inflow flow of fluid into the inner inflow control string.

[0009] In another aspect, an embodiment of the invention can include a method of gravel packing a well, comprising the steps of: providing an outer string including a plurality of perforated base pipe joints, wherein a plurality of such joints are perforated and open to flow of reservoir fluid from an annulus between the screen joints and a production zone of a reservoir; providing a gravel pack work string within the outer string; pumping a gravel slurry through the work string to deposit the gravel slurry within an annulus between the outer string and a wall of a wellbore; removing the work string from the outer string; providing an inner inflow control string within the outer string, the inner string including: at least a plurality of zonal isolation devices disposed along a string of non-perforated base pipe to control the flow of fluid along the inner string within an annulus between the inner and outer strings; and wherein at least one inflow control device between at least two of the zonal isolation devices to control the inflow flow of fluid into the inner inflow control string.

[0010] In yet another aspect of the invention, an inflow control system can provide inflow control to an existing completion having existing permanently deployed perforated base pipe. The system may comprise an inner inflow control string within the outer string, the inner string, and may include at least a plurality of zonal isolation devices disposed along a string of non-perforated base pipe to control the flow of fluid along the inner string within an annulus between the inner and outer strings. At least one inflow control device may be provided between

at least two of the zonal isolation devices to control the inflow flow of fluid into the inner inflow control string, and the inner inflow control string adapted to be deposited and deployed within the existing permanently deployed perforated base pipe.

[0011] In a further aspect, the invention may be directed to a method of remediating an existing well completion, which includes an existing perforated base pipe. In such an embodiment, an inner inflow control string may be provided within the outer string, wherein the inner string includes at least a plurality of zonal isolation devices disposed along a string of non-perforated base pipe to control the flow of fluid along the inner string within an annulus between the inner and outer strings. In such an embodiment, at least one inflow control device could be provided between at least two of the zonal isolation devices to control the inflow flow of fluid into the inner inflow control string.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a retrofit assembly for an existing screen assembly to provide flow balancing capability;

[0013] FIG. 2 is a new installation of a screen assembly with external annulus isolators and a series of inflow control devices delivered on an internal string with barriers to separate the inflow devices within the string assembly;

[0014] FIG. 3 is a section view of a portion of an outer screen assembly with the portion of the inner string assembly between two isolators installed in it.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] A pipe joint as used herein includes a section of interest along a continuous string of coiled tubing or other tubular goods and is not intended to be limited to threaded oil country tubular goods ("OCTG"). A stand is intended to mean a given length of interest of a tubular, and is not limited to any particular size or length or configuration of such tubulars. Perforated can include holes or other apertures, or any size and shape or configuration of slots or other openings designed to permit flow therethrough. An inflow control device some examples of which are a tortuous path, an orifice or other opening or path designed to limit or moderate flow at a desired rate of inflow in one zone of interest with respect to another zone of interest.

[0016] Referring to FIG. 1 a wellbore 10 which can be open hole or cased hole has a series of screen sections 12, 14, 16 and 18 joined together to make an assembly 20. Although no

blank pipe sections are illustrated in assembly 20 it is within the scope of the invention to use such blank pipe. An annular space 22 is defined between the assembly 20 and the wellbore 10. Incoming flow from the formation 10 is represented by arrows 24. That same flow enters the annulus 22 and flows along that annulus 22 as indicated by arrows 26. The annular space 22 may have been gravel packed (not shown). In the retrofit embodiment of the invention, the above described structures are in the wellbore and the screen assembly has no devices for balancing the incoming flow but production of water or the need to isolate a zone or zones that are producing undesired fluids is needed. In this embodiment of the invention, an inner string 28 that comprises preferably a plurality of inflow control devices (ICD) 30 that preferably differ in the offered resistance to a predetermined flow rate of a given fluid is run into position in the screen assembly 20. Each ICD allows flow into the inner string 28 as indicated by arrows 32. Isolation devices 34 preferably straddle the ICDs 30 internal to the assembly while it is possible that the topmost and lowermost ICDs may only have an isolation device on one side. It is also possible that some pairs of adjacent isolators 34 will have no ICDs. Zones of the assembly that need to be isolated will not have an ICD on inner string 28, for example. If the assembly 20 has blank pipe then the string 28 may also contain no ICDs 30 in the inner string 28 for proper spacing out of the ICDs 30 to be adjacent to a portion of the outer string assembly 20 that has screen sections.

[0017] Those skilled in the art will realize that the inner string 28 can have any number of ICDs 30 where adjacent ICDs 30 are separated by an isolator 34. The isolators 34 can be any style and can be permanent or retrievable. They can be swelling packers, mechanically set, hydraulically set or inflatables to name some possibilities. The ICDs 30 can be of a variety of types. They can be tortuous paths or orifices to name a few possibilities. They can be sensitive to density or other parameters to detect water or other undesirable fluid production and shut off. They can be selectively opened or closed and put into positions in between with tools run in from the surface or with locally associated valve and operators that can be operated by control line, wireline or by remote operation from the surface such as with acoustic signals or by a sonde delivered to the proximity of a given ICD 30 to move it fully open or closed or positions in between mechanically or by communicating to a locally mounted processor to trigger motor operation to reconfigure the ICD 30. If the barriers 34 are retrievable, the entire assembly of the string 28 with the ICDs 30 and barriers 34 can be pulled as an assembly to facilitate access for

further drilling or to complete a previously drilled portion of the well or laterals exiting from a main bore.

[0018] Those skilled in the art will now appreciate that an existing well bore having a screen assembly 20 that is made up of a series of perforated base pipes covered by a screen material that have no means for flow balancing in a given zone can be retrofitted with an interior flow control string 28 that at minimum has one ICD 30 and one barrier 34 for subdividing the existing assembly of the outer screen 20 so that flow can be balanced and even adjusted automatically or by surface intervention to change the flow regime through the assembly 20.

[0019] FIG. 2 is directed to a new completion and is virtually identical to FIG. 1 in all respects from an equipment standpoint except for the external isolators 36 placed between adjacent screen stands such as 14'. The method of use differs from FIG. 1 in that the assembly 20' is first run in with the external isolators 36 to the zone or zones in question. An optional gravel pack can take place outside the assembly 20' using known techniques with a crossover tool such that some or all of the annulus 22' can be filled. At this time the inner string 28' is not inside the assembly 20' so that the ICDs 30 do not restrict fluid circulation for the gravel pack and are not exposed to gravel erosion from the circulating fluid that is used to deposit the gravel. As a result a better gravel packing can be accomplished in less time than using a screen assembly with integrated ICDs known in the prior art.

[0020] After the gravel packing equipment is removed the inner string assembly 28' as previously described can be run in. The external isolators 36 can be set in a variety of ways after the gravel pack if one is required. The isolators 36 can set by swelling after a time exposure to well fluids or by introduction of well fluids from the surface that trigger the isolators 36 to set. The setting can be mechanical, hydraulic, hydrostatic or with a straddle tool to selectively actuate each isolator 36 in a desired order. For example a space between two isolators 36 can be gravel packed and an adjacent isolator 36 can be set before an adjacent annular zone 22' is gravel packed. With a straddle tool the preferred isolator style is an inflatable.

[0021] Alternatively, the inner assembly 28' can spaced seals with a port in between that can straddle a fill port for a given isolator 36 so that the isolators 36 can be set using the inner assembly 28' such as for example with a series of seats to accommodate different size balls for sequential setting of the isolators 36 with inner string 28'.

[0022] In the preferred embodiment, the isolators 36 create discrete zones within the annular space 22' while the isolators 34' create preferably aligned zones in annulus 38 between the inner assembly 28' and the outer screen assembly 20'. For example zones 40 and 42 are axially aligned. The isolators 36 and 34' are also axially aligned but offsets between such isolator pairs are contemplated.

[0023] While the assembly 20 or 20' is referred to as a screen assembly it is intended to encompass perforated pipe as well as a base pipe that has openings with a mesh or other type of overlay of a filtering device.

[0024] FIG. 3 illustrates a known screen 100 mounted over a perforated base pipe 102 with end seals 104 and 106. This assembly is a part of what has been referred to as screen assembly 20 or 20'. A portion of the inner tubular 28 or 28' has the inflow control device 30 between isolators or barriers 34.

[0025] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below:

We claim:

1. A flow distribution assembly for a screen assembly located downhole, comprising:
an inner tubular string assembly comprising at least one inflow control device and at least one isolator, said isolator selectively actuated into contact with the screen assembly when said inner tubular string is inserted downhole into the screen assembly to define at least two flow zones through which fluid flow is balanced.
2. The assembly of claim 1, wherein:
said at least one isolator comprises at least two isolators disposed on opposed ends of said inflow control device.
3. The assembly of claim 2, wherein:
said at least one flow control device comprises a plurality of flow control devices with each pair of flow control devices having an isolator between them.
4. The assembly of claim 3, wherein:
said flow control devices have differing resistance to the same flow rate of a predetermined fluid.
5. The assembly of claim 2, wherein:
said at least two isolators comprises a plurality of isolators with at least on pair of adjacent isolators not having an inflow control device between them.
6. The assembly of claim 4, wherein:
said isolators are retrievable to allow removal of said inner tubular string to facilitate access to the wellbore past said screen assembly.
7. The assembly of claim 1, wherein:
said isolator comprises a swelling packer.
8. The assembly of claim 4, wherein:
said isolator comprises a swelling packer.
9. An assembly for balancing flow from a formation, comprising:
an outer screen assembly defining an outer annulus between itself and a wellbore;
an inner tubular string assembly comprising at least one inflow control device and at least one inner isolator, said inner isolator selectively actuated into contact with the screen assembly when said inner tubular string is inserted downhole into the screen assembly to define at least

two flow zones through which fluid flow is balanced, said inner tubular string assembly defining an inner annulus between itself and said outer screen assembly in which said isolator is disposed.

10. The assembly of claim 9, further comprising:

at least one external isolator disposed in said outer annulus.

11. The assembly of claim 10, wherein:

said inner and outer isolators are axially aligned.

12. The assembly of claim 10, wherein:

said inner and outer isolators are not axially aligned.

13. The assembly of claim 10, wherein:

said external isolator comprises a swelling packer.

14. The assembly of claim 9, wherein:

said at least one isolator comprises at least two isolators disposed on opposed ends of said inflow control device.

15. The assembly of claim 14, wherein:

said at least one flow control device comprises a plurality of flow control devices with each pair of flow control devices having an isolator between them.

16. The assembly of claim 15, wherein:

said flow control devices have differing resistance to the same flow rate of a predetermined fluid.

17. The assembly of claim 14, wherein:

said at least two isolators comprises a plurality of isolators with at least on pair of adjacent isolators not having an inflow control device between them.

18. The assembly of claim 16, wherein:

said isolators are retrievable to allow removal of said inner tubular string to facilitate access to the wellbore past said screen assembly.

19. The assembly of claim 9, wherein:

said isolator comprises a swelling packer.

20. The assembly of claim 16, wherein:

said isolator comprises a swelling packer.

21. The assembly of claim 16, wherein:

said at least one external isolator comprises a plurality of spaced isolators and said at least one internal isolator comprises a plurality of internal isolators, said internal and external isolators closest to each other are either axially aligned or misaligned with each other.

22. The assembly of claim 21, wherein:

said outer annulus contains gravel between at least one pair of said outer isolators.

23. A completion method for downhole use, comprising:

providing an outer screen assembly in a wellbore to define an outer annulus;

inserting an inner assembly of a tubular string and at least one inflow control device and at least one internal isolator into the outer assembly that is already in the wellbore to define an inner annulus between said assemblies;

actuating the internal isolator into contact with the outer assembly;

defining by said internal isolator actuation a plurality of zones through the outer screen assembly for flow balancing therethrough.

24. The method of claim 23, comprising:

gravel packing the outer annulus before inserting said inner assembly.

25. The method of claim 23, comprising:

providing at least one external isolator in said outer annulus.

26. The method of claim 24, comprising:

setting said external isolator with swelling.

27. The method of claim 23, comprising:

setting said internal isolator with swelling.

28. The method of claim 24, comprising:

providing at least one external isolator in said outer annulus;

setting said external isolator after said gravel packing.

29. The method of claim 28, comprising:

using a swelling packer for said external isolator.

30. The method of claim 23, comprising:

providing, on said inner assembly, a plurality of spaced inflow control devices separated from each other with a plurality of internal isolators.

31. The method of claim 30, comprising:
providing different resistance to a given flow of a predetermined fluid among said inflow control devices.
32. The method of claim 25, comprising:
setting said external isolator with said inner assembly.
33. The method of claim 23, comprising:
making said internal isolator retrievable;
unsetting said internal isolator;
pulling the inner assembly out of said outer screen assembly;
conducting downhole operations beyond said outer screen assembly.

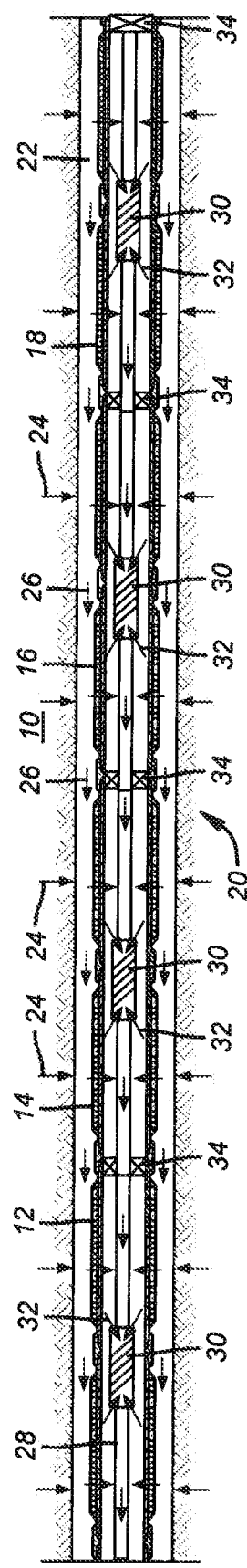


FIG. 1

1/2

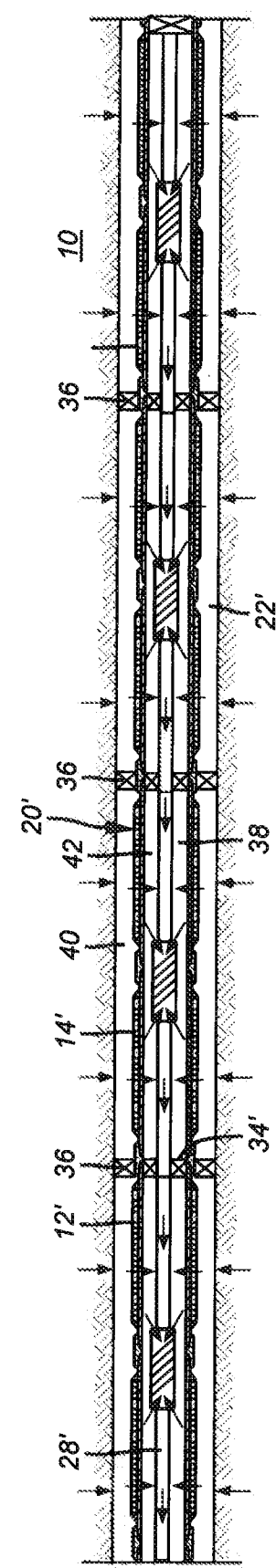


FIG. 2

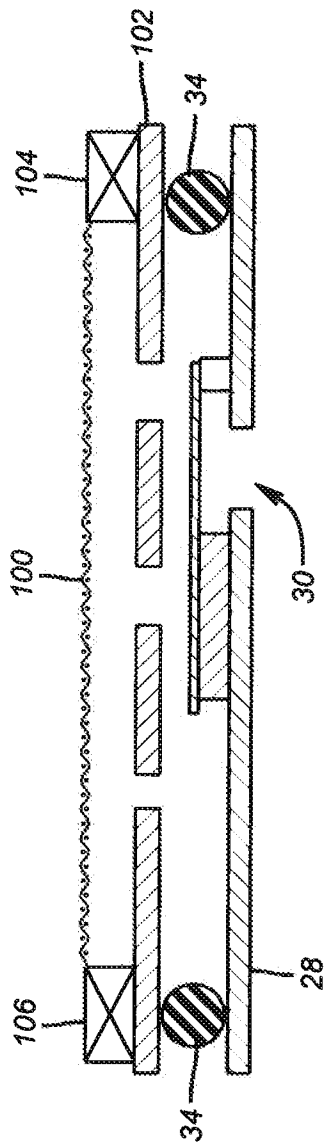


FIG. 3