Summary of the Invention

Systems and methods are provided for simultaneously dispensing precisely-controlled doses of a powder into multiple cartridges. The powder can contain a drug, and the cartridges can be used in inhalers. The fill state of each cartridge, typically the powder weight, is sensed during filling, and powder dispenser modules are individually controlled in response to the sensed weight to ensure accurate dosage. The system operates at high speed and can be very compact to enable production filling operations with minimal floor space requirements.

Disclosed herein is~~According to a first aspect of the invention,~~ a powder dispensing and sensing apparatus comprise~~s~~ing a tray support structure to receive a cartridge tray holding cartridges, a powder dispenser assembly including powder dispenser modules to dispense powder into respective cartridges of a batch of cartridges in the cartridge tray, a powder transport system to deliver powder to the powder dispenser modules, a sensor module including sensor cells to sense respective fill states of each of the cartridges in the batch of cartridges, and a control system to control the powder dispenser modules in response to the respective sensed fill states of each of the cartridges of the batch of cartridges.

The powder dispenser modules, the powder transport system and the sensor cells can be configured for concurrent dispensing of powder to the batch of cartridges and concurrent sensing of the fill state of each of the cartridges in the batch of cartridges. The sensor cells can comprise weight sensor cells. The cartridge tray can be configured to support the cartridges in a two-dimensional array of rows and columns.

The powder transport system can include a blower assembly to move a transport gas, a powder aerator to deliver powder to the powder dispenser

supply the transport gas to the powder aerator. The blower assembly can further comprise an induction rod to introduce conditioned transport gas into the flow of transport gas.

The powder aerator can include a manifold block defining a powder inlet, powder output ports coupled to the powder dispenser assembly and a gas inlet coupled to the blower assembly. The powder aerator can further include a pneumatic broom to deliver powder through riser tubes to the powder output ports and a dump valve to supply a quantity of powder from the powder inlet to the pneumatic broom. The dump valve also seals the closed loop transport gas system from the external environment. The powder aerator can further include a bypass manifold coupled to the powder output ports and a crossover valve that directs selected portions of the transport gas from the gas inlet to the pneumatic broom and to the bypass manifold.

Disclosed herein is~~According to a second aspect of the invention,~~ a method ~~is provided~~ for dispensing and sensing powder~~. The method~~ comprise~~s~~ing positioning cartridges in a cartridge tray, concurrently dispensing powder into a batch of cartridges in the cartridge tray, and concurrently sensing a fill state of each of the cartridges in the batch of cartridges.

Disclosed herein is~~According to a third aspect of the invention,~~ a powder aerator comprise~~s~~ing a manifold block defining a powder inlet, powder output ports and a transport gas inlet; a pneumatic broom to deliver powder to the powder output ports; a dump valve to supply a quantity of powder from the powder inlet to the pneumatic broom; a bypass manifold coupled to the powder output ports; and a crossover valve to direct selected portions of the transport gas from the gas inlet to the pneumatic broom and to the bypass manifold.

Disclosed herein is~~According to a fourth aspect of the invention,~~ a powder dispenser assembly comprise~~s~~ing an array block including an array of vertical ports and horizontal channels intersecting each of the vertical ports; and powder dispenser modules mounted in respective vertical ports of the array block, each of the powder dispenser modules having powder inlets communicating with the channels in the array block, wherein powder delivered to the channels in the array block is dispensed by each of the powder dispenser modules.

Disclosed herein is~~According to a fifth aspect of the invention,~~ a powder transport system comprise~~s~~ing a powder dispenser assembly to dispense powder into cartridges; a blower assembly to move a transport gas; and a powder aerator to deliver powder entrained in the transport gas to the powder dispenser assembly.

~~According to a sixth aspect of the invention, a powder dispenser module comprises a housing that defines a powder inlet for receiving powder, a powder outlet, and a powder delivery conduit connecting the powder inlet and the powder outlet; a feed wand to move powder through the powder delivery conduit; an actuator to operate the feed wand; a valve to control the powder outlet; and an actuator to operate the valve.~~

According to a first aspect, there is provided a powder dispenser module comprising: a housing that defines a powder inlet for receiving powder, a powder outlet, and a conduit connecting the powder inlet and the powder outlet; a feed wand to move powder through the conduit from the powder inlet to the powder outlet; and a wand actuator to rotate the feed wand in the conduit, wherein the conduit includes a powder bed preparation zone below the powder inlet, a powder bed compression zone below the powder bed preparation zone and a powder discharge zone below the

powder bed compression zone, and wherein the feed wand comprises a shaft, a powder bed preparation element in the powder bed preparation zone and a discharge element in the powder discharge zone.

Disclosed herein is~~According to a seventh aspect of the invention,~~ a blower assembly comprise~~s~~ing an impeller to move a transport gas; an impeller motor to rotate the impeller; a blower housing enclosing the impeller and having a discharge port for the transport gas; a manifold to receive transport gas; and a gas-particle separation device affixed to the manifold to accumulate agglomerates entrained in the transport gas.

Disclosed herein is~~According to an eighth aspect of the invention,~~ a powder handling apparatus comprise~~s~~ing a tray support structure to receive a cartridge tray

holding at least a first batch of cartridges and a second batch of cartridges; a dispensing subsystem to dispense powder into a batch of the cartridges in the cartridge tray; and a tray positioning mechanism to move the cartridge tray to sequentially position the first and subsequent batches of cartridges in the cartridge tray in alignment with the dispensing subsystem.

~~According to a ninth aspect of the invention, a method for dispensing powder into a cartridge comprises positioning a cartridge below a dispenser module having a hopper containing a powder, opening a valve that controls the hopper, operating a feed wand in the hopper to dispense powder through the valve to the cartridge, and closing the valve when a desired fill state of the cartridge is reached.~~

According to a second aspect, there is provided a method for dispensing powder into a cartridge, comprising: positioning a cartridge under a dispenser module having a dispenser hopper containing a powder; opening a valve that controls the dispenser hopper; operating a feed wand in the hopper to dispense powder through the valve to the cartridge, wherein operating the feed wand comprises operating a powder bed preparation element in a powder bed preparation zone of the hopper below a powder inlet and operating a discharge element in a powder discharge zone of the hopper; and closing the valve when a desired fill state of the cartridge is reached.

Operation of the feed wand can include rotating the feed wand and reversing rotation of the feed wand to condition the powder in the hopper. The feed wand can be rotated at variable speeds and can be dithered during rotation. The feed wand can reciprocate, causing the wand to quickly rotate clockwise and counterclockwise, during some portion of one or more revolutions. The method can include sensing a weight of powder in the cartridge and closing the valve when the sensed weight is equal to or greater

than a target weight. Opening the valve can include rotating a valve member in a selected direction, and closing the valve can include rotating the valve member in the same direction. Opening the valve can include post-positioning the valve member with respect to the dispenser nozzle opening.

The feed wand can be rotated at a selected maximum speed during a first portion of a fill cycle and then rotated at a reduced speed during a second portion of the fill cycle. The second portion of the fill cycle can be initiated when the powder dispensed into the cartridge is equal to or greater

than a selected weight. Proportional control and/or integral control can be utilized during any portion of the fill cycle.

Disclosed herein is~~According to a tenth aspect of the invention,~~ the powder dispensing and sensing apparatus comprising~~is~~ a highly compact, modular system which is operable both in a research laboratory and in a production plant. This feature facilitates regulatory approval for a common machine and results in cost reduction due to common technical support and training and reduced parts inventories.

Disclosed herein is~~According to an eleventh aspect of the invention,~~ the powder dispensing and sensing apparatus having~~has~~ the capability to fill inhaler cartridges, one time use inhalers and compact multiple use inhalers. This capability can be achieved by relatively minor changes to the system that delivers containers to be filled to the powder dispensing and sensing apparatus.

Brief Description of the Drawings

For a better understanding of the present invention, reference is made to the accompanying drawings, which are incorporated herein by reference and in which:

Fig. 1 is a perspective view of a powder dispensing and sensing apparatus in accordance with an embodiment of the invention;

Fig. 2 is an exploded view of the powder dispensing and sensing apparatus of Fig. 1;

Fig. 3 is a partial vertical cross-sectional view of the powder dispensing and sensing apparatus;

Fig. 3A is a schematic block diagram of the powder dispensing and sensing apparatus;

39. A powder transport system comprising:

a powder dispenser assembly to dispense powder into cartridges, wherein the powder dispenser assembly comprises: an array block including an array of vertical ports and horizontal channels intersecting respective rows of the vertical ports, the array block configured for mounting powder dispenser modules in respective vertical ports of the array block, each of the powder dispenser modules having a powder inlet communicating with the channel in the array block, wherein powder delivered to the channels in the array block is dispensed by each of the powder dispenser modules;

a blower assembly to move a transport gas; and

a powder aerator to deliver powder entrained in the transport gas to the powder dispenser assembly.

40. A powder transport system as defined in claim 39, further comprising a suction manifold to return the transport gas to the blower assembly, wherein the powder transport system comprises a gas transport loop.

41. A powder transport system as defined in claim 40, further comprising a transport gas conditioning system.

42. A powder transport system as defined in claim 41, wherein the transport gas conditioning system is configured to control relative humidity in the gas transport loop.

43. A powder transport system as defined in claim 40, further comprising a hopper assembly to supply powder to the powder aerator.

44. A powder transport system as defined in claim 43, wherein the hopper assembly includes a hopper body defining a powder reservoir and a granulator in a lower portion of the powder reservoir.

45. A powder transport system as defined in claim 44, wherein the granulator comprises first and second agglomerator rollers and first and second motors to rotate the first and second agglomerator rollers, respectively.

46. A powder transport system as defined in claim 45, wherein each of the agglomerator rollers is provided with a plurality of pins.

47. A powder transport system as defined in claim 45, wherein each of the agglomerator rollers is provided with a plurality of spaced-apart disks, the disks of the first and second agglomerator rollers being interdigitated.

48. A powder transport system as defined in claim 39, wherein each channel in the array block passes through the array block.

49. A powder transport system as defined in claim 39, wherein the powder inlets of the powder dispenser modules are alignable with the channels in the array block so that powder delivered to the channels in the

array block can pass through powder inlets to downstream powder dispenser modules.

50. A powder transport system as defined in claim 39, wherein the powder aerator comprises:

a manifold block defining a powder inlet, powder output ports and a transport gas inlet;

a pneumatic broom to deliver powder to the powder output ports; and

a dump valve to supply a quantity of powder from the powder inlet to the pneumatic broom.

51. A powder transport system as defined in claim 50, wherein the powder aerator further comprises a bypass manifold coupled to the powder output ports and a crossover valve to direct selected portions of the transport gas from the transport gas inlet to the pneumatic broom and to the bypass manifold.

52. A powder transport system as defined in claim 51, wherein the powder aerator further comprises flow straighteners and a contoured flow element to assist in providing a uniform flow of the transport gas through the powder output ports.

53. A powder transport system as defined in claim 50, wherein the manifold block further defines riser tubes connecting the pneumatic broom to the powder output ports.

54. A powder transport system as defined in claim 50, wherein the pneumatic broom includes a hollow aerator tube having discharge nozzles thereon.

55. A powder transport system as defined in claim 54, wherein the pneumatic broom further comprises one or more dividers, which define annular chambers.

56. A powder transport system as defined in claim 55, wherein the pneumatic broom further comprises one or more paddles in each of the annular chambers.

57. A powder transport system as defined in claim 39, wherein the blower assembly comprises:

an impeller to move the transport gas;

an impeller motor to rotate the impeller;

a blower housing enclosing the impeller and having a discharge port for the transport gas;

a manifold to receive the transport gas; and

a gas-particle separation device to accumulate agglomerates entrained in the transport gas.

58. A powder transport system as defined in claim 57, wherein the gas-particle separation device comprises a cyclone separator disposed between the manifold and the impeller.

59. A powder transport system as defined in claim 57, wherein the gas-particle separation device comprises a vane separator disposed between the manifold and the impeller.

60. A powder transport system as defined in claim 57, further comprising an induction rod to induce conditioned transport gas into the gas-particle separation device.

61. A powder transport system as defined in claim 41, wherein the transport gas conditioning system comprises a sensor chamber coupled in parallel with the gas transport loop, the sensor chamber including at least one sensor to sense a parameter of the transport gas, and a gas conditioning element responsive to the sensed parameter to condition the transport gas.

62. A powder transport system as defined in claim 61, wherein the sensor chamber includes a relative humidity sensor and a temperature sensor.

63. A powder transport system as defined in claim 61, wherein the sensor chamber includes a relative humidity sensor and two temperature sensors to enable cross checking of temperature readings.

64. A powder transport system as defined in claim 61, wherein the sensor chamber has an internal volume that is comparable to an internal volume of the powder dispenser assembly.

65. A powder transport system as defined in claim 61, wherein the gas conditioning element comprises an induction rod to introduce conditioned transport gas into the blower assembly.

66. In a powder transport system, a method for transporting a powder to be dispensed into cartridges, comprising:

moving a transport gas through the powder transport system with a blower assembly;

entraining powder into the transport gas with a powder aerator and delivering the powder entrained in the transport gas to a powder dispenser assembly, wherein the powder dispenser assembly includes an array block having an array of vertical ports and horizontal channels intersecting respective rows of the vertical ports, the array block configured for mounting powder dispenser modules in respective vertical ports of the array block, wherein powder is delivered through the channels in the array block to be dispensed by each of the powder dispenser modules; and

dispensing the delivered powder into the cartridges with the powder dispenser assembly.

67. A method as defined in claim 66, further comprising returning the transport gas to the blower assembly to form a closed loop powder transport system.

68. A method as defined in claim 67, further comprising supplying powder to the powder aerator from a hopper assembly having a powder reservoir and a granulator.

69. A method as defined in claim 66, wherein the powder aerator comprises a manifold block defining a powder inlet, powder output ports and a transport gas inlet, a pneumatic broom and a dump valve, wherein entraining powder in the transport gas comprises supplying a quantity of powder from the powder inlet to the pneumatic broom with the dump valve, supplying the transport gas to the pneumatic broom, and entraining powder in the transport gas with the pneumatic broom.

70. A method as defined in claim 66, wherein moving the transport gas comprises moving the transport gas with an impeller in the blower assembly, and accumulating agglomerates entrained in the transport gas with a gas-particle separation device.

71. A method as defined in claim 66, further comprising conditioning the transport gas.

72. A method as defined in claim 71, wherein conditioning the transport gas comprises sensing a parameter of the transport gas and conditioning the transport gas in response to the sensed parameter.

73. A method as defined in claim 71, wherein conditioning the transport gas comprises controlling relative humidity and/or temperature of the transport gas.

74. A powder dispensing and sensing apparatus having the capability to fill inhaler cartridges and characterized by:

an array of weight sensor assemblies; and

a sensor housing mounting the weight sensor assemblies of the array in fixed relative positions to sense weights of cartridges in a matching array of said cartridges.

75. Apparatus as defined in claim 74, wherein each of the weight sensor assemblies includes at least one weight sensor cell, each weight sensor cell including weight sensing components at the top of the weight sensor assembly, electronic circuitry below the weight sensing components and an electrical connector at the bottom of the weight sensor assembly.

76. Apparatus as defined in claim 75, wherein the weight sensor cells are located on 25.37 millimeter (one inch) centers in the array of weight sensor assemblies.

77. Apparatus as defined in claim 75, wherein the housing further includes a sensor backplane having connectors for engaging the electrical connectors of each of the sensor cells.

78. Apparatus as defined in claim 75, 76 or 77, wherein each sensor cell further includes a weight sensor probe configured to interface between the weight sensing components and a cartridge to be sensed.

79. Apparatus as defined in claim 75, 76, 77 or 78, wherein the weight sensing components of each sensor cell include an electrobalance beam.

80. Apparatus as defined in any one of claims 74-79, wherein the sensor housing includes a cooling system configured to direct cooling air over the weight sensor assemblies.

81. Apparatus as defined in any one of claims 74-80, wherein the sensor housing includes a locating plate configured to define positions of the weight sensor assemblies in the array.

82. Apparatus as defined in any one of claims 74-81, wherein the weight sensor assemblies are configured for simultaneous sensing of the weights of cartridges.

83. Apparatus as defined in claim 82, wherein the weight sensor assemblies are configured to control filling of the cartridges at a rate of 10.0 milligrams of powder in 10 seconds.

84. Apparatus as defined in claim 82 or 83, wherein the weight sensor assemblies are configured to control filling of the cartridges with an accuracy of 5 to 10 micrograms.

85. Apparatus as defined in claim 82 or 83, wherein the weight sensor assemblies are configured to control filling of the cartridges with powder in a dose having a weight within a range of from 5 to 30 milligrams.

86. Apparatus as defined in any one of claims 74-85 and including said array of cartridges, wherein the spacing of weight sensor assemblies in the array of weight sensor assemblies matches the spacing of at least a subset of the cartridges in the array of cartridges.

87. A method for dispensing and sensing powder comprising positioning cartridges in a cartridge tray, concurrently dispensing powder into a batch of cartridges in the cartridge tray, and concurrently sensing a fill state of each of the cartridges in the batch of cartridges, characterized by:

providing an array of weight sensor assemblies that matches positions of the cartridges in the batch of cartridges;

positioning the cartridges in the batch of cartridges in contact with respective weight sensor assemblies in the array of weight sensor assemblies; and

sensing weights of the cartridges in the batch of cartridges.

88. A method as defined in claim 87, wherein sensing weights comprises simultaneously sensing weights of the cartridges in the batch of cartridges as the cartridges are being filled.

89. A method as defined in claim 88, further comprising providing sensor signals in response to sensing weights of the cartridges, the sensor signals controlling filling of the cartridges in the batch of cartridges.

90. Powder handling apparatus comprising:

a tray support structure to receive a cartridge tray holding at least a first batch of cartridges and a second batch of cartridges;

a dispensing subsystem to dispense powder into a batch of the cartridges in the cartridge tray; and

a tray positioning mechanism to move the cartridge tray to sequentially position the first and second batches of cartridges in the cartridge tray in alignment with the dispensing subsystem.

91. A powder dispenser assembly comprising:

an array block including an array of vertical ports and horizontal channels intersecting respective rows of the vertical ports; and

powder dispenser modules mounted in respective vertical ports of the array block, each of the powder dispenser modules having a powder inlet communicating with the channel in the array block, wherein powder delivered to the channels in the array block is dispensed by each of the powder dispenser modules.

92. A powder aerator comprising:

a manifold block defining a powder inlet, powder output ports and a transport gas inlet;

a pneumatic broom to deliver powder to the powder output ports;

a dump valve to supply a quantity of powder from the powder inlet to the pneumatic broom;

a bypass manifold coupled to the powder output ports; and

a crossover valve to direct selected portions of a transport gas from the transport gas inlet to the pneumatic broom and to the bypass manifold.

93. A blower assembly comprising:

an impeller to move a transport gas;

an impeller motor to rotate the impeller;

a blower housing enclosing the impeller and having a discharge port for the transport gas;

a manifold to receive the transport gas; and

a gas-particle separation device to accumulate agglomerates entrained in the transport gas.