

DOWNHOLE FLUID FLOW CONTROL SYSTEM AND METHOD HAVING AUTONOMOUS CLOSURE

TECHNICAL FIELD OF THE DISCLOSURE

[0001] This disclosure relates, in general, to equipment utilized in conjunction with operations performed in subterranean wells and, in particular, to a downhole fluid flow control system and method having autonomous closure for controlling the inflow of an undesired production fluid.

BACKGROUND OF THE DISCLOSURE

[0002] Without limiting the scope of the present disclosure, its background will be described with reference to producing fluid from an unconsolidated or loosely consolidated hydrocarbon bearing subterranean formation, as an example.

[0003] During the completion of a well that traverses a hydrocarbon bearing subterranean formation, production tubing and various completion equipment are installed in the well to enable safe and efficient production of the formation fluids. For example, to prevent the production of particulate material from an unconsolidated or loosely consolidated subterranean formation, certain completions include one or more sand control screen assemblies positioned proximate the desired production interval or intervals. In other completions, to control the flowrate and/or composition of production fluids into the production tubing, it is common practice to install one or more flow control devices within the tubing string.

[0004] Attempts have been made to utilize fluid flow control devices within completions requiring sand control. For example, in certain sand control screen assemblies, after production fluids flow through the filter medium, the fluids are directed into a flow control section. The flow control section may include one or more flow control components such as flow tubes, nozzles, labyrinths or the like. Typically, the production flowrate through these flow control screens is substantially fixed prior to installation by the number and design of the flow control components.

[0005] It has been found, however, that due to changes in formation pressure and changes in formation fluid composition over the life of the well, it may be desirable to adjust the flow control characteristics of the flow control sections. In addition, for certain

completions, such as long horizontal completions having numerous production intervals, it may be desirable to independently control the inflow of production fluids into each of the production intervals. Further, in some completions, it would be desirable to adjust the flow control characteristics of the flow control sections without the requirement for well intervention.

[0006] Accordingly, a need has arisen for a flow control screen that is operable to control the inflow of formation fluids in a completion requiring sand control. A need has also arisen for flow control screens that are operable to independently control the inflow of production fluids from multiple production intervals. Further, a need has arisen for such flow control screens that are operable to control the inflow of production fluids without the requirement for well intervention as the composition of the fluids produced into specific intervals changes over time.

SUMMARY

[0006a] According to a first aspect of the present invention, there is provided a downhole fluid flow control system comprising: a flow control assembly having a fluid flow path for a flowing fluid; a first flow control component disposed in the fluid flow path having a positive flowrate response to decreasing fluid viscosity; a second flow control component disposed in the fluid flow path in parallel with the first flow control component having a negative flowrate response to decreasing fluid viscosity; and a valve disposed in the fluid flow path in series with and downstream of the first and second flow control components, the valve having a first inlet path for fluid from the first flow control component and a second inlet path for fluid from the second flow control component, wherein the valve comprises a valve seat, a plug and a magnet, and wherein the magnet supports the plug remote from the valve seat when the valve is in the open position; wherein, decreasing the fluid viscosity of the flowing fluid increases a ratio of the flowrate through the first control component to the flowrate through the second flow control component; and wherein, when the ratio reaches a predetermined level, the valve autonomously shifts from an open position to a closed position.

[0006b] According to a second aspect of the present invention, there is provided a flow control screen comprising: a base pipe with an internal passageway; a filter medium positioned around the base pipe; a housing positioned around the base pipe defining

a fluid passageway between the filter medium and the internal passageway; a flow control assembly positioned in the fluid passageway, the flow control assembly having a fluid flow path for a flowing fluid; a first flow control component disposed in the fluid flow path having a positive flowrate response to decreasing fluid viscosity; a second flow control component disposed in the fluid flow path in parallel with the first flow control component having a negative flowrate response to decreasing fluid viscosity; and a valve disposed in the fluid flow path in series with and downstream of the first and second flow control components, the valve having a first inlet path for fluid from the first flow control component and a second inlet path for fluid from the second flow control component, wherein the valve comprises a valve seat, a plug and a magnet, and wherein the magnet supports the plug remote from the valve seat when the valve is in the open position; wherein, decreasing the fluid viscosity of the flowing fluid increases a ratio of the flowrate through the first control component to the flowrate through the second flow control component; and wherein, when the ratio reaches a predetermined level, the valve autonomously shifts from an open position to a closed position.

[0006c] According to a third aspect of the present invention, there is provided a downhole fluid flow control method comprising: positioning a fluid flow control system at a target location downhole, the fluid flow control system including a flow control assembly having a fluid flow path for a flowing fluid, first and second flow control components disposed in parallel in the fluid flow path, the first flow control component having a positive flowrate response to decreasing fluid viscosity and the second flow control component having a negative flowrate response to decreasing fluid viscosity and a valve disposed in the fluid flow path in series with and downstream of the first and second flow control components, the valve having first and second inlet paths for fluid from the first and second flow control components, respectively; maintaining the valve in the open position by magnetically supporting a plug remote from a valve seat of the valve; flowing fluid through the fluid flow path of the flow control assembly through the first and second flow control components and the valve; decreasing the fluid viscosity of the flowing fluid; increasing a ratio of the flowrate through the first control component to the flowrate through the second flow control component; reaching a predetermined ratio of the flowrates; and autonomously shifting the valve from an open position to a closed position.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a more complete understanding of the features and advantages of the present disclosure, reference is now made to the detailed description along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0008] Figure 1 is a schematic illustration of a well system operating a plurality of flow control screens according to an embodiment of the present disclosure;

[0009] Figures 2A-2B are quarter sectional views of successive axial sections of a downhole fluid flow control system embodied in a flow control screen according to an embodiment of the present disclosure;

[0010] Figure 3 is a top view of a downhole fluid flow control system according to an embodiment of the present disclosure;

[0011] Figures 4A-4C are schematic illustration of various embodiments of flow control components having positive flowrate response to decreasing fluid viscosity for use in a downhole fluid flow control system according to an embodiment of the present disclosure;

[0012] Figures 5A-5C are schematic illustration of various embodiments of flow control components having negative flowrate response to decreasing fluid viscosity for use in a downhole fluid flow control system according to an embodiment of the present disclosure;

[0013] Figures 6A-6B are cross sectional views of an autonomous closure mechanism for use in a downhole fluid flow control system according to an embodiment of the present disclosure in its open and closed configurations, respectively; and

~~What is claimed is:~~ CLAIMS

1. A downhole fluid flow control system comprising:
 - a flow control assembly having a fluid flow path for a flowing fluid;
 - a first flow control component disposed in the fluid flow path having a positive flowrate response to decreasing fluid viscosity;
 - a second flow control component disposed in the fluid flow path in parallel with the first flow control component having a negative flowrate response to decreasing fluid viscosity; and
 - a valve disposed in the fluid flow path in series with and downstream of the first and second flow control components, the valve having a first inlet path for fluid from the first flow control component and a second inlet path for fluid from the second flow control component,

wherein the valve comprises a valve seat, a plug and a magnet, and wherein the magnet supports the plug remote from the valve seat when the valve is in the open position;

wherein, decreasing the fluid viscosity of the flowing fluid increases a ratio of the flowrate through the first control component to the flowrate through the second flow control component; and

wherein, when the ratio reaches a predetermined level, the valve autonomously shifts from an open position to a closed position.
2. The downhole fluid flow control system as recited in claim 1 wherein the first and second flow control components have viscosity dependent fluid flow resistance.
3. The downhole fluid flow control system as recited in claim 1 wherein the first flow control component is selected from the group consisting of nozzles, flow tubes, labyrinths and fluid selectors.
4. The downhole fluid flow control system as recited in claim 1 wherein the second flow control component is selected from the group consisting of vortex chambers, fluid selectors, fluid disrupters and fluid diodes.
5. ~~The downhole fluid flow control system as recited in claim 1 wherein the valve further comprises a valve seat, a plug and a magnet, and wherein the magnet supports the plug remote from the valve seat when the valve is in the open position.~~

65. The downhole fluid flow control system as recited in claim 51 wherein fluid flow into the first inlet path of the valve from the first flow control component biases the plug toward the valve seat and fluid flow into the second inlet path of the valve from the second flow control component biases the plug away from the valve seat.

76. The downhole fluid flow control system as recited in claim 1 wherein the first inlet path further comprises a plurality of first inlet openings and wherein the second inlet path further comprises a plurality of second inlet openings.

87. The downhole fluid flow control system as recited in claim 1 wherein fluid flow into the first inlet path of the valve from the first flow control component enters the valve in at least one substantially longitudinal direction and fluid flow into the second inlet path of the valve from the second flow control component enters the valve in at least one substantially radial direction.

98. A flow control screen comprising:

- a base pipe with an internal passageway;
- a filter medium positioned around the base pipe;
- a housing positioned around the base pipe defining a fluid passageway between the filter medium and the internal passageway;
- a flow control assembly positioned in the fluid passageway, the flow control assembly having a fluid flow path for a flowing fluid;
- a first flow control component disposed in the fluid flow path having a positive flowrate response to decreasing fluid viscosity;
- a second flow control component disposed in the fluid flow path in parallel with the first flow control component having a negative flowrate response to decreasing fluid viscosity; and
- a valve disposed in the fluid flow path in series with and downstream of the first and second flow control components, the valve having a first inlet path for fluid from the first flow control component and a second inlet path for fluid from the second flow control component,

wherein the valve comprises a valve seat, a plug and a magnet, and wherein the magnet supports the plug remote from the valve seat when the valve is in the open position;

wherein, decreasing the fluid viscosity of the flowing fluid increases a ratio of the flowrate through the first control component to the flowrate through the second flow control component; and

wherein, when the ratio reaches a predetermined level, the valve autonomously shifts from an open position to a closed position.

~~1409.~~ The flow control screen as recited in claim ~~98~~ wherein the first and second flow control components have viscosity dependent fluid flow resistance.

~~11.~~ ~~The flow control screen as recited in claim 9 wherein the valve further comprises a valve seat, a plug and a magnet, wherein the magnet supports the plug remote from the valve seat when the valve is in the open position.~~

~~14210.~~ The flow control screen as recited in claim ~~1418~~ wherein fluid flow into the first inlet path of the valve from the first flow control component biases the plug toward the valve seat and fluid flow into the second inlet path of the valve from the second flow control component biases the plug away from the valve seat.

~~14311.~~ The flow control screen as recited in claim ~~98~~ wherein the first inlet path further comprises a plurality of first inlet openings and wherein the second inlet path further comprises a plurality of second inlet openings.

~~14412.~~ The flow control screen as recited in claim ~~98~~ wherein fluid flow into the first inlet path of the valve from the first flow control component enters the valve in at least one substantially longitudinal direction and fluid flow into the second inlet path of the valve from the second flow control component enters the valve in at least one substantially radial direction.

~~14513.~~ A downhole fluid flow control method comprising:
positioning a fluid flow control system at a target location downhole, the fluid flow control system including a flow control assembly having a fluid flow path for a flowing fluid, first and second flow control components disposed in parallel in the fluid flow path, the first flow control component having a positive flowrate response to decreasing fluid viscosity and the second flow control component having a negative flowrate response to decreasing fluid

viscosity and a valve disposed in the fluid flow path in series with and downstream of the first and second flow control components, the valve having first and second inlet paths for fluid from the first and second flow control components, respectively;

maintaining the valve in the open position by magnetically supporting a plug remote from a valve seat of the valve;

flowing fluid through the fluid flow path of the flow control assembly through the first and second flow control components and the valve;

decreasing the fluid viscosity of the flowing fluid;

increasing a ratio of the flowrate through the first control component to the flowrate through the second flow control component;

reaching a predetermined ratio of the flowrates; and

autonomously shifting the valve from an open position to a closed position.

~~16~~14. The method as recited in claim ~~15~~13 wherein decreasing the fluid viscosity of the flowing fluid further comprises decreasing an oil to water ratio of the flowing fluid.

~~17. The method as recited in claim 15 further comprises maintaining the valve in the open position by magnetically supporting a plug remote from a valve seat of the valve.~~

~~18~~15. The method as recited in claim ~~17~~13 further comprising biasing the plug toward the valve seat responsive to fluid flow into the first inlet path of the valve from the first flow control component and biasing the plug away from the valve seat responsive to fluid flow into the second inlet path of the valve from the second flow control component.

~~19~~16. The method as recited in claim ~~15~~13 further comprising flowing fluid into a plurality of first inlet openings of the first inlet path and flowing fluid into a plurality of second inlet openings of the second inlet path.

~~20~~17. The method as recited in claim ~~15~~13 further comprising flowing fluid in at least one substantially longitudinal direction into the first inlet path of the valve from the first flow control component and flowing fluid in at least one substantially radial direction into the second inlet path of the valve from the second flow control component.