

CLAIMS

WE CLAIM:

1. An apparatus for suspending air bubbles in a fluid path of a fluid injector system, the apparatus comprising:
 - a housing;
 - an internal chamber having a curved interior wall defined within the housing;
 - an inlet fluid pathway in fluid communication with the internal chamber, the inlet fluid pathway extending into the chamber at a tangent to the curved interior wall; and
 - an outlet fluid pathway in fluid communication with the internal chamber, the outlet fluid pathway spaced from the inlet fluid pathway such that fluid flowing into the internal chamber via the inlet fluid pathway is directed away from the outlet fluid pathway,wherein the internal chamber is configured to create an internal fluid vortex in an injection fluid entering the internal chamber from the inlet fluid pathway, and wherein the internal fluid vortex at least temporarily suspends one or more air bubbles in the fluid in the internal vortex and delays the passage of the one or more air bubbles to the outlet fluid pathway.
2. The apparatus according to claim 1, wherein the outlet fluid pathway extends from the internal chamber in a direction perpendicular to a flow path of fluid within the internal chamber.
3. The apparatus according to claim 1 or 2, wherein at least a portion of the outlet fluid pathway has a cross-sectional area greater than a cross-sectional area of the inlet fluid pathway to reduce fluid velocity in the outlet fluid pathway relative to fluid velocity in the inlet fluid pathway.
4. The apparatus according to any of claims 1-3, wherein the outlet fluid pathway extends substantially parallel to the inlet fluid pathway.
5. The apparatus according to any of claims 1-4, wherein the internal chamber is at least partly spherical or hemispherical.
6. The apparatus according to any of claims 1-5, further comprising a recess extending radially outward from the internal chamber.

7. The apparatus according to any of claims 1-6, further comprising a valve in fluid communication with the internal chamber for draining air accumulated in the internal chamber.
8. The apparatus according to any of claims 1-7, wherein the housing comprises:
 - a first housing section comprising the inlet fluid pathway and the outlet fluid pathway;
 - and
 - a second housing section comprising at least a portion of the internal chamber,
 - wherein one of the first housing section and the second housing section comprises a flange for receiving the other of the first housing section and the second housing section.
9. The apparatus according to any of claims 1-8, wherein the housing comprises at least one strengthening rib extending radially outward from the outlet fluid pathway.
10. The apparatus according to any of claims 1-9, further comprising a screen disposed in the outlet fluid pathway such that fluid flowing out of the internal chamber passes through the screen.
11. The apparatus according to any of claims 1-10, wherein the housing comprises a light-transmissible material configured to illuminate air bubbles in the internal chamber.
12. The apparatus according to any of claims 1-11, wherein the housing comprises a connector arm configured for attachment to an injector housing of the fluid injector system.
13. The apparatus according to any of claims 1-12, further comprising an adjustable valve for changing a cross-sectional area of at least one of the inlet fluid pathway and the outlet fluid pathway.
14. An apparatus for suspending air bubbles in a fluid path of a fluid injector system, the apparatus comprising:
 - a housing defining an internal chamber;
 - an inlet fluid pathway in fluid communication with the internal chamber;
 - an outlet fluid pathway in fluid communication with the internal chamber; and
 - an extension tube in fluid communication with the inlet fluid pathway and extending into the internal chamber, the extension tube comprising a tip spaced apart from the outlet fluid

pathway such that fluid flowing into the internal chamber via the extension tube is directed away from the outlet fluid pathway.

15. The apparatus according to claim 14, further comprising a screen dividing the internal chamber into an inlet portion and an outlet portion,

wherein the screen comprises at least one aperture providing fluid communication between the inlet portion and the outlet portion, and

wherein fluid flowing into the internal chamber from the extension tube must flow through the at least one aperture of the screen to reach the outlet fluid pathway.

16. The apparatus according to claim 15, wherein a first portion of the screen adjacent to the tip of the extension tube is impermeable to fluid, and wherein a second portion of the screen adjacent to the outlet fluid pathway comprises the at least one aperture.

17. The apparatus according to claim 15 or 16, wherein the screen comprises a funnel defining the at least one aperture, the funnel tapering from a maximum cross-sectional area adjacent the inlet portion of the internal chamber to a minimum diameter extending into the outlet portion of the internal chamber.

18. The apparatus according to any of claims 15-17, wherein the screen comprises a hood at least partially obstructing the at least one aperture such that fluid must flow around the hood to flow through the at least one aperture.

19. The apparatus according to any of claims 15-18, wherein the screen comprises mesh.

20. The apparatus according to any of claims 15-19, wherein the at least one aperture comprises two or more apertures arranged in an arc.

21. The apparatus according to any of claims 14-20, wherein the housing comprises:
a first housing section comprising a flange configured to receive the screen; and
a second housing section received within the flange of the first housing section to capture the screen between the first housing section and the second housing section.

22. The apparatus according to any of claims 14-21, wherein the inlet fluid pathway tapers from a smaller cross-sectional area to a larger cross-sectional area in a direction of fluid flow through the inlet fluid pathway to reduce flow velocity of fluid flowing through the inlet fluid pathway.
23. The apparatus according to any of claims 14-22, wherein the extension tube extends parallel to an inner wall of the internal chamber.
24. The apparatus according to any of claims 14-23, wherein the outlet fluid pathway extends at an acute angle relative to the inlet fluid pathway.
25. The apparatus according to any of claims 14-24, wherein the housing comprises a light-transmissible material configured to illuminate air bubbles in the internal chamber.
26. The apparatus according to any of claims 14-25, wherein the housing comprises a connector arm configured for attachment to an injector housing of the fluid injector system.
27. The apparatus according to any of claims 14-26, further comprising an adjustable valve for changing a cross-sectional area of at least one of the inlet fluid pathway and the outlet fluid pathway.
28. A fluid injector system comprising:
at least one fluid reservoir configured for injecting medical fluid;
at least one bubble suspension apparatus in fluid communication with the at least one fluid reservoir; the at least one bubble suspension apparatus comprising:
a housing defining an internal chamber;
an inlet fluid pathway in fluid communication with the internal chamber;
an outlet fluid pathway in fluid communication with the internal chamber, the outlet fluid pathway spaced from the inlet fluid pathway such that fluid flowing into the internal chamber via the inlet fluid pathway is directed away from the outlet fluid pathway;
at least one air detector configured to detect one or more air bubbles in a fluid path connecting the at least one fluid reservoir to the at least one bubble suspension apparatus; and

at least one shutoff valve downstream of the at least one bubble suspension apparatus and configured to move from an open position to a closed position in response to the air detector detecting the one or more air bubbles in the fluid path,

wherein the internal chamber is configured to create an internal fluid vortex in an injection fluid entering the internal chamber from the inlet fluid pathway, and wherein the internal fluid vortex at least temporarily suspends one or more air bubbles in the fluid in the internal vortex and delays the passage of the one or more air bubbles to the outlet fluid pathway.

29. The fluid injector system according to claim 28, wherein the bubble suspension apparatus is movable between:

an injection position in which the outlet fluid pathway extends substantially vertically downward from the internal chamber such that buoyancy of air bubbles in the internal chamber further induces the one or more air bubbles to remain suspended in the internal fluid vortex in the internal chamber; and

a priming position in which the outlet fluid pathway extends substantially vertically upward from the chamber such that the buoyancy of air bubbles in the internal chamber induces the air bubbles to flow from the internal fluid vortex through the outlet fluid pathway.

30. The fluid injector system according to claim 28 or 29, wherein the internal chamber comprises at least one curved interior wall, and wherein the inlet fluid pathway extends into the internal chamber at a tangent to the curved interior wall.

31. The fluid injector system according to any of claims 28-30, wherein the outlet fluid pathway extends from the internal chamber in a direction substantially perpendicular to a flow path of fluid in the internal fluid vortex within the internal chamber.

32. The fluid injector system according to any of claims 28-31, wherein at least a portion of the outlet fluid pathway has a cross-sectional area greater than a cross-sectional area of the inlet fluid pathway to reduce fluid velocity in the outlet fluid pathway relative to fluid velocity in the inlet fluid pathway.

33. The fluid injector system according to any of claims 28-32, wherein the outlet fluid pathway extends substantially parallel to the inlet fluid pathway.

34. The fluid injector system according to any of claims 28-33, wherein the internal chamber is at least partially spherical or hemispherical.

35. The fluid injector system according to any of claims 28-34, wherein the bubble suspension apparatus further comprises a recess extending radially outward from the internal chamber in a direction substantially opposite the outlet fluid pathway.

36. The fluid injector system according to claim 35, further comprising a valve on the recess and in fluid communication with the internal chamber for draining air accumulated in the recess.

37. The fluid injector system according to any of claims 28-36, wherein the housing of the bubble suspension apparatus comprises:

- a first housing section comprising at least one of the inlet fluid pathway and the outlet fluid pathway; and

- a second housing section comprising at least a portion of the internal chamber,

- wherein one of the first housing section and the second housing section comprises a flange for receiving the other of the first housing section and the second housing section.

38. The fluid injector system according to any of claims 28-37, wherein the housing of the bubble suspension apparatus comprises at least one strengthening rib extending radially outward from outlet fluid pathway.

39. The fluid injector system according to any of claims 28-38, wherein the bubble suspension apparatus further comprises a screen disposed proximal to the outlet fluid pathway such that fluid flowing out of the internal chamber passes through the screen.

40. The fluid injector system according to claim 39, wherein one or more of the one or more air bubbles temporarily adhere to a surface of the screen as the fluid passes through the screen.

41. The fluid injector system according to claim 39, wherein the screen comprises a hydrophilic coating on at least a portion of a surface of the screen.

42. The fluid injector system according to any of claims 28-41, wherein the bubble suspension apparatus further comprises an extension tube in fluid communication with the inlet fluid pathway and extending into the internal chamber, the extension tube comprising a tip spaced apart from the outlet fluid pathway such that fluid flowing into the internal chamber via the extension tube is directed away from the outlet fluid pathway.

43. The fluid injector system according to any of claims 39-41, wherein the screen divides the internal chamber into an inlet portion and an outlet portion,

wherein the screen comprises at least one aperture providing fluid communication between the inlet portion and the outlet portion, and

wherein fluid flowing into the internal chamber from the inlet fluid pathway must flow through the at least one aperture of the screen to reach the outlet fluid pathway.

44. The fluid injector system according to claim 43, wherein a first portion of the screen adjacent to the tip of the extension tube is impermeable to fluid, and wherein a second portion of the screen adjacent to the outlet fluid pathway comprises the at least one aperture.

45. The fluid injector system according to claim 43 or 44, wherein the screen comprises a funnel defining the at least one aperture, the funnel tapering from a maximum cross-sectional area adjacent the inlet portion of the internal chamber to a minimum diameter extending into the outlet portion of the internal chamber.

46. The fluid injector system according to any of claims 43-45, wherein the screen comprises a hood at least partially obstructing the at least one aperture such that fluid must flow around the hood to flow through the at least one aperture.

47. The fluid injector system according to any of claims 43-46, wherein the screen comprises mesh.

48. The fluid injector system according to any of claims 43-47, wherein the at least one aperture comprises two or more apertures arranged in an arc.

49. The fluid injector system according to any of claims 28-48, wherein the bubble suspension apparatus delays passage of the one or more air bubbles to the outlet fluid pathway by at least 100 milliseconds.
50. The fluid injector system according to any of claims 43-49, wherein the housing comprises:
- a first housing section comprising a flange configured to receive the screen;
 - a second housing section received within the flange of the first housing section to capture the screen between the first housing section and the second housing section.
51. The fluid injector system according to any of claims 28-50, wherein the inlet fluid pathway tapers from a smaller cross-sectional area to a larger cross-sectional area in a direction of fluid flow through the inlet fluid pathway to reduce flow velocity of fluid flowing through the inlet fluid pathway.
52. The fluid injector system according to claim 42, wherein the extension tube extends parallel to an inner wall of the internal chamber.
53. The fluid injector system according to any of claims 28-52, wherein the outlet fluid pathway extends at an acute angle relative to the inlet fluid pathway.
54. The fluid injector system according to any of claims 28-53, wherein the housing of the bubble suspension apparatus comprises a light-transmissible material configured to illuminate air bubbles in the internal chamber.
55. The fluid injector system according to any of claims 28-54, wherein the housing of the bubble suspension apparatus comprises a connector arm configured for attachment to an injector housing of the fluid injector system.
56. The fluid injector system according to any of claims 28-55, further comprising an adjustable valve for changing a cross-sectional area of at least one of the inlet fluid pathway and the outlet fluid pathway.