(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 October 2019 (17.10.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/200237 A1

(51) International Patent Classification:
G05D 11/13 (2006.01)

(21) International Application Number:
PCT/US2019/027186

(22) International Filing Date:
12 April 2019 (12.04.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/656,967 12 April 2018 (12.04.2018) US

(71) Applicant: **NORDSON CORPORATION** [US/US]; 28601 Clemens Road, Westlake, OH 44145-1119 (US).

(72) Inventors: **SZUCH, Michael**; 2762 Loker Ave. West, Carslbad, CA 92010 (US). **SWENNEN, Tom**; Hasselstraat 43, 3990 Peer (BE). **FRANKEN, Ronny**; Koppelstraat 59, 3650 Dilsen-Stokkem (BE). **LEWIS, Alan, R.**; 2762 Loker Ave. West, Carslbad, CA 92010 (US).

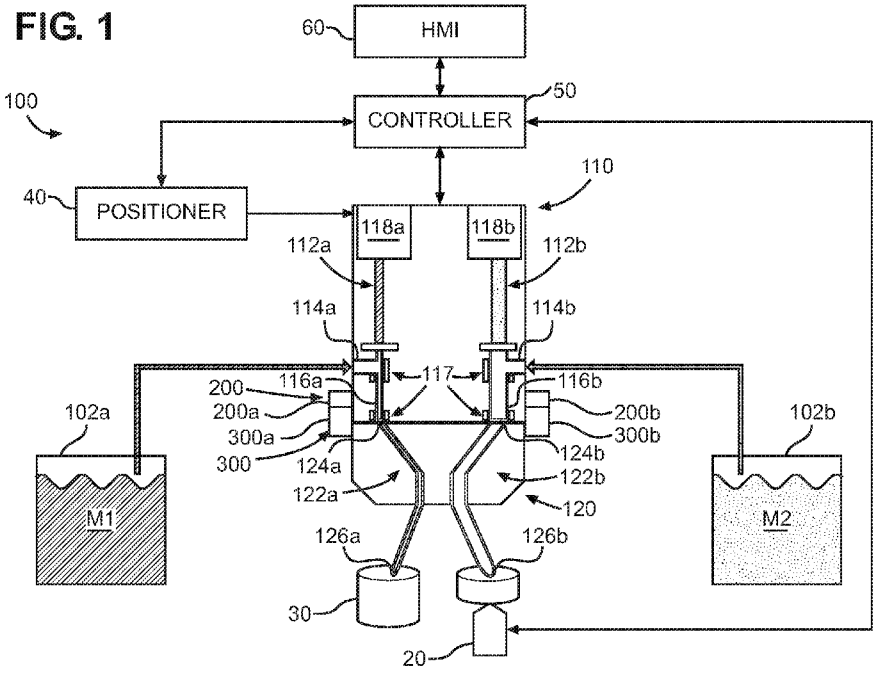
(74) Agent: **AKHAVANNIK, Hussein**; Baker & Hostetler LLP, 2929 Arch Street, Cira Centre 12th, Floor, Philadelphia, PA 19104-2891 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

(54) Title: SYSTEMS AND METHODS FOR DISPENSING MULTI-COMPONENT MATERIALS

FIG. 1



(57) Abstract: Systems and methods for applying a mixed material to a substrate are disclosed herein. The method includes receiving dispensing operating parameters and dispensing first and second materials at first and second material flow rates and determining amounts of the first and second materials dispensed. The method also includes automatically adjusting the dispensing of the first and second materials to adjusted first and second material flow rates based upon the determined amounts of the first and second materials dispensed. The method includes pumping the first and second materials at the adjusted first and second material flow rates, mixing the first material and the second material within a chamber of a mixer to form the mixed material, and dispensing the mixed material from a dispensing nozzle onto the substrate.

WO 2019/200237 A1

[Continued on next page]

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SYSTEMS AND METHODS FOR DISPENSING MULTI-COMPONENT MATERIALS

Cross Reference to Related Applications

[0001] This application claims the benefit of U.S. Provisional Patent App. No. 62/656,967, filed April 12, 2018, the disclosure of which is hereby incorporated in its entirety by reference herein.

Technical Field

[0002] The present disclosure relates generally to dispensing multi-component liquid materials and, more particularly, to systems and methods for precisely controlling the dispensing of multi-component liquid materials to a substrate.

Background

[0003] In manufacturing of e.g., printed circuit boards ("PCBs") it is frequently necessary to apply small amounts of vicious materials. Such materials include, for example, general purpose adhesives, solder paste, solder flux, solder mask, grease, oil, encapsulates, potting compounds, epoxies, die attach pastes, silicones, RTV, cyanoacrylates. There exists known methods for automatic control of dispensing of precise amounts of single component materials. Nevertheless, there exists a need for automatic precise control of dispensing amounts and/or ratios for multi-component dispensing operations.

Summary

[0004] Disclosed herein are systems and methods for dispensing a mixed material onto a substrate. In one embodiment, a method for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, includes receiving dispensing operating parameters. The method also includes dispensing a first material from a first pump at a first material flow rate and determining an amount of the first material dispensed. The method also includes dispensing a second material from a second pump at a second material flow rate and determining an amount of the second material dispensed. The method also includes automatically adjusting dispensing of the first material to an adjusted first material flow rate and dispensing of the second material to an adjusted second material flow rate based on the

determined amounts of the first and second materials dispensed. The method also includes pumping the first material from the first pump at the adjusted first material flow rate. The method also includes pumping the second material from the second pump at the adjusted second material flow rate. The method also includes mixing the first material and the second material within a chamber of a mixer to form the mixed material. The method also includes dispensing the mixed material from a dispensing nozzle onto the substrate.

[0005] In another embodiment, a dispense system for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate includes a first supply that is configured to contain the first material. The dispense system also includes a second supply that is configured to contain the second material and a pump system. The pump system includes a first pump having an inlet in fluid communication with the first supply and an outlet, the first pump being configured to pump the first material from the first supply through the outlet of the first pump at a first material flow rate. The pump system also includes a second pump having an inlet in fluid communication with the second supply and an outlet, the second pump being configured to pump the second material from the second supply through the outlet of the second pump at a second material flow rate. The dispense system also includes a mixer that is configured to be connected to the pump system and that includes a first inlet that is configured to be in fluid communication with the outlet of the first pump, a second inlet that is configured to be in fluid communication with the outlet of the second pump, and a chamber configured to mix the first material and the second material therein. The dispense system also includes a dispensing nozzle in fluid communication with the chamber, the dispensing nozzle being configured to dispense the mixed material. The dispense system also includes a sensor that is configured to determine an amount of the first material dispensed and an amount of a second material dispensed. The dispense system also includes a controller that is configured to determine an operating mix ratio of the first material and the second material based on the determined amount of the first material dispensed and the determined amount of the second material dispensed, to determine that the operating mix ratio is outside of a predetermined ratio control range, and to adjust the first material flow rate to an adjusted first material flow rate and the second material flow rate to an adjusted second material flow rate to control operation of the first and second pumps to dispense the mixed material from the dispensing nozzle onto the substrate.

[0006] In yet another embodiment, a dispense system for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, includes a first supply that is configured to contain the first material and a second supply that is configured to contain the second material. The dispense system also includes a pump system including a first inlet in fluid communication with the first supply and a first outlet, and a second inlet in fluid communication with the second supply and a second outlet, the pump system being configured to pump the first material from the first supply through the first outlet at a first material flow rate and to pump the second material from the second supply through the second outlet at a second material flow rate. The dispense system also includes a mixer having a first inlet that is configured to be in fluid communication with the first supply, a second inlet that is configured to be in fluid communication with the second supply, and a chamber configured to mix the first material and the second material therein. The dispense system also includes a dispensing nozzle in fluid communication with the chamber, the dispensing nozzle being configured to dispense the mixed material. The dispense system also includes a sensor that is configured to determine an amount of the mixed material dispensed from the dispensing nozzle. The dispense system also includes a controller that is configured to control operation of the pump system based on the mixed material amount received from the sensor by automatically adjusting the first material flow rate to an adjusted first material flow rate and the second material flow rate to an adjusted second material flow rate based on the mixed material amount to dispense the mixed material from the dispensing nozzle onto the substrate.

[0007] In another embodiment, a method for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, includes receiving dispensing operating parameters. The method also includes calculating a target flow rate for a first material and a target flow rate for a second material based upon the dispensing operating parameters, and setting an initial operating speed of a first pump and an initial operating speed of a second pump based upon the dispensing operating parameters. The method includes dispensing the first material from the first pump operating at the initial operating speed of the first pump, determining an initial operating flow rate of the first material, determining that the initial operating flow rate of the first material is outside of a first predetermined control range, and automatically adjusting the operating speed of the first pump to an adjusted operating speed of the first pump. The method further includes dispensing the second material from the second

pump operating at the initial operating speed of the second pump, determining an initial operating flow rate of the second material, determining that the initial operating flow rate of the second material is outside of a second predetermined control range, and automatically adjusting the operating speed of the second pump to an adjusted operating speed of the second pump. The method includes pumping the first material from the first pump at the adjusted operating speed of the first pump, pumping the second material from the second pump at the adjusted operating speed of the second pump, mixing the first material and the second material within a chamber of a mixer to form the mixed material, and dispensing the mixed material from a dispensing nozzle onto the substrate.

[0008] Various additional features and advantages of this invention will become apparent to those of ordinary skill in the art upon review of the following detailed description of the illustrative embodiments taken in conjunction with the accompanying drawings.

Brief Description of Drawings

[0009] The following detailed description is better understood when read in conjunction with the appended drawings. For the purposes of illustration, examples are shown in the drawings; however, the subject matter is not limited to the specific elements and instrumentalities disclosed. In the drawings:

[0010] FIG. 1 illustrates a dispense system in accordance with aspects of the invention;

[0011] FIG. 2 illustrates another view of the dispense system of FIG. 1 in accordance with aspects of the invention;

[0012] FIG. 3 illustrates yet another view of the dispense system of FIG. 1 in accordance with aspects of the invention;

[0013] FIG. 4 illustrates the dispense system in accordance with other aspects of the invention;

[0014] FIG. 5 illustrates a schematic view of stations of the dispense system in accordance with aspects of the invention;

[0015] FIGS. 6A – 6C illustrate views of a first and second connector of the dispense system in accordance with aspects of the invention;

[0016] FIG. 7 illustrates a flow diagram for an exemplary process in accordance with aspects of the invention; and

[0017] FIG. 8 illustrates a flow diagram for another exemplary process in accordance with aspects of the invention.

Detailed Description of Illustrative Embodiments

[0018] FIGS. 1-4 schematically illustrate aspects of an exemplary dispense system 100 for dispensing mixed material M, which includes at least a first material M1 and a second material M2 onto a substrate 10. The dispense system 100 may include a first supply 102a that may contain the first material M1 and a second supply 102b that may contain the second material M2.

[0019] The dispense system 100 may further include a pump system 110. The pump system 110 may include a first pump 112a and a second pump 112b. The first pump 112a may include an inlet 114a in fluid communication with the first supply 102a and an outlet 116a in fluid communication with the inlet 114a of the first pump 112a. The first pump 112a may pump the first material M1 from the first supply 102a through the outlet 116a of the first pump 112a at a first material flow rate. The second pump 112b may include an inlet 114b in fluid communication with the second supply 102b and an outlet 116b in fluid communication with the inlet 114b of the second pump 112b. The second pump 112b may pump the second material M2 from the second supply 102b through the outlet 116b of the second pump 112b at a second material flow rate.

[0020] The first and second pumps 112a, 112b may each pump consistent and/or constant amounts of material (i.e., the first material M1 and the second material M2, respectively) from the respective outlets 116a, 116b. The amount of materials pumped from the first and second pumps 112a, 112b may be equivalent or different from each other depending on, e.g., the size and/or pump speed of each of the respective first and second pumps 112a, 112b. The first and second pumps 112a, 112b may, for example, be progressive cavity pumps that pump the respective first and second materials M1, M2 at respective first and second pressures/amounts. Accordingly, the respective amounts (e.g., volume) of the first and second materials M1, M2 pumped from the outlets 116a, 116b of the first and second pumps 112a, 112b may be constant. The progressive cavity pumps may produce material feed pressures up to 30 barg (approximately 435.11 psig) at the respective outlets 116a, 116b of the first and second pumps 112a, 112b while requiring comparatively low pressures at the feed. This eliminates the

need for high pressure pneumatic systems in dispensing applications requiring a high pressure feed. A representative progressive cavity pump in accordance with aspects of the invention is described in U.S. Appl. No. 15/743,659, published as WO 2017/0023895, the disclosure of which is hereby incorporated by reference herein in its entirety.

[0021] As shown in FIGS. 1-3, the first pump 112a and the second pump 112b may independently pump the respective first and second materials M1, M2 such that a mix ratio between the first material M1 and the second material M2 may be varied. For example, the pump system 110 may include a first motor 118a that may be operatively connected to and may drive the first pump 112a. The pump system 110 may include a second motor 118b that may be operatively connected to and may drive the second pump 112b. By changing the pump speed(s) of at least one of the first and second motors 118a, 118b, the mix ratio may be adjusted. As shown in FIG. 4, the dispense system 100 may include an alternate pump system 110' embodiment that may employ a single motor 118.' The single motor 118' may drive both the first pump 112a and the second pump 112b such that a mix ratio between the first and second materials M1, M2 is fixed based upon the respective relative sizes of the first and second pumps 112a, 112b. Unless explicitly stated otherwise herein, the dispense system 100 including the alternate pump system 110' of the invention may be used with any components or processes described herein that do not require independent drive of the first and second pumps 112a, 112b. The first motor 118a, the second motor 118b, and/or the single motor 118' may include an encoder or other position/rotation/velocity measurement instrument that may measure a rotational speed of the motor to allow for precise motor control.

[0022] The pump system 110 may also include at least one sensor. For example, the pump system 110 may include a plurality of pressure sensors 117, such as a resistive transducer, a direct piezo load cell, a resistive diaphragm type, or any other type of sensor that is capable of measuring a fluid pressure and/or converting said fluid pressure into an electrical signal. The pressure sensors 117 may be positioned at the inlets 114a, 114b and/or the outlets 116a, 116b of the first and second pumps 112a, 112b.

[0023] As shown in FIG. 1, the dispense system 100 may further include an adapter 120 that may be interchangeably connected to the pump system 110. The adapter 120 may be used to check and/or control the mix ratio between the first material M1 and the second material M2, e.g., as described in the exemplary processes 700, 800 below. The adapter 120 may include

a first pathway 122a through which the first material M1 may flow and a second pathway 122b, that is separate and distinct from the first pathway 122a, through which the second material M2 may flow. The first pathway 122a may include a first inlet 124a the may be in fluid communication with outlet 116a of the first pump 112a. The second pathway 122b may include a second inlet 124b that may be in fluid communication with the outlet 116b of the second pump 112b. The first pathway 122a may further include a first outlet 126a in fluid communication with the first inlet 124a of the first pathway 122a and the second pathway 122b may further include a second outlet 126b in fluid communication with the second inlet 124b of the second pathway 122b. Accordingly, the adapter 120 may provide distinct pathways (i.e., the first pathway 122a and the second pathway 122b) through which the first material M1 and the second material M2 may respectively flow without mixing together.

[0024] As shown in FIGS. 2-6, the dispense system 100 may also include a mixer 130 that may be interchangeably connected to the pump system 110. The mixer 130 may be interchangeable with the adapter 120, i.e., either the mixer 130 or the adapter 120 may be connected to the pump system 110. The mixer 130 may include a first inlet 134a that may be in fluid communication with the outlet 116a of the first pump 112a and a second inlet 134b that may be in fluid communication with the outlet 116b of the second pump 112b. The mixer 130 may also include a chamber 135, within which the first and second materials M1, M2 may be mixed to form the mixed material M. For example, the chamber 135 may include a first opening 136a in fluid communication with the first inlet 134a and the second inlet 134b of the mixer 130. Accordingly, the first material M1 may flow from the first inlet 134a of the mixer 130 into the chamber 135 and the second material M2 may flow from the second inlet 134b of the mixer 130 into the chamber 135 and the first and second material M1, M2 may mix therein. The chamber 135 may also include a second opening 136b from which the mixed material M may flow out of the chamber 135.

[0025] The mixer 130 may include at least one sensor, such as a pressure sensor 137, a resistive transducer, a direct piezo load cell, a resistive diaphragm type, or any other type of sensor that is capable of measuring a fluid pressure and, preferably, converting said fluid pressure into an electrical signal. The pressure sensor 137 may be positioned at the second opening 136b of the chamber 135.

[0026] The dispense system 100 may include a first connector 200 and a second connector 300 that may interchangeably connect the pump system 110 to the adapter 120 and/or the mixer 130 to effectuate the interchangeable connection between the pump system 110 and the adapter 120 and/or the mixer 130. In an embodiment of the invention shown in FIGS. 1-4, the first connector 200, which may be two first connectors 200a, 200b positioned at opposing sides of the pump system 110, may be fixed to the pump system 110. Further, the second connector 300 may be fixed to each of the adapter 120 and the mixer 130. For example, the adapter 120 may include two second connectors 300a, 300b fixed thereto, and the mixer 130 may include another two second connectors 300c, 300d fixed thereto; each of which being positioned at opposing sides of the respective adapter 120 and mixer 130. In an alternate embodiment of the invention (not shown), the pump system 110 may include the second connector 300 and the adapter 120 and the mixer 130 may each include the first connector 200. The dispense system 100 may also include a vision and/or sensing system (not shown), that may include cameras or other sensors to enable automatic and/or manual location/detection of the adapter 120 and/or the mixer 130 during interchange.

[0027] The dispense system 100 may further include a dispensing nozzle 140. The dispensing nozzle 140 may be in fluid communication with the second opening 136b of the chamber 135 of the mixer 130. The dispensing nozzle 140 may dispense the mixed material M received from the second opening 136b of the chamber 135 of the mixer 130.

[0028] The dispense system 100 may also include a scale 20. The scale 20 may determine an amount (e.g., a weight or a mass) of material (e.g., the first material M1, the second material M2, and/or the mixed material) dispensed thereon. The dispense system 100 may also include a container 30. The first material M1 and the second material M2 may separately be dispensed directly onto the scale 20 via the respective first and second pathways 122a, 122b. As shown in FIG. 1, the adapter 120 may be connected to the pump system 110 and the first material M1 may be dispensed through the first pathway 122a onto the scale 20 as the second material M2 is dispensed from the second pathway 122b into the container 30, and vice versa. Further, the mixer 130 may be interchanged with the adapter 120 and connected to the pump system 110 such that the mixed material M may be dispensed from the dispensing nozzle 140 onto the scale 20, as shown in FIGS. 2 and 4.

[0029] The dispense system 100 may include a positioner 40. The positioner 40 may move the dispensing nozzle 140 relative to the scale 20, the container 30, and/or the substrate 10 along X, Y, and/or Z axes via, e.g., electromechanical components such as is disclosed in U.S. Pat. No. 5,906,682, the disclosure of which is hereby incorporated by reference herein in its entirety. For example, the positioner 40 may be operatively connected to the pump system 110, which may be interchangeably connected to either the adapter 120 or the mixer 130 and the dispensing nozzle 140. By moving the pump system 110, the positioner 40 may move the adapter 120 and/or the mixer 130 and the dispensing nozzle 140 attached thereto relative to the scale 20, the container 30, and/or the substrate 10. Alternatively, in embodiments not shown, the pump system 110 may be stationary and the positioner 40 may be connected to the adapter 120 and/or the mixer 130 and the dispensing nozzle 140 to effectuate movement relative to the pump system 110.

[0030] The dispense system 100 may also include a controller 50 that may automatically control operation of, e.g., the pump system 110, the first connector 200, the second connector 300, the scale 20, and/or the positioner 40. The controller 50 may be a programmable logic controller (PLC), a microprocessor based controller, personal computer, or another conventional control device capable of carrying out the functions described herein as understood by a person having ordinary skill in the art. For example, the controller 50 may automatically execute aspects of the dispense routine of the processes 700, 800, as described below. The dispense system 100 may also include a human machine interface (HMI) device 60 that may be operatively connected to the controller 50 in a known manner. The HMI device 60 may include input devices and controls, such as a keypad, pushbuttons, control knobs, a touch screen, etc., and output devices, such as displays and other visual indicators, that are used by an operator to control the operation of the controller 50 and, thereby, control the operation of the dispense system 100. The HMI device 60 may further include an audio output device, such as a speaker, by which an audio alert may be communicated to an operator.

[0031] The controller 50 may control operation of the first pump 112a to dispense the first material M1 at the first material flow rate onto the scale 20. The controller 50 may control operation of the first pump 112a by manipulating electrical current supplied to the first motor 118a to vary the operating speed thereof. Measurements of the position/velocity of the first motor 118a may be taken by the encoder of the first motor 118a and may be used by the

controller 50 for precise control of operation of the first pump 112a. The controller 50 may control operation of the second pump 112b to dispense the second material M2 at the second material flow rate. The controller 50 may control operation of the second pump 112b by manipulating electrical current supplied to the second motor 118b to vary the operating speed thereof. Measurements of the position/velocity of the second motor 118b may be taken by the encoder of the second motor 118b and may be used by the controller 50 for precise control of operation of the second pump 112b. In embodiments of the invention, by independently selectively varying current supplied to the first and second motors 118a, 118b, the controller 50 may variably control the mix ratio of the first and second materials M1, M2. For the alternate pump system embodiment 110,' the controller 50 may control operation of the single motor 118' connected to both the first and second pumps 112a, 112b to control operation of the first and second pumps 112a, 112b by varying electric current supplied to the single motor 118.' Accordingly, the mix ratio between the first material M1 and the second material M2 may be fixed based upon the respective sizes of the first and second pumps 112a, 112b.

[0032] The controller 50 may control operation of the pump system 110 such that the first material M1 is pumped from the first supply 102a through the first inlet 134a of the mixer 130 and to the first opening 136a of the chamber 135 at the first material flow rate. The controller 50 may control operation of the pump system 110 such that the second material M2 is pumped from the second supply 102b through the second inlet 134b of the mixer 130 and to the first opening 136a of the chamber 135. Accordingly, the first material M1 and the second material M2 may converge at the first opening 136a of the chamber 135 and mix within the chamber 135 to provide the mixed material M and the mixed material M may flow through the second opening 136b of the chamber 135 and may be dispensed from the dispensing nozzle 140 onto the scale 20.

[0033] The scale 20 may determine the amount of the first material M1 dispensed thereon and communicate a first output corresponding to the amount of the first material M1 to the controller 50. The scale 20 may determine the amount of the second material M2 dispensed thereon and communicate a second output corresponding to the amount of the second material M2 to the controller 50. The scale 20 may also determine the amount of the mixed material M dispensed thereon and communicate a mixed material output corresponding to the amount of the mixed material M to the controller 50. The controller 50 may control operation of the pump

system 110 (e.g., pump speeds of the first and second pumps 112a, 112b), based upon the outputs received from the controller 50 (e.g., the first output, the second output, and/or the mixed output) to respectively adjust the first material flow rate to an adjusted first material flow rate and the second material flow rate to an adjusted second material flow rate.

[0034] The controller 50 may also control operation of the first pump 112a and the second pump 112b to respectively pump the first material M1 at the adjusted first material flow rate and the second material M2 at the adjusted second material flow rate to dispense the mixed material M from the dispensing nozzle 140 onto the substrate 10. The dispensing processes 700, 800, described below, provide additional details regarding automatic control of the dispense system 100 in accordance with aspects of the controller 50 of the present invention.

[0035] As shown schematically in FIG. 5, the dispense system 100 may include a plurality of stations such as an interchange station 70, a ratio station 80, and/or a dispense station 90. The interchange station 70 may hold and/or store at least one of the adapter 120 and the mixer 130 while not connected to the pump system 110. Alternatively, the adapter 120 may be held and/or stored at the ratio station 80 and/or the mixer 130 may be held and/or stored at the dispense station 90. Still further, a plurality of interchange stations 70 may be provided. One of the plurality of interchange stations 70 may be dedicated to holding/storing the adapter 120 and another of the plurality of interchange stations 70 may be dedicated to holding/storing the mixer 130. In embodiments not shown, the interchange station 70 may hold a plurality of the adapters 120 and/or mixers 130 that may each be selectively automatically connected to the pump system 110.

[0036] According to aspects of the invention, the positioner 40 may move the pump system 110 to the interchange station 70 and the pump system 110 may be automatically connected to the adapter 120. The positioner 40 may move the pump system 110, with the adapter 120 connected thereto, to the ratio station 80, which may include the scale 20 and/or the container 30. At the ratio station 80, a mix ratio of the first and/or the second materials M1, M2 may be confirmed and/or controlled, as described in the exemplary processes 700, 800 below. The positioner 40 may move the pump system 110 to the interchange station 70 where the adapter 120 and the mixer 130 may be automatically interchanged. The positioner 40 may move the pump system 110, with the mixer 130 connected thereto, to the dispense station 90, which

may include the substrate 10. At the dispense station 90, the mixed material M may be dispensed from the mixer 130 onto the substrate 10.

[0037] FIGS. 6A-6C depict an exemplary embodiment the first connector 200 and the second connector 300 of the dispense system 100 in accordance with aspects of the invention. FIG. 6A shows the first connector 200 disconnected from the second connector 300. FIG. 6B shows the first connector 200 engaged with the second connector 300. FIG. 6C shows the first connector 200 latched to the second connector 300. In the exemplary embodiment, the first connector 200 is fixed to the pump system 110 and the second connector 300 is fixed to the mixer 130. As discussed above and shown schematically in FIG. 1, the second connector 300 may also similarly be fixed to the adapter 120.

[0038] The second connector 300 may include a tab 310 having a head 312 and a narrowed portion 314 disposed between the head 312 and the mixer 130. The second connector 300 may be integrally molded to the mixer 130. Alternatively, the second connector 300 may be fixed to the mixer 130 via a retainer (not shown). Though not shown, the second connector 300 may similarly be integrally molded, or alternatively fixed via a retainer (not shown), to the adapter 120.

[0039] The first connector 200 may include a base 210 that may be fixed to the pump system 110. The base 210 may include two pins 212 that project therefrom. The first connector 200 may also include a linkage 220. The linkage 220 may include a first link 222 having a first end and a second end. The linkage 220 may further include a second link 224 having a first end, a second end, and a central portion. The linkage 220 may also include a third link 226 that is slidably connected to the base 210. The third link 226 may be downwardly biased in a vertical direction. For example, the third link 226 may be connected to a spring (not shown) that may supply the downward bias and that may maintain a force on the second connector 300. The third link 226 may include a central portion that the second end of the second link 224 is rotatably connected to. The linkage 220 may also include a fourth link 228 having a first end and a second end. The second end of the fourth link 228 may be rotatably connected to the second end of the first link 222.

[0040] The first connector 200 may also include a claw 230. The claw 230 may have a first finger 232 and a second finger 234 that may surround the head 312 of the second connector 300 to effectuate the interchangeable connection between the first connector 200 and the

respective second connector 300. Each of the first finger 232 and the second finger 234 may respectively have a first end that is rotatably connected to the central portion of the second link 224, a second end. The second end of the first and second fingers 232, 234 may each include a hook that may connect to the narrowed portion 314 of the respective second connector 300, and a channel 235, 237 configured to respectively receive one of the two pins 212 of the base 210. The channels 235, 237 may respectively reinforce and guide movement of the fingers 232, 234. The downward bias of the third link 226 may be transferred through the second link 224 to bias the claw 230 in an open position, as shown in FIG. 6A. Further, the downward bias of the third link 226 transferred through the second link 224 to the claw 230 may cause the claw 230 to make a "click" sound as the fingers 232, 234 snap in place in the narrowed portion 314 of the second connector 300, as shown in FIG. 6B. By producing a "click" sound when the fingers 232, 234 snap in place in the narrowed portion 314 of the second connector 300, a user may receive audible feedback indicating that the first connector 200 and the second connector 300 are in position for connection.

[0041] The first connector 200 may also include an actuator 240, such as a solenoid or a pneumatic actuator. The actuator 240 may be fixed to the pump system 110 and may be rotatably coupled to the first end of the fourth link 228. The actuator 240 may drive the linkage 220 to initiate opening and closing of the claw 230. For example, the actuator 240 may rotate the fourth link 228 counter-clockwise to move the linkage 220 into an over-center cam position to lock the first connector 200 to the second connector 300, as shown in FIG. 6C. Similarly, the actuator 240 may rotate the fourth link 228 clockwise to unlock the first connector 200 and the second connector 300. The actuator 240 may be operatively connected to and subject to control by a controller 50.

[0042] FIG. 7 illustrates a flow diagram of an exemplary process 700 for dispensing the mixed material M, which includes at least the first material M1 and the second material M2, onto the substrate 10. The process 700 may be implemented with any suitable embodiments the dispensing system 100, described above. In addition, the process 700 may be automatically executed by the controller 50. Generally, the process 700 may include a flow control routine (steps 702-712) including receiving dispensing operating parameters, dispensing the first and second materials M1, M2 at respective first and second flow rates and determining the amounts of the first and second materials M1, M2 dispensed. The flow control routine of the process 700

may also include automatically adjusting the pump system 110 to adjusted first and second flow rates for the respective first and second materials M1, M2, and mixing and dispensing the first and second materials M1, M2 onto the substrate 10.

[0043] In particular, the process 700 may include, at step 702, receiving dispensing operating parameters for the dispense system 100. For example, a user may enter the operating parameters into the controller 50 via the HMI device 60. The dispensing operating parameters may include, e.g., a first pump constant C_1 for the first pump 112a (e.g., a fixed volume of material pumped per rotation of the first pump 112a), a second pump constant C_2 for the second pump 112b (e.g., a fixed volume of material pumped per rotation of the second pump 112b), a target mix ratio R_T of the first material M1 and the second material M2 (e.g., by mass or by volume), a density of the first material ρ_1, and/or a density of the second material ρ_2.

[0044] Step 702 may also include determining an operating speed ω_1 for the first pump 112a and an operating speed ω_2 for the second pump 112b based upon the received dispensing operating parameters. For example, using the received operating parameters for the target mix ratio R_T, the first pump constant C_1 for the first pump 112a, and the second pump constant C_2 for the second pump 112b, the operating speed ω_1 for the first pump 112a and the operating speed ω_2 for the second pump 112b may be selected from any operating speeds that satisfy equation 1 as follows:

$$R_T = \frac{(C_1 * \omega_1)}{(C_2 * \omega_2)} \quad [1]$$

[0045] As would be appreciate by a person having ordinary skill in the art, because the first and second pump constants C_1, C_2 may be fixed volumes of material pumped per rotation of the respective first and second pumps 112a, 112b, the target mix ratio R_T used in equation 1 will be a volumetric ratio. If the received target mix ratio R_T is a mass ratio, the process 700 may further include converting the target mix ratio R_T to a volumetric ratio using a ratio of the densities of the first and second materials ρ_1, ρ_2. For example, if the target mix ratio R_T is provided as a ratio of the mass Ma_1 of the first material M1 to the mass Ma_2 of the second material M2 (i.e. Ma_1/Ma_2), the target mix ratio R_T may be converted to a volumetric ratio ($R_{T\text{-}Volumetric}$) by multiplying the mass ratio by the inverse of the density ratio of the first and second materials, as provided in equation 2:

[2] $$R_{T_Volumetric} = \frac{\rho_2}{\rho_1} * \frac{Ma_1}{Ma_2}$$

[0046] In embodiments, the received target mix ratio R_T may be a volumetric ratio and the process 700 may further include converting the target mix ratio R_T to a mass ratio (e.g., for various dispensing calibration routines) using a ratio of the densities of the first and second materials ρ_1, ρ_2. For example, if the target mix ratio R_T is provided as a ratio of the volume V_1 of the first material M1 to the volume V_2 of the second material M2 (i.e., V_1/V_2), the target mix ratio R_T may be converted to a mass ratio ($R_{T\text{-}Mass}$) by multiplying the volumetric ratio by the density ratio of the first and second materials, as provided in equation 3:

[3] $$R_{T_Mass} = \frac{\rho_1}{\rho_2} * \frac{V_1}{V_2}$$

[0047] As discussed above, the densities of the first and second materials ρ_1, ρ_2 may be operating parameters received by the dispense system 100. Alternatively, the process 700 may include determining the respective densities of the first and second materials ρ_1, ρ_2. For example, the densities of the first and second materials ρ_1, ρ_2 may be calculated by measuring a mass of a known volume of material (i.e., the first material M1 and/or the second material M2) that may be dispensed from the dispense system 100, as would be readily understood by a person having ordinary skill in the art.

[0048] The process 700 may include, at step 704, dispensing the first material M1 from the first pump 112a at a first material flow rate onto the scale 20 and determining an amount (e.g., a volume, a mass, a weight, etc.) of the first material M1 dispensed onto the scale 20. The first material flow rate may result from operating the first pump 112a at the operating speed ω_1 (as determined at step 702). For example, the controller 50 may automatically control an amount of power supplied to the first motor 118a until the encoder of the first motor 118a indicates that the operating speed ω_1 has been achieved. The dispensing of the first material M1 onto the scale 20 may be performed over a first measurement period.

[0049] The process 700 may include, at step 706, dispensing the second material M2 from the second pump 112b at the second material flow rate onto the scale 20 and determining an amount (e.g., a volume, a mass, a weight, etc.) of the second material M2 dispensed onto the scale 20. The second material flow rate may result from operating the second pump 112b at the operating speed ω_2 (as determined at step 702). For example, the controller 50 may automatically

control an amount of power supplied to the second motor 118b until the encoder of the second motor 118b indicates that the operating speed ω_2 has been achieved. The dispensing of the second material M2 onto the scale 20 may be performed over a second measurement period. The duration of the first measurement period, during which the first material M1 is dispensed onto the scale 20 at step 704, and the duration of the second measurement period may be equivalent.

[0050] The process 700 may further include, at step 708, determining an operating mix ratio R_{OP} of the first material M1 and the second material M2 based upon the amount of the first material M1 dispensed onto the scale 20 over the first measurement period and the amount of the second material M2 dispensed onto the scale 20 over the second measurement period (as determined at steps 704 and 706). The operating mix ratio R_{OP} may be compared to the target mix ratio R_T (as received at step 702). If the operating mix ratio R_{OP} is within a predetermined ratio control range, the process 700 may proceed directly to step 712, described below. However, if the operating mix ratio R_{OP} is outside of the predetermined ratio control range, the process 700 may proceed to step 710, at which the first and second material flow rates are adjusted. The predetermined ratio control range may, for example, be within ±5% of the target mix ratio R_T. The predetermined ratio control range may also be within ±1% of the target mix ratio R_T.

[0051] The process 700 may include, at step 710, adjusting the dispensing of the first material M1 to an adjusted first material flow rate and the dispensing of the second material M2 to an adjusted second material flow rate based upon the amounts of the first and second materials M1, M2 dispensed onto the scale 20 (as determined at steps 704 and 706) and based upon the dispensing operating parameters for the dispense system 100 (as received at step 702). The dispensing of the first and second materials M1, M2 may include proportionally adjusting the first material flow rate and the second material flow rate. For example, the dispensing of the first and second materials M1, M2 may be adjusted from the first and second material flow rates in proportion to the amount that the operating mix ratio R_{OP} is outside of the predetermined ratio control range. The dispensing of the first and second materials M1, M2 may be adjusted by adjusting the operating speeds ω_1, ω_2 of the first and second pumps 112a, 112b. For example, the controller 50 may automatically control an amount of power supplied to the first and second motors 118a, 118b until the encoders of the first and second motor 118a, 118b indicate that desired adjusted operating speeds of the first and second motors 118a, 118b have been achieved. From step 710, the process 700 may proceed directly to step 712, described below. Alternatively,

aspects of the process 700 may be iterative. For example, upon completion of step 710 and prior to proceeding to step 712, the process 700 may repeat steps 704-708 at the adjusted first and second material flow rates to confirm that the adjustments brought the operating mix ratio R_{OP} within the predetermined ratio control range.

[0052] Upon completion of the flow control routine the process 700 may include, at step 712, pumping the first material M1 from the first pump 112a and pumping the second material M2 from the second pump 112b. If the operating mix ratio R_{OP} is determined to be within the predetermined ratio control range at step 708, the first material M1 and the second material M2 may be pumped at the first and second material flow rates, respectively. If the operating mix ratio R_{OP} is determined to be outside of the predetermined ratio control range, the first material M1 and the second material M2 may be respectively pumped at the adjusted first and second material flow rates (as determined at step 710). Step 712 may further include mixing the first material M1 and the second material M2 within the chamber 135 of the mixer 130 to form the mixed material M and dispensing the mixed material M from the dispensing nozzle 140 onto the substrate 10.

[0053] In addition, step 712 may include a verification of the flow rate of the mixed material M from the dispensing nozzle 140. The verification may be performed, for example, prior to dispensing on the substrate 10, after a fixed amount of substrates have been processed, after a fixed period of time, etc. For example, a target mixed material flow rate may be determined by adding the flow rates of the first and second materials M1, M2 utilized for the dispensing of the mixed material M. The process 700 may dispense the mixed material M over a period of time by operating the first and second pumps 112a, 112b, measuring the mass of the mixed material M dispensed for the period of time, and determining an operating mixed material flow rate from the measured mass of the mixed material and the period of time. The target mixed material flow rate may be compared to the determined operating mixed material flow rate. If the determined operating mixed material flow rate exceeds a predetermined flow rate control range, the dispense system 100 may shut down and indicate to a user that there is a system error via the HMI device 60. The predetermined flow rate control range may, for example, be within ±5% of the target mixed material flow rate. The predetermined ratio control range may be within ±1% of the target mixed material flow rate.

[0054] Conversely, if the determined operating mixed material flow rate is within the predetermined flow rate control range, the dispense system 100 may calibrate a dispense protocol based upon the determined operating mixed material flow rate. For example, a user may specify and input into the dispense system 100 (via the HMI 60) an amount of the mixed material M (e.g., a volume or mass) to be dispensed onto the substrate 10. The user may also input into the dispense system 100 (via the HMI 60) a predetermined location(s) and/or a line length on the substrate 10 at which the mixed material M is to be dispensed. The dispense system 100 may automatically convert the units (e.g., mass to volume and/or volume to mass) of the amount of the mixed material M to be dispensed onto the substrate 10 and/or of the determined operating mixed material flow rate using the densities of the first and second materials ρ_1, ρ_2. Units may be automatically converted to ensure that like-units are utilized during calibration of the dispense protocol.

[0055] The dispense system 100 may automatically calibrate a dispense protocol based upon the specified amount of the mixed material M to be dispensed onto to the substrate 10 and the determined operating mixed material flow rate. For example, the dispense system 100 may automatically calibrate a dispense protocol for dispensing a line of the mixed material M onto the substrate. The automatic calibration may include determining a velocity of the dispense nozzle 140 while the dispense nozzle 140 dispenses the mixed material M at the determined operating mixed material flow rate. Determining the velocity of the dispense nozzle 140 may include multiplying the determined operating mixed material flow rate by a length of the line on the substrate along which the mixed material M is to be dispensed and by a reciprocal of the amount of the mixed material M to be dispensed along the line on the substrate 10. In another example, the dispense system 100 may automatically calibrate a dispense protocol for at least one predetermined location of the substrate 10 (i.e., without moving the dispense nozzle 140 during the dispensing at the predetermined location). The automatic calibration may include determining a time for dispensing the mixed material M at the predetermined location. Determining the time for dispensing the mixed material M at the predetermined location may include dividing the amount of the mixed material M to be dispensed at the predetermined location by the determined operating mixed material flow rate.

[0056] Further, step 712 may include monitoring the dispense system 100 during the dispensing of the mixed material M from the dispensing nozzle 140 onto the substrate 10. For

example, a system pressure (e.g., a pressure measured at any of the pressure sensors 117, 137) may be monitored and the dispense system 100 may shut down and indicate to a user that there is a system error via the HMI device 60 if the system pressure deviates a predetermined amount from a predetermined system pressure threshold. Similarly, current supplied to any of the motors 118a, 118b, 118' of embodiments of the pump systems 110, 110' may be monitored and the dispense system 100 may shut down and indicate to a user that there is a system error via the HMI device 60 if the current deviates a specified amount from a predetermined current threshold.

[0057] According to aspects of the invention, the ratio/amounts of the first and second materials M1, M2 mixed and dispensed onto the substrate 10 may be precisely controlled thereby improving the dispensing of the mixed material M on the substrate 10.

[0058] FIG. 8 illustrates a flow diagram of another exemplary process 800 for dispensing the mixed material M, which includes at least the first material M1 and the second material M2, onto the substrate 10. The process 800 may be implemented with any suitable embodiments the dispensing system 100, described above. In addition, the process 800 may be automatically executed by the controller 50. Generally, the process 800 may include a flow control routine (steps 802-818) including receiving dispensing operating parameters, dispensing the first and second materials M1, M2, and determining operating flow rates for the first and second materials M1, M2. The flow control routine of the process 800 may also include automatically adjusting the pump system 110 to adjusted first and second flow rates for the respective first and second materials M1, M2, and mixing and dispensing the first and second materials M1, M2 onto the substrate 10.

[0059] In particular, the process 800 may include, at step 802, receiving dispensing operating parameters for the dispense system 100. For example, a user may enter the operating parameters into the controller 50 via the HMI device 60. The dispensing operating parameters may include, e.g., the first pump constant C_1 for the first pump 112a, the second pump constant C_2 for the second pump 112b, the target mix ratio R_T of the first material M1 and the second material M2, the density of the first material ρ_1, and/or the density of the second material ρ_2, as discussed in detail in the description of the process 700 above.

[0060] Step 802 may also include determining the operating speed ω_1 for the first pump 112a and the operating speed ω_2 for the second pump 112b based upon the received dispensing

operating parameters. As explained above in the description of the process 700 above, using the received operating parameters for the target mix ratio R_T, the first pump constant C_1 for the first pump 112a, and the second pump constant C_2 for the second pump 112b, the operating speed ω_1 for the first pump 112a and the operating speed ω_2 for the second pump 112b may be selected from any operating speeds that satisfy equation 1:

$$R_T = \frac{(C_1 * \omega_1)}{(C_2 * \omega_2)} \quad [1]$$

[0061] As would be appreciated by a person having ordinary skill in the art, because the first and second pump constants C_1, C_2 may be fixed volumes of material pumped per rotation of the respective first and second pumps 112a, 112b, the target mix ratio R_T used in equation 1 will be a volumetric ratio. If the received target mix ratio R_T is a mass ratio, the process 800 may further include converting the target mix ratio R_T to a volumetric ratio using a ratio of the densities of the first and second materials ρ_1, ρ_2, as explained in detail in the description of the process 700 above. In embodiments, the received target mix ratio R_T may be a volumetric ratio and the process 800 may further include converting the target mix ratio R_T to a mass ratio (e.g., for various dispensing calibration routines) using a ratio of the densities of the first and second materials ρ_1, ρ_2, as is also explained in detail in the description of the process 700 above.

[0062] The process 800 may also include, at step 804, calculating a target flow rate for the first material M1 and a target flow rate for the second material M2. The target flow rates may, for example, be calculated based upon the dispensing operating parameters (i.e., the first pump constant C_1 for the first pump 112a, the second pump constant C_2 for the second pump 112b, and the operating speed ω_1 for the first pump 112a and the operating speed ω_2 for the second pump 112b, determined at step 802). The target flow rate for the first material M1 may be calculated by multiplying the first pump constant C_1 for the first pump 112a by the operating speed ω_1 for the first pump 112a determined at step 802 (i.e., $C_1 * \omega_1$). The target flow rate for the second material M2 may be calculated by multiplying the second pump constant C_2 for the second pump 112b by the operating speed ω_2 for the second pump 112b determined at step 802 (i.e., $C_2 * \omega_2$). Step 804 may further include calculating a target flow rate for the mixed material M. The target flow rate for the mixed material M may be calculated by adding the target flow rate for the first material M1 and the target flow rate for the second material M2.

[0063] The process 800 may further include, at step 806, setting initial operating speeds for the first pump 112a and the second pump 112b. The initial operating speeds for the first pump 112a and the second pump 112b may be based upon the dispense operating parameters received at step 802. For example, the operating speed of the first pump 112a may be set to the operating speed ω_1 for the first pump 112a determined at step 802 and the operating speed for the second pump 112b may be set to the operating speed ω_2 for the second pump 112b determined at step 802. As discussed at step 804, the operating speed ω_1 for the first pump 112a determined at step 802 is expected to produce the target flow rate for the first material M1 and the operating speed ω_2 for the second pump 112b determined at step 802 is expected to produce the target flow rate for the second material M2.

[0064] The process 800 may include steps for ensuring that an operating flow rate of the first material M1 is within a predetermined control range (steps 808a–812a) and steps for ensuring that an operating flow rate of the second material M2 is within a predetermined control range (steps 808b–812b). Ensuring that the operating flow rate of the first material M1 is within the predetermined control range (steps 808a–812a) may occur before, after, or concurrently with ensuring that the operating flow rate of the second material M2 is within the predetermined control range (steps 808b–812b). For example, according to aspects of the process 800 disclosed in detail below, steps 808a-812a are executed prior to steps 808b-812b. Nevertheless, in accordance with other embodiments of the invention, steps 808b-812b may be executed prior to steps 808a-812a. Further, in accordance with embodiments of the invention, steps 808a-812a may be executed concurrently with steps 808b-812b, provided that the pump system 110 is equipped with the adapter 120 and more than one scale is provided for calculating operating flow rates.

[0065] Ensuring that the operating flow rate of the first material M1 is within the predetermined control range may begin, at step 808a, by determining the operating flow rate of the first material M1 (i.e., an initial operating flow rate of the first material or an adjusted operating flow rate of the first material). Determining the operating flow rate of the first material M1 may include dispensing the first material M1 onto the scale 20 and measuring an amount (e.g., a volume, a mass, a weight, etc.) of the first material M1 dispensed onto the scale 20. The first material M1 is dispensed by operating the first pump 112a at an operating speed set at either step 806 (i.e., the operating speed ω_1, which is also referred to as an initial operating speed of the

first pump 112a) or step 812a (i.e., an adjusted operating speed of the first pump 112a), described below. For example, the controller 50 may automatically control an amount of power supplied to the first motor 118a until the encoder of the first motor 118a indicates that the set operating speed has been achieved. The pump system 110 may be equipped with the adapter 120 during execution of each of steps 808a–812a. The pump system 110 may be connected with the adapter 120 at any point prior to execution of step 808a. Accordingly, the first material M1 may be pumped by the first pump 112a, through the first pathway 122a, and onto the scale 20. The dispensing of the first material M1 onto the scale 20 may be performed over a first measurement period. The operating flow rate of the first material M1 may be determined by dividing the amount of first material M1 dispensed onto the scale 20 during the first measurement period by the time that elapsed over the first measurement period.

[0066] The process 800 may proceed from step 808a to step 810a, at which the process 800 determines whether the operating flow rate of the first material M1 is within the predetermined control range (i.e., a first predetermined control range). If the operating flow rate of the first material M1 is within the predetermined control range, the process 800 may proceed directly to step 808b, described below. However, if the operating flow rate of the first material M1 is outside of the predetermined control range, the process 800 may proceed to step 812a, at which the set operating speed of the first pump 112a is automatically adjusted. The predetermined control range may, for example, be within ±5% of the target flow rate for the first material M1, as calculated at step 804. The predetermined control range may also be within ±1% of the target flow rate for the first material M1, as calculated at step 804.

[0067] Step 812a may include automatically adjusting the set operating speed of the first pump 112a to an adjusted operating speed of the first pump 112a. The set operating speed of the first pump 112a may be proportionally adjusted based upon the difference between the operating flow rate of the first material M1 determined at step 808a, and the target flow rate for the first material M1 calculated at step 804. Steps 808a-812a may be iteratively performed until the operating flow rate of the first material M1 is determined to be within the predetermined control range at step 810a.

[0068] Ensuring that the operating flow rate of the second material M2 is within the predetermined control range may begin, at step 808b, by determining the operating flow rate of the second material M2 (i.e., an initial operating flow rate of the second material or an adjusted

operating flow rate of the second material). Determining the operating flow rate of the second material M2 may include dispensing the second material M2 onto the scale 20 and measuring an amount (e.g., a volume, a mass, a weight, etc.) of the second material M2 dispensed onto the scale 20. The second material M2 is dispensed by operating the second pump 112b at an operating speed set at either step 806 (i.e., the operating speed ω_2, which is also referred to as an initial operating speed the second pump 112b) or step 812b (i.e., an adjusted operating speed of the second pump 112b), described below. For example, the controller 50 may automatically control an amount of power supplied to the second motor 118b until the encoder of the second motor 118b indicates that the set operating speed has been achieved. The adapter 120 may also be connected to the pump system 110 during execution of each of steps 808b–812b. Accordingly, the second material M2 may be pumped by the second pump 112b, through the second pathway 122b, and onto the scale 20. The dispensing of the second material M2 onto the scale 20 may be performed over a second measurement period. The operating flow rate of the second material M2 may be determined by dividing the amount of second material M2 dispensed onto the scale 20 during the second measurement period by the time that elapsed over the second measurement period.

[0069] The process 800 may proceed from step 808b to step 810b, at which the process 800 determines whether the operating flow rate of the second material M2 (i.e., the initial operating flow rate of the second material or the adjusted operating flow rate of the second material) M2is within the predetermined control range (i.e., a second predetermined control range). If the operating flow rate of the second material M2 is within the predetermined control range, the process 800 may proceed directly to step 814, described below. However, if the operating flow rate of the second material M2 is outside of the predetermined control range, the process 800 may proceed to step 812b, at which the set operating speed of the second pump 112b is adjusted. The predetermined control range may, for example, be within ±5% of the target flow rate for the second material M2, as calculated at step 804. The predetermined control range may also be within ±1% of the target flow rate for the second material M2, as calculated at step 804.

[0070] Step 812b may include automatically adjusting the set operating speed of the second pump 112b to an adjusted operating speed of the second pump 112b. The set operating speed of the second pump 112b may be proportionally adjusted based upon the difference between the operating flow rate of the second material M2 determined at step 808b and the target

flow rate for the second material M2 calculated at step 804. Steps 808b-812b may be iteratively performed until the operating flow rate of the second material M2 is determined to be within the predetermined control range at step 810b.

[0071] Step 814 may include determining the operating flow rate of the mixed material M. Determining the operating flow rate of the mixed material M may include removing the adapter 120 from the pump system 110 and connecting the mixer 130 to the pump system 110. Once the pump system 110 is connected to the mixer 130, step 814 may include dispensing the mixed material M onto the scale 20 and measuring an amount (e.g., a volume, a mass, a weight, etc.) of the mixed material M dispensed onto the scale 20. The mixed material M is dispensed by operating the first pump 112a at an operating speed set at either step 806 (i.e., the initial operating speed of the first pump 112a) or step 812a (i.e., the adjusted operating speed of the first pump 112a), and by operating the second pump 112b at an operating speed set at either step 806 (i.e., the initial operating speed of the second pump 112b) or step 812b (i.e., the adjusted operating speed of the second pump 112b). The first material M1 and the second material M2 may be respectively pumped by the first pump 112a and the second pump 112b at the set operating speeds, and mixed within the chamber 135 of the mixer 130 to form the mixed material M. From the chamber 135, the mixed material M may be dispensed through the dispensing nozzle 140 onto the scale 20. The dispensing of mixed material M onto the scale 20 may be performed over a third measurement period. The operating flow rate of the mixed material M may be determined by dividing the amount of mixed material M dispensed onto the scale 20 during the third measurement period by the time that elapsed over the third measurement period.

[0072] The process 800 may proceed from step 814 to step 816, at which the process 800 determines whether the operating flow rate of the mixed material M is within a predetermined control range (i.e., a third predetermined control range). If the operating flow rate of the mixed material M is within the predetermined control range, the process 800 may proceed directly to step 818, described below. However, if the operating flow rate of the mixed material M (i.e., an initial operating flow rate of the mixed material M) is outside of the predetermined control range, the process 800 may repeat steps 808a–816 (i.e., automatically readjust the operating speed of the first pump 112a and/or the operating speed of the second pump 112b) to troubleshoot the problem. Alternatively, if the determined operating flow rate of the mixed material M exceeds the predetermined control range, the dispense system 100 may shut down

and indicate to a user that there is a system error via the HMI device 60. The predetermined control range may, for example, be within ±5% of the target flow rate for the mixed material M, which may be as calculated at step 804 as the summation of the target flow rate for the first material M1 and the target flow rate for the second material M2. The predetermined control range may also be within ±1% of the target flow rate for the mixed material M.

[0073] Upon completion of the flow control routine the process 800 may include, at step 818, dispensing the mixed material M onto the substrate 10. The mixed material M is dispensed by operating the first pump 112a at an operating speed set at either step 806 (i.e., the initial operating speed of the first pump 112a) or step 812a (i.e., the adjusted operating speed of the first pump 112a), and by operating the second pump 112b at an operating speed set at either step 806 (i.e., the initial operating speed of the second pump 112b) or step 812b (i.e., the adjusted operating speed of the second pump 112b). The first material M1 and the second material M2 may be respectively pumped by the first pump 112a and the second pump 112b at the set operating speeds, and mixed within the chamber 135 of the mixer 130 to form the mixed material M. From the chamber 135, the mixed material M may be dispensed through the dispensing nozzle 140 onto the substrate 10.

[0074] Dispensing the mixed material M onto the substrate 10 at step 818 may include calibrating a dispense protocol based upon the determined operating flow rate of the mixed material M. For example, a user may specify and input into the dispense system 100 (via the HMI 60) an amount of the mixed material M (e.g., a volume or mass) to be dispensed onto the substrate 10. The user may also input into the dispense system 100 (via the HMI 60) a predetermined location(s) and/or a line length on the substrate 10 at which the mixed material M is to be dispensed. The dispense system 100 may automatically convert the units (e.g., mass to volume and/or volume to mass) of the amount of the mixed material M to be dispensed onto the substrate 10 and/or of the operating flow rate mixed material M using the densities of the first and second materials ρ_1, ρ_2. Units may be automatically converted to ensure that like-units are utilized during calibration of the dispense protocol.

[0075] Step 818 may also include automatically calibrating a dispense protocol based upon the specified amount of the mixed material M to be dispensed onto to the substrate 10 and the determined operating flow rate of the mixed material M. For example, the dispense system 100 may automatically calibrate a dispense protocol for dispensing a line of the mixed material

M onto the substrate. The automatic calibration may include determining a velocity of the dispense nozzle 140 while the dispense nozzle 140 dispenses the mixed material M at the determined operating flow rate of the mixed material M. Determining the velocity of the dispense nozzle 140 may include multiplying the determined operating mixed material flow rate by a length of the line on the substrate along which the mixed material M is to be dispensed and by a reciprocal of the amount of the mixed material M to be dispensed along the line on the substrate 10. In another example, the dispense system 100 may automatically calibrate a dispense protocol for at least one predetermined location of the substrate 10 (i.e., without moving the dispense nozzle 140 during the dispensing at the predetermined location). The automatic calibration may include determining a time for dispensing the mixed material M at the predetermined location. Determining the time for dispensing the mixed material M at the predetermined location may include dividing the amount of the mixed material M to be dispensed at the predetermined location by the determined operating flow rate of the mixed material M.

[0076] Further, step 818 may include monitoring the dispense system 100 during the dispensing of the mixed material M from the dispensing nozzle 140 onto the substrate 10. For example, a system pressure (e.g., a pressure measured at any of the pressure sensors 117, 137) may be monitored and the dispense system 100 may shut down and indicate to a user that there is a system error via the HMI device 60 if the system pressure deviates a predetermined amount from a predetermined system pressure threshold. Similarly, current supplied to any of the motors 118a, 118b, 118' of embodiments of the pump systems 110, 110' may be monitored and the dispense system 100 may shut down and indicate to a user that there is a system error via the HMI device 60 if the current deviates a specified amount from a predetermined current threshold.

[0077] According to aspects of the invention, the ratio and/or amounts of the first and second materials M1, M2 mixed and dispensed onto the substrate 10 may be precisely controlled thereby improving the dispensing of the mixed material M on the substrate 10.

[0078] While the disclosure has been described in connection with the various embodiments of the various figures, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments. Therefore, the

methods and systems as described herein should not be limited to any single embodiment, but rather should be construed in breadth and scope in accordance with the appended claims.

What is claimed is:

1. A method for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, the method comprising:

receiving dispensing operating parameters;

dispensing a first material from a first pump at a first material flow rate and determining an amount of the first material dispensed;

dispensing a second material from a second pump at a second material flow rate and determining an amount of the second material dispensed;

automatically adjusting dispensing of the first material to an adjusted first material flow rate and dispensing of the second material to an adjusted second material flow rate based on the determined amounts of the first and second materials dispensed;

pumping the first material from the first pump at the adjusted first material flow rate;

pumping the second material from the second pump at the adjusted second material flow rate;

mixing the first material and the second material within a chamber of a mixer to form the mixed material; and

dispensing the mixed material from a dispensing nozzle onto the substrate.

2. The method of claim 1, wherein:

determining the amount of the first material dispensed comprises determining the amount of the first material dispensed using a scale; and

determining the amount of the second material dispensed comprises determining the amount of the second material dispensed using the scale.

3. The method of claim 1, wherein receiving the dispensing operating parameters comprises receiving a first pump constant for the first pump, a second pump constant for the second pump, and a target mix ratio of the first material and the second material.

4. The method of claim 3, further comprising:

determining a first operating speed for the first pump and a second operating speed for the second pump based upon the received dispensing operating parameters, wherein:

dispensing the first material from the first pump at the first material flow rate includes operating the first pump at the first operating speed for the first pump, and

dispensing the second material from the second pump at the second material flow rate includes operating the second pump at the second operating speed for the second pump.

5. The method of claim 4, wherein dispensing the first material is performed over a first measurement period and dispensing the second material is performed over a second measurement period, a duration of first measurement period being equal to a duration of the second measurement period.

6. The method of claim 5, further comprising:

determining an operating mix ratio of the first material and the second material based upon the determined amount of the first material dispensed over the first measurement period and the determined amount of the second material dispensed over the second measurement period; and

determining that the operating mix ratio is outside of a predetermined ratio control range,

wherein automatically adjusting dispensing of the first and second materials in response to the determination that the operating mix ratio is outside of the predetermined ratio control range.

7. The method of claim 6, wherein receiving the dispensing operating parameters comprises receiving a density of the first material and a density of the second material.

8. The method of claim 7, wherein the target mix ratio is a mass ratio, and the method further comprises determining a volumetric target mix ratio from the mass ratio and the densities of the first and second materials, wherein the first operating speed for the first pump and the second operating speed for the second pump is further based upon the determined volumetric target mix ratio.

9. The method of claim 7, wherein the target mix ratio is a volumetric ratio.

10. The method of claim 7, further comprising determining a target mixed material flow rate from the adjusted first material flow rate and the adjusted second material flow rate.

11. The method of claim 10, further comprising:
determining an operating mixed material flow rate; and
comparing the operating mixed material flow rate to the target mixed material flow rate.

12. The method of claim 11, further comprising determining that the operating mixed material flow rate is outside of a predetermined flow rate control range and indicating a system error.

13. The method of claim 11, further comprising determining that the operating mixed material flow rate is within a predetermined flow rate control range and calibrating a dispense protocol based upon the operating mixed material flow rate and a predetermined amount of the mixed material to be dispensed onto the substrate.

14. The method of claim 13, wherein calibrating of the dispense protocol includes determining a velocity of the dispense nozzle while the dispense nozzle dispenses the predetermined amount of the mixed material along a line on the substrate at the operating mixed material flow rate.

15. The method of claim 14, wherein determining the velocity of the dispense nozzle includes multiplying the operating mixed material flow rate by a length of the line on the substrate and by a reciprocal of the predetermined amount of the mixed material to be dispensed onto the substrate.

16. The method of claim 13, wherein calibrating of the dispense protocol includes determining a time for dispensing the predetermined amount of the mixed material onto the substrate.

17. The method of claim 16, wherein determining the time for dispensing includes dividing the predetermined amount of the mixed material to be dispensed onto the substrate by the operating mixed material flow rate.

18. The method of claim 6, further comprising determining a density of the first material and a density of the second material.

19. The method of claim 18, wherein the target mix ratio is a mass ratio, and the method further comprising determining a volumetric target mix ratio from the mass ratio and the determined densities of the first and second materials, wherein the first operating speed for the first pump and the second operating speed for the second pump is further based upon the determined volumetric target mix ratio.

20. The method of claim 18, wherein the target mix ratio is a volumetric ratio.

21. The method of claim 18, further comprising determining a target mixed material flow rate from the adjusted first material flow rate and the adjusted second material flow rate.

22. The method of claim 21, further comprising:
determining an operating mixed material flow rate; and
comparing the operating mixed material flow rate to the target mixed material flow rate.

23. The method of claim 22, further comprising determining that the operating mixed material flow rate is outside of a predetermined flow rate control range and indicating a system error.

24. The method of claim 22, further comprising determining that the operating mixed material flow rate is within a predetermined flow rate control range and calibrating a dispense protocol based upon the operating mixed material flow rate and a predetermined amount of the mixed material to be dispensed onto the substrate.

25. The method of claim 24, wherein calibrating of the dispense protocol includes determining a velocity of the dispense nozzle while the dispense nozzle dispenses the predetermined amount of the mixed material along a line on the substrate at the operating mixed material flow rate.

26. The method of claim 25, wherein determining the velocity of the dispense nozzle includes multiplying the operating mixed material flow rate by a length of the line on the substrate and by a reciprocal of the predetermined amount of the mixed material to be dispensed onto the substrate.

27. The method of claim 24, wherein calibrating of the dispense protocol includes determining a time for dispensing the predetermined amount of the mixed material onto the substrate.

28. The method of claim 27, wherein determining the time for dispensing includes dividing the predetermined amount of the mixed material to be dispensed onto the substrate by the operating mixed material flow rate.

29. The method of claim 1, further comprising:

monitoring a system pressure;

determining that the system pressure deviates a predetermined amount from a predetermined system pressure threshold; and

indicating a system error.

30. The method of claim 1, wherein the adjustment to the adjusted first material flow rate and the adjusted second material flow rate includes proportionally adjusting the first material flow rate and the second material flow rate.

31. The method of claim 1, further comprising:

monitoring a current supplied to at least one of the first and the second pumps;

determining that the current deviates a predetermined amount from a predetermined current threshold; and

indicating a system error.

32. A dispense system for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, the dispense system comprising:

a first supply that is configured to contain the first material;

a second supply that is configured to contain the second material;

a pump system including:

a first pump having an inlet in fluid communication with the first supply and an outlet, the first pump being configured to pump the first material from the first supply through the outlet of the first pump at a first material flow rate; and

a second pump having an inlet in fluid communication with the second supply and an outlet, the second pump being configured to pump the second material from the second supply through the outlet of the second pump at a second material flow rate;

a mixer that is configured to be connected to the pump system, the mixer including:

a first inlet that is configured to be in fluid communication with the outlet of the first pump;

a second inlet that is configured to be in fluid communication with the outlet of the second pump; and

a chamber configured to mix the first material and the second material therein;

a dispensing nozzle in fluid communication with the chamber, the dispensing nozzle being configured to dispense the mixed material;

a sensor that is configured to determine an amount of the first material dispensed and an amount of a second material dispensed; and

a controller that is configured to:

determine an operating mix ratio of the first material and the second material based on the determined amount of the first material dispensed and the determined amount of the second material dispensed;

determining that the operating mix ratio is outside of a predetermined ratio control range; and

respectively adjust the first material flow rate to an adjusted first material flow rate and the second material flow rate to an adjusted second material flow rate to control operation of the first and second pumps to dispense the mixed material from the dispensing nozzle onto the substrate.

33. The dispense system of claim 32, wherein the sensor is a scale.

34. The dispense system of claim 33, wherein the controller is configured to:

control operation of the first pump to dispense the first material onto the scale and receive the amount of the first material from the scale; and

control operation of the second pump to dispense the second material onto the scale and receive the amount of the second material from the scale.

35. The dispense system of claim 32, wherein the first pump and the second pump are configured to independently pump the respective first and second materials such that the mix ratio between the first material and the second material is configured to be varied.

36. The dispense system of claim 32, wherein the pump system comprises a first motor that is configured to drive the first pump and a second motor that is configured to drive the second pump, and the controller is configured to control the first and second motors.

37. The dispense system of claim 32, further comprising an adapter that is configured to be removably connected to the pump system, the adapter including:

a first inlet that is configured to be in fluid communication with the outlet of the first pump;

a second inlet that is configured to be in fluid communication with the outlet of the second pump;

a first outlet; and

a second outlet,

wherein the mixer and the adapter are configured to be interchangeably connected to the pump system.

38. The dispense system of claim 37, further comprising:

a first connector fixed to the pump system; and

two second connectors that are each configured to be interchangeably connected to the first connector, one of the two second connectors being fixed to the mixer and the other of the two second connectors being fixed to the adapter.

39. The dispense system of claim 38, wherein the controller is further configured to control operation of the first connector to automatically control interchangeable connection between the pump system and the adapter or the mixer.

40. The dispense system of claim 38, further comprising:

a claw configured to surround part of each of the two second connectors to effectuate the interchangeable connection between the first connector and the two second connectors; and

an actuator configured to initiate opening and closing of the claw in response to the controller.

41. A dispense system for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, the dispense system comprising:

a first supply that is configured to contain the first material;

a second supply that is configured to contain the second material;

a pump system including a first inlet in fluid communication with the first supply and a first outlet, a second inlet in fluid communication with the second supply and a second outlet, the pump system being configured to pump the first material from the first supply through the first

outlet at a first material flow rate and to pump the second material from the second supply through the second outlet at a second material flow rate;

a mixer including:

a first inlet that is configured to be in fluid communication with the first supply;

a second inlet that is configured to be in fluid communication with the second supply; and

a chamber configured to mix the first material and the second material therein;

a dispensing nozzle in fluid communication with the chamber, the dispensing nozzle being configured to dispense the mixed material;

a sensor that is configured to determine an amount of the mixed material dispensed from the dispensing nozzle; and

a controller that is configured to control operation of the pump system based on the mixed material amount received from the sensor by automatically adjusting the first material flow rate to an adjusted first material flow rate and the second material flow rate to an adjusted second material flow rate based on the mixed material amount to dispense the mixed material from the dispensing nozzle onto the substrate.

42. The dispense system of claim 41, wherein the sensor is a scale.

43. The dispense system of claim 41, wherein the pump system comprises a motor, and the controller is configured to control the motor.

44. The dispense system of claim 41, further comprising an adapter that is configured to be removably connected to the pump, the adapter including:

a first inlet that is configured to be in fluid communication with a first outlet of the pump system;

a second inlet that is configured to be in fluid communication with a second outlet of the pump system;

a first outlet; and

a second outlet,

wherein the mixer and the adapter are configured to be interchangeably connected to the pump system.

45. The dispense system of claim 44, further comprising:

a first connector fixed to the pump system; and

two second connectors that are each configured to be interchangeably connected to the first connector, one of the two second connectors is fixed to the mixer and the other of the two second connectors is fixed to the adapter.

46. The dispense system of claim 45, wherein the controller is further configured to control operation of the first connector to automatically control interchangeable connection between the pump system and the adapter or the mixer.

47. The dispense system of claim 45, further comprising:

a claw configured to surround part of each of the two second connectors to effectuate the interchangeable connection between the first connector and the two second connectors; and

an actuator configured to initiate opening and closing of the claw in response to the controller.

48. The dispense system of claim 41, wherein the pump system is configured to pump the first material and the second material at a fixed ratio.

49. A method for dispensing a mixed material, which includes at least a first material and a second material, onto a substrate, the method comprising:

receiving dispensing operating parameters;

calculating a target flow rate for a first material and a target flow rate for a second material based upon the dispensing operating parameters;

setting an initial operating speed of a first pump and an initial operating speed of a second pump based upon the dispensing operating parameters;

dispensing the first material from the first pump operating at the initial operating speed of the first pump and determining an initial operating flow rate of the first material;

determining that the initial operating flow rate of the first material is outside of a first predetermined control range and automatically adjusting the operating speed of the first pump to an adjusted operating speed of the first pump;

dispensing the second material from the second pump operating at the initial operating speed of the second pump and determining an initial operating flow rate of the second material;

determining that the initial operating flow rate of the second material is outside of a second predetermined control range and automatically adjusting the operating speed of the second pump to an adjusted operating speed of the second pump;

pumping the first material from the first pump at the adjusted operating speed of the first pump and pumping the second material from the second pump at the adjusted operating speed of the second pump;

mixing the first material and the second material within a chamber of a mixer to form the mixed material; and

dispensing the mixed material from a dispensing nozzle onto the substrate.

50. The method of claim 49, wherein the initial operating speed of the first pump is expected to produce the target flow rate for the first material and the initial operating speed of the second pump is expected to produce the target flow rate for the second material.

51. The method of claim 49, wherein, prior to pumping the first material from the first pump at the adjusted operating speed of the first pump and pumping the second material from the second pump at the adjusted operating speed of the second pump, the method further comprising:

dispensing the first material from the first pump operating at the adjusted operating speed of the first pump and determining an adjusted operating flow rate of the first material;

determining that the adjusted operating flow rate of the first material is within the first predetermined control range;

dispensing the second material from the second pump operating at the adjusted operating speed of the second pump and determining an adjusted operating flow rate of the second material; and

determining that the adjusted operating flow rate of the second material is within the second predetermined control range.

52. The method of claim 49, wherein, prior to dispensing the mixed material from the dispensing nozzle onto the substrate, the method further comprising determining that an operating flow rate of the mixed material is within a third predetermined control range.

53. The method of claim 52, wherein, prior to determining that an operating flow rate of the mixed material is within the third predetermined control range, the method further comprising:

determining that an initial operating flow rate of the mixed material is outside of the predetermined control range and automatically readjusting the operating speed of the first pump and the operating speed of the second pump.

54. The method of claim 49, wherein receiving the dispensing operating parameters comprises receiving a first pump constant for the first pump, a second pump constant for the second pump, and a target mix ratio of the first material and the second material.

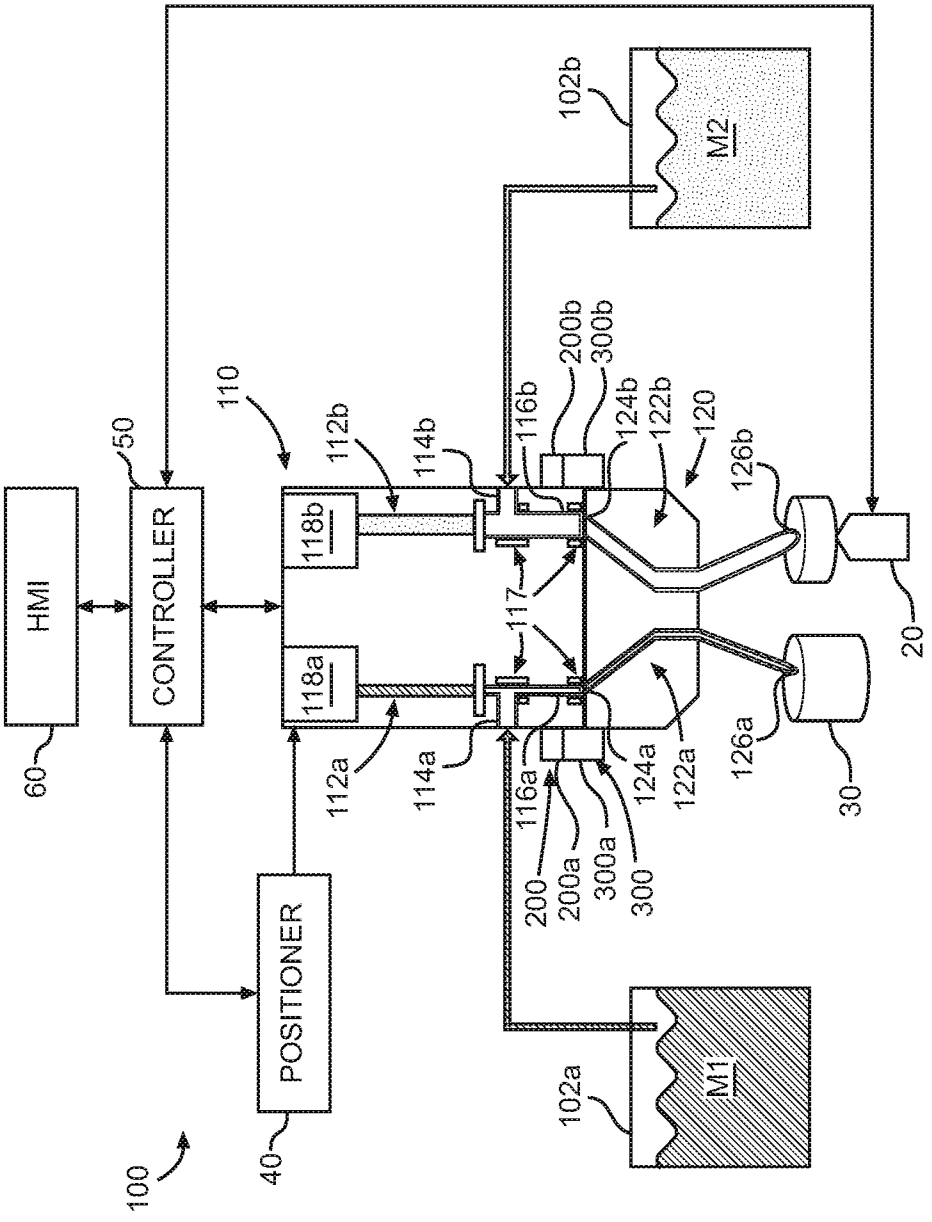

HMI
CONTROLLER
POSITIONER
M1
M2
100
110
112a
112b
114a
114b
116a
116b
117
118a
118b
120
122a
122b
124a
124b
126a
126b
200
200a
200b
300
300a
300b
20
30
40
50
60
102a
102b

FIG. 1

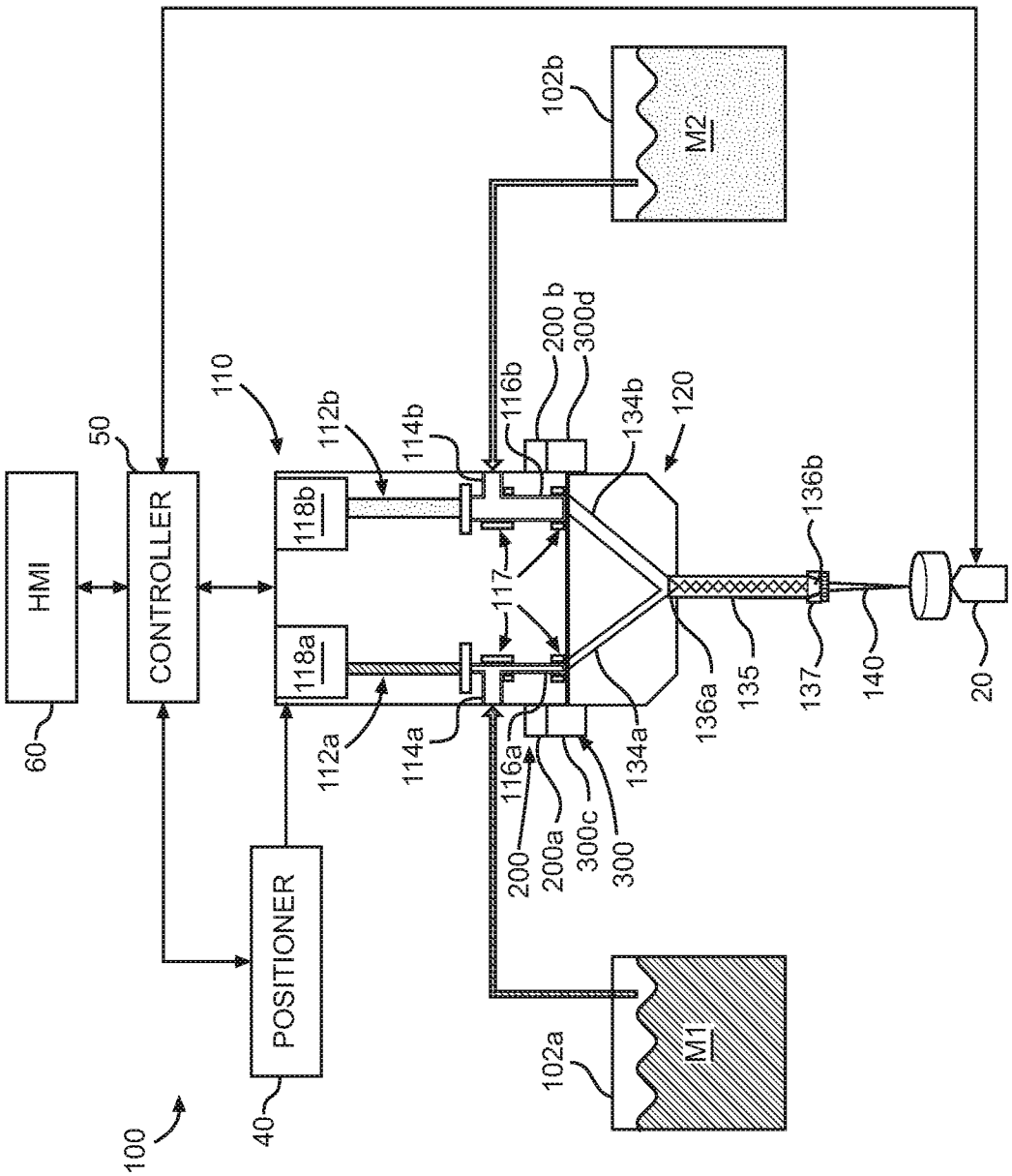

HMI
CONTROLLER
POSITIONER
M1
M2
100
110
120
20
40
50
60
102a
102b
112a
112b
114a
114b
116a
116b
117
118a
118b
134a
134b
135
136a
136b
137
140
200
200a
200 b
300
300c
300d

FIG. 2

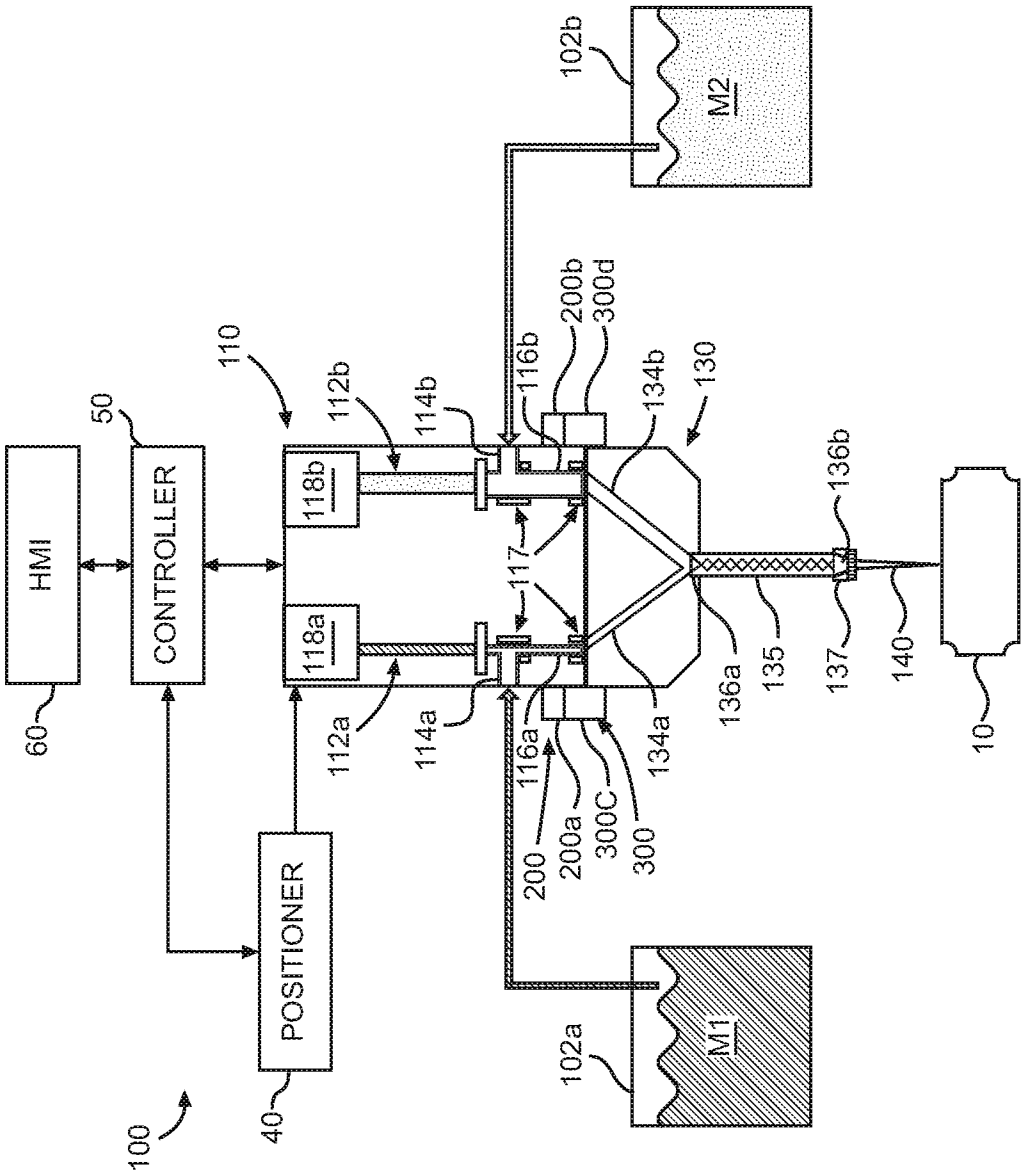

HMI
CONTROLLER
POSITIONER
M1
M2
100
110
112a
112b
114a
114b
116a
116b
117
118a
118b
130
134a
134b
135
136a
136b
137
140
200
200a
200b
300
300C
300d
40
50
60
102a
102b
10

FIG. 3

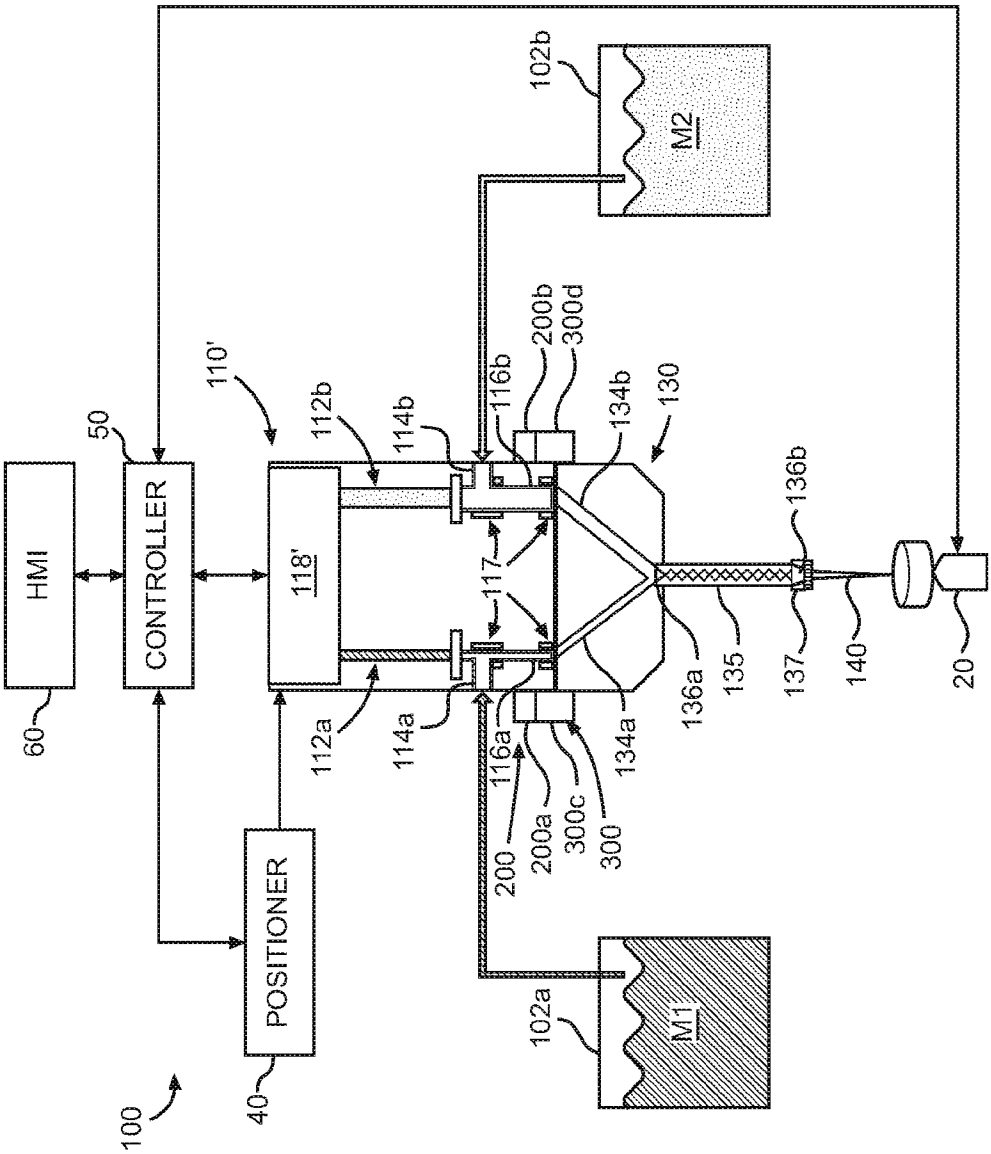

HMI
CONTROLLER
POSITIONER
M1
M2
118'
110'
50
60
40
100
20
102a
102b
112a
112b
114a
114b
116a
116b
117
130
134a
134b
135
136a
136b
137
140
200
200a
200b
300
300c
300d

FIG. 4

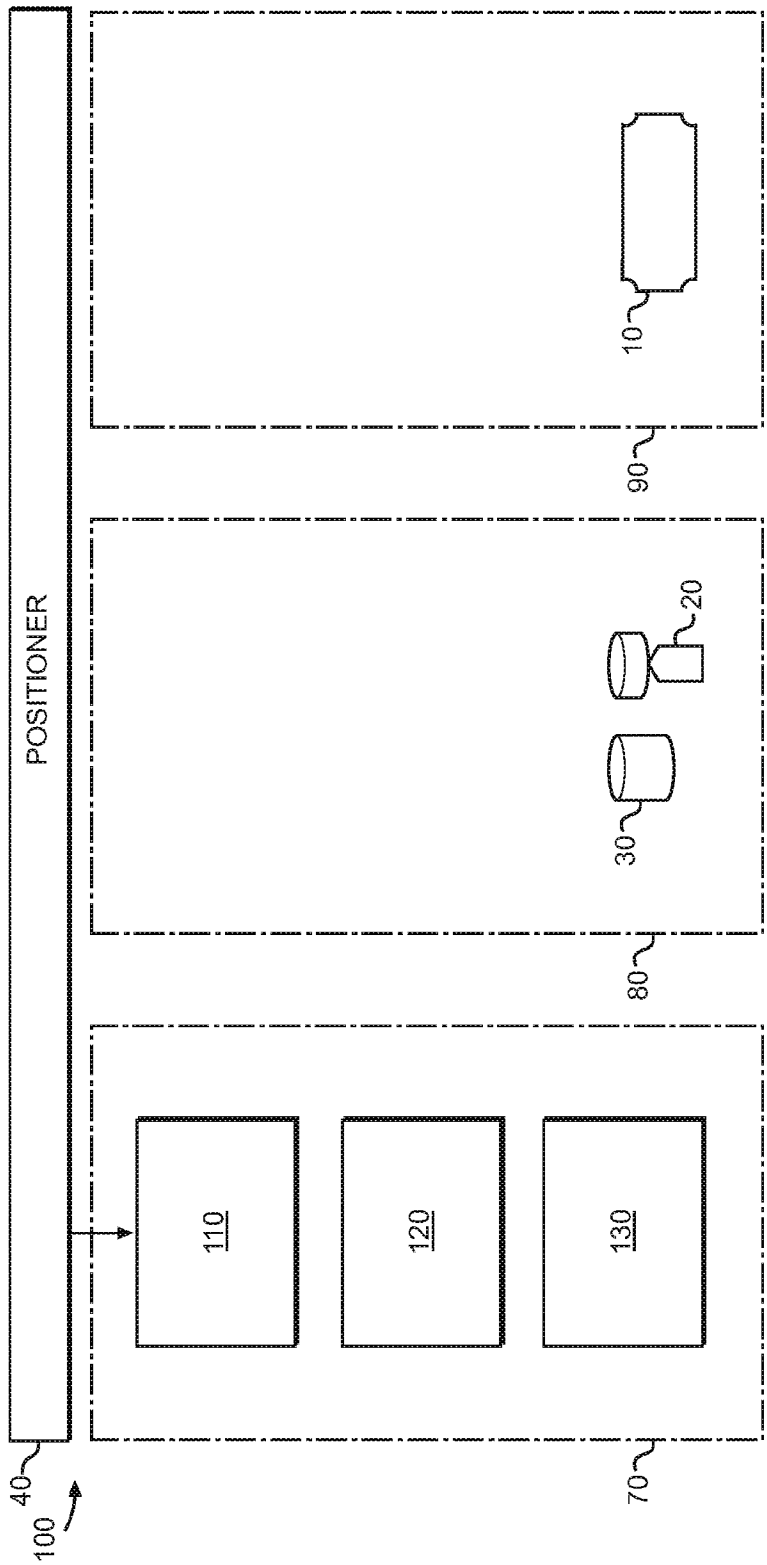


FIG. 5

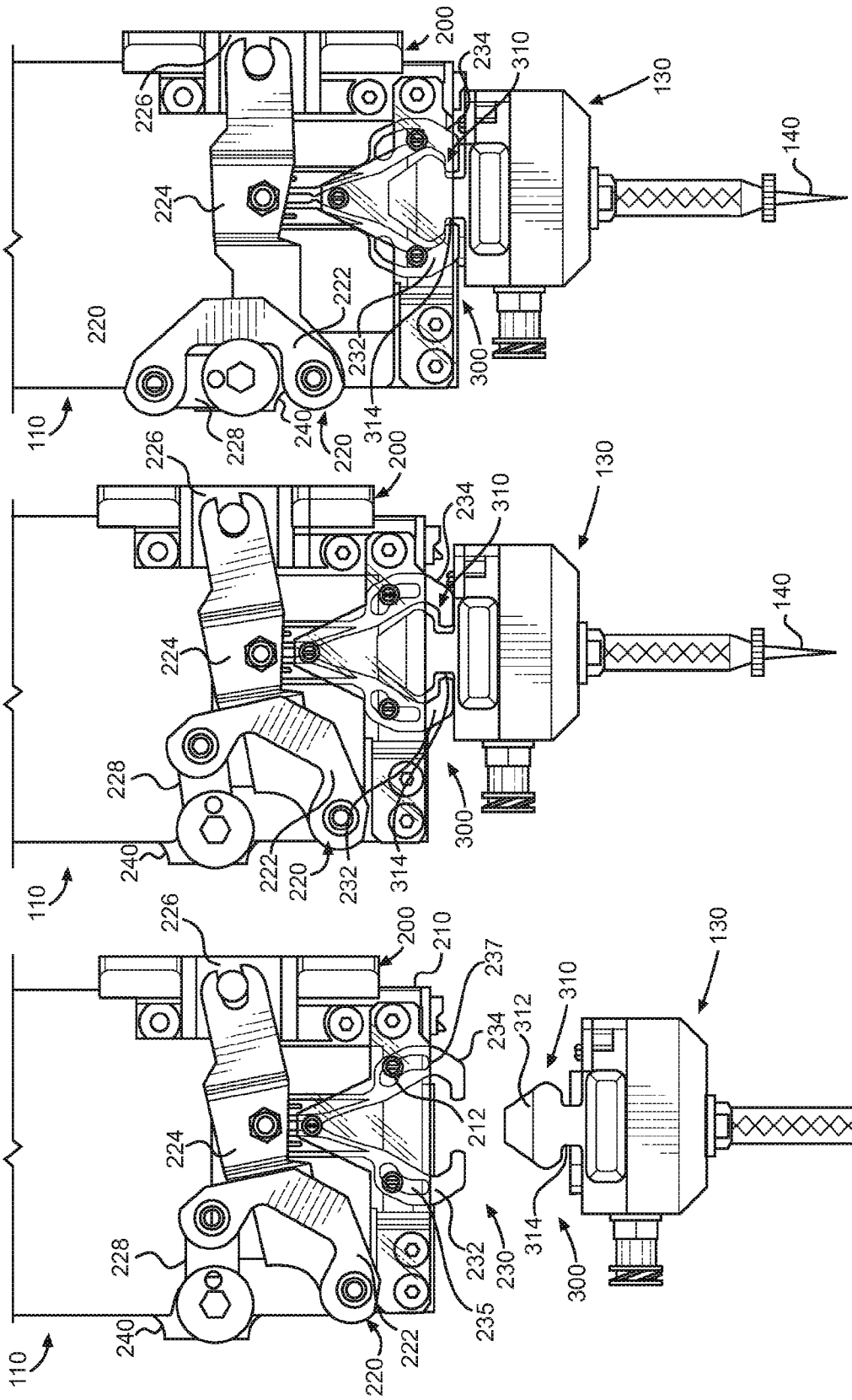


FIG. 6A

FIG. 6B

FIG. 6C

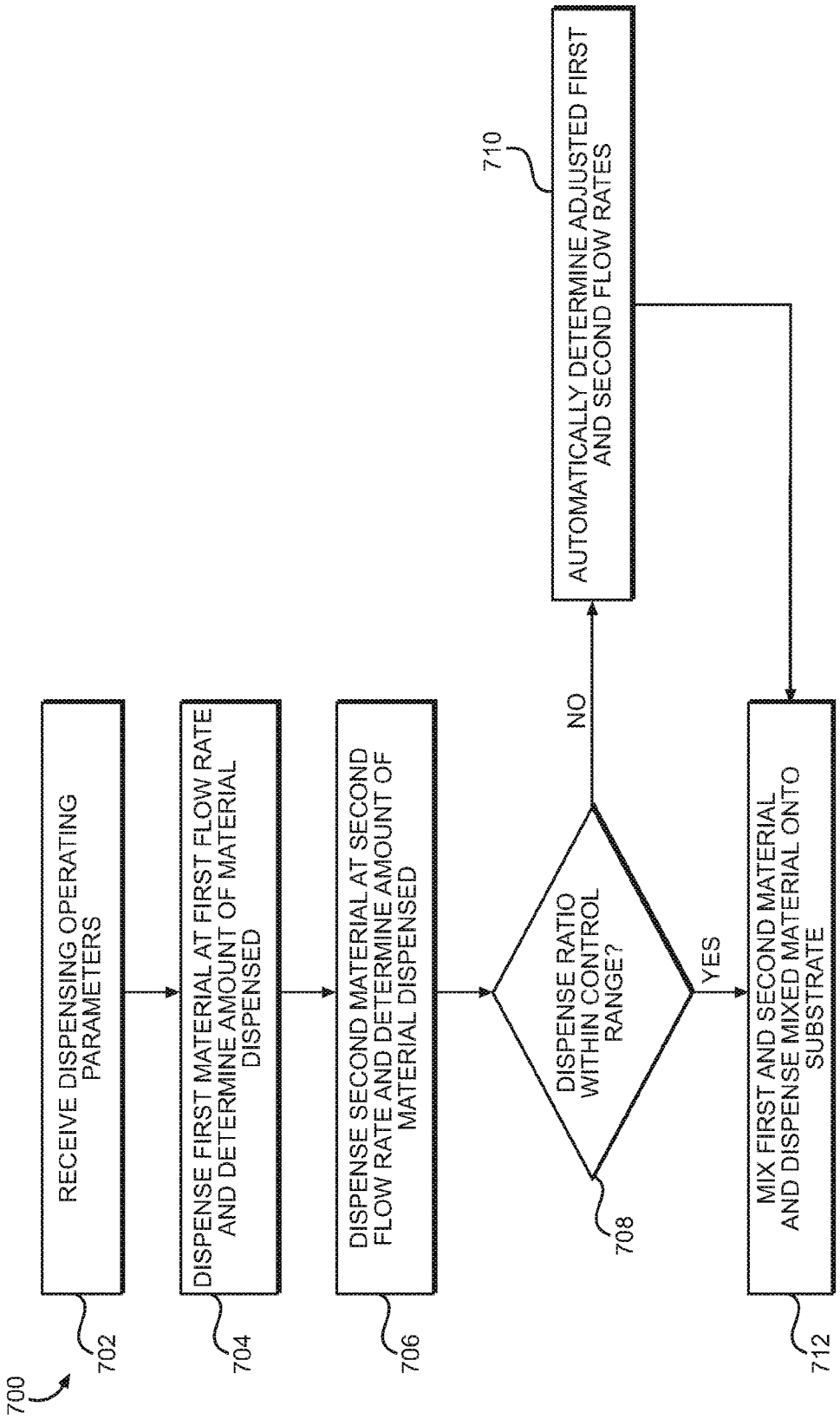

700
RECEIVE DISPENSING OPERATING PARAMETERS
702
DISPENSE FIRST MATERIAL AT FIRST FLOW RATE AND DETERMINE AMOUNT OF MATERIAL DISPENSED
704
DISPENSE SECOND MATERIAL AT SECOND FLOW RATE AND DETERMINE AMOUNT OF MATERIAL DISPENSED
706
DISPENSE RATIO WITHIN CONTROL RANGE?
708
NO
YES
AUTOMATICALLY DETERMINE ADJUSTED FIRST AND SECOND FLOW RATES
710
MIX FIRST AND SECOND MATERIAL AND DISPENSE MIXED MATERIAL ONTO SUBSTRATE
712

FIG. 7

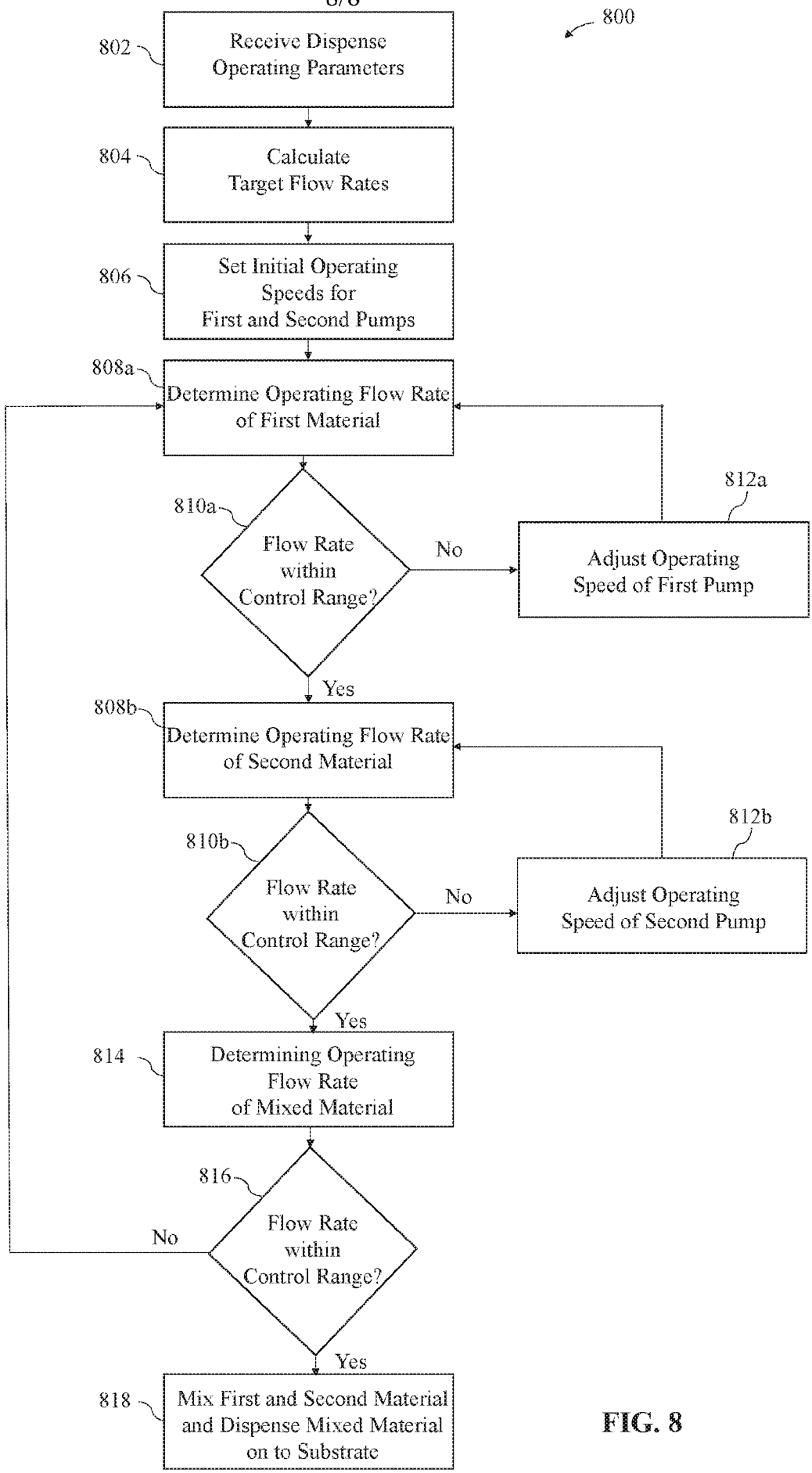

800
802
Receive Dispense Operating Parameters
804
Calculate Target Flow Rates
806
Set Initial Operating Speeds for First and Second Pumps
808a
Determine Operating Flow Rate of First Material
810a
Flow Rate within Control Range?
No
812a
Adjust Operating Speed of First Pump
Yes
808b
Determine Operating Flow Rate of Second Material
810b
Flow Rate within Control Range?
No
812b
Adjust Operating Speed of Second Pump
Yes
814
Determining Operating Flow Rate of Mixed Material
816
Flow Rate within Control Range?
No
Yes
818
Mix First and Second Material and Dispense Mixed Material on to Substrate

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/027186

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05D11/13
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/109888 A1 (BORDWELL DAVID A [US] ET AL) 21 April 2016 (2016-04-21) paragraphs [0023] - [0030]; figure 2 -----	1-13, 16-24, 29-54
X	US 2002/014496 A1 (CLINE DAVID J [US] ET AL) 7 February 2002 (2002-02-07) paragraphs [0054], [0104]; figure 1 -----	1-13, 16-24, 29-54
X	US 2003/158630 A1 (PHAM XUYEN [US] ET AL) 21 August 2003 (2003-08-21) paragraphs [0041] - [0048]; figures 2, 3 -----	1-13, 16-24, 29-54
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 July 2019	14/08/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Camerer, Stephan

3

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/027186

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 271 521 A (NOSS JEFFREY S [US] ET AL) 21 December 1993 (1993-12-21) column 5, line 30 - column 7, line 31; figure 1 -----	1-13, 16-24, 29-54
A	US 6 410 080 B1 (ITO SHINICHI [JP]) 25 June 2002 (2002-06-25) figures 1-25 -----	14,15, 25-28

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2019/027186

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016109888 A1	21-04-2016	CN 105142798 A	09-12-2015
		EP 2988879 A1	02-03-2016
		JP 2016524210 A	12-08-2016
		KR 20160003667 A	11-01-2016
		TW 201501784 A	16-01-2015
		US 2016109888 A1	21-04-2016
		WO 2014176589 A1	30-10-2014
US 2002014496 A1	07-02-2002	AU 734299 B2	07-06-2001
		CA 2272626 A1	11-06-1998
		EP 0990198 A2	05-04-2000
		NZ 336247 A	27-09-2002
		TW 382615 B	21-02-2000
		US 5857589 A	12-01-1999
		US 6126039 A	03-10-2000
		US 6286566 B1	11-09-2001
		US 2002014496 A1	07-02-2002
		WO 9824722 A2	11-06-1998
US 2003158630 A1	21-08-2003	AU 2002359867 A1	09-09-2003
		CN 1620639 A	25-05-2005
		EP 1474729 A1	10-11-2004
		JP 4646517 B2	09-03-2011
		JP 2005518660 A	23-06-2005
		KR 20040085187 A	07-10-2004
		US 2003158630 A1	21-08-2003
		US 2004199293 A1	07-10-2004
		WO 03071369 A1	28-08-2003
US 5271521 A	21-12-1993	AU 668227 B2	26-04-1996
		CA 2109376 A1	24-05-1994
		DE 69326596 D1	04-11-1999
		DE 69326596 T2	18-05-2000
		EP 0599104 A1	01-06-1994
		JP 3512836 B2	31-03-2004
		JP H06210227 A	02-08-1994
		KR 940011052 A	20-06-1994
		US 5271521 A	21-12-1993
US 6410080 B1	25-06-2002	JP 3697389 B2	21-09-2005
		JP 2001168021 A	22-06-2001
		TW 476121 B	11-02-2002
		US 6410080 B1	25-06-2002
		US 2003044542 A1	06-03-2003
		US 2004091606 A1	13-05-2004