A well completion includes a downhole steam generator (DSG) having a water inlet and a discharge to convey a hot effluent away from the DSG, a stinger having an inner mandrel forming a stinger bore in communication with the discharge and an outer mandrel carrying a seal element, and a passage located between the inner mandrel and the outer mandrel to circulate a cooling fluid from an inlet port to an outlet port. The outlet port may be in communication with the water inlet of the DSG or the stinger bore.
THERMAL REGULATING WELL COMPLETION DEVICES AND METHODS

SUMMARY

[0001] A thermal regulating completion device in accordance to one or more embodiments includes an inner mandrel having an outer mandrel carrying a seal element, and a passage located between the inner and outer mandrels to circulate a cooling fluid between an inlet port and an outlet port. A completion in accordance to one or more embodiments includes a downhole steam generator (DSG) having a water inlet and a discharge to convey a hot effluent away from the DSG, a stinger having an inner mandrel forming a stinger bore in communication with the discharge and an outer mandrel carrying a seal element, and a passage located between the inner mandrel and the outer mandrel to circulate a cooling fluid from an inlet port to an outlet port. A method includes generating a hot effluent at a downhole steam generator, discharging the hot effluent through a bore of a stinger landed in a packer, and circulating water through a passage located proximate to the stinger seal.

[0002] The foregoing has outlined some of the features and technical advantages in order that the detailed description of thermal regulating well completion devices, systems and methods that follows may be better understood. Additional features and advantages of the thermal regulating well completion devices, systems and methods will be described hereinafter which form the subject of the claims of the invention. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Embodiments of thermal regulating well completion devices, systems and methods are described with reference to the following figures. The same numbers are used throughout the figures to reference like features and components. It is emphasized that, in accordance with standard practice in the industry, various features are not necessarily drawn to scale. In fact, the dimensions of various features may be arbitrarily increased or reduced for clarity of discussion.

[0004] FIG. 1 illustrates a well system and completion in which thermal regulating devices, systems and methods may be incorporated and utilized.

[0005] FIG. 2 illustrates a well system and completion in which thermal regulating devices, systems and methods may be incorporated and utilized.

[0006] FIG. 3 illustrates a thermal regulating device incorporated in a completion and discharging an outlet fluid to a downhole steam generator in accordance to one or more embodiments.

[0007] FIG. 4 illustrates a thermal regulating device incorporated in a completion and discharging an outlet fluid through a lower completion in accordance to one or more embodiments.

[0008] FIG. 5 illustrates a thermal regulating device incorporated in a completion having insulation and a cooling fluid passage in accordance to one or more embodiments.

[0009] FIG. 6 illustrates a well completion incorporating thermal regulating devices and methods in accordance to one or more embodiments.

DETAILED DESCRIPTION

[0010] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0011] As used herein, the terms “connect,” “connection,” “connected,” “in connection with,” and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements”; and the term “set” is used to mean “one element” or “more than one element”. Further, the terms “couple,” “coupling,” “coupled,” “coupled together,” and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements”. As used herein, the terms “up” and “down”; “upper” and “lower”; “top” and “bottom”; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements. Commonly, these terms relate to a reference point as the surface from which drilling operations are initiated as being the top point and the total depth being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface.

[0012] FIG. 1 illustrates a well system 5 having a completion 10 in which thermal regulating devices, systems and methods may be incorporated and utilized. A wellbore 12 extends from a surface 14 to a formation 16 which is in communication with wellbore 12. At least a portion of wellbore 12 may be lined with casing 18. Completion 10 is illustrated in FIG. 1 as a steam injection and production completion. The thermal regulating devices, systems and method are not limited to the completion illustrated in FIG. 1. Completion 10 includes a lower completion 20 installed downhole above formation 16 and an upper completion 22 deployed below wellhead 24 and landed in lower completion 20.

[0013] Lower completion 20 includes a packer 26 (i.e. production packer) having a polished bore receptacle (PBR) 28 and a tail pipe 30 extending below packer 26. Lower completion 20 may include an isolation device 32 such as a valve (i.e. flow control device) located in tail pipe 30 below packer 26. The thermal regulating devices, systems and methods may be utilized to protect temperature-sensitive components of the lower completion 20 (e.g. seal elements) from the downhole temperatures that may be elevated for example in response to hot effluent 74 (e.g., steam, gas, liquid) discharged from upper completion 22.

[0014] Upper completion 22 includes a downhole steam generator (DSG) 36 (e.g. combustor) that utilizes a fuel such as natural gas or methane, and air to convert water to a hot effluent 74, for example steam, for injection into formation 16. Upper completion 22 may include a control line 38 extending from the surface to one or more downhole devices. Control line 38 may be a cable, or umbilical, having more than one conduit for transmitting power and or signals. For example, control line 38 may include hydraulic conduits, electrical conductors, optic fibers and the like. Control line 38 is illustrated in FIG. 1 connecting a surface controller 40 with downhole steam generator 36. Control line 38 may be con-
nected for example to sensors, gauges, hydraulic and electrically operated flow control devices, and artificial lift devices (e.g. pumps). Controller 40 may include without limitation electronic circuits, processors, transmitters, receivers and power supplies (i.e. hydraulic, electric), and valves (valve manifolds).

[0015] Upper completion 22 is deployed in the wellbore on a tubing 42 extending from the wellhead to a stinger 44 (seal assembly, stabber assembly) which is landed in PBR 28 of lower completion 20. In accordance to one or more embodiments stinger 44 is configured as a thermal regulating device 44 to thermally regulate lower completion 20, including stinger seals 84. The systems and methods of the present disclosure can be used with any type of packer and with any type of lower completions component that may be sensitive to elevated temperatures. The thermal regulating systems and methods of the present disclosure distributes high-temperature fluids and low-temperature fluids as appropriate to protect such temperature-sensitive components and to efficiently selectively distribute thermal energy.

[0016] Upper completion 22 includes a Y-tool 76 at a top end that separates or splits a second or bypass conduit 78 from tubing 42. Bypass conduit 78 is connected back to or combined with tubing 42 downhole at a lower inverted Y-tool 46. Bypass 42 is connected to a thermal regulating stinger 44 below inverted Y-tool 46. The section of tubing 42 located between Y-tool 76 and inverted Y-tool 46 is referred to as continuous conduit 80 from time to time.

[0017] Downhole steam generator 36 is connected to bypass conduit 78 and it is in communication with air supply 60 or water supply 64 via tubing 42 to receive air or water during steaming operations. Hot effluent 74 (e.g. steam and flue gas) is discharged from DSG 36 into a section of bypass conduit 78 referred to as discharge 48. Discharge 48 of DSG 36 is connected to thermal regulating stinger 44 through inverted Y-tool 46. In accordance with some embodiments a valve 50 (e.g. check valve) is connected within steam discharge 48 between DSG 36 and inverted Y-tool 46 to prevent back flow into DSG 36 from below lower completion 20, e.g. formation fluid. Tubing 42 may include a include a barrier 52, for example a valve or nipple and plug, located in continuous conduit 80 to selectively close the conduit to divert supply fluid (i.e. water or air) to DSG 36 through bypass conduit 78. A plug 53 is illustrated in FIG. 1 landed in barrier 52 blocking tubing 42 in continuous conduit 80. Continuous conduit 80 can be blocked or closed for example during steam generating and injection operations so that a DSG operational fluid such as water or air can be supplied through tubing 42 into bypass conduit 78. During production operations tubing 42 is opened so that formation fluid 72 can be produced to the surface.

[0018] Upper completion 22 includes a fuel supply tubing 54 in communication between DSG 36 and a fuel supply 56 (e.g. natural gas, methane, hydrogen, etc.) located at the surface. Fuel supply 56 may include a compressor. Air is communicated to DSG 36 from air supply 60 for example via tubing 42 and bypass conduit 78 or through supply tubing 66. Water may be supplied from water supply 64 for example via tubing 42 and bypass conduit 78, via supply tubing 66, or through the tubing-casing annulus (i.e. wellbore 12). The air and gas are combusted at DSG 36 to convert the supplied water into a hot effluent 74 which is discharged through the lower completion and into the formation. Hot effluent 74 may include the flue gas from the combustion at DSG 36.

[0019] Cooling or insulating fluid, for example water, may be supplied (i.e. communicated) to a cooling inlet port 34 of regulating device 44 for example from water supply 64. The cooling fluid may be communicated to regulating device 44 for example through a supply conduit or through wellbore 12. The cooling fluid may be discharged below packer 26 (e.g., into tail pipe 30) or discharged above lower completion 20 and in some embodiments communicated to the inlet of DSG 36. For example, with reference to FIG. 1, cooling fluid is communicated from water supply 64 through a supply conduit 58 to inlet port 34 of thermal regulating stinger device 44. The cooling fluid may be discharged below packer 26 (e.g., FIG. 4) or communicated to DSG 36. In the FIG. 1 illustration, DSG supply water may be communicated directly to DSG 36 from the surface for example through tubing 42 and bypass 78 or via supply tubing 66. In accordance to some embodiments, DSG supply water may include the fluid discharged from the outlet of the thermal regulating device.

[0020] FIG. 2 illustrates a steam completion 10 installed in wellbore 12. In this embodiment upper completion 22 is configured to be deployed during steaming operations and then pulled out of the wellbore prior to placing the well on production. A production completion may be run into the wellbore for the production stage. Upper completion 22 includes a fuel supply conduit 54 and an air supply conduit 66 extending from the surface to DSG 36. In the depicted completion, water 62 is supplied as cooling fluid from water supply 64 (FIG. 1) into wellbore 12 and into cooling inlet port 34 of the seal element regulating device 44. Inlet port 34 is open to and in communication with the annulus (i.e. wellbore 12) above packer 26 in FIG. 2. Water 62 may be supplied to inlet port 34 through a supply conduit, such as supply tubing, for example tubing 58 (FIG. 1), instead of through wellbore 12. Water 62 is circulated through regulating device 44 and discharged as outlet or preheated water 63 through an outlet port 35. Inlet port 34 and or outlet port 35 may include or be formed by a one-way flow control device (e.g., check valve) allowing in one direction from inlet port 34 to outlet port 35 and blocking flow in the reverse direction.

[0021] Outlet port 35 may be in communication with the water inlet of the DSG or the stinger bore. In FIG. 2, outlet water 63 is discharged above packer 26 and communicated to inlet 65 of DSG 36 via conduit 67. In accordance to some embodiments, outlet water 63 may be discharged back into wellbore 12 above packer 26. In some embodiments, outlet water 63 is discharged into wellbore 12 and communicated to DSG 36 through inlet 65 that is open to wellbore 12. Water 62 may be heated when it is circulated through regulating device 44 and the preheated outlet water 63 communicated to DSG 36 may aid in generating higher quality steam.

[0022] FIG. 3 illustrates a regulating device 44 utilized in a completion 10 in accordance to some embodiments. Packer 26 is deployed and set in the well with packer seal element 68 and slips 70 engaging casing 18. Thermal regulating stinger 44 includes an outer mandrel or sleeve 82 carrying one or more seal elements 84 for sealing with polished bore receptacle 28 of packer 26. Thermal regulating stinger 44 includes an inner sleeve or mandrel 86 forming a stinger bore 88. Stinger bore 88 is in communication with discharge 48 of DSG 36 and tail pipe 30.

[0023] In accordance to one or more embodiments, a passage 92 in communication with or connecting inlet port 34 and outlet port 35 is located between inner mandrel 86 and outer mandrel 82. Inlet port 34 and or outlet port 35 may
include or be formed by a one-way flow control device allowing one-way fluid flow in the direction from inlet port 34 to outlet port 35 and blocking fluid flow in the direction from outlet port 35 through inlet port 34. Passage 92 may be formed by a member 90 (e.g. sleeve or coil) surrounding inner mandrel 86. For example, with reference to FIG. 3, member 90 is illustrated as a coil member surrounding inner mandrel 86 (e.g. co-axially aligned) and providing passage 92 as a helical path around the inner mandrel. Passage 92 is illustrated in FIGS. 4 and 5 formed by a sleeve member 90. Cooling fluid 62 (e.g. water) is circulated through passage 92 and discharged as a preheated outlet fluid 63 and supplied into DSG 36 and converted to hot effluent 74 in FIG. 3. Circulating the water through passage 92 may provide a thermal regulating layer between hot effluent 74 and the stinger seal elements 84 and packer 26. FIG. 3 illustrates water 62 being supplied to inlet port 34 through supply tubing 58 and outlet water 63 communicated from outlet port 35 to DSG inlet 65 through a conduit 67. Outlet port 35 is located at an upper end 43 of thermal regulating stinger device 44 in FIG. 3. FIG. 4 illustrates thermal regulating stinger 44 discharging the cooling fluid through lower completion 20 in accordance to one or more embodiments. Passage 92 is illustrated in FIG. 4 formed by sleeve member 90. Cooling fluid 62 is supplied via wellbore 12 or supply tubing, for example tubing 58, to inlet port 34 of thermal regulating stinger 44 and is circulated through passage 92 from inlet port 34 located at an upper end 43 of thermal regulating device 44 to outlet port 35, which is in communication with bore 88, located at a lower end 45 of thermal regulating device. Fluid flow through passage 92 may be limited to one-way fluid flow from inlet port 34 through discharge port 35. For example, inlet port 34 and or outlet port 35 may include or be formed by a one-way flow control device allowing one-way fluid flow in the direction from inlet port 34 to outlet port 35 and blocking fluid flow in the direction from outlet port 35 through inlet port 34. The circulated fluid 62 may remove heat (i.e. conduction) and thermally regulate elements such as seal elements 84 and 68 that are exterior of passage 92 from the hot effluent 74 passing from DSG 36 through stinger bore 88 of thermal regulating device 44. The cooling fluid is discharged as outlet fluid 63 at outlet port 35 into wellbore 12 below lower completion 20 for example into stringer bore 88 and tailpipe 30. Outlet fluid 63 may mix with hot effluent 74. In this example, water 62 may be supplied to inlet 65 of DSG 36 through wellbore 12 or through a supply conduit, for example supply tubing 42.

FIG. 5 illustrates thermal regulating stinger device 44 having thermal insulation 94 located with passage 92 between outer mandrel 82 and inner mandrel 86. In this example, insulation 94 is illustrated as a tubular member (e.g. sleeve) located concentrically around inner mandrel 86. Insulation 94 may be made of various materials including solids, gases and liquids and constructed in various configurations to provide thermal insulation between hot effluent 74 and the exterior elements such as seal elements 84, 68. Insulation 94 may be constructed of one or more materials that have a low thermal conductivity and or to reflect thermal radiation. Insulation 94 may include a material or fluid disposed in a wall portion of insulation sleeve 94.

Passage 92 extends between inlet port 34 and outlet port 35 for example spiraling about inner mandrel 86. Passage 92 is illustrated in FIG. 5 formed by sleeve member 90. Water 62 may be communicated into inlet port 34 through wellbore 12. For example with additional reference to FIG. 2, inlet port 34 may be open to the annulus (wellbore 12) above packer 26 and water 62 may be supplied through wellhead 24 (FIG. 1) into wellbore 12 and communicated into open inlet port 34. Water 62 may be communicated for example from the surface through supply tubing, for example tubing 58, through inlet port 34 and into passage 92. Water 62 may be discharged from outlet port 35 as outlet water 63 into wellbore 12 above packer 26, below packer 26 into tail pipe 30 or stinger bore 88 for example as illustrated in FIG. 4, or directly into DSG 36 for example as illustrated in FIGS. 2 and 3. In accordance to some embodiments, fluid flow may be restricted to one-way flow through passage 92 in the direction from inlet port 34 to outlet port 35.

FIG. 6 illustrates an example of a completion 10 incorporating thermal insulated stinger 44 and a thermal regulating device 144. In this example, thermal regulating stinger 44 includes insulation 94 disposed between outer mandrel 82 and inner mandrel 86. In accordance to embodiments, thermal regulating stinger 44 does not include cooling fluid passage 92. Thermal regulating device 144 includes a coil shaped member 90 forming a cooling passage 92 (FIGS. 3-5) in communication between inlet port 34 and outlet port 35. Thermal regulating device 144 is deployed proximate to thermal insulating stinger 44 and packer 26. Thermal insulating device 144 may be in contact with stinger 44 and or packer 26. Cooling fluid 62 may be supplied from water supply 64 (FIG. 1) for example through wellbore 12 or supply tubing 58 and circulated through coil member 90 of thermal insulating device 144 and discharged through outlet port 35. For example, the water may be discharged as outlet water 63 into wellbore 12 or into a conduit 67 and communicated to inlet 65 of DSG 36. The supply tubing 58 can discharge fluid such as water into a space 91 above the stinger 44 through openings 93 in the supply tubing. The supply tubing 58 can include one-way valves or other mechanisms to control flow of fluid into and out of the supply tubing 58. The loose fluid cools temperature-sensitive components, such as seal elements 68.
The loose water discharged can be left in the well or removed through the supply tubing or another conduit.

[0030] The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the disclosure. Those skilled in the art should appreciate that they may readily use the disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the disclosure. The scope of the invention should be determined only by the language of the claims that follow. The term "comprising" within the claims is intended to mean "including at least" such that the recited listing of elements in a claim are an open group. The terms "a," "an" and other singular terms are intended to include the plural forms thereof unless specifically excluded.

What is claimed is:

1. A thermal regulating device, comprising:
   a downhole steam generator;
   a supply line to the downhole steam generator configured
to deliver fluid to the downhole steam generator from
which the downhole steam generator is configured to
generate a hot effluent;
   a temperature-sensitive completion component in the well;
   and
   a heat sink configured to insulate the temperature-sensitive
completion component from thermal energy in the hot
effluent.

2. The thermal regulating device of claim 1 wherein the
heat sink includes the fluid from the supply line before reaching
the downhole steam generator.

3. The thermal regulating device of claim 1 wherein the
temperature-sensitive completion component is in thermal contact with a formation in the well.

4. The thermal regulating device of claim 1 wherein the
supply line is configured to discharge at least a portion of the
fluid out of the supply line and into thermal contact with the
temperature-sensitive completion component.

5. A thermal regulating completion device, the device comprising:
   an inner mandrel having a bore;
   an outer mandrel surrounding the inner mandrel and carrying
   a seal element; and
   a passage located between the inner mandrel and the outer
   mandrel and the outer mandrel to circulate a cooling fluid from an inlet port to an outlet port.

6. The device of claim 5, wherein the inlet port and the
   outlet port are located at an upper end of the device.

7. The device of claim 5, wherein the inlet port is located at an
   upper end of the device and the outlet port is in communication with the bore.

8. The device of claim 5, comprising an insulation located between
   the inner mandrel and the outer mandrel.

9. The device of claim 5, comprising an insulation located between
   the inner mandrel and the outer mandrel; and
   the inlet port and the outlet port are located at an upper end
   for the device.

10. The device of claim 5, comprising an insulation located between
    the inner mandrel and the outer mandrel; and
    the inlet port is located at an upper end of the device and the
    outlet port is in communication with the bore.

11. A completion, comprising:
    a downhole steam generator (DSG) having a water inlet
    and a discharge to convey a hot effluent away from the
    DSG;
    a stinger having an inner mandrel forming a stinger bore in
    communication with the discharge and an outer mandrel
    carrying a seal element; and
    a passage located between the inner mandrel and the outer
    mandrel to circulate a cooling fluid from an inlet port to an
    outlet port.

12. The completion of claim 11, wherein the outlet port is in
    communication with the stinger bore.

13. The completion of claim 11, wherein the outlet port is in
    communication with the water inlet of the DSG.

14. The completion of claim 11, wherein the stinger includes an insulation located between the inner mandrel and the outer mandrel.

15. The completion of claim 11, wherein:
    the stinger is landed in a packer set in a wellbore;
    the inlet port is located at an upper end of the stinger above
    the packer; and
    the outlet port is located at an upper end of the stinger above
    the packer.

16. The completion of claim 15, wherein the outlet port is in
    communication with the water inlet of the DSG.

17. The completion of claim 11, wherein:
    the stinger is landed in a packer set in a wellbore;
    the inlet port is located at an upper end of the stinger above
    the packer; and
    the outlet port is in communication with the stinger bore.

18. A method, comprising:
    generating a hot effluent at a downhole steam generator
    (DSG) incorporated in an upper completion that is
    deployed in a wellbore;
    discharging the hot effluent through a bore of a stinger
    landed in a packer; the stinger carrying a seal element;
    and
    circulating a water through a passage from an inlet port to
    an outlet port, the passage located proximate to the
    stinger seal.

19. The method of claim 18, wherein the outlet port is in
    communication with one of the stinger bore and a water inlet
to the DSG.

20. The method of claim 18, wherein the passage is located
    between an inner mandrel forming the stinger bore and an
    outer mandrel carrying the seal element.

21. The method of claim 18, wherein:
    the circulating the water includes communicating the water
    from the wellbore through the inlet port into the passage;
    and
    the outlet port is in communication with one of the stinger
    bore and a water inlet to the DSG.

22. The method of claim 18, wherein:
    the circulating the water includes communicating the water
    through a supply tubing to the inlet port into the passage;
    and
    the outlet port is in communication with one of the stinger
    bore and a water inlet to the DSG.

23. The method of claim 18, wherein the stinger comprises:
    an inner mandrel forming the stinger bore;
    an outer mandrel carrying the seal element; and
    an insulation located between the inner mandrel and the mandrel.
24. The method of claim 18, wherein:
the passage is located between an inner mandrel forming
the stinger bore and an outer mandrel carrying the seal
element;
the outlet port is in communication with one of the stinger
bore and a water inlet to the DSG; and
the circulating the water includes communicating the water
to the inlet port through one selected from the wellbore
and a supply tubing.

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