CLAIMS:

1. An electrostatic spray drying system for drying liquid into powder comprising: an elongated structural body supported in upright position;
a an upper end closure arrangement and a lower end closure arrangement at opposite upper and lower ends of the elongated body, respectively for forming a drying chamber within said elongated body; a non-structural non-metallic liner disposed within said elongated body in spaced relation to an inner wall surface of the elongated body for defining an internal drying zone within said elongated body; one of said upper end closure arrangementsarrangement and lower end closure arrangement including a drying gas inlet for coupling to a drying gas source and for directing drying gas into said drying zone; an electrostatic spray nozzle assembly supported in one of the closure arrangements; said electrostatic spray nozzle assembly including a nozzle body having a discharge spray tip assembly at a downstream end thereof for directing liquid to be dried into said drying zone; said electrostatic spray nozzle assembly having a liquid inlet for coupling to a supply of liquid to be discharged into the drying zone and an electrode for coupling to an electrical source for electrically charging liquid passing through said spray nozzle assembly for discharge from said discharge spray tip assembly into said drying zone; and a circumferentially disposed support for releasably supporting said liner within said elongated body and for enabling selective removal and replacement of the liner following usage of the electrostatic spray drying system.

2. The spray drying system of claim 1 in which said electrostatic spray nozzle assembly has an atomizing gas inlet for coupling to a pressurized gas supply for directing pressurized atomizing gas through said nozzle body for atomizing electrostatically charged liquid discharging from the discharge nozzle assembly.

3. The spray drying system of claim 2 in which said atomizing gas inlet is connected to a supply of inert gas, and a heater for heating the inert gas as it is directed to said atomizing gas inlet of the spray nozzle assembly.

4. The spray drying system of claim 1 in which said liner is centrally disposed within said elongated body so as to define an air space of at least two inches between the liner and the inside wall surface of the elongated body.

5. The spray drying system of claim 1 in which said liner is made of a flexible non-permeable plastic material.

6. The spray drying system of claim 1 in which said liner is made of a permeable filter material.

7. The spray drying system of claim 1 in which said elongated body is cylindrical in shape and made of steel.

8. The spray drying system of claim 1 in which said circumferentially disposed support includes a plurality of circumferentially spaced non-metallic stand offs for supporting said liner in electrically isolated relation to the elongated body.

9. The spray drying system of claim 1 in which said circumferentially disposed support includes ring assemblies for supporting the liner in electrically isolated relation to said elongated body, said ring assemblies each including an inner ring to which an end of the liner is secured, an outer ring secured to the body, and a plurality of circumferentially spaced electrically non-conductive studs fixed in radial relation between the inner and outer rings.

10. The spray drying system of claim 1 in which said closure arrangement at the lower end of the

elongated body includes a powder collection chamber and a filter element housing having an exhaust gas outlet for filtering gas borne particulate matter from drying gas exiting the collection chamber through said filter element housing and exhaust gas outlet, a recirculation conduit coupled between said exhaust gas outlet and said drying gas inlet for reintroducing exhaust gas into the drying chamber and drying zone, and a heating element in said recirculation conduit for heating exhaust gas prior to reintroduction into the drying chamber and heating zone.

11. The spray drying system of claim 1 in which a plurality of said electrostatic spray nozzle assemblies are supported in the closure member at an upper end of the elongated body.

12. The spray drying system of claim 1 in which said nozzle body is an elongated hollow body, an input head supporting said nozzle body, said liquid inlet being in said input head, said electrode having a liquid passage communicating with said liquid inlet, an elongated feed tube made of electrically conductive material disposed within said elongated nozzle body having a liquid passage communicating with said electrode liquid passage, said feed tube and elongated nozzle body defining a gas flow passage having a pressurized gas inlet for coupling to a pressurized gas source, and said discharge spray tip assembly including a spray tip made of electrically conductive material at a downstream end of said nozzle body having a liquid passage in communication with said feed tube liquid passage and a discharge orifice for discharging liquid from the spray nozzle assembly.

13. The spray drying system of claim 1 in which said elongated body has a multipart modular construction comprising a plurality of cylindrical modules, quick disconnect couplings for releasably connecting together adjacent cylindrical modules, and at least one of the cylindrical modules being selectively removable and replaceable for altering the length of the drying chamber for a particular spray application, and said liner being removable and replaceable with a replaceable liner of a length corresponding to the altered length of the drying chamber.

14. The spray drying system of claim 13 in which said quick disconnect couplings are releasable latches.

15. The spray drying system of claim 1 including a pump for directing liquid from the liquid supply to the liquid inlet of the spray nozzle assembly, an electric drive motor for driving said pump, and said electric drive motor being electrically isolated to the pump for preventing an electrical charge to the electric motor from liquid electrostatically charged by said electrostatic spray nozzle assembly or electrically charged liquid directed through said spray nozzle assembly.

16. The spray drying system of claim ~~13~~15 in which said drive motor has an output drive shaft coupled to a drive shaft of the pump by a non-electrically conductive drive segment.

~~17. An electrostatic spray drying system for drying liquid into powder form comprising:~~

~~an elongated structural body supported in upright position;~~

~~a closure arrangement at opposite upper and lower ends of the elongated body for forming a drying chamber within said elongated body;~~

~~an electrostatic spray nozzle assembly supported in said upper closure arrangement;~~

~~said electrostatic spray nozzle assembly including a nozzle body having a discharge spray~~

~~tip assembly at a downstream end thereof for directing liquid to be dried into said drying~~

~~chamber;~~

~~said electrostatic spray nozzle assembly having a liquid inlet for coupling to a supply of liquid to be discharged into the drying chamber and an electrode for coupling to an electrical source for electrically charging liquid passing through said spray nozzle assembly for discharge from said discharge spray tip assembly into said drying zone;~~

~~said electrostatic spray nozzle assembly having an atomizing gas inlet for coupling to a pressurized gas supply for directing pressurized atomizing gas through said nozzle body for atomizing electrostatically charged liquid discharging from the discharge nozzle assembly; and~~

~~said closure arrangement at the lower end of the elongated body having a powder collection chamber and a filter element housing having an exhaust gas outlet for filtering airborne particulate matter from gas exiting the powder collection chamber through said filter element housing and the exhaust gas outlet, and a recirculation conduit coupled between said exhaust gas outlet and a drying gas inlet in the closure arrangement of the upper end of the elongated body for reintroducing exhaust gas into the drying chamber and drying zone.~~

~~18. The electrostatic spray drying system of claim 17 including a heating element in said recirculation conduit for heating exhaust gas prior to reintroduction into the drying chamber.~~

~~19. The electrostatic spray drying system of claim 17 in which said atomizing gas inlet is connected to a supply of inert gas, and including a heater for heating the inert gas as it is directed to said atomizing gas inlet of the spray nozzle assembly.~~

~~20. The electrostatic spray drying system of claim 17 including a non- structural non-metallic liner concentrically disposed within said elongated body in spaced relation to an inner wall surface of the elongated body for defining an internal drying chamber within the elongated body into which liquid is discharged by said electrostatic spray nozzle assembly.~~

~~21. The electrostatic spray drying system of claim 20 in which said non-metallic liner is releasably supported within said elongated body for enabling selective removable and replacement of the liner following usage of the electrostatic spray drying system.~~

~~22.~~17. A method of electrostatically spray drying liquid including the steps of: providing an electrostatic spray dryer having an elongated structural body and a ~~nonstructural~~non-structural non-metallic first liner concentrically disposed within the elongated body in spaced relation to an inner wall surface of the elongated body for defining an internal drying zone within the elongated body and an electrostatic spray nozzle assembly for directing electrostatically charged liquid to be dried into the drying zone; spraying electrostatically charged liquid into the drying zone by said electrostatic spray nozzle assembly during a first selected usage of the electrostatic spray dryer; removing the first liner from the elongated body following the first selective usage of the electrostatic spray dryer and replacing the first liner with a replacement liner for a second selected usage of the spray dryer, and spraying electrostatically charge liquid from the electrostatic spray nozzle assembly into a drying zone defined by the replacement liner during the second selected usage of the spray dryer.

~~23~~18. The method of claim ~~22~~17 including replacing the first liner with ~~a~~said replacement liner which is sized differently than the first liner.

~~24~~19. The method of claim ~~22~~17 including replacing the first liner with ~~a~~said replacement liner ~~that~~which defines a larger diameter heating zone than the first liner.

~~25~~20. The method of claim ~~22~~17 including replacing the first liner with ~~a~~said replacement liner ~~having~~which has a longer length than the first liner.

~~26~~21. The method of claim ~~22~~17 including atomizing electrostatically sprayed liquid directed into the drying zone by heated pressurized inert gas.

~~27~~22. The method of claim ~~22~~17 including introducing heated drying gas into a dryer gas inlet of the elongated structural body during the first and second selected usage of the electrostatic spray dryer, and recirculating the drying gas discharging from a drying gas outlet of the elongated structural body into the drying gas inlet of the elongated structural body for continued usage.

~~28~~23. The method of claim ~~27~~22 including reheating the recirculating drying gas following discharge from the drying outlet and prior to direction into the drying gas inlet.

~~29. A spray dryer for drying liquid into powder comprising:~~

~~an elongated body supported in upright position;~~

~~a closure arrangement at opposite upper and lower ends of the elongated body for forming a drying chamber within said elongated body;~~

~~a spray nozzle assembly supported in said upper end closure arrangement;~~

~~said spray nozzle assembly including a nozzle body having a liquid inlet for coupling to a supply of liquid and a discharge spray tip assembly at a downstream end for directing liquid to be dried into said drying chamber;~~

~~said upper end closure arrangement having a drying gas inlet for introducing drying gas into said drying chamber for drying liquid directed into the drying chamber into powder;~~

~~said closure arrangement at the lower end of said elongated body including powder collection chamber for collecting powder dried in said drying zone and a filter housing having an exhaust gas outlet for filtering drying gas borne powder from drying gas exiting the powder collection chamber through said filter element housing and the exhaust gas outlet;~~

~~said filter element housing including a plurality of cylindrical filter elements supported in a wall of an exhaust chamber communicating with said exhaust gas outlet; and~~

~~said cylindrical filter elements each being closed at one end and having an opposite open axial end communicating with said exhaust chamber such that drying gas exiting the powder collection chamber passes through a cylindrical side of the filter element which restrains gas borne powder with drying gas which then proceeds out the open axial end into and through said exhaust chamber and exhaust gas outlet.~~

~~30. The spray dryer of claim 29 including a recirculation conduit coupled between said exhaust gas outlet and the drying gas inlet for reintroducing drying gas into the drying chamber.~~

~~31. The spray dryer of claim 29 in which said filter elements each are supported in depending relation to said exhaust chamber wall with the open axial end at an upper end communicating with said exhaust chamber such that drying gas and powder directed into said powder collection chamber and filter element housing passes through cylindrical sides of the filter elements and exits the upper open axial ends of the filter elements into the exhaust chamber.~~

~~32. The spray dryer of claim 31 in which said filter elements each are part of a respective filter cartridge comprising a sealing plate closing a lower end of the filter element and an support plate at an upper end, a connecting member coupled between the sealing plate and support plate, and said support plate having a central opening communicating between the upper open axial end of the cylindrical filter element and the exhaust chamber.~~

~~33. The spray drying system of claim 29 in which said filter element housing includes an outer cylindrical housing wall and an inner cylindrical shroud surrounding said filter elements, said inner cylindrical shroud and outer filter element cylindrical housing wall defining an annular drying gas passageway communicating between said drying chamber and said powder collection chamber.~~

~~34. The spray dryer of claim 33 in which said powder collection chamber is disposed below said filter element housing, and said filter element shroud having an open lower end overlying to a central area of the powder collection chamber.~~

~~35. The spray dryer of claim 33 in which said exhaust chamber is defined at least in part by a downwardly opening conical exhaust plenum supported above said inner cylindrical shroud, and an outer surface of said conical exhaust plenum guides drying gas and powder from said drying chamber~~

into the annular passageway between said cylindrical shroud and outer housing wall of the filter element housing.

36. The spray dryer of claim 29 in which the said exhaust chamber filter element support wall is a circular plate formed with a plurality of circular openings from which said filter elements are supported in depending relation.

37. The spray dryer of claim 29 including a gas direction plenum between an underside of said drying chamber and said filter element housing, said powder collection chamber being disposed below said filter element housing , said filter element housing having an outer cylindrical housing wall and an inner cylindrical shroud surrounding said filter elements, and said outer cylindrical wall and inner cylindrical shroud defining an annular drying gas and powder passage communicating between said gas direction plenum and said powder collection chamber.

38. The spray dryer of claim 37 in which said exhaust chamber is defined at least in part by a downwardly opening conical plenum disposed within said gas direction plenum, said exhaust gas outlet communicating through a side of said conical plenum, and an upper outer side of said conical plenum being effective for directing drying gas and powder from said drying chamber into said annular passage for direction into the powder collection chamber.

39. The spray dryer of claim 38 including a powder direction cone between an underside of said filter element housing and said powder collection chamber for directing powder from said filter housing into the powder collection chamber.

40. The spray dryer of claim 29 in which said powder collection chamber includes a valve that is operable between an open position for permitting the direction of powder from said filter element housing into said powder collection chamber and a closed position which interrupts the flow of powder into the collection chamber for enabling removal of powder from the collection chamber.

41. The spray dryer of claim 29 in which said spray nozzle assembly is an

electrostatic spray nozzle assembly having an electrode for coupling to an electrical source for electrically charging liquid passing through the spray nozzle assembly for discharge from said discharge spray assembly into said drying zone, and said nozzle body has an atomizing gas inlet for coupling to a pressurized gas supply for directing pressurized atomizing air through said nozzle body for atomizing electrostatically charged liquid discharging from the discharge spray tip assembly.

42. The spray dryer of claim 31 in which said filter elements each have a respective reverse gas pulse directing device cyclically operateable for directing pulses of pressurized gas into an interior of the cylindrical filter element for removing the buildup of powder on an outside cylindrical surface thereof.

43. The spray dryer of claim 42 in which each said reverse gas pulse directing device includes an gas directing tube having a discharge end centered above the upper open axial end of the cylindrical filter element, and said gas direction tube of each gas pulse directing device having an upstream end coupled to a respective pressurized control valve.

44. The spray dryer of claim 43 in which said control valve of each reverse gas pulse directing device has a respective gas pressure supply line coupled between the respective control valve and a common pressurized gas manifold chamber which in turn is coupleable to a pressurized gas supply.

45. The spray dryer of claim 42 in which the discharge end of each reverse gas pulse directing tube is disposed a distance of at least about two inches above the upper open axial end of the respective filter element.

46. The spray dryer of claim 29 in which each said cylindrical filter element has a respective reverse gas pulse filter cleaning device having a selectively operable reverse gas pulse nozzle coupled to a pressurized gas source for directing pressurized gas into the cylindrical filter element for dislodging powder accumulated on an outside surface of the cylindrical filter element, a plunger mounted for movement between an open position that permits the flow of drying gas through said cylindrical filter element and axially through the open axial end communicating with the exhaust chamber and a closing position that interrupts and prevents the flow of drying gas from within the collection chamber

to said exhaust chamber, and said plunger being moveable from said open position to said closed position as an incident to the direction of pressurized gas through said reverse pulse nozzle for enabling pressurized gas from the reverse pulse nozzle to be directed into the cylindrical filter element and outwardly through the cylindrical sides thereof without the flow of drying gas into said exhaust chamber.

47. The spray dryer of claim 46 in which each said reverse gas pulse nozzle has a hollow construction through which pressurized gas is directed, said reverse pulse gas nozzle having a first portion disposed within said exhaust chamber and a second portion disposed within and extending substantially the length of the cylindrical filter element, and said plunger being supported for movement along said first portion of said reverse pulse nozzle.

48. The spray dryer of claim 47 in which each said reverse gas pulse nozzle first portion is formed with a plurality of apertures for permitting communication of pressurized gas from said reverse pulse nozzle and into said plunger cylinder for moving said plunger to said closing position, and said nozzle second portion being formed with a plurality of apertures smaller in size than the apertures in the first portion for permitting the flow of pressurized air from said reverse pulse nozzle into said cylindrical filter element and outwardly cylindrical sides thereof when said valve plunger is in said second position.

49. An electrostatic spray drying system for drying liquid into powder comprising:

a drying chamber;

an electrostatic spray nozzle having a spray tip assembly arranged to discharge a supply of liquid into the drying chamber, the electrostatic spray nozzle being configured to discharge the supply of liquid based on a duty cycle signal provided to the electrostatic spray nozzle assembly, the duty cycle signal determining periods at which the electrostatic spray nozzle is open to inject the supply of liquid or closed;

a controller associated with the electrostatic spray nozzle and operating to provide the duty cycle signal to the electrostatic spray nozzle, the controller being programmed and operating to:

activate a pulse width modulation (PWM) mode of operation for the electrostatic spray assembly;

initiate a first timer;

provide a first duty cycle signal to the electrostatic spray nozzle at a first PWM activation frequency while the first timer has not reached a first pulse duration;

initiate a second timer when the first timer has reached the first pulse duration; and

provide a second duty cycle signal to the electrostatic spray nozzle at a second PWM activation frequency while the second timer has not reached a second pulse duration.

50. The electrostatic spray system of claim 49, further comprising a voltage source, wherein the electrostatic spray nozzle is connected to the voltage source and configured to impart an electrostatic charge to the supply of liquid that is discharged into the drying chamber through the spray tip assembly, and wherein the controller is further associated with the voltage source and configured to control a voltage setpoint of the voltage source.

51. The electrostatic spray system of claim 50, wherein the controller is programmed to activate the PWM mode of operation when a voltage control mode of operation is not active.

52. The electrostatic spray system of claim 51, wherein the controller is further programmed to activate the voltage control mode of operation and to control the voltage setpoint of the voltage source while the duty cycle signal is maintained at a predefined PWM activation frequency.

53. The electrostatic spray system of claim 49, wherein the first PWM activation frequency is lower than the second PWM activation frequency.

~~54. The electrostatic spray system of claim 49, further comprising a pump configured to pressurize the supply of liquid provided to the electrostatic spray nozzle to an injection pressure, wherein the pump is associated with the controller and operates to set the injection pressure in response to a pressure signal provided by the controller, and wherein the controller is further programmed to selectively vary the injection pressure over time.~~

~~55. The electrostatic spray system of claim 49, wherein the electrostatic spray nozzle is configured to receive a pressurized gas that it combines with the supply of liquid to atomize the liquid discharged into the drying chamber.~~

~~56. The electrostatic spray system of claim 55, further comprising a compressor configured to compress a supply of gas into the pressurized gas provided to the electrostatic spray nozzle at an atomizing gas pressure, wherein the compressor is associated with the controller and operates to set the atomizing gas pressure in response to a gas pressure signal provided by the controller, and wherein the controller is further programmed to selectively vary the atomizing gas pressure.~~

~~57. The electrostatic spray system of claim 55, further comprising a gas heater associated with the controller and configured to heat the pressurized gas to an atomizing gas temperature in response to a gas temperature command signal provided by the controller, wherein the controller is further configured to selectively vary the gas temperature command signal over time.~~

~~58. The electrostatic spray system of claim 49, further comprising a fan configured to provide a flow of drying gas through the drying chamber, the drying gas provided at a moisture content and temperature that are selectively determined at a drying gas conditioning module, the conditioning module being associated with the controller and responsive to signals provided from the controller to selectively set the moisture content and temperature of the flow of drying gas, wherein the controller is programmed to selectively vary at least one of the moisture content and temperature of the flow of drying gas.~~

~~59. The electrostatic spray system of claim 58, wherein the fan is configured to selectively provide the flow of drying gas at a mass airflow rate, the mass airflow rate being determined based on a control signal from the controller, wherein the controller is further programmed to selectively vary the mass airflow rate over time.~~

~~60. A method for controlling a size of agglomerates in an electrostatic spray system, comprising:~~

~~providing an electrostatic sprayer configured to discharge a flow of liquid into a drying chamber;~~

~~activating the electrostatic sprayer using a pulse width modulated (PWM) signal;~~

~~alternating between a first PWM signal having a first duty cycle at a first activation frequency and a second PWM signal having a second duty cycle at a second activation frequency, wherein the first activation frequency is lower than the second activation frequency;~~

~~operating the electrostatic sprayer at the first PWM signal for a first time to cause agglomerates to condense at a first size, and~~

~~operating the electrostatic sprayer at the second PWM signal for a second time to cause agglomerates to condense at a second size,~~

~~wherein the second size is larger than the first size; and~~

~~wherein controlling the average size of agglomerates includes adjusting the first time and the second time during operation.~~

~~61. The method of claim 60, wherein an electronic controller is used to provide the first and second PWM signals to the electrostatic sprayer.~~

~~62. The method of claim 60, further comprising selectively regulating a voltage potential communicated to the electrostatic sprayer.~~

~~63. The method of claim 60, further comprising pressurizing the flow of liquid to an injection pressure, wherein the method further includes selectively varying the injection pressure over time.~~

~~64. The method of claim 60, further comprising providing a pressurized gas to the electrostatic sprayer at an atomizing gas pressure to atomize the flow of liquid discharged into the drying chamber, wherein the method further includes selectively varying the atomizing gas pressure.~~

~~65. The method of claim 64, further comprising providing the pressurized gas to the electrostatic sprayer at an atomizing gas temperature, wherein the method further includes selectively varying the atomizing gas temperature.~~

~~66. The method of claim 60, further comprising providing a flow of drying gas through the drying chamber, the drying gas provided at a moisture content and temperature, wherein the method further includes varying the moisture content of the flow of drying gas.~~

~~67. The method of claim 66, further comprising varying the temperature of the flow of drying gas.~~

~~68. The method of claim 66, wherein the flow of drying gas is provided at a mass airflow rate, and wherein the method further includes selectively varying the mass airflow rate.~~