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Seed Metering and Discharge System with Adjustable Gate Control

Abstract

Disclosed is an automated agricultural seed discharge system and method with adjustable gate control for seed metering. The method includes a step of receiving a stream of agricultural seed into a metering assembly. The method then includes a step of determining an inflow rate of the stream of agricultural seed based on a measurement of the agricultural seed within the metering assembly. Further, the method includes a step of commanding an adjustable gate into a command position to discharge the agricultural seed from the metering assembly at an outflow rate that matches the inflow rate.

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Background/Summary

CROSS-REFERENCES TO RELATED APPLICATIONS [0001] This patent application is an international application which claims the benefit of U.S. Provisional Patent Application No. 63/480,048, entitled "Methods for Maintaining a Continuously Metered Seed Flow," filed on Jan. 16, 2023, and U.S. Provisional Patent Application No. 63/491,553, entitled "Methods for Maintaining a Continuously Metered Seed Flow," filed on Mar. 22, 2023, and U.S. Provisional Patent Application No. 63/591,967, entitled "Agricultural Seed Discharge System with Adjustable Gate Control for Seed Metering," filed on Oct. 20, 2023, the entire contents of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION
Technical Field
[0002] The invention presented herein is generally directed toward an automated agricultural seed metering and discharge system with adjustable gate control and an automated method for seed metering, more particularly, to the control, metering, and continuous discharge of large volumes of particulate materials in bulk form, such as crop seeds, from a metering assembly that is operable to measure an inflow rate of an inflowing stream of particulate material and adjust a variable gate position in response so that an outflow rate of an outflow stream of particulate material matches the inflow rate.
Description of the Related Art
[0003] Bulk materials, particularly crop seeds, are commonly stored in elevated hoppers, from which the material is discharged for distribution or utilization. The release of seeds can occur either manually or automatically, either based on a predetermined time schedule or a specified weight. Various mechanisms, including drop gates, seed wheels, and adjustable slide gates, are employed to regulate the flow of seeds from the hopper. Before planting, the discharged seeds may undergo applications of different nutrients, inoculants, fungicides, and pesticides. These seed treatments are applied to enhance the size, health, and overall value of the crop produced by the seeds.
SUMMARY OF THE INVENTION
[0004] An automated agricultural seed metering and discharge system with adjustable gate control and an automated method for seed metering are provided, as shown in and/or described in connection with at least one of the figures.
[0005] One aspect of the present disclosure relates to an automated agricultural seed discharge method that includes a step of receiving a stream of agricultural seed into a metering assembly. The method then includes a step of determining an inflow rate of the stream of agricultural seed based on a measurement of the agricultural seed within the metering assembly. Further, the method includes a step of commanding an adjustable gate into a command position to discharge the agricultural seed from the metering assembly at an outflow rate that matches the inflow rate.
[0006] In some aspects, the automated method includes steps of receiving the stream of agricultural seed into an upper hopper of the metering assembly; measuring the weight of the agricultural seed within the upper hopper; and discharging the agricultural seed from the upper hopper, with a binary gate mounted to the upper hopper, into a lower hopper of the metering assembly.

[0007] In some aspects, the automated method includes a step of adjusting the command position of the adjustable gate that is mounted to the lower hopper to regulate the outflow rate from the lower hopper to match the inflow rate into the upper hopper.
[0008] In some aspects, the adjustable gate is continuously adjusted while the binary gate is closed.
[0009] In some aspects, the automated method includes the step of determining a set point for the command position of the adjustable gate while the binary gate is closed. In an aspect, the set point is based on the measurement of the agricultural seed within the metering assembly. In additional method examples, the automated method includes a step of setting the command position of the adjustable gate at the set point when the binary gate is opened.
[0010] In some aspects, the automated method includes a step of maintaining the command position of the adjustable gate at the set point during a refill period.
[0011] In some aspects, the automated method includes a step of maintaining the command position at a set point until a load cell mounted to the metering assembly reports a loss-in-weight over a refill period.
[0012] In some aspects, the refill period is an interval of time between 0.1 second and 30 seconds.
[0013] In some aspects, the automated method includes a step of decreasing an opening created by the adjustable gate upon a loss-in-weight of the metering assembly over a measurement period.
[0014] In some aspects, the automated method includes a step of increasing an opening created by the adjustable gate upon a gain-in-weight of the metering assembly over a measurement period.
[0015] In some aspects, the automated method includes a step of commanding a treatment rate based on the command position of the adjustable gate.
[0016] In some aspects, the automated method includes a step of applying a treatment to the agricultural seed discharged according to a recipe based on the outflow rate.
[0017] In some aspects, the automated method includes steps of increasing a treatment flow rate in response to an increase in an opening of the adjustable gate; and decreasing the treatment rate in response to a decrease in the opening of the adjustable gate.
[0018] In some aspects, the inflow rate is determined based on a measurement of weight during a measurement period between receiving a low-level signal and a high-level signal.
[0019] In some aspects, the automated method includes a step of filling the metering assembly with agricultural seed at a percentage range of between 5 percent to 80 percent of the maximum capacity of the metering assembly.
[0020] In some aspects, the automated method includes a step of adjusting the command position of the adjustable gate to maintain the agricultural seed within the metering assembly at the percentage range of between 5 percent to 80 percent of the maximum capacity.
[0021] In some aspects, the automated method includes steps of measuring the weight of the agricultural seed within the metering assembly; receiving a plurality of weight measurements of the metering assembly; and regulating the command position of the adjustable gate based upon the plurality of weight measurements in real-time.
[0022] In some aspects, the automated method includes steps of setting the command position of the adjustable gate at a set point during a calibration period; discharging, over the calibration period, a portion of the agricultural seed through an opening created by the adjustable gate at the command position; and associating the outflow rate with the command position of the adjustable gate at the set point.
[0023] In some aspects, the automated method includes a step of obtaining a plurality of outflow rates that correspond with a plurality of command positions of the adjustable gate.
[0024] In some aspects, the automated method includes a step of storing the plurality of outflow rates that correspond with the plurality of command positions in a database accessible by a controller.
[0025] In some aspects, the automated method includes a step of adjusting a treatment rate according to a recipe based on the outflow rate.

[0026] In some aspects, the automated method includes steps of generating a signal upon a change in the command position of the adjustable gate to a second position; and adjusting the treatment rate to correspond with the outflow rate correlated with the second position upon generation of the signal.
[0027] The above advantages and features are of representative embodiments only and are presented only to assist in understanding the invention. It should be understood that they are not to be considered limitations on the invention as defined by the claims. Additional features and advantages of embodiments of the invention will become apparent in the following description, from the drawings, and from the claims.
[0028] Other embodiments and advantages will become readily apparent to those skilled in the art upon viewing the drawings and reading the detailed description hereafter, all without departing from the scope of the disclosure. The drawings and detailed descriptions presented are to be regarded as illustrative in nature and not in any way as restrictive.
[0029] Other features of the examples will be apparent from the drawings and from the detailed description that follow.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0030] Aspects are illustrated by way of example, and not by way of limitation, in the accompanying drawings, wherein:
[0031] FIG. **1**A shows a perspective view of an example metering and discharge system utilizing a continuous flow sensor.
[0032] FIG. **1**B shows a metering and discharge system receiving and discharging a continuous metered stream of bulk material.
[0033] FIG. **2** shows a graphic performance estimation of a metering and discharge system conducting a continuous discharge cycle.
[0034] FIG. **3** depicts a flowchart for a method of discharging a continuous metered stream of agricultural seed.
[0035] FIG. **4** depicts a flowchart for a method of calibrating a metering and discharge system.
[0036] FIG. **5** shows an example of a metering and discharge system having a metering assembly without the upper hopper.
[0037] FIG. **6** shows a graphic performance estimation of a metering and discharge system with consistent inflow.
[0038] FIG. **7** shows a graphic performance estimation of a metering and discharge system with inconsistent inflow.
[0039] FIG. **8** shows an example flowchart of an automated method for calibrating a metering assembly to discharge agricultural seed at an outflow rate that matches the inflow rate.
[0040] FIG. **9** shows an example of a metering assembly with an upper hopper and a lower hopper.
[0041] FIG. **10** shows a graphic performance estimation of a seed metering and discharge system.
[0042] FIG. **11** shows a graphic estimation of the adjustable gate position during the continuous discharge cycle.
[0043] FIG. **12** shows an example flowchart of an automated method for discharging agricultural seed from a metering assembly at an outflow rate that matches the inflow rate.
[0044] FIG. **13**A shows a loading period in a series of chronological depictions of the metering assembly where an inflow stream of bulk material is discharged from the upper hopper to the lower hopper during a continuous discharge cycle.
[0045] FIG. **13**B shows a first measurement period in a series of chronological depictions of the metering assembly operating under a variable position mode during the continuous discharge cycle.

[0046] FIG. **13**C shows the first measurement period in a series of chronological depictions of the metering assembly operating under the variable position mode during the continuous discharge cycle.
[0047] FIG. **13**D shows a first refill period in a series of chronological depictions of the metering assembly operating under a fixed position mode during the continuous discharge cycle.
[0048] FIG. **13**E shows the first refill period in a series of chronological depictions of the metering assembly operating under the fixed position mode without the inflow stream of bulk material into the supply hopper during the continuous discharge cycle.
[0049] FIG. **13**F shows a second measurement period in a series of chronological depictions of the metering assembly operating under a variable position mode during the continuous discharge cycle.
[0050] Although the specific features of the embodiments herein are shown in some drawings and not in others. This is done for convenience only as each feature may be combined with any or all of the other features in accordance with the embodiments herein.
DETAILED DESCRIPTION
[0051] The disclosure will be described more fully hereinafter with reference to the accompanying drawings, in which examples shown are not intended to be limiting.
[0052] A metering and discharge system-hereinafter referred to as a system-includes a metering assembly that forms a continuous metered stream of a bulk material such as a dry granular free-flowing product. The system discharges the continuous metered stream of the bulk material at an outflow rate that matches an inflow rate based on measurements collected within the metering assembly. The system may be used with virtually any type of bulk material (i.e., a large mass, or volume, of particulate material).
[0053] In one example, the system dispenses bulk material such as agricultural products including corn seeds, soybeans, wheat, rice, etc. The system may provide the continuous metered stream of bulk agricultural products to a downstream treatment applicator. The downstream applicator may apply a liquid treatment at a treatment flow rate that matches the outflow rate of the continuous metered stream.
[0054] As shown in FIG. **1**A, system **100** can discharge the continuous metered stream through a metering assembly **30** which comprises two hoppers. The metering assembly **30** shown includes a lower hopper **20**—which can be referred to as a weigh hopper—and an upper hopper **40**—which can be referred to as a surge hopper. Both the lower hopper **20** and the upper hopper **40** may be made from coated or stainless-steel sheets or metallic framework. The upper hopper **40** and the lower hopper **20** may or may not be bolted to a frame assembly and/or rack to support the weight of the hoppers and the bulk material. The lower hopper **20** and the upper hopper **40** may include a lower tapered portion, that is a first tapered portion **21**, and a second tapered portion **41**, respectively, for directing a quantity of the bulk material. The lower hopper **20** is shown disposed below the upper hopper **40**.
[0055] In one example, as shown in FIG. **1**A, a plurality of proximity level sensors may be disposed along a sidewall of the upper hopper **40**. The plurality of proximity level sensors disposed along the sidewall may include a first high-level proximity sensor **48** and a first low-level proximity sensor **46**. The first high-level proximity sensor **48** may detect a high fill-level of bulk material present within the upper hopper **40**. The first low-level proximity sensor **46** may detect a low fill-level of bulk material present within the upper hopper **40**. Alternatively, an operator of a system **100**, in which the system **100** is not automated, or is partially automated, may visually detect the bulk material present at the high-fill level and/or low-fill level if a first high-level window and a first low-level window are disposed in the sidewall of the upper hopper **40** in place of the proximity sensors. Fill-level windows may be made of plexiglass and bolted to apertures disposed through the sidewall of a hopper. A plurality of proximity level sensors or fill-level windows may be disposed along a sidewall of the lower hopper **20**.
[0056] The fill-level sensor may be a continuous-level sensor **27**, such as an ultrasonic level sensor

disposed vertically above a central portion of the upper hopper **40**. Alternatively, the continuous-level sensor **27** may be installed along an interior, vertical surface of the upper hopper **40**. The continuous-level sensor **27** can detect fill levels of the bulk material from 0% to 100% of the hopper's holding capacity or volume. The continuous-level sensor **27** may generate a fill-level signal **63**, such as a low-level signal, a high-level signal, or an intermediate-level signal. The fill-level signal **63** generated may correlate with a fill-level volume of the upper hopper **40** such as 20%, 40%, 60%, 80%, or 100% filled. Other types of sensors or detectors may be used, such as touch, optical, or pressure types.

[0057] The continuous-level sensor **27** may be used in combination with the first high-level proximity sensor **48** and the first low-level proximity sensor **46** to detect the high fill-level and the low fill-level, respectively. During operation, a fill-level sensor generates a low-level signal as the upper hopper **40**, which starts empty, begins to fill with the bulk material. The upper hopper **40** is filled until the fill-level sensor generates a high-level signal. The first high-level proximity sensor **48** disposed in the upper portion **47** of the upper hopper **40** may generate a first high-level signal **208**. The first low-level proximity sensor **46** disposed in the lower portion **45** of the upper hopper **40** may generate a first low-level signal **202**.

[0058] The placement of the first low-level proximity sensor **46** may indicate a fill level of approximately 1% of the hopper's holding capacity or volume. The high-level placement of the first high-level proximity level sensor **48** may be up to a position that correlates with 100% of the hopper's holding capacity or volume. As shown in FIG. **1**B, this may be indicated by a second high-level signal **210**. As a safety measure, the first high-level proximity sensor **48** may also serve to prevent an overflow of a quantity of bulk material beyond the holding capacity or volume of the upper hopper **40**. Multiple proximity level sensors may be placed between the low-level placement and high-level placement positions.

[0059] The fill-level signal **63** emitted by the fill-level sensor measures the fill-level of the bulk material within the upper hopper **40**. As shown in FIG. **1**B, the continuous-level sensor **27** mounted vertically above the upper hopper **40** generates the fill-level signal **63**. A plurality of measured fill-level signals **200** may be received from the continuous-level sensor **27** as the flowing bulk material reaches various fill-levels of the upper hopper **40**.

[0060] The fill-level sensor may provide an electronic signal, such as the plurality of measured fill-level signals **200**, to a controller **60** of the system **100**. The controller **60** receives the plurality of measured fill-level signals **200** from the fill-level sensor as the volume of the upper hopper **40** fills with bulk material. For example, a first low-level signal **202** may be generated by the continuous-level sensor **27** when the bulk material fills approximately 20% of the upper hopper **40**. A second low-level signal **204** may be generated by the continuous-level sensor **27** when the bulk material fills approximately 40% of the upper hopper **40**. An intermediate-level signal **206** may be generated by the continuous-level sensor **27** when the bulk material fills approximately 60% of the upper hopper **40**. A first high-level signal **208** may be generated by the continuous-level sensor **27** when the bulk material fills approximately 80% of the upper hopper **40**. The second high-level signal **210** may be generated by the continuous-level sensor **27** when the bulk material fills approximately 100% of the upper hopper **40**.

[0061] The controller **60** may be an automated controller such as a programmable logic controller (PLC). The controller **60** may have a display **174** to allow operator commands. The display **174** may be a touch screen that includes a graphical user interface (GUI). Database files may be selected and edited from the display of the controller **60**. System **100** may receive command signals from the controller **60** as the display **174** is activated by an operator. The controller **60** may include programming for interfacing with various load cells, scales, level sensors, and gate control mechanisms automatically. The controller **60** may be operably connected to the system **100** level sensors, load cells, scales, and gate control mechanisms by being hardwired (i.e., ethernet, data communications protocol, serial communication link) or wireless (i.e., Wi-Fi, Bluetooth, mobile, wireless networking). The controller **60** interfaces with the various system components for monitoring and controlling a discharge flow **270** of bulk material from the system **100**.

[0062] Quantities of bulk material may be continuously received by the system **100** from a conveyor, hopper, bin, or other bulk material dispenser. As shown in FIG. **1**B, the upper hopper **40** receives an inbound flow **250** of bulk material while the discharge flow **270** of bulk material dispenses from the lower hopper **20**. The discharge flow **270** may be controlled gravimetrically at a variable rate while the inbound flow **250** enters the system **100** volumetrically.

[0063] A graphic performance estimation of system **100** is shown in FIG. **2**, where a discharge flow rate **272** closely correlates with an inbound flow rate **252** throughout multiple fill-time and release-time intervals.

[0064] The upper hopper **40**, having the fill-level sensor, provides the plurality of measured fill-level signals **200** so that the controller **60** can calculate an inbound flow rate **252**. In one example, the controller **60** may determine the inbound flow rate **252** for the inbound flow **250** by calculating the time between receiving the first low-level signal **202** and the first high-level signal **208**. The controller **60** may associate the plurality of measured fill-level signals **200** with a digital database containing pre-determined fill-level volumes and/or weight values. The association made allows the controller **60** to establish a discharge flow rate **272** that matches the inbound flow rate **252**. Correlating the discharge flow rate **272** with the inbound flow rate **252** provides accurate discharge of the continuous metered stream of bulk material.

[0065] The discharge flow rate **272** correlates with the inbound flow rate **252** as determined by the controller **60**. Controller **60** determines the inbound flow rate **252** by measuring the time to fill the upper hopper **40** and calculating a fill-time value based on the measured time to fill the upper hopper **40**. The controller **60** determines the measured time to fill the upper hopper **40** by monitoring the fill-level signal **63** generated by the fill-level sensor.

[0066] The discharge flow rate **272** begins to correlate with the inbound flow rate **252** in response to the fill-time value calculated by the controller **60**. Real-time weight readings from the load cells supporting the lower hopper **20** may provide additional information for adjustment of the discharge flow **270**.

[0067] The controller **60** can correlate readings from a timer **66**, that is mounted internally or externally to the controller **60**, with fill-level signal readings from the fill-level sensor to set the discharge flow rate **272** from the lower hopper **20**. Timer **66** may start when the fill-level within the upper hopper **40** begins to increase, as shown at the beginning of fill-time interval **315** in FIG. **2**. Timer **66** may stop when a first high-level within the upper hopper **40** is detected and a first high-level signal **208** is generated by the fill-level sensor, as shown at the end of fill-time interval **315**. The fill-time value determined from receipt of the low-level signal and the high-level signal may be assessed by the controller **60** to correlate the discharge flow rate **272** with the inbound flow rate **252**. In the case where system **100** is being used to discharge a continuous metered stream of seed, the controller **60** determines subsequent discharge flow rates based on the fill-time value calculated over time. Subsequent discharge flow rates may be adjusted to match changes in the inbound flow rate **252** as calculated by the controller **60** from the plurality of measured fill-level signals **200** received over time.

[0068] At the end of fill-time interval **315**, the continuous-level sensor **27** signals that a quantity of bulk material has reached a first high-level signal **208** within the upper hopper **40**. As an alternative, the first high-level proximity sensor **48** mounted on a sidewall of the upper hopper **40** may signal when the first high-level signal **208** has been reached. The quantity of bulk material discharges in an intermediate flow **262** from the upper hopper **40** into the lower hopper **20** during a first release-time interval **325**. At the start of the first release-time interval **325**, the fill-level sensor may generate the first low-level signal **202** when a minimum fill-level has been reached.

[0069] Iterative intervals of the continuous discharge cycle may follow, including a second fill-time interval **335**, a second release-time interval **345**, a third fill-time interval **355**, a third release-time interval **365**, and so on, until a delivered seed amount is discharged. A discharge period **375** ends the continuous discharge cycle as shown in FIG. **2**. The discharge period **375** may occur when the inbound flow **250** of bulk material into the upper hopper **40** stops and the remaining quantity of bulk material discharges from the lower hopper **20** with the discharge flow **270** of bulk material. System **100** may turn off as soon as the delivered seed amount is discharged thereby completing the continuous discharge cycle. The system **100** may automatically turn back on as soon as the upper hopper **40** is available to refill the lower hopper **20** again.

[0070] The controller **60** converts the fill-time value corresponding to the interval between receipt of a low-level signal and a high-level signal into the inbound flow rate **252**. The controller **60** calculates the inbound flow rate **252** from the fill-time value based on changes to the fill-level signal over time. The inbound flow rate **252** can be calculated as a volumetric flow rate by accessing the fill-level volume from a database file. The inbound flow rate **252** can be converted to a weight-based flow rate based on a previously calibrated relationship between volume and weight for a given material within the hopper or may be calculated based on a known or measured density of the material.

[0071] The discharge flow rate **272** from the lower hopper **20** may be synchronized with the inbound flow rate **252** into the upper hopper **40** by calibrating the system **100**. The upper hopper **40** may be calibrated by an operator to determine pre-determined fill-level volumes and/or weights. The pre-determined fill-level volumes and/or weight values may be entered into the digital database along with corresponding density values based on a commodity selected and measured. Database files may contain anticipated discharge flow rates based on calculations between the pre-determined fill-level volume and density values entered in the digital database. Alternatively, the controller **60** may make the calculations in real-time as the plurality of measured fill-level signals **200** are received. The controller **60** may calculate the weight values of the bulk material within the upper hopper **40** based on the fill-level volumes sensed by the fill-level sensor.

[0072] The plurality of measured fill-level signals **200** may be associated with the weight values. The weight values associated with the plurality of measured fill-level signals **200** may be stored as entries in the database file in the digital database. The measured values of volume and weight readings may be tabulated and accessed from the database file by the controller **60** for calibration of the system **100**. In one example, the controller **60** may determine the discharge flow rate **272** by accessing the database file to obtain weight values corresponding to the plurality of measured fill-level signals **200**. Alternatively, the controller **60** may access the database file to obtain volume values corresponding to the plurality of measured fill-level signals **200** and a density value corresponding to the bulk material selected.

[0073] Table 1, which follows, sets forth a hypothetical database file of the system:

TABLE-US-00001 TABLE 1 Fill-level Percentage Volume Weight Weight (%) (Units of seeds) (lbs) (approx. kg) 10 3 133 60 20 6 267 120 30 9 400 180 40 12 533 240 50 15 667 300 60 18 800 360 70 21 933 420 80 24 1066 480 90 27 1200 540 100 30 1333 600

[0074] The measured fill-level signals can be correlated with known volumes and weights of bulk material commodities such as corn and soybeans. A volume-to-weight relationship based on the bulk material commodity can be entered and established in the digital database. The controller **60** can access the database file where the association between the plurality of measured fill-level signals and corresponding weight values for each bulk material are entered. The weight may be calculated based on the fill-level volume if the density of the bulk material is known.

[0075] For example, before operating the system **100**, the upper hopper **40** may be partially filled to a first fill-level, such as 20% filled, with a first portion of bulk material. A first-low-level signal **202** may be generated by the continuous-level sensor **27**. The first fill-level corresponding to the first low-level signal **202** may be recorded in a database file, as shown in Table 1. The first portion of the bulk material may be dispensed from the upper hopper **40** into the lower hopper **20**. The first portion of the bulk material may partially fill the lower hopper **20**. In this case, the lower hopper **20** may be partially filled, that is 20% filled, by the first portion of the bulk material when hoppers of the stacked arrangement have the same capacity and dimensions. A first weight value is obtained by weighing the first portion of the bulk material within the lower hopper **20**. The first weight value may be obtained from a measurement of weight made by load cells supporting the lower hopper **20**. A first calibration weight signal **212** may be generated by the load cells and received by the controller **60** for calibration of the system **100**. The first weight value may be recorded in the database file in response to the first calibration weight signal **212** being received by the controller **60**.

[0076] The load cells may provide a plurality of measured fill-weight signals **230** to a controller **60** of the system **100**. Thus, additional portions of bulk material may be weighed by the lower hopper **20** for further calibration of the system **100**. A second calibration weight signal **214** may be generated and a second weight value recorded when a second portion of bulk material fills the lower hopper **20**. The second weight value may be associated with the second low-level signal **204** in the database file. A third calibration weight signal **216** may be generated and a third weight value recorded when a third portion of bulk material fills the lower hopper **20**. The third weight value may be associated with the intermediate-level signal **206** in the database file. A fourth calibration weight signal **218** may be generated and a fourth weight value recorded when a fourth portion of bulk material fills the lower hopper **20**. The fourth weight value may be associated with the first high-level signal **208** in the database file. A fifth calibration weight signal **220** may be generated and a fifth weight value recorded when a fifth portion of bulk material fills the lower hopper **20**. The fifth weight value may be associated with the second high-level signal **210** recording in the database file.

[0077] The discharge flow rate **272** may be commanded based on the weight value correlations made. Bulk material is discharged from the lower hopper **20** at the discharge flow rate **272** correlated to the inbound flow rate **252** into the upper hopper **40**. The agricultural seed is discharged at the discharge flow rate **272** as a continuous metered stream of agricultural seed from the lower hopper **20**. The controller **60** may command a first control mechanism **50** to position an adjustable gate **24**—which can be referred to as a variable position gate—of the lower hopper **20**, as shown in FIG. **1**A. The first control mechanism **50** may precisely control the open/close positions of the adjustable gate **24** into commanded positions. An electric power source may be coupled to the first control mechanism **50** to provide for precise and accurate control of the adjustable gate **24**. The electric power source is not shown in the figure for simplicity. A metered stream of bulk material may be continuously discharged as the discharge flow **270** through the first discharge opening **22** of the lower hopper **20** at the discharge flow rate **272**. The first control mechanism **50** may command adjustment of the adjustable gate **24** in proportion to the discharge flow rate **272**.

[0078] The discharge flow rate **272** may be adjusted dynamically based on the continuous fill-level change within the upper hopper **40**. As a result, a continuous metered stream of bulk material may be discharged from the lower hopper **20** that corresponds to the inbound flow rate **252**. Therefore, the discharge flow rate **272** from the lower hopper **20** may be adjusted to synchronize and match the inbound flow rate **252** into the upper hopper **40**. Commands to the position of the adjustable gate **24** may occur in real-time as communicated by the controller **60**.

[0079] During operations of system **100**, as shown in FIG. **1**B, the controller **60** will monitor the continuous-level sensor **27** for how fast or slow the surge level of the bulk material is increasing or decreasing within the upper hopper **40**. The continuous-level sensor **27** operates to detect the fill-level from a lower portion **45** of the upper hopper **40** to an upper portion **47** of the upper hopper **40**. The fill-level signal **63** generated by the continuous-level sensor **27** in response to the fill-level within the upper hopper **40** is received by the controller **60**. The controller **60** adjusts the discharge flow rate **272** upon receipt of the fill-level signal **63**. For example, if the surge level is increasing within the upper portion **47** of the upper hopper **40**, a calculation and corresponding positive adjustment will be made by the controller **60** to automatically increase the discharge flow rate **272** upon receipt of a first high-level signal **208** generated by the continuous-level sensor **27**. If the surge level is decreasing within the lower portion **45** of the upper hopper **40**, a calculation and corresponding negative adjustment will be made by the controller **60** to automatically decrease the discharge flow rate **272** upon receipt of a first low-level signal **202** generated by the continuous-level sensor **27**.

[0080] Synchronization between the discharge flow rate **272** from the lower hopper **20** and the inbound flow rate **252** into the upper hopper **40** may be constrained by preset target adjustment limits and minimum/maximum flow rate values. A preset target rate minimum and a preset target rate maximum can be entered and established in the digital database. The controller **60** can access the database files for the preset target adjustment limits to constrain the discharge flow rate **272** based on the flow rate values being calculated. The controller **60** may adjust the target flow rate between the preset target rate minimum and the preset target rate maximum relative to the operational constraints of a seed treatment applicator (not shown).

[0081] For example, the discharge flow rate **272** may be adjusted by up to 50 pounds per minute (lbs./min) (approximately 25 kilograms per minute (kg/min)) while the system **100** is operating. The discharge flow rate **272** may be further adjusted in smaller increments, including 25 lbs./min (approx. 11 kg/min), 20 lbs./min (approx. 9 kg/min), 10 lbs./min (approx. 5 kg/min), 5 lbs./min (approx. 2 kg/min), down to approximately 2 lbs./min (approx. 1 kg/min). The preset discharge rate minimum may be set at least to 300 lbs./min (approx. 140 kg/min). The preset discharge rate minimum may be further set below 300 lbs./min (approx. 140 kg/min), including 200 lbs./min (approx. 90 kg/min), 100 lbs./min (approx. 45 kg/min), or down to approximately 50 lbs./min (approx. 20 kg/min). The preset discharge rate maximum may be set at most to 2,000 lbs./min (approx. 900 kg/min). The preset discharge rate maximum may be further set above 2,000 lbs./min (approx. 900 kg/min), including 2,500 lbs./min (approx. 1,100 kg/min), 3,000 lbs./min (approx. 1,400 kg/min), or up to approximately 5,000 lbs./min (approx. 2,300 kg/min).

[0082] Agricultural seed may be ordered in seed amounts of between 1,000 pounds (lbs.) to 100,000 lbs. (approximately 454 kg to 45,400 kg). Ordered seed amounts may flow through the system **100** at a substantially constant rate during multiple fill-time and release-time intervals of the continuous discharge cycle. Agricultural seed in amounts of greater than 100,000 lbs. (approx. 45,400 kg) may flow through the system **100** at a substantially constant rate during an extended continuous discharge cycle having extended intervals including multiple fill-time and release-time intervals performed consecutively.

[0083] A flowchart for a method **300** that comprises steps for discharging a continuous metered stream of an agricultural seed is shown in FIG. **3**. An upper hopper is filled, according to step **302**. Step **302** comprises the following substeps: a fill level of the agricultural seed within the upper hopper is measured with a fill-level sensor, according to step **304**; an initial fill-level signal of the upper hopper is received, according to step **306**; an initial weight and/or volume value corresponding to the fill-level signal of the upper hopper is retrieved, according to step **308**; a subsequent fill-level signal of the upper hopper is received, according to step **310**; and a subsequent weight or volume value corresponding to the subsequent fill-level signal of the upper hopper is retrieved, according to step **312**. A time-value from the initial fill-level signal and the subsequent fill-level signal is recorded, according to step **314**. Step **314** comprises the following substeps: a total weight and/or volume as the difference between the subsequent weight and/or volume and the initial weight and/or volume is calculated, according to step **316**; and an inbound seed inflow rate that is the total weight and/or volume divided by the time value is calculated, according to step **318**. The upper hopper is emptied to fill a lower hopper, according to step **320**.

[0084] Discharge of a seed flow from a lower hopper disposed below the upper hopper is regulated by commanding a position of an adjustable gate, according to step **322**. Step **322** comprises the following substeps: optionally, a preset discharge rate minimum and a preset discharge rate maximum are set, according to step **324**, wherein the discharge seed outflow rate may be adjusted between the preset discharge rate minimum and the preset discharge rate maximum; and the discharge seed outflow rate is adjusted to match the inbound seed inflow rate that was calculated, according to step **326**, wherein the discharge outflow rate may be further regulated by adjusting the position of the adjustable gate in a variable position mode based on a plurality of loss-in-weight measurements of the lower hopper measured in real-time. Step **326** comprises the following substeps: the discharge seed outflow rate is increased upon receipt of a high-level signal generated in response to the fill-level within the upper hopper, according to step **328**; the discharge seed outflow rate is increased from the lower hopper by widening the gap of the adjustable gate upon receipt of the high-level signal generated by the fill-level sensor, according to step **330**; the discharge seed outflow rate is decreased upon receipt of a low-level signal generated in response to the fill-level within the upper hopper, according to step **332**; and the discharge seed outflow rate from the lower hopper is decreased by narrowing the gap of the adjustable gate upon receipt of the low-level signal generated by the fill-level sensor, according to step **334**. The method repeats when the upper hopper fills for a second interval.

[0085] A flowchart for a method **400** that comprises steps for calibrating a metering and discharge system is shown in FIG. **4**. The upper hopper is partially filled with an agricultural seed, according to step **402**. A first calibration fill-level signal is recorded, according to step **404**. The agricultural seed is dispensed from the upper hopper into a lower hopper, according to step **406**. The agricultural seed is weighed within the lower hopper and a first calibration weight value is stored in a digital database, according to step **408**. The first calibration weight value is associated with the first calibration fill-level signal, according to step **410**.

[0086] As depicted in FIG. **5**, a metering assembly **530** of the system **500** may be assembled without an upper hopper **940** so that only a lower hopper **525** is utilized in the metering assembly **530**. As shown, lower load cells **234**, and **236** are disposed on lower load cell platforms **215**, and **217**, respectively, to measure the weight of the agricultural seed within the lower hopper **525**. During a calibration period, the lower hopper **525** of the metering assembly **530** may be filled with a quantity of agricultural seed to a scale set point **420**, which may be based on a fill-level, weight amount, or fill amount.

[0087] During the calibration period, a first weight measurement is taken by the load cells when agricultural seed fills the lower hopper **525** to the scale set point **420**. A gap opening is created by adjustable gate **160** being moved into a command position by a lower control mechanism **350**. The adjustable gate **160** is moved into the command position at a gate set point associated with a target gap opening percentage. A first portion of the agricultural seed in the lower hopper **525** is discharged through the gap opening for a set discharge period. The gap opening is closed by adjustable gate **160** at the end of the set discharge period. A second weight measurement of the agricultural seed within the lower hopper **525** is taken. An outflow rate is calculated by taking the difference between the first weight measurement and the second weight measurement divided by the interval of time in the set discharge period. The outflow rate is associated with the command position of the adjustable gate **160** at the gate set point. The treatment flow rate is associated with the command position of adjustable gate **160**. The calibration process may have between two to twenty calibration points. In one example, between five to ten calibration points were taken. These steps may be repeated for each new command position.

[0088] As a result, a plurality of outflow rates can be associated with a plurality of command positions of the adjustable gate **160** and stored in a database made accessible to a controller **260**. In addition, a plurality of treatment flow rates can be calculated by an operator in accordance with recipes based on the plurality of outflow rates, which may also be stored in the database. Each portion of agricultural seed discharged during the calibration period is applied with an accurate amount of seed treatment according to the recipe based on the outflow rate. The calibration process may be repeated when other agricultural seed sizes or types are to be treated or after a treatment cycle.

[0089] Table 2, which follows, sets forth a hypothetical calibration period of the system: TABLE-US-00002 TABLE 2 Gap Opening Discharge Quantity Percentage Period Discharged Outflow Rate Treatment Rate (%) (seconds) (pounds) (lbs./min) (lbs./min.) 10 15 10 40 0.2 20 15 20 80 0.4 40 15 40 160 0.8 60 15 60 240 1.2 80 15 80 320 2.0 100 15 100 400 2.8

[0090] Once the calibration period is completed, a measurement period may be started when the inflow stream of agricultural seed fills the lower hopper **525** to the scale set point **420**. A high-level sensor **412** may be stationed on an upper end of the lower hopper **525** to prevent overflow of agricultural seed. The inflow stream of agricultural seed shuts down when the high-level sensor **412** generates a high-level signal to the controller **260**. Controller **260** may adjust command positions of the adjustable gate **160** proportionally over the measurement period to maintain the agricultural seed in the lower hopper **525** at, or near, the scale set point **420**. A level sensor, such as a proximity sensor, may be stationed at, or near, scale set point **420** to facilitate maintenance of the level of agricultural seed in the lower hopper **525** at a set fill-level.

[0091] The inflow stream of agricultural seed may continuously and sporadically enter the metering assembly **530** at a variable rate. Even so, the quantity of agricultural seed within the lower hopper **525** is maintained at, or near, the scale set point **420**. The controller **260** operably connected to load cells **234**, **236** monitors the quantity of agricultural seed and commands the adjustable gate **160** to maintain the quantity of agricultural seed at, or near, the scale set point **420** within the target percentage range. A real-time measurement signal generated by the load cells may cause the controller **260** to increase or decrease the gap opening of the adjustable gate **160**. Therefore, adjustable gate **160** moves to maintain the quantity of agricultural seed in the lower hopper **525** at, or near, the scale set point **420**.

[0092] The scale set point **420** may be set within a target percentage range of the maximum capacity of the metering assembly **530**. The maximum capacity of the metering assembly **530** may be based on volume, fill level, weight, or other measuring parameter. During the measurement period, the metering assembly **530** may be filled with agricultural seed within the target percentage range. The target percentage range may be between 5% to 80% of the maximum capacity of the metering assembly **530**. The target percentage range may be further between 5% to 25%, between 25% to 50%, between 50% to 80%, between 30% to 70%, between 15% to 45%, between 20% to 40%, between 40% to 70%, or between 50% to 60% of the maximum capacity of the metering assembly **530**. In one example, the lower hopper **525** may hold a maximum capacity of eight units (approx. 400 lb. or 180 kg) of agricultural seed. If the target percentage of the maximum capacity is set at 50%, then the scale set point **420** may correlate with 200 lbs. (approx. 90 kg) of agricultural seed to be maintained within the lower hopper **525** by adjustable gate **160**. In a preferred example, the lower hopper **525** may hold a maximum capacity of six units (approx. 300 lb. or 140 kg) of agricultural seed. If the target percentage of the maximum capacity is set at 33.3%, then the scale set point **420** may correlate with 100 lbs. (approx. 45 kg) of agricultural seed to be maintained within the lower hopper **525** by adjustable gate **160**. The maximum capacity of the lower hopper **525** may be between 100 pounds to 500 pounds (approx. 45 kg to 230 kg).

[0093] The metering assembly **530** may be sized to discharge with smaller outflow rates. In such cases, the outflow rate of the agricultural seed discharged through the adjustable gate **160** may be between 25 lbs./min and 1,000 lbs./min (approx. 10 kg/min and 454 kg/min). The outflow rate of the agricultural seed discharged through the adjustable gate **160** may be further between 50 lbs./min and 800 lbs./min (approx. 20 kg/min and 360 kg/min), between 50 lbs./min and 600 lbs./min (approx. 20 kg/min and 270 kg/min), between 50 lbs./min and 400 lbs./min (approx. 20 kg/min and 180 kg/min), between 100 lbs./min and 800 lbs./min (approx. 45 kg/min and 360 kg/min), between 100 lbs./min and 600 lbs./min (approx. 45 kg/min and 270 kg/min), between 100 lbs./min and 400 lbs./min (approx. 45 kg/min and 180 kg/min), between 100 lbs./min and 300 lbs./min (approx. 45 kg/min and 140 kg/min), between 200 lbs./min and 400 lbs./min (approx. 90

kg/min and 180 kg/min), between 300 lbs./min and 500 lbs./min (approx. 140 kg/min and 230 kg/min), between 50 lbs./min and 150 lbs./min (approx. 20 kg/min and 70 kg/min), or approximately 100 lbs./min (approx. 45 kg/min).

[0094] System **500** may be used in collaboration with a treatment applicator **435**. The treatment applicator **435** is shown disposed within a treatment chamber **430** positioned downstream of the metering assembly **530** in FIG. **5**. A transfer chute **222** positioned downstream of the lower hopper **525** may transfer metered agricultural seed from the lower hopper **525** to the treatment chamber **430** utilized for treating. A discharge chute **440** positioned downstream of the treatment chamber **430** may transfer freshly treated agricultural seed from the treatment chamber **430** to a conveyor, drum, or other apparatus utilized for mixing and conditioning.

[0095] One such example of a treatment applicator **435** used in seed treatment is KSi's patented applicator atomizer, which is disclosed in U.S. Pat. No. 9,675,001 B2. The applicator atomizer controls the spread of liquid treatment as agricultural seed falls through the treatment chamber **430** by the force of gravity. A smaller scale version of KSi's applicator atomizer may be utilized as the treatment applicator **435** when smaller outflow rates are to be treated.

[0096] The treatment flow rate **690** may be adjusted during the operation of system **500** to treat agricultural seed discharged from the metering assembly **530** with an accurate amount of treatment. The treatment flow rate **690** may be adjusted as load cells or a level sensor, such as a continuous level sensor, indicate an increase or decrease in the weight or level, respectively, of the quantity of material within the hopper.

[0097] The load cells mounted to the metering assembly **530** may signal the controller **260** with measured weights of the agricultural seed within the metering assembly **530**. A plurality of weight measurements of the metering assembly **530** may be received by the controller **260** in real-time. Based on the plurality of weight measurements, controller **260** may adjust the command position **650** of the adjustable gate **160** to regulate the agricultural seed within the metering assembly **530** at the percentage range of maximum capacity. The adjustable gate **160** may move from a first command position **652** to a second command position **654** upon generation of a measurement signal received by the controller **260**. Controller **260** may adjust the treatment flow rate **690** in response to the change in the command position **650** of the adjustable gate **160**. The controller **260** will increase the treatment flow rate **690** in response to an increase in the gap opening of the adjustable gate **160**. Controller **260** will decrease the treatment flow rate **690** in response to a decrease in the gap opening of the adjustable gate **160**. The treatment flow rate **690** may correlate with the outflow rate of the outflow stream of agricultural seed based on the command position of the adjustable gate **160**.

[0098] Downstream processing may include accurately treating the outflow stream of agricultural seed with a pre-determined quantity of liquid treatment. The treatment flow rate **690** may correlate to the outflow rate in real-time as the controller **260** adjusts the adjustable gate **160** during the operation of system **500**. The treatment flow rate **690** may be pre-determined to correlate with command positions of adjustable gate **160** that are based on outflow rates calculated during the calibration period. Liquid treatment(s) may be accurately applied at treatment flow rates that correlate to commanded gate positions made in response to real-time measurement signals made by load cells that are received by the controller **260**. The liquid treatment may be applied to the agricultural seed while discharged from the metering assembly **530** in accordance with a pre-determined recipe based on the outflow rate.

[0099] System **500** may be used in collaboration with a control software platform or program that serves as a measuring and control device for the treatment applicator **435** positioned downstream of the system **500**. One such example used in seed treatment is KSi® AutoTreat®. The control software platform controls the treatment flow rate **690** of the auto treater based on a recipe input (i.e., oz./per 100 lbs. of seed (or mL/kg)) and the outflow rate measured from the system **500**. As a measuring and control device, the control software platform may control the adjustable gate **160** concurrently with the speed of the seed treatment pumps to match an outflow rate. Controller **260** may be installed with the program to have multi-functionality capabilities to receive measured outflow rates and calibrate seed treatment parameters based on the predetermined recipes from the operator.

[0100] FIG. **6** shows a graphic performance estimation of system **500** under operation. The lower hopper **525** of system **500** receives an inflow stream of bulk material, such as agricultural seed, at an inflow rate that is substantially consistent. For example, a conveyor may be dispensing a continuous stream of agricultural seed into an inlet side of the lower hopper **525**. The continuous stream may have consistent inflow. The continuous stream may have a variable rate. An adjustable gate **160** of the lower hopper **525** may remain closed for a hopper fill period until a hopper weight **670** that matches a target hopper weight is measured. Then, as shown in FIG. **6**, adjustable gate **160** opens to a first command position **652** that allows the discharge of an outflow stream of agricultural seed from the lower hopper **525** at an outflow rate that begins to correspond with the inflow rate. The relative position of adjustable gate **160** in the first command position **652** correlates with a gap opening percentage of approximately 25%. If the hopper weight **670** measurement increases above the target hopper weight, the adjustable gate **160** opens to a second command position **654** so that the outflow rate corresponds with the inflow rate. The relative position of adjustable gate **160** in the second command position **654** correlates with a gap opening percentage of approximately 50%. If the hopper weight **670** measurement decreases below the target hopper weight, the adjustable gate **160** closes to a third command position **656** so that the outflow rate corresponds with the inflow rate. The relative position of adjustable gate **160** in the third command position **656** correlates with a gap opening percentage of approximately 35%. Adjustment of the gap opening percentage by adjustable gate **160** maintains the hopper weight **670** at, or near, the target hopper weight. The treatment flow rate **690** for a liquid treatment applied to the agricultural seed by a treatment applicator may be adjusted based on the relative position of the adjustable gate **160**. Adjustment to the treatment flow rate **690** may be instantaneous with a change in the gap opening percentage of the adjustable gate **160**. Alternatively, adjustment of the treatment flow rate **690** may be delayed based on an interval of time for the outflow stream of agricultural seed to reach the treatment applicator.

[0101] FIG. **7** shows a graphic performance estimation of system **500** under operation. The lower hopper **525** of system **500** receives an inflow stream of bulk material, such as agricultural seed, at an inflow rate that is inconsistent. The inflow stream of bulk material may be a discontinuous stream. For example, a loader may be dispensing loads of agricultural seed into an inlet side of the lower hopper **525**. The loads may be dispensed as dumps at irregular intervals. An adjustable gate **160** of the lower hopper **525** may remain closed for a hopper fill period until a hopper weight **670** that matches the target hopper weight is measured. Then, as shown in FIG. **7**, adjustable gate **160** opens to a first command position **652** that allows the discharge of an outflow stream of agricultural seed from the lower hopper **525** at an outflow rate that begins to correspond with the inflow rate.

[0102] The relative position of adjustable gate **160** in the first command position **652** correlates with a gap opening percentage of approximately 25%. If the hopper weight **670** measurement increases above the target hopper weight, the adjustable gate **160** opens to a second command position **654** so that the outflow rate corresponds with the inflow rate. The relative position of adjustable gate **160** in the second command position **654** correlates with a gap opening percentage of approximately 50%. If the hopper weight **670** measurement increases substantially above the target hopper weight for a second period, the adjustable gate **160** opens further to a third command position **658** so that the outflow rate corresponds with the inflow rate. The relative position of adjustable gate **160** in third command position **658** correlates with a gap opening percentage of approximately 60%. Adjustment of the gap opening percentage by adjustable gate **160** maintains the hopper weight **670** at, or near, the target hopper weight.

[0103] The treatment flow rate **690** for a liquid treatment applied to the agricultural seed by a treatment applicator may be adjusted based on the relative position of the adjustable gate **160**. Adjustment to the treatment flow rate **690** may be instantaneous with a change in the gap opening percentage of the adjustable gate **160**. Alternatively, adjustment of the treatment flow rate **690** may be delayed based on an interval of time for the outflow stream of agricultural seed to reach the treatment applicator.

[0104] FIG. **8** is an example flowchart of an automated method **800** for calibrating the metering assembly to discharge agricultural seed at an outflow rate that matches the inflow rate. At step **810**, an inflow stream of agricultural seed fills a metering assembly to a percentage range of the maximum capacity of the metering assembly. At step **820**, the controller sets an adjustable gate mounted to the metering assembly to a command position. At step **830**, the metering assembly discharges a portion of the agricultural seed through an opening created by the adjustable gate set at the command position. At step **840**, the controller associates an outflow rate with the adjustable gate set at the command position. At step **850**, load cells measure a plurality of weights of the metering assembly. At step **860**, the controller obtains a plurality of outflow rates that correspond with a plurality of command positions of the adjustable gate. At step **870**, the metering assembly determines an inflow rate of the stream of agricultural seed based on the plurality of weight measurements. At step **880**, the controller regulates the command position of the adjustable gate, optionally in real-time, to maintain the agricultural seed within the metering assembly at the percentage range of the maximum capacity. At step **890**, the controller adjusts a treatment rate in response to an increase or decrease in an opening of the adjustable gate. A treatment recipe may be based on the outflow rate according to the command position of the adjustable gate.

[0105] An example of a metering assembly **930** is presented in FIG. **9**. The metering assembly **930** has a mechanical sub-assembly made from coated or stainless-steel sheets or metallic framework. The metering assembly **930** may include at least two hoppers, an upper hopper **940** and a lower hopper **920**, respectively. The upper hopper **940** and the lower hopper **920** may or may not be bolted to a frame assembly and/or rack to support the added weight of the agricultural seed. The upper hopper **940** is disposed above the lower hopper **920**.

[0106] Each of the hoppers may be configured to support up to 10,000 lbs. (approx. 4,540 kg), or more, of weight. In the example shown, each hopper is configured to support between 1,500 lbs. to 2,000 lbs. (approx. 680 kg to 907 kg) of weight. The holding capacity of the upper hopper **940** may equal that of the lower hopper **920**. Alternatively, the holding capacity of the upper hopper **940** may be greater than or less than that of the lower hopper **920**.

[0107] Legs of the upper hopper **940** and lower hopper **920** are each disposed upon vertical support members **913**, **915**, and **917**. Vertical support members **913**, **915**, and **917** may be connected to the foundation of a lower sub-frame **910**. A load cell may be attached to the lower ends of each of the legs to support the upper hopper **940** and lower hopper **920**. The load cell may be selected from several common types such as electronic, strain gauge, hydraulic, electropneumatic, or hydraulic pneumatic.

[0108] Readings by the load cell may be given in English (or metric) increments of a half-pound (approx. 0.25 kg), one pound (approx. 0.5 kg), 2 lbs. (approx. 1 kg), 5 lbs. (approx. 2.5 kg), 10 lbs. (approx. 5 kg), 20 lbs. (approx. 10 kg), 100 lbs. (approx. 50 kg), depending on the quality of adjustment for operation and calibration of the system **100**. The load cell may have a capacity to read up to 2,500 lbs. (approx. 1,134 kg), or more, of weight. In that case, a total capacity of up to 10,000 lbs. (approx. 4,540 kg) of weight may be read by four load cells used in combination together with an associated hopper.

[0109] The load cell may transmit a wireless data input signal via a transmitter or be electrically connected directly to a controller **962**. Controller **962** may have a network connection with system **900**. The load cell may provide a change-in-weight reading, which may be a loss-in-weight reading or a gain-in-weight reading, of the associated hopper to the controller **962** as the quantity of seed within the hopper changes. The controller **962** may further measure the rate of weight change of the associated hopper. The load cell may be electrically or wirelessly connected to a load scale. Alternatively, the load cell may coordinate readings with a legal for the trade scale or beam scale.

[0110] The controller may be operably connected to system **900**. An operator may be given mastery over the system **900** with a built-in programmable automation controller that is hardwired (i.e., ethernet, data communications protocol, serial communication link) or wireless (i.e., Wi-Fi, Bluetooth, mobile, wireless networking). The controller may include a central processing unit with programming for interfacing with load cells, scales, level sensors, gate position sensors, and control mechanisms for monitoring and controlling the flow of seed from the hoppers and seed treatment from the seed treatment pumps. The controller may have a touch screen to allow for operator commands. Various data input signals may be sent to the controller from the plurality of load cells. Various command output signals may be sent from the controller based on the data received. In a hardwired system, the load cells may be electrically linked to the controller through a plurality of cables.

[0111] As shown in FIG. **9**, both the upper hopper **940** and the lower hopper **920** may be supported directly with a plurality of load cells. Lower hopper **920** is mounted with lower load cells **931**, **933**, and **935**, and upper hopper **940** is mounted with upper load cells **951**, **953**, and **957**. The number of load cells utilized may depend on the shape of the hoppers, whether round, triangular, square, or rectangular. The first lower load cell **931** is mounted to the lower hopper **920** at a lower end between a first leg of the lower hopper **920** and a lower load cell platform. The weight of the lower hopper **920** and a quantity of agricultural seed within, pushes against the first lower load cell **931** by the force of gravity. Alternatively, the first lower load cell **931** may be mounted above the top side of the lower hopper **920**. In this case, the weight of the lower hopper **920** and a quantity of agricultural seed within, pulls against the first lower load cell **931** by the force of gravity. The first upper load cell **951** is mounted to the upper hopper **940** at a lower end between a first leg of the upper hopper **940** and an upper load cell platform. The weight of the upper hopper **940** and a quantity of agricultural seed within, pushes against the first upper load cell **951** by the force of gravity. Alternatively, the first upper load cell **951** may be mounted above the top side of the upper hopper **940**. In this case, the weight of the upper hopper **940** and a quantity of agricultural seed within, pulls against the first upper load cell **951** by the force of gravity.

[0112] Load cells may be mounted to the upper hopper **940** and lower hopper **920** upon load cell platforms mounted generally above vertical support members **913**, **915**, and **917**. Lower load cell platforms **919**, **922**, and **923** may be disposed upon and supported by the lower sub-frame **910** which also provides support for the lower hopper **920**. Upper load cell platforms **963**, **965**, and **969** may be disposed upon and supported by the lower sub-frame **910** which also provides support for the upper hopper **940**. The lower sub-frame **910** disposed below each of the hoppers may be mounted to and supported by a plurality of support members, which may include the vertical support members **913**, **915**, and **917**. The vertical support members **913**, **915**, and **917** may be connected to the support rack or supportive framework of the lower sub-frame **910**. Alternatively, each of the hoppers may be supported vertically, from above, by the plurality of support members, which may include chains or rods.

[0113] A first tapered portion **921** of the lower hopper **920** and a second tapered portion **941** of the upper hopper **940** may be sufficiently steep and smooth to reduce friction and direct a quantity of the bulk material for discharge. In the case of using a round hopper, less friction may reduce instances where seed flow forms a central flow path (funnel flow) within the hopper while non-flowing seed is left along the inside margins within the hopper. An upper discharge opening **942** of the metering assembly **930** is positioned in the bottom of the second tapered portion **941** of the upper hopper **940**. A lower discharge opening (not shown) of the metering assembly **930** is positioned at the bottom of the first tapered portion **921** of the lower hopper **920**. A binary gate **944** may be mounted against the upper hopper **940** at the upper discharge opening **942**. The adjustable gate **960** may be mounted against the lower hopper **920** at the lower discharge opening.

[0114] Metering assembly **930** is operable to intermittently dispense a seed amount from the upper hopper **940** into the lower hopper **920**, while the lower hopper **920** continuously delivers seed at an outflow rate **1080** for downstream processing. The inflow stream of agricultural seed is received into the upper hopper **940** of the metering assembly **930**. System **900** monitors the upper hopper **940** for when a quantity of seed reaches a predetermined target weight. An upper control mechanism **955** may be operably connected to the binary gate **944** of the upper hopper **940**. Dual gates of binary gate **944** may be opened by means of activating the upper control mechanism **955**. The upper control mechanism **955** may be powered by a pneumatic pressure source to provide for simultaneous, independent control of each of the gates of the binary gate **944**, although the pneumatic pressure source is not shown in the figures for simplicity. The upper control mechanism **955** may be a pair of air-assisted cylinders operably connected to dual gates of binary gate **944**. The upper control mechanism **955** provides regulated air to first and second pneumatic air-assist cylinders for quick and accurate control of the open and closed positions of the binary gate **944**. The upper control mechanism **955** may quickly open and close the binary gate **944** based on commands received from the controller **962**.

[0115] Binary gate **944** opens to discharge a surge of agricultural seed from the upper hopper **940** into the lower hopper **920** of the metering assembly **930** when the lower hopper **920** is running low on a quantity of seed. The binary gate **944** may be opened quickly periodically for quicker refill periods of the lower hopper **920**. The binary gate **944** may be closed quickly and periodically for longer measurement periods of the lower hopper **920**. The adjustable gate **960** may be continuously adjusted while the binary gate **944** is closed.

[0116] Both the upper hopper **940** and the lower hopper **920** of the metering assembly **930** are measured continuously in real-time as the agricultural seed is discharged gravimetrically. Loss-in-weight measurement signals may be generated by the load cells mounted to the upper hopper **940** and the lower hopper **920**. The loss-in-weight measurement signals may be received by controller **962** in real-time as the agricultural seed is discharged gravimetrically. Controller **962** may decrease an opening created by the adjustable gate **960** upon a loss-in-weight of the upper hopper **940** over a measurement period. Controller **962** may increase the opening created by the adjustable gate **960** upon a gain-in-weight of the upper hopper **940** over a measurement period.

[0117] A program of system **900** may calculate set points based on hopper weights and start/stop commands for each of the hopper gates involved in the seed metering and discharge operation. More specifically, set points may be established on timer settings based on calculated intervals of time, weight measurements obtained from the upper hopper **940** and/or the lower hopper **920**, high/low weight readings from load cells, indications by high/low-level sensors (proximity) having a fixed position within the hoppers, or another predetermined parameter. The bulk density of the agricultural seed may be used to calibrate the set points based on weight. An operator may adjust established set points such as weight limits, command positions of the adjustable gate **960**, or time intervals stored in the controller **962** as needed.

[0118] Set points may be determined based on a plurality of measurements of agricultural seed within the metering assembly **930**. A set point for a command position of adjustable gate **960** may be determined while the binary gate **944** is closed. In one example, the set point is based on the measurement of agricultural seed within the lower hopper **920** during a measurement period. In another example, the set point is based on the measurement of agricultural seed within the upper hopper **940** during the measurement period. The refill period may be triggered by controller **962** once a refill set point has been met. The refill set point may correlate to a high-weight set point being reached, as indicated by load cells of the upper hopper **940**. The refill set point may correlate to a low-weight set point being reached, as indicated by load cells of the lower hopper **920**.

[0119] The refill set point may correlate to a timer set point being reached, as indicated by a timer of the system **900**. The timer set point may be based on a refill period of between 0.1 seconds and

10 minutes. The refill period may be further between 1 second and 5 minutes, between 1 minute and 5 minutes, between 2 minutes and 8 minutes, between 5 minutes and 10 minutes, or between 30 seconds and 5 minutes.

[0120] The refill period may be allowed to continue even after the lower hopper **920** has been refilled. Agricultural seed filling the lower hopper **920** may begin to choke feed through the binary gate **944** that remains opened and backfill into the upper hopper **940**. A set surge fill level in the upper hopper **940** may be maintained and monitored during the refill period. The command position of adjustable gate **960** may be set in a fixed position when the binary gate **944** is opened. The command position of adjustable gate **960** may be maintained at the set point during the refill period of the lower hopper **920**. The command position of adjustable gate **960** may be maintained at the set point during the refill period of both the lower hopper **920** and the upper hopper **940** of the metering assembly **930**.

[0121] Controller **962** may adjust the command positions of the adjustable gate **960** proportionally over the measurement period. During the refill period, controller **962** may fix the command position of the adjustable gate **960** at a set point that was calculated during a previous measurement period. During a subsequent measurement period, controller **962** may trigger an adjustment to the outflow rate **1080** controlled by the adjustable gate **960**. Adjustment to the outflow rate **1080** may be based on monitoring of the upper hopper **940** for variable accumulations or depletions in the inflow rate **1070** during the refill period. Advantages to monitoring the upper hopper **940** having load cells include less likelihood in the system **900** running out of seed during processing and more accuracy in matching the outflow rate **1080** to the inflow rate **1070**.

[0122] The transition time between adjusting and fixing the command positions of adjustable gate **960** may occur over a period of a few seconds. Alternatively, time-off and time-on delays may be programmed into controller **962** to establish a transition phase between modes. This may allow the loss-in-weight readings by the load cells to "catch up" since readings for differences in weight may be taken sequentially, such as ten times each second. Calculations based on an average of the last ten seconds logged by the load cells may allow for transition to occur over an interval of time between three to five seconds.

[0123] The command position may be maintained at the set point until a load cell mounted to the lower hopper **920** reports a loss-in-weight over the refill period. The refill period may occur over an interval of time lasting between 0.1 second to 30 seconds in length. The interval of time over the refill period may be further between 1 second to 20 seconds, between 2.5 seconds to 15 seconds, between 5 seconds to 10 seconds, between 5 seconds to 25 seconds, between 10 seconds to 20 seconds, or between 5 seconds to 15 seconds. The measurement period may occur over an interval of time lasting between 30 seconds to 10 minutes in length. The interval of time over the measurement period may be further between 30 seconds to 8 minutes, between 40 seconds to 6 minutes, between 50 seconds to 4 minutes, between 1 minute to 3 minutes, or between 1 minute and 2 minutes.

[0124] The upper control mechanism **955** and lower control mechanism (not shown) may be electrically, mechanically, hydraulically, or pneumatically powered. Gate operation may be actuated by devices such as cylinders, servomechanisms, or worm screws. Pneumatic air-assist cylinders and electric actuators, having position control, may be selected to operate the hopper gates because of their rapid precision control. Control of the hopper gates may be provided by other means than pneumatic cylinders or electric actuators. The upper control mechanism **955** and lower control mechanism may be coupled with a controller to receive various control inputs.

[0125] The controller may be an automated controller such as a computer serving as a programmable logic controller (PLC) that automatically controls the functions of the system **900**. The controller may be an automated controller such as a proportional integral derivative (PID) loop controller that automatically controls the functions of system **900**. The controller may be operably connected to the upper control mechanism **955**, the lower control mechanism, and load cells **931**,

933, **935**, **951**, **953**, and **957**. Controller **962** may receive multiple mass measurement input signals from load cells **931**, **933**, **935**, **951**, **953**, and **957**. The controller **962** may be programmed to send command output signals to activate and operate the upper control mechanism **955** and the lower control mechanism. The controller **962** is also responsive to position feedback input signals received from the upper control mechanism **955** and the lower control mechanism. A transmitter operably connected to the upper control mechanism **955** and the lower control mechanism may transmit the position feedback input signals to the controller.

[0126] Agricultural seed may be processed in seed amounts of between 1,000 pounds (lbs.) to 50,000 lbs. (approximately 454 kilograms (kg) to 22,680 kg). Agricultural seed may flow through system **900** at a substantially constant rate during a continuous discharge cycle. Agricultural seed in amounts greater than 50,000 lbs. (approx. 22,680 kg) may flow through the system **900** at a substantially constant rate during an extended continuous discharge cycle or throughout an extended interval that includes multiple continuous discharge cycles performed consecutively.

[0127] FIG. **10** shows a graphic performance estimation of system **900** in operation during a continuous discharge cycle. The upper hopper **940** is filled with a first quantity of bulk material during a loading period **815**. During the loading period **815**, the inflow rate **1070** may be determined based on a plurality of weight measurements of agricultural seed within the upper hopper **940**. Once filled, the upper hopper **940** discharges the first quantity of bulk material to the lower hopper **920** during a first refill period **825** to form a second quantity of bulk material.

[0128] At the start of the first refill period **825**, the fixed position mode may be activated when a first low-level sensor of the lower hopper **920** signals that the second quantity of bulk material has reached a low-level within the lower hopper **920**. If the fixed position mode is activated, the lower control mechanism moves the adjustable gate into a fixed position. The upper hopper **940** may have a second high-level sensor that signals the program to initiate the fixed position mode. As one alternative, load cells **931**, **933**, and **935** supporting the lower hopper **920** may signal that a first low-weight set point has been reached so that the program initiates the fixed position mode. As another alternative, load cells **951**, **953**, and **957** supporting **11** the upper hopper **940** may signal that a second high-weight set point has been reached so that the program initiates the fixed position mode.

[0129] At the end of the first refill period **825**, the upper control mechanism **955** closes the binary gate **944** of the upper hopper **940**, and the upper hopper **940** begins to fill with a third quantity of bulk material. Over a matching phase **832** of the first measurement period **835**, the outflow rate **1080** of the agricultural seed discharged from the lower hopper **920** begins to correlate with the inflow rate **1070** as the lower control mechanism proportionately adjusts the adjustable gate based on real-time readings from load cells **931**, **933**, **935** supporting the lower hopper **920**.

[0130] During the first measurement period **835**, the inflow rate **1070** may be determined based on a plurality of weight measurements of agricultural seed within the lower hopper **920**. The inflow rate **1070** continues to be monitored over a monitoring phase **842** of the continuous discharge cycle by load cells **931**, **933**, **935**, and **951**, **953**, **957** supporting the lower hopper **920** and upper hopper **940**, respectively, so the outflow rate **1080** matches the inflow rate **1070** by control and adjustment of the adjustable gate **960**.

[0131] Iterative periods of the continuous discharge cycle may follow, including a second refill period **845**, a second measurement period **855**, a third refill period **865**, and so on, until a delivered seed amount is discharged. A discharge period **875** ends the continuous discharge cycle as shown in FIG. **10**. The discharge period **875** may occur when the inflow stream of bulk material into the upper hopper **940** stops and the output flow of bulk material discharges the remaining quantity of bulk material from the lower hopper **920**. System **900** may turn off as soon as a delivered seed amount is discharged thereby completing the continuous discharge cycle. System **900** may automatically turn back on as soon as the upper hopper **940** is available to refill the lower hopper **920** again.

[0132] Referring now to FIG. **11** in comparison to the graphic performance estimation shown in FIG. **10**, the command position **1150** of the adjustable gate **960** may be variably adjusted during the measurement periods and discharge period previously discussed. The adjustable gate **960** moves into a plurality of command positions, between fully opened and fully closed, so that the outflow rate **1080** may closely match the inflow rate **1070** as shown in FIG. **10**. Adjustment of the adjustable gate **960** into the plurality of command positions maintains the outflow rate **1080** of the agricultural seed near the inflow rate **1070**. The outflow rate **1080** that is measured is defined as a quantity of seed that flows through the lower discharge opening over time during the measurement period. The outflow rate **1080** that is measured may be based on loss-in-weight measurements measured in real-time by the load cells.

[0133] The adjustable gate **960** may be in a fixed position during refill periods as previously discussed and shown in FIG. **10**. However, system **900** does not necessarily have to be operated in a fixed position mode, where the adjustable gate **960** is placed in a fixed position. Load cells supporting the upper hopper **940** provide weight measurements over time which give readings on the inflow rate **1070** even when the bulk material flow is variable. Alternatively, a metering assembly **530** without the upper hopper but with a lower hopper **525** that has been calibrated, as discussed above, can read the inflow rate **1070** by maintaining the level of bulk material in the lower hopper **525** at the scale set point **420**. When utilizing the metering assembly **930** in the fixed position mode, fixing the position of the adjustable gate **960** into a static position maintains an outflow rate **1080** of the agricultural seed that is assumed near the inflow rate **1070**. The outflow rate **1080** which is assumed is defined as a quantity of seed that flows through the lower discharge opening over time during the refill period. The outflow rate **1080** may be based on loss-in-weight measurements of the lower hopper **920** previously measured during the measurement period. Alternatively, the outflow rate **1080** may be based on loss-in-weight measurements of the upper hopper **940** during the refill period or from gain-in-weight measurements of the upper hopper **940** previously measured during the measurement period.

[0134] During the measurement period, controller **962** may place the system **900** back into the variable position mode. Partially opening and closing the adjustable gate **960** adjusts the outflow rate **1080** to match the inflow rate **1070** that is measured. In turn, a treatment flow rate that is downstream may correlate with the outflow rate **1080** of the seed in real-time.

[0135] FIG. **12** is an example flowchart of an automated method **1200** for discharging agricultural seed from the metering assembly at an outflow rate that matches the inflow rate. At step **1210**, the metering assembly receives an inflow stream of agricultural seed into an upper hopper of the metering assembly. At step **1220**, load cells measure the weight of the agricultural seed within the upper hopper. At step **1230**, the metering assembly determines an inflow rate of the stream of agricultural seed based on the measurements of agricultural seed within the metering assembly. At step **1240**, a program determines a set point for a command position of an adjustable gate mounted to a lower hopper of the metering assembly. The set point may be based on the measurement of the agricultural seed. At step **1250**, the controller commands the adjustable gate into a command position to discharge an outflow stream of agricultural seed from the metering assembly that matches the inflow rate. At step **1260**, the controller adjusts the command position of the adjustable gate to regulate an outflow rate of the outflow stream to match the inflow rate of the inflow stream. At step **1270**, the controller commands a treatment rate based on the command position of the adjustable gate. At step **1280**, a treatment applicator applies a treatment to the discharged agricultural seed. A treatment recipe may be based on the outflow rate according to the command position of the adjustable gate.

[0136] Referring now to another example of a continuous discharge cycle **1300**, the metering assembly is shown operating chronologically, as shown by arrows **702**, **704**, **706**, **708**, and **710**, in various periods of operation, as depicted by FIGS. **13**A, **13**B, **13**C, **13**D, **13**E, **13**F. The series of periods may be carried out by the system during the continuous discharge cycle **1300** to maintain a regulated continuous flow of metered seed. The upper hopper **740** receives and discharges a product flow intermittently throughout the continuous discharge cycle **1300**. After an initial loading period, the lower hopper **720** continuously dispenses the product. Bulk material may be discharged from the upper hopper **740** during the loading period and the refill period. Bulk material is discharged continuously from the lower hopper **720** during the measurement period and the refill period.

[0137] A loading period **715** is depicted in FIG. **13**A. In this period, bulk material is discharged through the upper hopper **740** to load the lower hopper **720**. A seed source (not shown for the sake of simplicity) provides an inflow stream **745** of bulk material into the upper hopper **740**. The seed source may be supplied by another hopper, a box stand, an auger, a bucket elevator, or input into the system **700** by a conveyor. The inflow stream **745** of bulk material is directed by the upper tapered portion **741** to the upper discharge opening **742** of the upper hopper **740**. The inflow stream **745** of bulk material fills the lower hopper **720** when the binary gate **744** of the upper hopper **740** is open. The adjustable gate may be closed during the loading period **715** by the lower control mechanism **750** if the lower hopper **720** is being filled. The inflow stream **745** of bulk material is directed by the upper tapered portion **741** to form a first quantity of bulk material **723**. When the first quantity of bulk material **723** reaches a first high-target weight as measured by load cells **732**, and **734** supporting the lower hopper **720**, the controller transitions the system **700** out of the loading period **715** and into a variable position mode, according to arrow **702**. Alternatively, when the first quantity of bulk material **723** reaches a first high-level sensor **728** mounted to the lower hopper **720**, the controller transitions the system **700** out of the loading period **715** and into the variable position mode, according to arrow **702**.

[0138] A first measurement period **730** is depicted in FIG. **13**B. During the first transition into the first measurement period **730**, the controller commands the binary gate **744** closed by the upper control mechanism **755**. The controller begins adjusting the adjustable gate by the lower control mechanism **750** proportionally based on the gravimetric readings to achieve and maintain a selected seed flow rate during the first measurement period **730**. To regulate seed flow rates based on real-time measurements, the controller monitors the rate of change on the load cells **732**, and **734** as seed flows from the lower hopper **720** during the continuous discharge cycle **1300**. The controller compares the inflow rate calculations and adjusts the adjustable gate accordingly to provide an outflow stream **725** of agricultural seed at an outflow rate that matches the inflow rate. The controller adjusts the lower control mechanism **750** based on electrical signals that are proportional to the mass of the bulk material as read by the load cells **732**, and **734** to command the positioning of the adjustable gate.

[0139] During the first measurement period **730**, the first quantity of bulk material **723** is directed by the lower tapered portion **721** to flow through the lower discharge opening **722** of lower hopper **720** as the outflow stream **725** of bulk material. During this period, the bulk material is discharged gravimetrically from the lower hopper **720** based on the loss-in-weight measurements. Meanwhile, the inflow stream **745** of bulk material begins to form a second quantity of bulk material **743** within the upper hopper **740** when the binary gate **744** is closed. Bulk material is not discharged into the lower hopper **720** from the upper hopper **740** during the first measurement period **730**. Bulk material continues to discharge from the lower hopper **720** to the seed receiving equipment (not shown for the sake of simplicity) during the second transition, according to arrow **704** in FIG. **13**C.

[0140] When the second quantity of bulk material **743** reaches a second high-target weight as measured by load cells **752**, and **754** supporting the upper hopper **740**, the controller may transition the system out of the variable position mode and into a fixed position mode, according to arrow **706**. Opening of the binary gate **744** of the upper hopper **740** may occur when the second high-target weight is sensed by load cells **752**, and **754**. The second quantity of bulk material **743** fills the lower hopper **720** when the binary gate **744** of the upper hopper **740** is open. During this second transition, the adjustable gate may be moved into a fixed position by a lower control mechanism

750.

[0141] Alternatively, or in combination with measurements by the load cells, when the second quantity of bulk material **743** reaches a second high-level sensor **748** within the upper hopper **740** or the first quantity of bulk material **723** reaches a first low-level sensor **726** within the lower hopper **720**, the controller may transition the system **700** out of the variable position mode and into a fixed position mode, according to arrow **706**. Opening of the upper hopper **740**, when the second high-level sensor **748** is triggered, may allow for a volumetric measurement estimate of the second quantity of bulk material **743**. During this second transition, the adjustable gate may be moved into a fixed position by the lower control mechanism **750**.

[0142] As system **700** completes the transition into a first refill period **760**, as shown in FIG. **13**D, bulk material may begin to discharge at a constant rate from the lower hopper **720**. System **700** may be engaged in the fixed position mode during the first refill period **760**. Bulk material continues to discharge from the upper hopper **740** into the lower hopper **720** while bulk material discharges from the lower hopper **720** to the seed receiving equipment. Bulk material may continue to discharge from the seed transfer equipment to the upper hopper **740** during the first refill period **760**, as shown in FIG. **13**D. The inflow stream **745** of bulk material **21** fills the upper hopper **740** while the binary gate **744** of the upper hopper **740** is open.

[0143] Bulk material may cease to discharge from the seed transfer equipment to the upper hopper **740** during the first refill period **760**, as shown in FIG. **13**E, which may allow for a gravimetric measurement of the second quantity of bulk material **743**. The discharge from the seed transfer equipment may depend on the second target weight-level being sensed by load cells **752**, and **754** of the upper hopper **740**. Alternatively, or in combination with measurements by the load cells, the discharge from the seed transfer equipment may depend on a signal from the second high-level sensor **748** in the upper hopper **740**.

[0144] When a third quantity of bulk material **763** reaches the first high target weight within the lower hopper **720** as measured by load cells **732**, **734** or the second quantity of bulk material **743** reaches a second low-target weight within the upper hopper **740** as measured by load cells **752**, **754**, the controller converts the system **700**, if in the fixed position mode, back into the variable position mode, according to arrow **710**. During this transition, the controller commands the upper control mechanism **755** to close the binary gate **744**. The adjustable gate returns to being proportionally adjusted by the lower control mechanism **750** based on the controller receiving real-time gravimetric readings.

[0145] Alternatively, or in combination with measurements by the load cells, when the third quantity of bulk material **763** reaches the first high-level sensor **728** within the lower hopper **720** or the second quantity of bulk material **743** reaches a second low-level sensor **746** within the upper hopper **740**, the controller converts the system **700**, if in the fixed position mode, back into the variable position mode, according to arrow **710**. During this transition, the controller commands the upper control mechanism **755** to close the binary gate **744**. The adjustable gate returns to being proportionally adjusted by the lower control mechanism **750** based on the controller receiving real-time gravimetric readings.

[0146] A second measurement period **770** is depicted in FIG. **13**F. During the second measurement period, the third quantity of bulk material **763** flows through the lower discharge opening **722** of the lower hopper **720** as the outflow stream **725** of bulk material continues. The third quantity of bulk material **763** is discharged gravimetrically from the lower hopper **720** based on the loss-in-weight measurements. Meanwhile, the inflow stream **745** of bulk material may begin to form a fourth quantity of bulk material **783** within the upper hopper **740** when the binary gate **744** is closed. Alternatively, the inflow stream **745** of bulk material may be stopped and a discharge period started. In the discharge period, a last quantity of bulk material may flow through the lower discharge opening **722** with the system **700** in the variable position mode. The discharge period continues until the outflow stream **725** discharges the last quantity of bulk material from the lower

hopper **720** into the seed receiving equipment (not shown for the sake of simplicity).
[0147] It is understood that the invention is not confined to the particular construction and arrangement of parts herein described. That although the drawings and specification set forth a preferred embodiment, and although specific terms are employed, they are used in a description sense only and embody all such forms as come within the scope of the following claims.
[0148] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, are possible from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims.
[0149] For the convenience of the reader, the above description has focused on a representative sample of all possible embodiments, a sample that teaches the principles of the invention and conveys the best mode contemplated for carrying it out. Throughout this application and its associated file history, when the term “invention” is used, it refers to the entire collection of ideas and principles described; in contrast, the formal definition of the exclusive protected property right is set forth in the claims, which exclusively control. The description has not attempted to exhaustively enumerate all possible variations. Other undescribed variations or modifications may be possible. Where multiple alternative embodiments are described, in many cases it will be possible to combine elements of different embodiments, or to combine elements of the embodiments described here with other modifications or variations that are not expressly described. A list of items does not imply that any or all of the items are mutually exclusive, nor that any or all of the items are comprehensive of any category, unless expressly specified otherwise. In many cases, one feature or group of features may be used separately from the entire apparatus or methods described. Many of those undescribed variations, modifications and variations are within the literal scope of the following claims, and others are equivalent.
[0150] In the foregoing description, it will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims by their language expressly state otherwise.
[0151] All terms used in the claims are intended to be given their ordinary meanings as understood by those knowledgeable in the technologies described herein unless an explicit indication to the contrary is made herein. In particular, the use of the singular article such as “a,” “the,” “said,” etc. should be read to recite one or more of the indicated elements unless a claim recites an explicit limitation to the contrary. Conditional language, such as, among others, “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments could include, while other embodiments may not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more embodiments.

Claims

1. An automated method comprising the steps of: a. receiving a stream of agricultural seed into a metering assembly; b. determining an inflow rate of the stream of agricultural seed into the metering assembly, wherein the inflow rate is based on a measurement of the agricultural seed within the metering assembly; and c. commanding an adjustable gate into a command position to discharge the agricultural seed from the metering assembly at an outflow rate that matches the inflow rate.
2. The automated method of claim 1, further comprising the steps of: a. receiving the stream of

agricultural seed as a continuous stream into an upper hopper of the metering assembly, wherein a binary gate mounted to the upper hopper is closed; b. measuring the weight of the agricultural seed within the upper hopper; and c. opening the binary gate to discharge the agricultural seed from the upper hopper into a lower hopper of the metering assembly.
3. The automated method of claim 2, further comprising the step of: a. adjusting the command position of the adjustable gate, wherein the adjustable gate is mounted to the lower hopper, to regulate the outflow rate from the lower hopper in response to variations of the inflow rate of the agricultural seed received into the upper hopper.
4. The automated method of claim 3, wherein the adjustable gate is disposed below the binary gate and is continuously adjusted while the binary gate is closed.
5. The automated method of claim 3, further comprising the steps of: a. determining a set point for the command position of the adjustable gate while the binary gate is closed, wherein the set point is based on the measurement of the agricultural seed within the metering assembly; and b. setting the command position of the adjustable gate at the set point when the binary gate is opened.
6. The automated method of claim 5, further comprising the step of: a. maintaining the command position of the adjustable gate at the set point during a refill period.
7. The automated method of claim 1, further comprising the steps of: a. maintaining the command position of the adjustable gate at a set point until a load cell mounted to the metering assembly reports a change-in-weight over a refill period.
8. The automated method of claim 7, wherein the refill period is an interval of time between 0.1 second and 10 minutes.
9. The automated method of claim 1, further comprising the step of: a. decreasing an opening created by the adjustable gate upon a loss-in-weight of the metering assembly over a measurement period.
10. The automated method of claim 1, further comprising the step of: a. increasing an opening created by the adjustable gate upon a gain-in-weight of the metering assembly over a measurement period.
11. The automated method of claim 1, further comprising the step of: a. commanding a treatment rate based on the command position of the adjustable gate.
12. The automated method of claim 11, further comprising the step of: a. applying a treatment to the agricultural seed discharged according to a recipe based on the outflow rate.
13. The automated method of claim 1, further comprising the steps of: a. increasing a treatment rate in response to an increase in an opening of the adjustable gate; and b. decreasing the treatment rate in response to a decrease in the opening of the adjustable gate.
14. The automated method of claim 1, wherein the inflow rate is determined based on a measurement of weight during a measurement period between receiving a low-level signal and a high-level signal.
15. The automated method of claim 1, further comprising the step of: a. maintaining a fill-level within the metering assembly to determine the inflow rate.
16. The automated method of claim 1, further comprising the steps of: a. filling the metering assembly with agricultural seed at a percentage range of between 5 percent to 80 percent of the maximum capacity of the metering assembly.
17. The automated method of claim 16, further comprising the step of: a. adjusting the command position of the adjustable gate to maintain the agricultural seed within the metering assembly at the percentage range of between 5 percent to 80 percent of the maximum capacity.
18. The automated method of claim 16, further comprising the steps of: a. measuring the weight of the agricultural seed within the metering assembly; b. receiving a plurality of weight measurements of the metering assembly; and c. regulating the command position of the adjustable gate based upon the plurality of weight measurements in real time.
19. The automated method of claim 18, further comprising the steps of: a. setting the command

position of the adjustable gate at a set point during a calibration period; b. discharging, over the calibration period, a portion of the agricultural seed through an opening created by the adjustable gate at the command position; and c. associating the outflow rate with the command position of the adjustable gate at the set point.
20. The automated method of claim 19, further comprising the step of: a. obtaining a plurality of outflow rates that correspond with a plurality of command positions of the adjustable gate.
21. The automated method of claim 20, further comprising the step of: a. storing the plurality of outflow rates that correspond with the plurality of command positions in a database accessible by a controller.
22. The automated method of claim 16, further comprising the step of: a. adjusting a treatment rate according to a recipe based on the outflow rate.
23. The automated method of claim 22, further comprising the step of: a. generating a signal upon a change in the command position of the adjustable gate to a second position; and b. adjusting the treatment rate to correspond with the outflow rate correlated with the second position upon generation of the signal.
24. The automated method of claim 1, further comprising the steps of: a. receiving the measurement from a fill-level sensor in response to a fill-level of the agricultural seed within the metering assembly.
25. The automated method of claim 24, further comprising the steps of: a. increasing an opening of the adjustable gate upon receipt of a high-level signal generated by the fill-level sensor; and b. decreasing the opening of the adjustable gate upon receipt of a low-level signal generated by the fill-level sensor.
26. The automated method of claim 24, further comprising a calibration subprocess comprising the steps of: a. receiving a low-level signal from the fill-level sensor related to the agricultural seed beginning to fill the metering assembly that starts empty; b. receiving a high-level signal from the fill-level sensor related to the agricultural seed filling the metering assembly; and c. calculating the inflow rate into the metering assembly based on the time between receiving the low-level signal and the high-level signal.
27. The automated method of claim 26, wherein the calibration subprocess further comprises the steps of: a. calculating a total weight as the difference between a subsequent weight value corresponding to the high-level signal and an initial weight value corresponding to the low-level signal.
28. The automated method of claim 1, further comprising the step of: a. constraining the outflow rate between a preset discharge rate minimum and a preset discharge rate maximum by a controller based on the inflow rate.
29. The automated method of claim 28, further comprising the step of: a. adjusting the command position of the adjustable gate based on a plurality of loss-in-weight measurements of the metering assembly measured in real-time.
30. The automated method of claim 1, further comprising the step of: a. applying a liquid treatment to the agricultural seed discharged from the metering assembly at a treatment rate in response to the outflow rate.
31. The automated method of claim 1, further comprising a calibration subprocess comprising the steps of: a. filling the metering assembly with the stream of agricultural seed to a first fill-level; b. dispensing the agricultural seed from the first fill-level; c. measuring the difference in weight of the agricultural seed within the metering assembly; d. calculating the inflow rate based on the difference in weight measured over time to determine a first calibration value; and e. associating the first calibration value with the first fill-level.
32. The automated method of claim 1, wherein the inflow rate and the outflow rate are determined from a same hopper of the metering assembly that received and discharged the stream of agricultural seed.