(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 April 2008 (17.04.2008)

PCT

(10) International Publication Number
WO 2008/045408 A1

(51) International Patent Classification:
E21B 36/02 (2006.01) *E21B 43/24* (2006.01)
E21B 43/16 (2006.01)

(21) International Application Number: PCT/US2007/021530

(22) International Filing Date: 9 October 2007 (09.10.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/850,181	9 October 2006 (09.10.2006)	US
60/857,073	6 November 2006 (06.11.2006)	US
60/885,442	18 January 2007 (18.01.2007)	US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *with amended claims and statement*

Date of publication of the amended claims and statement: 3 July 2008

(54) **Title:** METHOD FOR PRODUCING VISCOUS HYDROCARBON USING STEAM AND CARBON DIOXIDE

(57) **Abstract:** A downhole burner is used for producing heavy-oil formations. Hydrogen, oxygen, and steam are pumped by separate conduits to the burner, which burns at least part of the hydrogen and forces the combustion products out into the earth formation. The steam cools the burner and becomes superheated steam, which is injected along with the combustion products into the earth formation. Carbon dioxide is also pumped down the well and injected into the formation.

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CLAIMS AMENDED UNDER ARTICLE 19 (PCT) FOR PCT/US/2007/021530

1. A downhole burner for a well, comprising:

a burner casing;

a liner coupled to the burner casing for combusting a fuel and an oxidizer;

an injector coupled to the burner casing for injecting the fuel and the oxidizer into the liner;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner; and

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the steam is superheated by combustion of the fuel and oxidizer to increase a steam quality of the steam, the combusted fuel and oxidizer and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

2. A downhole burner according to Claim 1, wherein the liner comprises an upper section located adjacent to the injector, and a lower section located adjacent to the upper section.

3. A downhole burner according to Claim 2, wherein the upper section has a plurality of holes for injecting steam through the liner.

4. A downhole burner according to Claim 3, wherein the holes extend through the liner at an angle relative to a longitudinal axis of the liner.

5. A downhole burner according to Claim 2, wherein the lower section has a plurality of first holes and a plurality of second holes, the second holes being larger than the first holes, and the second holes being oriented at a 90° angle relative to an internal surface of the liner.

6. A downhole burner according to Claim 1, wherein the injector comprises a first plate having a plurality of holes.

7. A downhole burner according to Claim 6, wherein the holes in the first plate are arranged in concentric rings.

8. A downhole burner according to Claim 1, wherein the injector comprises four plates, each of which has holes.

9. A system for producing viscous hydrocarbons from a well having a casing, comprising:

a plurality of conduits for delivering fuel, an oxidizer and steam from a surface down through the casing;

a downhole burner secured to the plurality of conduits, the downhole burner comprising:

a burner casing;

an injector coupled to the plurality of conduits for injecting the fuel and oxidizer into the well;

a liner coupled to the burner casing located below the injector for combusting the fuel and oxidizer;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner; and

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the steam is superheated by combustion of the fuel and oxidizer to increase a steam quality of the steam, the combusted fuel and oxidizer and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

10. A system according to Claim 9, wherein the liner comprises a first section located adjacent to the injector, and a second section located adjacent to the first section.

11. A system according to Claim 9, wherein the holes extend through the liner at an angle relative to a longitudinal axis of the liner.

12. A system according to Claim 10, wherein the second section has a plurality of first holes and a plurality of second holes, the second holes being larger than the first holes, and the second holes being oriented at a 90° angle relative to an internal surface of the liner.

13. A system according to Claim 9, wherein the injector comprises a first plate having a plurality of holes for injecting the fuel and oxidizer into the burner.

14. A system according to Claim 9, wherein the holes in the first plate are arranged in concentric rings.

15. A system according to Claim 9, wherein the injector comprises four plates, each of which has holes.

16. A method of producing viscous hydrocarbons from a well having a casing, comprising:

(a) providing a downhole burner having a burner casing, an injector, and a liner;

(b) lowering the downhole burner into the well;

(c) delivering fuel, an oxidizer and steam from a surface down through the casing to the downhole burner;

(d) injecting the fuel and oxidizer into the downhole burner with the injector;

(e) combusting the fuel and oxidizer with the liner;

(f) delivering steam through a steam channel located between the burner casing and the injector and liner;

(g) injecting steam from the steam channel, through holes in the liner, to an interior of the liner to superheat the steam with the combusted fuel and oxidizer to increase a steam quality of the steam; and

(h) releasing the combusted fuel and oxidizer and the superheated steam from the liner into an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

17. A method according to Claim 16, wherein the liner comprises a first section located adjacent to the injector, and a second section located adjacent to the first section, the first section having a plurality of holes for injecting steam through the liner.

18. A method according to Claim 17, wherein the holes extend through the liner at an angle relative to a longitudinal axis of the liner.

19. A method according to Claim 17, wherein the second section has a plurality of first holes and a plurality of second holes, the second holes being larger than the first holes, and the second holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

20. A method according to Claim 16, wherein the injector comprises four plates, at least one of which has holes arranged in concentric rings.

21. A system for producing viscous hydrocarbons from a well having a casing, comprising:

a plurality of conduits for delivering fuel, an oxidizer, CO_2 and steam from a surface down through the casing;

a downhole burner secured to the plurality of conduits, the downhole burner comprising:

a burner casing;

an injector coupled to the plurality of conduits for injecting the fuel, oxidizer and CO_2 into the well;

a liner coupled to the burner casing located below the injector for combusting the fuel and oxidizer and releasing exhaust gases including the CO_2;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner;

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, and the steam is superheated by the combusted fuel and oxidizer to increase a steam quality of the steam; and the exhaust gases and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

22. A system according to Claim 21, wherein the liner comprises a first section located adjacent to the injector, and a second section located adjacent to the first section, the first section having a plurality of holes for injecting steam through the liner.

23. A system according to Claim 22, wherein the holes extend through the liner at an angle relative to a longitudinal axis of the liner.

24. A system according to Claim 22, wherein the second section has a plurality of first holes and a plurality of second holes, the second holes being larger than the first holes, and the second holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

25. A system according to Claim 21, wherein the injector comprises four plates, at least one of which has holes arranged in concentric rings.

26. A downhole burner for a well, comprising:

a burner casing;

a liner coupled to the burner casing for combusting a fuel and an oxidizer;

an injector coupled to the burner casing for injecting the fuel and the oxidizer into the liner;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner; and

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the steam is superheated by combustion of the fuel and oxidizer to increase a steam quality of the steam, the combusted fuel and oxidizer and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

27. A downhole burner according to Claim 26, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section.

28. A downhole burner according to Claim 27, wherein the effusion cooling section has a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner.

29. A downhole burner according to Claim 28, wherein the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, for moving the injected steam along an interior wall of the liner to lower a temperature thereof.

30. A downhole burner according to Claim 27, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

31. A downhole burner according to Claim 26, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

32. A downhole burner according to Claim 31, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

33. A downhole burner according to Claim 26, wherein the injector comprises (a) a cover plate having an oxidizer inlet, (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes.

34. A downhole burner according to Claim 26, wherein the injector comprises a cover plate on top of an oxidizer distribution manifold plate, the oxidizer distribution manifold plate is on top of a fuel distribution manifold plate, and the fuel distribution manifold plate is on top of an injector face plate.

35. A system for producing viscous hydrocarbons from a well having a casing, comprising:

a plurality of conduits for delivering fuel, an oxidizer and steam from a surface down through the casing;

a downhole burner secured to the plurality of conduits, the downhole burner comprising:

a burner casing;

an injector coupled to the plurality of conduits for injecting the fuel and oxidizer into the well;

a liner coupled to the burner casing located below the injector for combusting the fuel and oxidizer;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner; and

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the steam is superheated by combustion of the fuel and oxidizer to increase a steam quality of the steam, the combusted fuel and oxidizer and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

36. A system according to Claim 35, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section.

37. A system according to Claim 36, wherein the effusion cooling section has a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner.

38. A system according to Claim 37, wherein the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, such that the injected steam moves along an interior wall of the liner to lower a temperature thereof.

39. A system according to Claim 36, wherein approximately 37.5% of the steam provided through the steam channel is injected into the liner by the effusion cooling section.

40. A system according to Claim 36, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

41. A system according to Claim 35, wherein the steam has a steam quality of approximately 80% to 100% formed at the surface of the well that is fluidly communicated to the steam channel at a pressure of about 1600 psi.

42. A system according to Claim 35, wherein the downhole burner has a power output of approximately 13 MMBtu/hr for producing about 3200 bpd of superheated steam with an outlet temperature of about 700°F.

43. A system according to Claim 35, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the

injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

44. A system according to Claim 43, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

45. A system according to Claim 35, wherein the injector comprises (a) a cover plate having an oxidizer inlet, (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes.

46. A system according to Claim 35, wherein the injector comprises a cover plate on top of an oxidizer distribution manifold plate, the oxidizer distribution manifold plate is on top of a fuel distribution manifold plate, and the fuel distribution manifold plate is on top of an injector face plate.

47. A method of producing viscous hydrocarbons from a well having a casing, comprising:

(a) providing a downhole burner having a burner casing, an injector, and a liner;

(b) lowering the downhole burner into the well;

(c) delivering fuel, an oxidizer and steam from a surface down through the casing to the downhole burner;

(d) injecting the fuel and oxidizer into the downhole burner with the injector;

(e) combusting the fuel and oxidizer with the liner;

(f) delivering steam through a steam channel located between the burner casing and the injector and liner;

(g) injecting steam from the steam channel, through holes in the liner, to an interior of the liner to superheat the steam with the combusted fuel and oxidizer to increase a steam quality of the steam; and

(h) releasing the combusted fuel and oxidizer and the superheated steam from the liner into an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

48. A method according to Claim 47, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section, the effusion cooling section having a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner.

49. A method according to Claim 48, wherein the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, such that the injected steam moves along an interior wall of the liner to lower a temperature thereof.

50. A method according to Claim 48, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

51. A method according to Claim 47, wherein the steam has a steam quality of approximately 80% to 100% formed at the surface of the well that is fluidly communicated to the steam channel at a pressure of about 1600 psi.

52. A method according to Claim 47, wherein the downhole burner has a power output of approximately 13 MMBtu/hr for producing about 3200 bpd of superheated steam with an outlet temperature of about 700°F.

53. A method according to Claim 47, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

54. A method according to Claim 53, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

55. A method according to Claim 47, wherein the injector comprises (a) a cover plate having an oxidizer inlet, (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes.

56. A method according to Claim 47, wherein the well comprises a wellbore configuration selected from the group consisting of vertical and horizontal.

57. A system for producing viscous hydrocarbons from a well having a casing, comprising:

a plurality of conduits for delivering fuel, an oxidizer, CO_2 and steam from a surface down through the casing;

a downhole burner secured to the plurality of conduits, the downhole burner comprising:

a burner casing;

an injector coupled to the plurality of conduits for injecting the fuel, oxidizer and CO_2 into the well;

a liner coupled to the burner casing located below the injector for combusting the fuel and oxidizer and releasing exhaust gases including the CO_2;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner;

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the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the exhaust gases and the steam cool the liner, and the steam is superheated by the combusted fuel and oxidizer to increase a steam quality of the steam; and

the exhaust gases and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

58. A system according to Claim 57, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section.

59. A system according to Claim 58, wherein the effusion cooling section has a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner, and the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, such that the injected steam moves along an interior wall of the liner to lower a temperature thereof.

60. A system according to Claim 58, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

61. A system according to Claim 57, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

62. A system according to Claim 61, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face

plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

63. A system according to Claim 57, wherein the injector comprises (a) a cover plate having an oxidizer inlet, the cover plate is located on (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and the oxidizer distribution manifold plate is on top of (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes, and the fuel distribution manifold plate is located on top of (d) an injector face plate.

64. A downhole burner for a well, comprising:

a burner casing;

a liner coupled to the burner casing for combusting a fuel and an oxidizer;

an injector coupled to the burner casing for injecting the fuel and the oxidizer into the liner;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner; and

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the steam is superheated by combustion of the fuel and oxidizer to increase a steam quality of the steam, the combusted fuel and oxidizer and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

65. A downhole burner according to Claim 64, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section.

66. A downhole burner according to Claim 65, wherein the effusion cooling section has a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner.

67. A downhole burner according to Claim 66, wherein the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, for moving the injected steam along an interior wall of the liner to lower a temperature thereof.

68. A downhole burner according to Claim 65, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

69. A downhole burner according to Claim 64, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

70. A downhole burner according to Claim 69, wherein a gap is formed between an outer diameter of the injector face plate and an inner diameter of the liner so that steam can leak past and cool the injector face plate.

71. A downhole burner according to Claim 70, wherein the burner casing and the liner each have a wall thickness of about 0.125 inches, the steam channel has an annular width between the liner and the burner casing of about 0.375 inches.

72. A downhole burner according to Claim 69, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

73. A downhole burner according to Claim 64, wherein the injector comprises (a) a cover plate having an oxidizer inlet, (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes.

74. A downhole burner according to Claim 64, wherein the injector comprises a cover plate on top of an oxidizer distribution manifold plate, the oxidizer distribution manifold plate is on top of a fuel distribution manifold plate, and the fuel distribution manifold plate is on top of an injector face plate.

75. A system for producing viscous hydrocarbons from a well having a casing, comprising:

a plurality of conduits for delivering fuel, an oxidizer and steam from a surface down through the casing;

a downhole burner secured to the plurality of conduits, the downhole burner comprising:

a burner casing;

an injector coupled to the plurality of conduits for injecting the fuel and oxidizer into the well;

a liner coupled to the burner casing located below the injector for combusting the fuel and oxidizer, the liner having an interior that defines a gap between the interior and an exterior of the injector for permitting steam to leak past and cools the injector;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner; and

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the steam is superheated by combustion of the fuel and oxidizer to increase a steam quality of the steam, the combusted fuel and oxidizer and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

76. A system according to Claim 75, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section.

77. A system according to Claim 76, wherein the effusion cooling section has a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner.

78. A system according to Claim 77, wherein the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, such that the injected steam moves along an interior wall of the liner to lower a temperature thereof.

79. A system according to Claim 76, wherein approximately 37.5% of the steam provided through the steam channel is injected into the liner by the effusion cooling section.

80. A system according to Claim 76, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

81. A system according to Claim 75, wherein the steam has a steam quality of approximately 80% to 100% formed at the surface of the well that is fluidly communicated to the steam channel at a pressure of about 1600 psi.

82. A system according to Claim 75, wherein the downhole burner has a power output of approximately 13 MMBtu/hr for producing about 3200 bpd of superheated steam with an outlet temperature of about 700°F.

83. A system according to Claim 75, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the

injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

84. A system according to Claim 83, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

85. A system according to Claim 75, wherein the injector comprises (a) a cover plate having an oxidizer inlet, (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes.

86. A system according to Claim 75, wherein the injector comprises a cover plate on top of an oxidizer distribution manifold plate, the oxidizer distribution manifold plate is on top of a fuel distribution manifold plate, and the fuel distribution manifold plate is on top of an injector face plate.

87. A method of producing viscous hydrocarbons from a well having a casing, comprising:

(a) providing a downhole burner having a burner casing, an injector, and a liner;

(b) lowering the downhole burner into the well;

(c) delivering fuel, an oxidizer and steam from a surface down through the casing to the downhole burner;

(d) injecting the fuel and oxidizer into the downhole burner with the injector;

(e) combusting the fuel and oxidizer with the liner;

(f) delivering steam through a steam channel located between the burner casing and the injector and liner;

(g) injecting steam from the steam channel, through holes in the liner, to an interior of the liner to superheat the steam with the combusted fuel and oxidizer to increase a steam quality of the steam; and

(h) releasing the combusted fuel and oxidizer and the superheated steam from the liner into an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

88. A method according to Claim 87, wherein step (g) further comprises leaking steam past the injector and cooling the injector with a gap located between an interior of the liner and an exterior of the injector.

89. A method according to Claim 87, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section, the effusion cooling section having a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner.

90. A method according to Claim 89, wherein the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, such that the injected steam moves along an interior wall of the liner to lower a temperature thereof.

91. A method according to Claim 89, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

92. A method according to Claim 87, wherein the steam has a steam quality of approximately 80% to 100% formed at the surface of the well that is fluidly communicated to the steam channel at a pressure of about 1600 psi.

93. A method according to Claim 92, wherein the steam arriving at the steam channel has a steam quality of about 70% to 90%, and wherein approximately 37.5% of the steam provided through the steam channel is injected into the liner by the effusion cooling section.

94. A method according to Claim 87, wherein the downhole burner has a power output of approximately 13 MMBtu/hr for producing about 3200 bpd of superheated steam with an outlet temperature of about 700°F.

95. A method according to Claim 87, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner.

96. A method according to Claim 95, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

97. A method according to Claim 87, wherein the injector comprises (a) a cover plate having an oxidizer inlet, (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes.

98. A method according to Claim 87, wherein the well comprises a wellbore configuration selected from the group consisting of vertical and horizontal.

99. A system for producing viscous hydrocarbons from a well having a casing, comprising:

a plurality of conduits for delivering fuel, an oxidizer, CO_2 and steam from a surface down through the casing;

a downhole burner secured to the plurality of conduits, the downhole burner comprising:

a burner casing;

an injector coupled to the plurality of conduits for injecting the fuel, oxidizer and CO_2 into the well;

a liner coupled to the burner casing located below the injector for combusting the fuel and oxidizer and releasing exhaust gases including the CO_2, the liner having an interior that defines a gap between the interior and an exterior of the injector for permitting steam to leak past and cools the injector;

a steam channel located inside the burner casing and surrounding exterior surfaces of the injector and the liner;

the liner having a plurality of holes for communicating steam from the steam channel to an interior of the liner downstream from the injector, such that the exhaust gases and the steam cool the liner, and the steam is superheated by the combusted fuel and oxidizer to increase a steam quality of the steam; and

the exhaust gases and the superheated steam exiting the liner to enter an oil-bearing formation to upgrade and improve a mobility of heavy crude oils held in the oil-bearing formation.

100. A system according to Claim 99, wherein the liner comprises an effusion cooling section located adjacent to the injector, and an effusion cooling and jet mixing section located adjacent to the effusion cooling section.

101. A system according to Claim 100, wherein the effusion cooling section has a plurality of effusion holes that inject small jets of steam through the liner to provide a layer of cooler gases to protect the liner, and the effusion holes extend through the liner at a 20° angle relative to a longitudinal axis of the liner and are oriented to inject steam downstream of the injector, such that the injected steam moves along an interior wall of the liner to lower a temperature thereof.

102. A system according to Claim 100, wherein the effusion cooling and jet mixing section has a plurality of effusion holes and a plurality of mixing holes, the mixing holes being larger

than the effusion holes, and the mixing holes being oriented at a 90° angle relative to an internal surface of the liner to inject steam further toward a longitudinal axis of the liner.

103. A system according to Claim 99, wherein the injector comprises an injector face plate having a plurality of injection holes for injecting the fuel and oxidizer into the burner, the injector face plate also having an igniter for igniting the fuel and oxidizer injected into the burner, the burner casing and the liner each have a wall thickness of about 0.125 inches, the steam channel has an annular width between the liner and the burner casing of about 0.375 inches.

104. A system according to Claim 103, wherein the injector face plate has fuel holes and oxidizer holes, each of which is arranged in concentric rings to produce a shower head stream pattern of fuel and oxidizer to move streams of the fuel and oxidizer away from the injector face plate, such that a stand-off distance is provided between a flame of the combusted fuel and oxidizer and the injector face plate to reduce a temperature of the injector face plate.

105. A system according to Claim 99, wherein the injector comprises (a) a cover plate having an oxidizer inlet, the cover plate is located on (b) an oxidizer distribution manifold plate having an oxidizer manifold and oxidizer holes coupled to the oxidizer inlet, and the oxidizer distribution manifold plate is on top of (c) a fuel distribution manifold plate having oxidizer holes, a fuel inlet, a fuel manifold for routing fuel through an interior of the fuel distribution manifold plate for cooling the fuel distribution plate, and fuel holes, and the fuel distribution manifold plate is located on top of (d) an injector face plate.

STATEMENT UNDER ARTICLE 19 (1)

Sirs:

In accordance with PCT Article 19, Applicant has submitted amendments to the claims. All of the originally filed claims are canceled, and are replaced by new Claims 1-105.

Very truly yours,

Bracewell & Giuliani LLP

Michael E. Noe Jr.
Attorney for Applicants

New Claims 1-25 are based solely on the as-filed text and drawings of the PCT application. Claims 26-63 are based solely on the subject matter of the two priority documents (i.e., US Provisional Applications 60/857,073 filed 6 November 2006, and 60/850,181 filed 9 October 2006) that are now incorporated by reference into the application. Finally, Claims 64-105 are based on both the as-filed text and drawings of the PCT application, and the subject matter of the two priority documents that are now incorporated by reference into the application.