

CLAIMS

WHAT IS CLAIMED IS:

1. A plunger for use with a syringe, the plunger comprising:
a plunger body defining a central longitudinal axis and having a proximal end, a distal end, and a circumferential sidewall connecting the proximal end and the distal end; and
at least one retaining member associated with and extending proximally from the plunger body, the at least one retaining member comprising:
a first end connected to the plunger body;
a second end proximal to the first end and radially and resiliently deflectable relative to the first end; and
at least one catch on the second end,
wherein the at least one retaining member has an outer surface configured to engage a plunger engagement sleeve of a plunger engagement mechanism on a piston of a fluid injector system when the plunger is in a locked state with the piston,
wherein the at least one retaining member has an inner surface configured to engage a plunger engagement post of the plunger engagement mechanism when the plunger is in the locked state with the piston,
wherein the at least one catch is configured to engage a locking feature on one of the plunger engagement sleeve and the plunger engagement post when the plunger is in the locked state with the piston to prevent axial movement of the plunger relative to the piston, and
wherein the at least one catch is configured to radially deflect the second end of the at least one retaining member upon axial movement of the piston relative to the plunger in an unlocked state of the plunger from the piston due to engagement of the at least one catch with the locking feature on one of the plunger engagement sleeve and the plunger engagement post.
2. The plunger according to claim 1, wherein the at least one retaining member comprises a plurality of retaining members spaced apart around the central longitudinal axis.
3. The plunger according to claim 2, wherein the plurality of retaining members are spaced apart at equal intervals around the central longitudinal axis.
4. The plunger according to any of claims 1 to 3, wherein the at least one retaining member extends proximally in a direction parallel with the central longitudinal axis.

5. The plunger according to any of claims 1 to 3, wherein the at least one retaining member extends proximally in a direction angled relative to the central longitudinal axis.
6. The plunger according to any of claims 1 to 5, wherein the at least one retaining member is linearly contiguous between the first end and the second end.
7. The plunger according to any of claims 1 to 5, wherein the at least one retaining member is curvilinearly contiguous between the first end and the second end.
8. The plunger according to any of claims 1 to 7, wherein the plunger is configured to engage the plunger engagement mechanism regardless of angular orientation of the plunger relative to the piston of the fluid injector.
9. The plunger according to any of claims 1 to 8, wherein the at least one catch has a first surface at a proximal end of the at least one catch configured for engaging a distal end of the locking feature on one of the plunger engagement sleeve and the plunger engagement post during engagement of the plunger to the piston, and a second surface at a distal end of the at least one catch configured for engaging a proximal end of the locking feature on one of the plunger engagement sleeve and the plunger engagement post during disengagement of the plunger from the piston.
10. The plunger according to any of claims 1 to 9, wherein the at least one catch protrudes radially inward from the inner surface of the at least one retaining member in a direction toward the central longitudinal axis.
11. The plunger according to any of claims 1 to 10, wherein the at least one catch protrudes radially outward from the outer surface of the at least one retaining member in a direction away from the central longitudinal axis.
12. The plunger according to any of claims 1 to 11, wherein the at least one catch defines a locking recess for receiving at least a portion of the plunger engagement mechanism when the plunger is connected to the piston.

13. The plunger according to any of claims 1 to 12, wherein the at least one catch protrudes radially inward from the inner surface of the at least one retaining member in a direction toward the central longitudinal axis, and wherein the at least one catch is configured to be received within the locking feature that is shaped as a locking groove protruding radially inward from an outer surface of the plunger engagement post when the plunger is in the locked state with the piston.
14. The plunger according to any of claims 1 to 13, wherein the plunger body has conical-shaped portion at the distal end and a cylindrical-shaped portion at the proximal end.
15. The plunger according to claim 14, wherein the at least one retaining member protrudes proximally from an inner surface of the conical-shaped portion.
16. The plunger according to claim 14 or 15, further comprising a plurality of release tabs protruding radially inward from an inner surface of the cylindrical-shaped portion or proximally from the inner surface of the cylindrical-shaped portion, each of the plurality of release tabs configured for interacting with the plunger engagement sleeve to effect a release of the plunger from the piston upon rotation of the plunger about the central longitudinal axis.
17. The plunger according to claim 16, wherein a proximal end of each of the plurality of release tabs has a pointed guide surface.
18. The plunger according to any of claims 1 to 17, further comprising a plunger cover covering at least a portion of a distal surface of the plunger body and comprising a seal disposed around at least a portion of the circumferential sidewall of the plunger body.
19. The plunger according to any of claims 1 to 18, wherein the plunger is configured to be slidably positioned within a barrel of a syringe.
20. The plunger according to claim 19, wherein the plunger is configured for reciprocal movement within the barrel of the syringe.
21. A fluid injector system comprising:
at least one reciprocally operable piston having a piston head; and

a plunger engagement mechanism associated with the piston head and configured for engaging a plunger of a syringe connected to the fluid injector system for reciprocally driving the plunger in the syringe due to movement of the at least one piston, the plunger engagement mechanism comprising:

a plunger engagement sleeve having a hollow body;

a plunger engagement post receivable within the hollow body of the plunger engagement sleeve; and

an actuator operatively connected to one of the plunger engagement sleeve and the plunger engagement post, and configured for moving one of the plunger engagement sleeve and the plunger engagement post between an engaged position and a disengaged position,

wherein, in the engaged position, the plunger engagement post is positioned within the hollow body of the plunger engagement sleeve to capture at least one resiliently flexible retaining member associated with the plunger in a receiving space between the plunger engagement collar and the plunger engagement post, and

wherein, in the disengaged position, the plunger engagement post is positioned at least partially outside of the hollow body of the plunger engagement sleeve to permit flexible insertion or removal of the at least one resiliently flexible retaining member of the plunger from the receiving space.

22. The fluid injector system according to claim 21, wherein the actuator is a rotary electric motor, a linear electric motor, a linear actuator, or a solenoid.

23. The fluid injector system according to claim 21, wherein the actuator is manually operated.

24. The fluid injector system according to any of claims 21 to 23, wherein the actuator has engaged state for moving one of the plunger engagement sleeve and the plunger engagement post to the engaged position and a disengaged state for moving one of the plunger engagement sleeve and the plunger engagement post to the disengaged position.

25. The fluid injector system according to any of claims 21 to 24, wherein the actuator is automatically moved to the disengaged state during power loss to the actuator.

26. The fluid injector system according to any of claims 21 to 25, wherein the actuator is in the engaged state only during proximal movement of the at least one piston.
27. The fluid injector system according to any of claims 21 to 26, further comprising at least one biasing element for moving the actuator from the engaged state to the disengaged state.
28. The fluid injector system according to any of claims 21 to 27, wherein rotational movement of the actuator moves one of the plunger engagement sleeve and the plunger engagement post proximally or distally in a linear direction.
29. The fluid injector system according to any of claims 21 to 28, wherein linear movement of the actuator moves one of the plunger engagement sleeve and the plunger engagement post proximally or distally in a linear direction.
30. The fluid injector system according to any of claims 21 to 29, wherein the actuator is operatively connected to a controller configured for controlling actuation of the actuator.
31. The fluid injector system according to any of claims 21 to 30, wherein one of the plunger engagement sleeve and the plunger engagement sleeve is linearly or rotatably movable relative to the piston, while the other of the plunger engagement sleeve and the plunger engagement sleeve is stationary relative to the piston.
32. The fluid injector system according to any of claims 21 to 31, wherein the plunger engagement post and the plunger engagement collar are linearly or rotatably movable relative to the piston.
33. The fluid injector system according to any of claims 21 to 32, further comprising at least one sensor configured for detecting a position of at least one of the plunger engagement collar and the plunger engagement post between the engaged position and the disengaged position.
34. The fluid injector system according to any of claims 21 to 33, further comprising a plunger detection sensor configured for detecting a presence of the at least one retaining

member of the plunger in the receiving space between the plunger engagement collar and the plunger engagement post.

35. The fluid injector system according to any of claims 21 to 34, wherein the hollow body of the plunger engagement sleeve has an opening with a stepped inner diameter that decreases in a direction from a distal end of the plunger engagement sleeve to a proximal end of the plunger engagement sleeve.

36. The fluid injector system according to any of claims 21 to 35, wherein the plunger engagement post comprises a locking groove protruding radially inward from an outer surface of the plunger engagement post, and wherein the locking groove is configured for receiving at least one catch on the at least retaining member of the plunger.

37. The fluid injector system according to claim 36, wherein a distal edge of the locking groove is configured for flexibly deflecting the at least retaining member of the plunger during axial movement of the plunger relative to the piston to move the at least one catch of the at least one retaining member out of engagement with the locking groove when one of the plunger engagement sleeve and the plunger engagement post is moved to the disengaged position.

38. The fluid injector system according to any of claims 21 to 37, wherein the plunger engagement post has a body with a stepped outer diameter that decreases in a direction from a distal end of the plunger engagement post to a proximal end of the plunger engagement post.

39. The fluid injector system according to any of claims 21 to 38, wherein the plunger engagement collar comprises a locking feature protruding radially inward from an inner surface of the plunger engagement collar, and wherein the locking feature is configured for engaging at least one catch on the at least retaining member of the plunger when one of the plunger engagement sleeve and the plunger engagement post is moved to the engaged position.

40. The fluid injector system according to claim 39, wherein the locking feature is configured for flexibly deflecting the at least retaining member of the plunger during axial movement of the plunger relative to the piston to move the at least one catch of the at least one retaining member out of engagement with the locking feature when one of the plunger engagement sleeve and the plunger engagement post is moved to the disengaged position.

41. The fluid injector system according to any of claims 21 to 39, further comprising the syringe, the syringe comprising: a barrel having a barrel proximal end, a barrel distal end having a discharge nozzle, and a barrel sidewall extending between the barrel proximal end and the barrel distal end; and the plunger slidably disposed within the barrel and reciprocally movable between the barrel proximal end and the barrel distal end.

42. The fluid injector system according to claim 41, wherein the plunger comprises:
a plunger body defining a central longitudinal axis and having a proximal end, a distal end, and a circumferential sidewall connecting the proximal end and the distal end; and
the at least one retaining member associated with and extending proximally from the plunger body.

43. The fluid injector system according to claim 41 or 42, wherein the at least one retaining member comprises:

a first end connected to the plunger body;

a second end proximal to the first end and radially and resiliently deflectable relative to the first end; and

at least one catch on the second end,

wherein the at least one retaining member has an outer surface configured to engage the plunger engagement sleeve when the plunger is engaged with the piston,

wherein the at least one retaining member has an inner surface configured to engage the plunger engagement post when the plunger is engaged with the piston,

wherein the at least one catch is configured to engage a locking feature on one of the plunger engagement sleeve and the plunger engagement post when the plunger is engaged with the piston to prevent axial movement of the plunger relative to the piston, and

wherein the at least one catch is configured to radially deflect the second end of the at least one retaining member upon axial movement of the piston relative to the plunger in a disengaged state of the plunger due to contact of the at least one catch with the locking feature.

44. The fluid injector system according to any of claims 41 to 43, wherein the plunger is configured to engage the plunger engagement mechanism regardless of angular orientation of the plunger relative to the piston of the fluid injector.

45. The fluid injector system according to any of claims 41 to 44, wherein the at least one catch protrudes radially inward from the inner surface of the at least one retaining member in a direction toward the central longitudinal axis, and wherein the at least one catch is configured to be received within the locking feature that is shaped as a locking groove protruding radially inward from an outer surface of the plunger engagement post when the plunger is in the locked state with the piston.

46. The fluid injector system according to any of claims 41 to 45, wherein the at least one catch protrudes radially inward from the inner surface of the at least one retaining member in a direction toward the central longitudinal axis, or wherein the at least one catch protrudes radially outward from the outer surface of the at least one retaining member in a direction away from the central longitudinal axis.

47. The fluid injector system according to any of claims 41 to 46, wherein the plunger body has conical-shaped portion at the distal end and a cylindrical-shaped portion at the proximal end.

48. The fluid injector system according to claim 47, wherein the at least one retaining member protrudes proximally from an inner surface of the conical-shaped portion.

49. The fluid injector system according to claim 47 or 48, further comprising a plurality of release tabs protruding radially inward from an inner surface of the cylindrical-shaped portion, each of the plurality of release tabs configured for interacting with the plunger engagement sleeve to effect a release of the plunger from the piston upon rotation of the plunger about the central longitudinal axis.

50. The fluid injector system according to claim 49, wherein a proximal end of each of the plurality of release tabs has a pointed guide surface.

51. A fluid injector system comprising:
at least one reciprocally operable piston having a piston head; and
a plunger engagement mechanism associated with the piston head and configured for engaging a plunger of a syringe connected to the fluid injector system for reciprocally driving

the plunger in the syringe due to movement of the at least one piston, the plunger engagement mechanism comprising:

a plunger engagement sleeve having a hollow body with a longitudinal axis;

a plunger engagement post receivable within the hollow body of the plunger engagement sleeve and axially movable relative to the plunger engagement sleeve between an engaged position and a disengaged position,

wherein the plunger engagement sleeve is rotatable about the longitudinal axis between a first position and a second position,

wherein the plunger engagement post is movable axially along the longitudinal axis from the engaged position to the disengaged position via rotation of the plunger engagement sleeve.

52. The fluid injector system according to claim 51, wherein the plunger engagement post is movable axially from a proximal end of the piston toward a distal end of the piston.

53. The fluid injector system according to 51 or 52, wherein the plunger release sleeve comprises a plurality of plunger release teeth protruding radially outward from an outer surface of the hollow body.

54. The fluid injector system according to claim 53, wherein the plurality of plunger release teeth are configured to engage a plurality of release tabs on the plunger such that rotation of the plunger about a plunger longitudinal axis causes a rotation of the plunger engagement sleeve about the longitudinal axis.

55. The fluid injector system according to any of claims 51 to 54, further comprising a plunger release sleeve surrounding at least a portion of the plunger engagement sleeve, wherein the plunger release sleeve is configured to rotate about the longitudinal axis with rotation of the plunger engagement sleeve.

56. The fluid injector system according to any of claims 51 to 55, wherein the plunger release sleeve comprises an opening having a ramped surface that is angled relative to a direction of the longitudinal axis in a direction from a distal end of the plunger release sleeve toward a proximal end of the plunger release sleeve.

57. The fluid injector system according to claim 56, wherein the plunger engagement post has a guiding pin extending in a direction perpendicular to the longitudinal axis, and wherein the guiding pin is received within the opening of the plunger release sleeve.

58. The fluid injector system according to claim 57, wherein rotation of the plunger engagement sleeve causes a corresponding rotation of the plunger release sleeve, and wherein the guiding pin is guided along the ramped surface from a proximal end toward a distal end of the ramped surface, thereby moving the plunger engagement post from the engaged position to the disengaged position.

59. The fluid injector system according to any of claims 51 to 58, further comprising a biasing member operatively connected to the plunger engagement sleeve and the plunger engagement post.

60. The fluid injector system according to claim 59, wherein the biasing member is configured to bias the plunger engagement sleeve to the first position.

61. The fluid injector system according to any of claims 51 to 60, further comprising an actuator operatively connected to the plunger engagement post and configured for moving the plunger engagement post between the engaged position and the disengaged position.

62. The fluid injector system according to claim 61, wherein, in the engaged position, the plunger engagement post is positioned within the hollow body of the plunger engagement sleeve and is configured to capture at least one resiliently flexible retaining member associated with the plunger in a receiving space between the plunger engagement collar and the plunger engagement post, and

wherein, in the disengaged position, the plunger engagement post is positioned at least partially outside of the hollow body of the plunger engagement sleeve to permit flexible insertion or removal of the at least one resiliently flexible retaining member of the plunger from the receiving space.

63. The fluid injector system according to claim 61 or 62, wherein the actuator is a rotary electric motor, a linear electric motor, a linear actuator, or a solenoid.

64. The fluid injector system according to any of claims 61 to 63, wherein the actuator is manually operated.

65. The fluid injector system according to any of claims 61 to 63, wherein the actuator has engaged state for moving one of the plunger engagement sleeve and the plunger engagement post to the engaged position and a disengaged state for moving one of the plunger engagement sleeve and the plunger engagement post to the disengaged position.

66. The fluid injector system according to any of claims 61 to 65, wherein the actuator is automatically moved to the disengaged state during power loss to the actuator.

67. The fluid injector system according to any of claims 61 to 66, wherein the actuator is in the engaged state only during proximal movement of the at least one piston.

68. The fluid injector system according to any of claims 61 to 67, further comprising at least one biasing element for moving the actuator from the engaged state to the disengaged state.

69. The fluid injector system according to any of claims 61 to 68, wherein rotational movement of the actuator moves one of the plunger engagement sleeve and the plunger engagement post proximally or distally in a linear direction.

70. The fluid injector system according to any of claims 61 to 69, wherein linear movement of the actuator moves one of the plunger engagement sleeve and the plunger engagement post proximally or distally in a linear direction.

71. The fluid injector system according to any of claims 61 to 70, wherein the actuator is operatively connected to a controller configured for controlling actuation of the actuator.

72. The fluid injector system according to any of claims 51 to 71, further comprising at least one sensor configured for detecting a position of at least one of the plunger engagement collar and the plunger engagement post between the engaged position and the disengaged position.

73. The fluid injector system according to any of claims 51 to 72, further comprising a plunger detection sensor configured for detecting a presence of the at least one retaining member of the plunger in the receiving space between the plunger engagement collar and the plunger engagement post.

74. The fluid injector system according to any of claims 51 to 73, wherein the hollow body of the plunger engagement sleeve has an opening with a stepped inner diameter that decreases in a direction from a distal end of the plunger engagement sleeve to a proximal end of the plunger engagement sleeve.

75. The fluid injector system according to any of claims 51 to 74, wherein the plunger engagement post comprises a locking groove protruding radially inward from an outer surface of the plunger engagement post, and wherein the locking groove is configured for receiving at least one catch on at least retaining member of the plunger.

76. The fluid injector system according to claim 75, wherein a distal edge of the locking groove is configured for flexibly deflecting the at least retaining member of the plunger during axial movement of the plunger relative to the piston to move the at least one catch of the at least one retaining member out of engagement with the locking groove when one of the plunger engagement sleeve and the plunger engagement post is moved to the disengaged position.

77. The fluid injector system according to any of claims 51 to 76, further comprising the syringe, the syringe comprising: a barrel having a barrel proximal end, a barrel distal end having a discharge nozzle, and a barrel sidewall extending between the barrel proximal end and the barrel distal end; and the plunger slidably disposed within the barrel and reciprocally movable between the barrel proximal end and the barrel distal end.

78. The fluid injector system according to claim 77, wherein the plunger comprises: a plunger body defining a central longitudinal axis and having a proximal end, a distal end, and a circumferential sidewall connecting the proximal end and the distal end; and the at least one retaining member associated with and extending proximally from the plunger body.

79. The fluid injector system according to claim 77 or 78, wherein the at least one retaining member comprises:

a first end connected to the plunger body;

a second end proximal to the first end and radially and resiliently deflectable relative to the first end; and

at least one catch on the second end,

wherein the at least one retaining member has an outer surface configured to engage the plunger engagement sleeve when the plunger is engaged with the piston,

wherein the at least one retaining member has an inner surface configured to engage the plunger engagement post when the plunger is engaged with the piston,

wherein the at least one catch is configured to engage a locking feature on one of the plunger engagement sleeve and the plunger engagement post when the plunger is engaged with the piston to prevent axial movement of the plunger relative to the piston, and

wherein the at least one catch is configured to radially deflect the second end of the at least one retaining member upon axial movement of the piston relative to the plunger in a disengaged state of the plunger due to contact of the at least one catch with the locking feature.

80. The fluid injector system according to any of claims 77 to 79, wherein the plunger is configured to engage the plunger engagement mechanism regardless of angular orientation of the plunger relative to the piston of the fluid injector.

81. The fluid injector system according to any of claims 77 to 80, wherein the at least one catch protrudes radially inward from the inner surface of the at least one retaining member in a direction toward the central longitudinal axis, and wherein the at least one catch is configured to be received within the locking feature that is shaped as a locking groove protruding radially inward from an outer surface of the plunger engagement post when the plunger is in the locked state with the piston.

82. The fluid injector system according to any of claims 77 to 81, wherein the at least one catch protrudes radially inward from the inner surface of the at least one retaining member in a direction toward the central longitudinal axis, or wherein the at least one catch protrudes radially outward from the outer surface of the at least one retaining member in a direction away from the central longitudinal axis.

83. The fluid injector system according to any of claims 77 to 82, wherein the at least one catch defines a locking recess for receiving at least a portion of the plunger engagement mechanism when the plunger is connected to the piston.

84. The fluid injector system according to any of claims 77 to 83, wherein the plunger body has conical-shaped portion at the distal end and a cylindrical-shaped portion at the proximal end.

85. The fluid injector system according to claim 84, wherein the at least one retaining member protrudes proximally from an inner surface of the conical-shaped portion.

86. The fluid injector system according to claim 84 or 85, further comprising a plurality of release tabs protruding radially inward from an inner surface of the cylindrical-shaped portion or proximally from the inner surface of the cylindrical-shaped portion, each of the plurality of release tabs configured for interacting with the plunger engagement sleeve to effect a release of the plunger from the piston upon rotation of the plunger about the central longitudinal axis.

87. The fluid injector system according to claim 86, wherein a proximal end of each of the plurality of release tabs has a pointed guide surface.