CLAIMS

What is claimed is:

1. An apparatus comprising:

a chamber comprising an interior surface and configured to contain a gas;

a first liquid source configured to deliver a first liquid at a first pressure;

a first injector coupled to the chamber and the first liquid source, the first injector configured to receive the first liquid from the first liquid source and to inject the received first liquid into the chamber, the first injector including a first nozzle having:

a first orifice having a first size; and

a first shape;

the first injector and the first pressure of the first liquid source configured to cause the first liquid to form a first liquid spray upon being sprayed from the first orifice into the chamber, the first liquid spray comprising droplets of the first liquid having a first spray velocity;

the chamber, the first liquid source, and the first injector configured such that a majority of the droplets within the first liquid spray decelerate from the first spray velocity to a terminal spray velocity that is less than 50% of the first spray velocity before contacting the interior surface of the chamber.

2. The apparatus of claim 1, wherein the first spray velocity is greater than 100 feet per second, and the terminal spray velocity is less than 20 feet per second.

3. The apparatus of claim 1, further comprising a first inner wall having a first gap through the first inner wall, wherein the first injector is further configured to inject the delivered first liquid through the first gap.

4. The apparatus of claim 3, wherein the first shape is configured to form the received first liquid into a fan-shaped first liquid spray, and the first gap includes a first gap shape that is substantially the same as a cross section of the fan-shaped first liquid spray at the first gap.

5. The apparatus of claim 3, wherein the first inner wall forms a first inner chamber within the first chamber, and the first gap is a first gas inlet to deliver the gas into the first inner chamber.

6. The apparatus of claim 3, wherein the first inner wall forms a first inner chamber within the first chamber, and the first gap is a first gas outlet to convey the gas from the first inner chamber.

7. The apparatus of claim 1, wherein at least a portion of the chamber is cylindrical about an axis, and the first injector is further configured to inject the first liquid in a manner that causes the gas within the portion to circulate circumferentially about the axis.

8. The apparatus of claim 7, wherein the chamber further comprises at least one of a gas inlet and a gas outlet that is disposed in an end of the chamber intersected by the axis, in a location proximate to the intersection of the axis with the end.

9. The apparatus of claim 1, further comprising:

a second liquid source configured to deliver a second liquid, at a second pressure;

a second injector coupled to the chamber and the second liquid source, the second injector configured to receive the second liquid from the second liquid source and to inject the received second liquid into the chamber, the second injector including a second nozzle having:

a second orifice having a second size and second shape,

the second nozzle and second pressure configured to cause the second liquid to form a second liquid spray upon being injected from the second orifice into the chamber.

10. The apparatus of claim 9, wherein:

at least a portion of the chamber is cylindrical about an axis;

the first injector is configured to impart a first force to the gas that pushes the gas in a first direction about the axis; and

the second injector is configured to impart a second force to the gas that pushes the gas in a second direction about the axis.

11. The apparatus of claim 10, wherein, with respect to a circulation direction about the axis, the first injector and the second injector are configured to push the gas in the circulation direction.

12. The apparatus of claim 9, further comprising an inner wall within the chamber, the inner wall configured as an inner chamber inside the chamber, the inner wall having first and second gaps through the inner wall into the inner chamber, the first gap configured as a gas inlet into the inner chamber, the second gap configured as a gas outlet from the inner chamber, the first injector configured to inject the first liquid through the first gap into the inner chamber, the second injector configured to inject the second liquid through the second gap into the inner chamber.

13. The apparatus of claim 1, wherein:

the chamber includes:

a chamber wall separating an interior of the chamber from an exterior of the chamber,

a throat through the chamber wall providing for fluidic communication between the interior and exterior of the chamber; and

the first injector sprays the first liquid spray through the throat.

14. The apparatus of claim 13, wherein the droplets enter the throat at a velocity higher than the terminal velocity and decelerate to the terminal spray velocity before exiting the throat.

CLAIMS

1. An apparatus for removing contaminants from a gas stream, the apparatus comprising:

a chamber comprising an interior surface and configured to contain a gas; the chamber having a gas inlet and a gas outlet;

a first liquid source configured to deliver a first liquid at a first pressure greater than 500 psi;

a first injector coupled to the chamber and the first liquid source, the first injector configured to receive the first liquid from the first liquid source and to inject the received first liquid into the chamber, the first injector including a first nozzle having:

a first orifice having a first size that does not exceed 0.01 square inches of orifice area; and

a first shape configured to generate a spray of droplets of liquid;

the first injector and the first pressure configured to cause the first liquid to form a first liquid spray upon being sprayed from the first orifice into the chamber, the first liquid spray comprising droplets of the first liquid having a first spray velocity;

the chamber, the first liquid source, and the first injector configured such that a majority of the droplets within the first liquid spray decelerate from the first spray velocity to a terminal spray velocity that is less than 10% of the first spray velocity before contacting the interior surface of the chamber.

2. The apparatus of claim 1, wherein the first spray velocity is greater than 400 feet per second, and the terminal spray velocity is less than 0.1 feet per second.

3. The apparatus of claim 1, further comprising an inner wall within the chamber, the inner wall having a first gap through the inner wall, the first gap having a first gap width and a first gap height;

wherein:

the first injector is further configured to inject the first liquid spray through the first gap.

4. The apparatus of claim 3, wherein:

the first nozzle has a first shape that is configured to form the received first liquid into a fan-shaped first liquid spray having a first spray height at the inner wall that is greater than five times the first spray width,

the first gap height is greater than five times the first gap width; and

the first injector is configured to align the first spray width with the first gap width and the first spray height with the first gap height.

5. The apparatus of claim 4, wherein:

the first spray height at the inner wall is greater than ten times the first spray width; and the first gap height is greater than ten times the first gap width.

6. The apparatus of claim 4, wherein a first distance from the first nozzle to the first gap is less than one foot.

7. The apparatus of claim 4, wherein a first distance from the first nozzle to the first gap is less than two times the first gap height and greater than 10% of the first gap height.

8. The apparatus of claim 3, wherein:

the first liquid spray has a first spray height and a first spray width, as measured at the first gap; and

the first gap height is between 70% and 130% of the first spray height, and the first gap width is between 70% and 130% of the first spray width.

9. The apparatus of claim 3, wherein the inner wall forms an inner chamber within the chamber, and the first gap delivers the gas into or out of the inner chamber.

10. The apparatus of claim 3, wherein the inner wall separates the gas inlet from the gas outlet.

11. The apparatus of claim 1, wherein the first pressure of the first liquid is greater than 1000 psi.

12. The apparatus of claim 1, wherein the first pressure is greater than 1000 psi and the first size does not exceed 0.008 square inches of orifice area.

13. The apparatus of claim 1, wherein the first orifice is elliptical, having a major length at least three times a minor length, and the major length is below 0.05 inches.

14. The apparatus of claim 3, wherein at least a portion of the inner wall forms an inner chamber that is cylindrical about an axis, and the first injector is further configured to inject the first liquid in a manner that causes the gas within the portion to circulate circumferentially about the axis.

15. The apparatus of claim 14, wherein the inner chamber further comprises at least one of a gas inlet and a gas outlet that is disposed in an end of the inner chamber intersected by the axis, in a location proximate to the intersection of the axis with the end.

16. The apparatus of claim 1, wherein:

at least a portion of the chamber is cylindrical about an axis; and

the first nozzle generates a fan-shaped spray having a first spray height greater than a first spray width, the first spray height oriented substantially parallel to the axis.

17. The apparatus of claim 3, wherein the inner wall separates the gas inlet from the gas outlet, the apparatus further comprising:

a second gap through the inner wall;

a second liquid source configured to deliver a second liquid, at a second pressure;

a second injector coupled to the chamber and the second liquid source, the second injector configured to receive the second liquid from the second liquid source and to inject the received second liquid through the second gap, the second injector including a second nozzle having:

a second orifice having a second size and second shape,

the second nozzle and second pressure configured to cause the second liquid to form a second liquid spray upon being injected from the second orifice.

18. The apparatus of claim 17, wherein the first gap and second gap are different gaps.

19. The apparatus of claim 17, wherein, with respect to a flow of gas from the gas inlet to the gas outlet:

the first injector is configured to inject the first liquid spray in a downstream direction through the first gap; and

the second injector is configured to inject the second liquid spray in an upstream direction through the second gap.

20. The apparatus of claim 17, wherein:

the inner wall forms a cylindrical inner chamber inside the chamber, the cylindrical inner chamber having an axis, and with respect to a circulation direction about the axis, and the first and second injectors are configured to push the gas in the circulation direction.

21. The apparatus of claim 17, wherein the inner wall forms an inner chamber inside the chamber, the inner wall having first and second gaps through the inner wall into the inner chamber, the first gap configured as a gas inlet into the inner chamber, the second gap configured as a gas outlet from the inner chamber, the first injector configured to inject the first liquid through the first gap into the inner chamber, the second injector configured to inject the second liquid through the second gap into the inner chamber.

22. The apparatus of claim 17, further comprising:

a control mechanism coupled to at least one of the first and second injectors, the control mechanism configured to control at least one of the first and second liquid sprays; and

a sensor coupled the control mechanism, the sensor configured to sense at least one of a gas flow rate, a liquid flow rate, a gas pressure, and a particle concentration,

the control mechanism further configured to receive an input from the sensor and control the at least one of the first and second liquid sprays in response to the input.

23. The apparatus of claim 1, wherein:

the chamber includes:

a chamber wall separating an interior of the chamber from an exterior of the chamber,

a throat through the chamber wall providing for fluidic communication between the interior and exterior of the chamber;

the first injector sprays the first liquid spray through the throat; and

the droplets enter the throat at a velocity higher than the terminal spray velocity and decelerate to the terminal spray velocity before exiting the throat.

24. The apparatus of claim 10, further comprising:

a controller coupled to the first injector, the controller configured to control the first liquid spray; and

a sensor coupled the controller, the sensor configured to sense at least one of a gas flow rate, a liquid flow rate, a gas pressure, and a particle concentration,

the controller further configured to receive an input from the sensor and control the first liquid spray in response to the input.

25. The apparatus of claim 23, wherein the chamber wall includes the interior surface.

26. An apparatus for controlling flow rate of a gas stream, the apparatus comprising:

a chamber configured to contain a gas, the chamber having a gas inlet to deliver the gas into the chamber and a gas outlet to convey the gas out of the chamber, a gas flow through the chamber characterized by a downstream direction from the gas inlet to the gas outlet and an upstream direction from the gas outlet to the gas inlet;

an inner wall separating the gas inlet from the gas outlet, the inner wall having a first gap and a second gap, the first and second gaps providing for the only fluidic communication between the gas inlet and gas outlet;

a first liquid source configured to deliver a first liquid at a first pressure greater than 500 psi;

a first injector coupled to the chamber and the first liquid source, and configured to spray the first liquid into the chamber through the first gap at a first velocity that imparts a downstream momentum to the gas in the chamber, the first injector including a first nozzle having:

a first orifice having a first size that does not exceed 0.01 square inches of orifice area; and

a first shape configured to generate a spray of droplets of liquid;

a second injector coupled to the chamber and configured to spray a second liquid into the chamber through the second gap at a second velocity that imparts an upstream momentum to the gas in the chamber;

a sensor coupled to at least one of the chamber, the first injector, and the second injector, the sensor configured to measure a control parameter of the gas flow through the chamber; and

a controller coupled to the sensor and at least one of the first and second injectors, the controller configured to receive the control parameter and adjust at least one of the first velocity of the first liquid sprayed from the first injector and the second velocity of the second liquid sprayed from the second injector in response to the received control parameter.

27. The apparatus of claim 26, wherein the control parameter includes at least one of a gas flow rate, a liquid flow rate, a pressure, and a contaminant count.

28. The apparatus of claim 26, wherein the inner wall forms an inner chamber that is cylindrical about an axis, the first injector is configured to cause the gas to circulate in a circumferential direction about the axis.

29. The apparatus of claim 28, wherein the second injector is configured to cause the gas to circulate in the circumferential direction about the axis.

30. The apparatus of claim 26, wherein the inner wall forms an inner chamber that is cylindrical about an axis, and each of the first and second injectors comprises a fan nozzle configured to generate a fan-shaped liquid spray, the fan shaped liquid spray having a spray height oriented parallel to the axis.

31. The apparatus of claim 1, wherein the first liquid source comprises a pump having metallic pumping components.

32. The apparatus of claim 1, wherein the first size is less than 0.003 square inches area.

33. The apparatus of claim 1, wherein the first orifice has an orifice equivalent diameter that is at least 0.28 mm and does not exceed 1.1 mm.

34. The apparatus of claim 1, further comprising:

a second liquid source configured to deliver a second liquid at a second pressure;

a second injector coupled to the chamber and the second liquid source, the second injector configured to receive the second liquid from the second liquid source and to inject the received second liquid into the chamber.

35. The apparatus of claim 1, wherein the first liquid source is configured to deliver the first liquid at a pressure greater than 2,000 psi.

36. The apparatus of claim 26, wherein the first size is less than 0.003 square inches area.

37. The apparatus of claim 26, wherein the first liquid source is configured to deliver the first liquid at a pressure greater than 1000 psi.