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Inventor(s)	Sudoff; Kenton Thomas et al.

CONTROLLING DISCHARGE SYSTEM AND METHOD FOR MULTI-HOPPER VEHICLES

Abstract

A vehicle contains multiple cargo hoppers. A system opens the first hopper, which discharges its cargo into a chute. After discharge completes, a driver moves the vehicle forward, and the system opens the second hopper, which discharges into the chute. After the discharge is completed, the driver moves the vehicle forward, and the system opens the third hopper, which discharges into the chute, and so on. The process and system repeat for as many hoppers need to be unloaded.

Inventors: **Sudoff; Kenton Thomas (Fort Recovery, OH), Bruns; Greg Michael (Coldwater, OH)**

Applicant: **Liberty Wayne Electric, LLC** (Coldwater, OH)

Family ID: **1000007698872**

Assignee: **Liberty Wayne Electric, LLC (Coldwater, OH)**

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Background/Summary

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention concerns bulk transport trucks, semi-trailers, rail cars, cargo devices or other vehicles having multiple hoppers for transporting bulk materials, such as sand, gravel, and agricultural feed or grains. In one illustrative embodiment, the invention responds to an initiation signal by opening the doors of the hoppers in a predetermined sequence and at predetermined intervals, without human intervention.

2. Description of the Related Art

[0002] FIG. **1** shows a prior art bottom-dumping hopper trailer **10**. It contains two hopper areas H**1** and H**2** in the illustration, but it could contain more hopper areas, such as four or six hopper areas (not shown). The contents are dumped or pass through slide doors or gates **12** and **14**, respectively. FIG. **2** is an enlarged view of one type of one prior art slide door or gate **12**.

[0003] FIGS. **2** and **3** illustrate features of the prior art doors or gates **12** and **14**. FIG. **3** shows part of the doors or gates **12** and **14** having a crank mechanism **20** which opens the gate **12**, with the door or gate **14** being similarly constructed. A shaft **20***a* rotates a pinion gear (not shown) and a rack **16** cooperates with a concealed pinion on the concealed shaft **20***a* to move the rack **16** to open the gate **12**. Gate **14** works similarly.

[0004] FIG. **1** shows a trailer having the two hoppers H**1** and H**2**. Some trailers have multiple hoppers and thus multiple gates. The driver of the truck pulling the trailer (neither driver nor truck are shown) is generally the one responsible for manually opening each gate, as by applying a crank (not shown) to the shaft **20***a* in FIG. **3**. This requires the driver to (1) exit the truck, (2) apply the crank to a gate, (3) return to the cabin of the truck, (4) move the truck into position suitable for the next gate, (5) exit the cabin to apply the crank, and so on. These procedures are time-consuming.

[0005] Also, in snowy, icy, or rainy weather, the procedures can be dangerous to the driver because the floor of the cabin of the truck can lie a few feet above the roadway. Semi-trailer tractors are generally not equipped with catwalks which are optimally designed for safety, nor with optimally safe handholds, stairsteps, and ladders.

[0006] What is needed, therefore, is a system and method for controlling a delivery of bulk materials from multiple hoppers and a system that allows door slides and gates to operate automatically.

SUMMARY OF THE INVENTION

[0007] An object of the invention is to improve safety and efficiency in the unloading of multi-hopper vehicles.

[0008] In one form of the invention, solenoids or pistons, such as electronic or pneumatic pistons operate a plurality of gates associated with a plurality of hoppers on a vehicle. The invention schedules opening of the gates, such that (1) the first gate to be opened is located at one end of a row of gates and (2) after a discharging gate finishes discharging, the other gate, such as an adjacent gate, is opened.

[0009] In one aspect, one embodiment of the invention comprises a vehicle for transporting bulk materials, the vehicle comprising a plurality of hoppers for holding the bulk materials; a plurality of doors associated with the plurality of hoppers, respectively; a plurality of drivers coupled to the plurality of doors, respectively; each of the plurality of drivers being capable and adapted to drive the door between a closed position and an open position, the open position permitting the bulk materials to unload from at least one hopper to a predetermined unload area; a control system for controlling the operation of each of the plurality of drivers in order to open each one of the plurality of doors in a predetermined order and for a predetermined unload time in order to unload the contents of at least one of the plurality of hoppers in order to unload the bulk materials therefrom, the predetermined unload time generally corresponding to a predetermined delay time and a predetermined unload time generally corresponding to a time it takes for the bulk materials to

empty or unload from at least one of the plurality of hoppers.
[0010] In another aspect, another embodiment of the invention comprises an apparatus for a vehicle which contains hoppers that hold bulk materials each of which has a discharge gate, and has a source of compressed air, comprising an input for receiving a start signal; a controller which in response to the start signal, delivers compressed air which opens a first discharge gate and then opens a second discharge gate in a predetermined order after the vehicle is positioned in delivery relationship to a desired delivery area.
[0011] In another aspect, another embodiment of the invention comprises a control apparatus for a vehicle which contains hoppers, each of which has a discharge gate comprising a start switch; and a controller which responds to the start switch by opening a first discharge gate when it is in proximate relationship to a desired delivery area, and opening a second discharge gate when it is in proximate relationship to a desired delivery area.
[0012] In another aspect, another embodiment of the invention comprises an apparatus for a vehicle which contains hoppers, each of which has a discharge gate, comprising a start switch; and a programmable digital controller, PDL, which responds to the start switch by opening gates in sequence.
[0013] In still another aspect, another embodiment of the invention comprises for a vehicle which contains hopper H**1** having a gate G**1** which discharges bulk materials in the hopper H**1** and hopper H**2** having a gate G**2** which discharges bulk materials in the hopper H**2**, a control comprising a scheduling unit in which a person specifies times T**1** and T**2**; an actuation unit which opens gate G**1** at time T**1**, and opens gate G**2** at time T**2**; and an indicator which tells the values of T**1** and T**2** to a person.
[0014] In yet another aspect, another embodiment of the invention comprises a vehicle for transporting bulk materials wherein a plurality of drivers comprises a plurality of drivers **1**-N; a plurality of hoppers **1**-N, a plurality of time-delay relays **1**-N for actuating the plurality of drivers, respectively, a control system that (a) closes a first one of the plurality of time-delay relays **1**-N in response to an initiation by a user and actuates a first one of the plurality of drivers to open a first one of a plurality of hopper doors associated with the first one of the plurality of drivers; (b) causes a first time delay to occur in response to the closure of the first one of the plurality of time delay relays, and after the first time delay, closes a second one of the plurality of time delay relays and actuates a second one of the plurality of drivers to actuate a second one of the plurality of drivers to open a second one of the plurality of hopper doors associated with the second one of the plurality of drivers and then causes a second time delay to occur in response to the closure of the second one of the plurality of time-delay relays; (c) causes a third one of the plurality of time-delay relays to close after the second time delay to actuate a third one of the plurality of drivers to open a third one of the plurality of hopper doors associated with the third one of the plurality of drivers and then cause a third time delay to occur in response to the closure of the third one of the plurality of time-delay relays; (d) repeats (b) and (c) until the Nth one of the plurality of time-delay relays to close after the N−1 time delay associated with the preceding N−1 of the plurality of time-delay relays to actuate an Nth one of the plurality of drivers to open a Nth one of the plurality of hopper doors associated with the Nth one of the plurality of drivers the then cause a Nth time delay to occur in response to the closure of the Nth one of the plurality of time-delay relays.
[0015] In one aspect, one embodiment of the invention comprises a method for unloading bulk materials from a vehicle having a plurality of hoppers and associated plurality of hopper doors, respectively, and a plurality of drivers associated with each of the plurality of hopper doors for driving each the plurality of hopper doors, respectively, between an open position and a closed position, and a control system for controlling an operation of each of the plurality of drivers, the plurality of drivers comprises plurality of drivers **1**-N and the plurality of hoppers comprises plurality of hoppers **1**-N, the control system comprising a plurality of time-delay relays **1**-N for actuating the plurality of drivers **1**-N, respectively; the method comprising the steps of (a) closing a

first one of the plurality of time-delay relays **1**-N in response to an initiation by a user and actuates a first one of the plurality of drivers to open a first one of the plurality of hopper doors associated with the first one of the plurality of drivers; (b) causing a first time delay to occur in response to the closure of the first one of the plurality of time delay relays, and after the first time delay, closes a second one of the plurality of time delay relays and actuates a second one of the plurality of drivers to actuate a second one of the plurality of drivers to open a second one of the plurality of hopper doors associated with the second one of the plurality of drivers and then causes a second time delay to occur in response to the closure of the second one of the plurality of time-delay relays; (c) causing a third one of the plurality of time-delay relays to close after the second time delay to actuate a third one of the plurality of drivers to open a third one of the plurality of hopper doors associated with the third one of the plurality of drivers and then cause a third time delay to occur in response to the closure of the third one of the plurality of time-delay relays; (d) repeating steps (b) and (c) until the Nth one of the plurality of time-delay relays to close after the N−1 time delay associated with the preceding N−1 of the plurality of time-delay relays to actuate an Nth one of the plurality of drivers to open a Nth one of the plurality of hopper doors associated with the Nth one of the plurality of drivers the then cause a Nth time delay to occur in response to the closure of the Nth one of the plurality of time-delay relays.

[0016] In yet another aspect, one embodiment of the invention comprises an apparatus for use in a vehicle containing multiple hoppers, each having a discharge gate, comprising a) a plurality of actuators, each for opening a respective discharge gate; and b) a control system which induces the actuators to open the gates in sequence, beginning with a leading gate.

[0017] In one aspect, one embodiment of the invention comprises a method of operating a vehicle containing multiple cargo hoppers, each having a gate, comprising initiating a control which opens the gates, one at a time, at predetermined intervals, and moving the vehicle so that every gate discharges its cargo into a stationary chute located below the vehicle.

[0018] In still another aspect, one embodiment of the invention comprises an apparatus for opening hoppers in a vehicle, each hopper having a respective gate, the hoppers being numbered **1** through N comprising a) a plurality of pneumatic valves, numbered **1** through N, b) a plurality of pneumatic pistons, numbered **1** through N, each i) actuated by a respective valve, and ii) connected to a respective gate; c) a group of time-delay relays, numbered **1** through N, each associated with a respective valve **1** through N, wherein i) relay **1** closes in response to a signal from a human, and actuates valve **1**, to thereby actuate piston **1** to open the gate of hopper **1**; ii) in response to the closure of relay **1**, a time delay occurs after which relay **2** closes and actuates valve **2** to actuate piston **2** to open the gate of hopper **2**; iii) in response to the closure of relay **2**, a time delay occurs after which relay **3** closes and actuates valve **3** to actuate piston **3** to open the gate of hopper **3**; and iv) in response to closure of each relay **3**-N, a time delay occurs after which the relay **3**-N causes and independently activates associated valve **3**-N to activate piston **3**-N to open their respective gates.

[0019] In another aspect, one embodiment of the invention comprises a method of operating a vehicle which comprises (A) a hopper **1** having a first gate and (B) a hopper **2** having a second gate, comprising a) positioning the first gate over a chute which leads to a collection pit; b) issuing a start signal to a controller, which, in response, i) opens the first gate, and ii) after a time delay, opens the second gate, and c) moving the vehicle so that the second gate stands over the chute before the second gate opens.

[0020] In another aspect, one embodiment of the invention comprises an apparatus for controlling discharge doors of hoppers in a vehicle, comprising a first pneumatic piston, which opens a first door; a second pneumatic piston, which opens a second door; a first actuator which actuates the first piston after it receives a start signal; a second actuator which actuates the second piston at a predetermined time after the start signal.

[0021] In another aspect, one embodiment of the invention comprises an apparatus for controlling

discharge doors of hoppers in a vehicle, comprising a first pneumatic piston which opens a first door of a first hopper; a second pneumatic piston which opens a second door of a second hopper; a control system which receives a start signal and, in response, actuates the first piston to open the first door and actuates the second piston to open the second door, after the first hopper has discharged fully.

[0022] In yet another aspect, one embodiment of the invention comprises a control system for opening gates of hoppers in a vehicle, which applies a first voltage to a first solenoid which opens a first valve which delivers air pressure to a first piston which opens a first gate; and detects the first voltage and, in response, pauses for a delay and then applies a second voltage to a second solenoid which opens a second valve which delivers air pressure to a second piston which opens a second gate.

[0023] In another aspect, one embodiment of the invention comprises a method of discharging cargo from multiple hoppers in a vehicle, each having a respective discharge gate, comprising maintaining a control on the vehicle; issuing a start signal to the control, thereby inducing the control to open the leading gate at a time T**1**; and open the gate adjacent to the leading gate after a predetermined time delay.

[0024] In yet another aspect, one embodiment of the invention comprises a kit for modifying a vehicle which contains a number N hoppers, each having a gate, comprising N pneumatic actuators; N brackets, each for connecting an actuator to a respective gate, to allow an actuator to open its gate; and a control which actuates a first one of the N pneumatic actuators and then actuates the remaining actuators, one at a time, at predetermined intervals.

[0025] In yet another aspect, another embodiment of the invention comprises an apparatus for controlling discharge doors of hoppers in a vehicle, comprising a first pneumatic piston, which opens a first door, of a first hopper; a second pneumatic piston, which opens a second door, of a second hopper; a programmable logic controller, which contains program code, which receives a start signal and, in response, actuates the first piston to open the first door, in accordance with the program code, and actuates the second piston to open the second door, after the first hopper has discharged fully, in accordance with the program code.

[0026] In one aspect, one embodiment of the invention comprises an apparatus for use in a vehicle containing multiple hoppers, each having a discharge gate comprising a plurality of actuators, each for opening a respective discharge gate; and a control system which induces the actuators to open the gates in sequence.

[0027] In another aspect, one embodiment of the invention comprises a method of operating a vehicle containing multiple cargo hoppers, each having a gate, comprising initiating a control which opens the gates, one-at-a-time, at predetermined intervals, and moving the vehicle so that every gate discharges its cargo into a stationary chute located below the vehicle.

[0028] In still another aspect, one embodiment of the invention comprises a control system for opening gates of hoppers in a vehicle, which applies a first voltage to a first solenoid which opens a first valve which delivers air pressure to a first piston which opens a first gate; and detects the first voltage and, in response, pauses for a delay and then applies a second voltage to a second solenoid which opens a second valve which delivers air pressure to a second piston which opens a second gate.

[0029] In one aspect, one embodiment of the invention comprises a kit for modifying a vehicle which contains a number N hoppers, each having a gate, comprising N pneumatic actuators; N brackets, each for connecting an actuator to a respective gate, to allow an actuator to open its gate; and a control which actuates a first actuator, and then actuates the remaining actuators, one-at-a-time, at predetermined intervals.

[0030] In yet another aspect, one embodiment of the invention comprises an apparatus for controlling discharge doors of hoppers in a vehicle, comprising a first pneumatic piston, which opens a first door of a first hopper; a second pneumatic piston, which opens a second door of a

second hopper; a programmable logic controller, which contains program code, which receives a start signal and, in response, actuates the first piston to open the first door, in accordance with the program code, and actuates the second piston to open the second door, after the first hopper has discharged fully, in accordance with the program code.

[0031] This invention, including all embodiments shown and described herein, could be used alone or together and/or in combination with one or more of the features covered by one or more of the following list of features: [0032] The vehicle wherein the plurality of hoppers is arranged in at least one row, the control system causing the plurality of hoppers to open one at a time. [0033] The vehicle wherein the plurality of hoppers opens in a serial order. [0034] The vehicle wherein the vehicle has a direction of travel, the serial order begins with a first one of the plurality of hoppers at the beginning of the at least one row and nearest the direction of travel and then each other one of the plurality of hoppers in the serial order until each one of the plurality of hoppers has been emptied, the control system energizing each one of the plurality of drivers to open each one of the plurality of doors when each of the plurality of doors is situated over the predetermined unload area. [0035] The vehicle wherein each of the plurality of drivers comprises at least one piston which drives at least one of the plurality of doors, the control system actuates a first of the at least one piston to open the its associated hopper to unload the contents thereof, the control system thereafter actuating another of the plurality of doors to open another one of the plurality of hoppers to unload its contents, the control system causing each one of the plurality of doors in the at least one row to open after each preceding door one of the plurality of doors. [0036] The vehicle wherein the control system opens the plurality of doors in a serial and non-random order. [0037] The vehicle wherein the control system opens the plurality of doors in a non-serial order. [0038] The vehicle wherein the control system actuates a first one of the plurality of drivers to cause a first one of the plurality of hopper, respectively, to be emptied and after a predetermined delay time, the control system opens the next one of the plurality of doors to unload the next one of the plurality of hoppers. [0039] The vehicle wherein the control system repeats and continues the process until each one of the plurality of hoppers is unloaded. [0040] The vehicle wherein the control system delays the opening of each of the plurality of doors for a predetermined time which is generally greater than a time it takes to unload a preceding one of the plurality of hoppers and a time vehicle time it takes to move the vehicle so that the next one of the plurality of hoppers that is desired to be unloaded is position over the predetermined unload area. [0041] The apparatus wherein during operation, the controller opens a gate only when the gate is engaged with a discharge chute. [0042] The apparatus wherein, during operation, the controller opens a gate only when the gate is positioned above the desired delivery area, the desired delivery area comprising at least one grate or surface onto which the bulk materials may be dumped. [0043] The apparatus wherein each discharge gate opens while a driver is situated inside the vehicle. [0044] The control apparatus wherein the controller causes each discharge gate to be held open for a sufficient time to allow discharge of the contents of its associated hopper. [0045] The control apparatus wherein the controller is of the programmable digital logic type, PDL. [0046] The apparatus wherein the PDL receives no input signals other than a start signal to open the gates in the sequence. [0047] The apparatus wherein the PDL opens a first discharge gate when it is in proximate relationship to a discharge area; opens a second discharge gate when it is in proximate relationship to a discharge area. [0048] The apparatus wherein the vehicle occupies a first position when a first discharge gate is in proximate relationship to a discharge area; the vehicle occupies a second position when the second discharge gate is in proximate relationship to a discharge area; and the PDL imposes a time delay between opening of the first discharge gate and opening of the second discharge gate, and that delay is selectable by a human operator. [0049] The apparatus wherein a transit time occurs while the vehicle moves from the first position to the second position, and the time delay is greater than the transit time. [0050] The apparatus wherein the vehicle spends a first dwell time D**1** at the first position, the PDL holds the first discharge gate open for at least a first open time T**1**, and the

first dwell time D**1** is greater than first open time T**1**. [0051] The apparatus wherein the vehicle spends a second dwell time D**2** at the second position, the PDL holds the second discharge gate open for at least a second open time T**2**, and the second dwell time D**2** is greater than second open time T**2**. [0052] The control further comprises a weather-resistant container surrounding the control, which contains a display indicating values of T**1** and T**2**. [0053] The vehicle wherein the plurality of hoppers are aligned in a row on the vehicle, the control system causes (a)-(d) to occur in the serially in the order that the hoppers are arranged on the vehicle, beginning with at least one of the plurality of hoppers in the on an end of the row. [0054] The vehicle wherein the plurality of hoppers are aligned in a row on the vehicle, the control system causes (a)-(d) to occur in a random order selected by the user. [0055] The vehicle wherein the plurality of hoppers are aligned in a row on the vehicle, the control system causes (a)-(d) to occur in the serially in the beginning with at least one of the plurality of hoppers located on an end of the row. [0056] The vehicle wherein each of the first-time delay, second time delay, third time delay or Nth time delay is programmed by the user and is generally greater than a time it takes for the vehicle to be advanced until the next one of the plurality of hoppers is aligned over a predetermined unload area and after the preceding one of the plurality of hoppers has been unloaded. [0057] The vehicle wherein each of the plurality of time-delay relays programmable by the user so the user can independently adjust the first-time delay, second time delay, third time delay or Nth time to a desired time. [0058] The vehicle wherein the bulk materials are sand, gravel, salt, grain, feed or agricultural materials and the vehicle is a truck or trailer. [0059] The vehicle wherein the method further comprises the step of using the method with a vehicle comprising a plurality of hoppers that are aligned in a row on the vehicle, the method causing steps (a)-(d) to occur in the serially in the order that the hoppers are arranged on the vehicle, beginning with at least one of the plurality of hoppers in the on an end of the row. [0060] The vehicle wherein the method further comprises the step of using the method with a vehicle comprising a plurality of hoppers aligned in a row on the vehicle, the method causing steps (a)-(d) to occur in a random order selected by the user. [0061] The vehicle wherein the method further comprises the step of using the method with a vehicle comprising a plurality of hoppers aligned in a row on the vehicle, the method causing steps (a)-(d) to occur serially, with the first one of the plurality of hoppers **1**-N to be unloaded is located on an end of the row. [0062] The vehicle wherein each of the first-time delay, second time delay, third time delay or Nth time delay is programmed by the user and is generally greater than a time it takes for the vehicle to be advanced until the next one of the plurality of hoppers is aligned over the predetermined unload area and after the preceding one of the plurality of hoppers has been unloaded. [0063] The vehicle wherein each of the plurality of time-delay relays programmable by the user so the user can independently adjust the first-time delay, second time delay, third time delay or Nth time to a desired time. [0064] The vehicle wherein the bulk materials are sand, gravel, salt, grain, feed or agricultural materials and the vehicle is a truck or trailer. [0065] The apparatus in which the control system opens each gate after its preceding gate has fully discharged its hopper. [0066] The apparatus in which each gate is opened at a predetermined time after its preceding gate has opened. [0067] The apparatus in which timing of the sequence of gate openings is adjustable by a human. [0068] The apparatus in which the timing is adjusted by a human to suit the vehicle. [0069] The apparatus in which a human starts operation of the control system, which operates without human intervention after initiation. [0070] The apparatus wherein the vehicle comprises a) a hopper H**1** having a first gate; b) a hopper H**2**, having a second gate which is adjacent the first gate; c) a hopper H**3** having a third gate which is adjacent the second gate; d) a hopper H**4**, having a fourth gate which is adjacent the third gate; wherein the control system e) opens the first gate at time T**1** in response to a start signal issued by a human, f) opens the second gate after a time delay following opening of the first gate; g) opens the third gate after a time delay following opening of the second gate; h) opens the fourth gate after a time delay following the opening of the third gate. [0071] The apparatus in which the time delays are programmable by the human. [0072] The method in which the vehicle does not

change direction during the predetermined intervals. [0073] The apparatus further comprising a third pneumatic piston, which opens a third door; a third actuator which actuates the third piston at a predetermined time after actuation of the second piston. [0074] The apparatus and further comprising a third pneumatic piston, which opens a third door of a third hopper; wherein the control system actuates the third piston to open the third door, after the second hopper has discharged fully. [0075] The apparatus in which the control system opens each gate after its preceding gate has fully discharged its hopper. [0076] The apparatus in which each gate is opened at a predetermined time after its preceding gate has opened. [0077] The apparatus in which timing of the sequence of gate openings is adjustable by a human. [0078] The apparatus in which the timing is adjusted by a human to suit the vehicle. [0079] The apparatus in which a human initiates operation of the control system, which operates without human intervention after initiation. [0080] The apparatus wherein the vehicle comprises hopper H**1** having a leading gate G**1**, hopper H**2**, having a gate G**2** which is adjacent gate G**1**, hopper H**3** having a gate G**3** which is adjacent gate G**2**, hopper H**4**, having a gate G**4** which is adjacent gate G**3**, wherein the control system opens gate G**1** at time T**1** in response to a start signal issued by a human, opens gate G**2** after a time delay following opening of gate G**1**, opens gate G**3** after a time delay following opening of gate G**2**, opens gate G**4** after a time delay following opening of gate G**3**. [0081] The apparatus in which the time delays are programmable by the human. [0082] The apparatus in which the sequence begins with a leading gate. [0083] The apparatus in which the vehicle contains a source of compressed air, and the vehicle contains an input for receiving a start signal; the control system, in response to the start signal, delivers compressed air which (i) opens a first discharge gate and then (ii) opens a second discharge gate. [0084] The apparatus in which, during operation, the control system opens a gate only when the gate is engaged with a discharge chute. [0085] The apparatus in which, during operation, the control system opens a gate only when the gate is positioned above a grate which leads to a collection pit at a grain elevator. [0086] The method in which the vehicle does not change direction during the intervals. [0087] The method in which the vehicle changes direction during the intervals. [0088] The apparatus in which each hopper has a respective gate, the hoppers being numbered **1** through N, in which the actuators comprise a plurality of pneumatic valves, numbered **1** through N, a plurality of pneumatic pistons, numbered **1** through N, each actuated by a respective valve, and connected to a respective gate; the control system comprises a group of time-delay relays, numbered **1** through N, each associated with a respective valve, wherein relay **1** closes in response to a signal from a human, and actuates valve **1**, to thereby actuate piston **1**, to thereby open the gate of hopper **1**; in response to the closure of relay **1**, a time delay occurs, after which relay **2** closes and actuates valve **2** to thereby actuate piston **2**, to thereby open the gate of hopper **2**; and in response to the closure of relay **2**, a time delay occurs, after which relay **3** closes and actuates valve **3** to thereby actuate piston **3**, to thereby open the gate of hopper **3**. [0089] The apparatus in which the plurality of actuators comprising a first pneumatic piston which opens a first gate; a second pneumatic piston which opens a second gate; the control system induces a first actuator to actuate the first piston after it receives a start signal; and a second actuator to actuate the second piston at a predetermined time after the start signal. [0090] The apparatus and further comprising a third pneumatic piston, which opens a third gate; a third actuator which actuates the third piston at a predetermined time after actuation of the second piston. [0091] The apparatus in which the vehicle empties the hoppers into a stationary chute, and the discharge gates are manually operable by a person, and the control system responds to a start signal issued by a person by opening a first discharge chute when it is engaged with a stationary chute, and opening a second discharge chute when it is engaged with the stationary chute. [0092] The apparatus in which each gate is held open for a sufficient time to allow discharge of the contents of its hopper. [0093] The apparatus in which the controller is of the Programmable Digital Logic type, PDL. [0094] The apparatus further comprises a start switch; and the control system comprises a Programmable Digital Controller, PDL, which responds to the start switch by opening gates in sequence. [0095]

The apparatus in which the PDL receives no input signals other than the start signal and possibly a termination signal. [0096] The apparatus in which the PDL opens a first discharge gate when it is engaged with a stationary chute, and opens a second discharge gate when it is engaged with the stationary chute. [0097] The apparatus in which the vehicle occupies a first position when the first discharge gate is engaged with the stationary chute, the vehicle occupies a second position when the second discharge gate is engaged with the stationary chute, and the PDL imposes a time delay between opening of the first discharge gate and opening of the second discharge gate, and that delay is selectable by a human operator. [0098] The apparatus in which a transit time occurs while the vehicle moves from the first position to the second position, and the time delay is greater than the transit time. [0099] The apparatus in which the vehicle spends a first dwell time D**1** at the first position, the PDL holds the first discharge gate open for at least a first open time T**1**, and the first dwell time D**1** is greater than first open time T**1**. [0100] The apparatus in which the vehicle spends a second dwell time D**2** at the second position, the PDL holds the second discharge gate open for at least a second open time T**2**, and the second dwell time D**2** is greater than second open time T**2**. [0101] These and other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

Description

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS
[0102] FIG. **1** illustrates a hopper trailer of the prior art;
[0103] FIG. **2** is a bottom view of one type of gate in a prior art hopper trailer;
[0104] FIG. **3** shows a prior art mechanism for opening a gate of the type shown in FIG. **2**;
[0105] FIGS. **4** and **4**A illustrate how a spool valve operates a pneumatic piston;
[0106] FIG. **5** illustrates one form of the invention;
[0107] FIGS. **6** and **6**A illustrate operation of the piston/valve combination in response to the signal online in FIG. **5**;
[0108] FIG. **7** illustrates potentiometers P**1**-P**8**, which deliver voltages to the controller **50** of FIG. **5**, to thereby define times T**1**-T**4** and D**1**-D**4**;
[0109] FIG. **7**A illustrates a trailer having four hoppers, with respective gates **30**, **32**, **34** and **36**;
[0110] FIG. **8** illustrates another form of the invention;
[0111] FIGS. **8**A-**8**C show how timer TR**1**T and relay TR**1** can be incorporated into modular housings **90**;
[0112] FIGS. **9**A, **9**B, **9**C, and **9**D illustrate symbolically the operation of a timer TR**1**T and its associated relay TR**1**;
[0113] FIG. **10** illustrates sequences of events implemented by one form of the invention;
[0114] FIGS. **11**A-**11**F illustrate programmable logic controllers (PLCs) used by one form of the invention;
[0115] FIG. **12** defines time intervals;
[0116] FIG. **13**A illustrates the functioning of one type of Programmable Digital Logic controller, PDL;
[0117] FIG. **13**B illustrates a digital logic circuit which can deliver the signals indicated onto lines **101**-**104** in FIG. **13**A;
[0118] FIG. **13**C illustrates a fuse, which can replace switches shown in FIG. **13**A;
[0119] FIGS. **14**A, **14**B, **14**C and **14**D illustrate how switches can act as memory within a PDL;
[0120] FIG. **15**A shows a protective container which contains a panel which supports the solenoid valves and the timers; and
[0121] FIG. **15**B shows the container mounted on the trailer.
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0122] Referring now to FIGS. **4**-**15**B, a system **100** and method for automatically controlling flow of materials M (FIGS. **10** and **12**), such as sand, gravel, agricultural corn, beans, grain or the like (collectively referred to as "materials") out of a plurality of hoppers H**1**-H**5** and through a plurality of slide doors or gates **30**, **32**, **34**, **36** and **38**, respectively. FIGS. **4** and **5** illustrate an embodiment with only four controlled slide doors or gates **30**-**36** with four associated hoppers H**1**-H**4**, while the embodiments of FIGS. **10** and **12** show five slide doors or gates **30**-**38** with five associated hoppers H**1**-H**5**, respectively. Thus, it should be understood that the invention may be applied to any multi-door, multi-hopper vehicle and is not limited to any specific number of slide doors or gates or hoppers. In one embodiment, the system **100** and method control the opening and closing of the plurality of slide doors or gates **30**-**38** in a predetermined sequence or manner as described herein. In one form of the invention, each of the plurality of slide doors or gates **30**-**38** are equipped with at least one driver **39** (FIGS. **4**-**6**) coupled to each slide door or gate **30**-**38**. In the illustration, the at least one driver **39** drives its associated slide door or gate **30**-**38** between open and closed positions and may comprise a controlled electrical solenoid, a hydraulic solenoid, a pneumatic solenoid or a piston, such as a piston **40** shown in FIG. **6**. For ease of illustration and description, the at least one driver **39** associated with slide door or gate **30** will now be described, with it being understood that the other slide doors or gates **32**-**38** have the same or similar at least one driver **39**.

[0123] The piston **40** of the at least one driver **39** is connected to slide door or gates **30**-**38** by a bracket **131**. The energization or actuation of each piston **40** opens its respective slide door or gate **30**-**38**. For example, an illustrative trailer TK is shown in FIGS. **10** and **12** and it contains five hoppers H**1**, H**2**, H**3**, H**4** and H**5**, and the invention opens the slide doors or gates **30**-**38** associated with the hoppers H**1**-H**5**, respectively, in a predetermined or desired order. In one embodiment, the slide doors or gates **30**-**38** are opened in a serial order so that slide door or gate **30** for hopper H**1** opens first, then slide door or gate **32** for hopper H**2** is opened, then slide door or gate **34** for hopper H**3**, then slide door or gate **36** for hopper H**4** and then finally slide door or gate **38** for hopper H**5**. After all slide doors or gates **30**-**38** are opened, all hoppers H**1**-H**5** are cleared of their contents and the system **100** causes all slide doors or gates **30**-**38** to close so the hoppers H**1**-H**5** can be refilled. It should be understood that during unloading of the hoppers H**1**-H**5**, an operator, such as a truck driver, advances the trailer TK after each hopper H**1**-H**5** is emptied so that the next unemptied hopper H**2**-H**5** becomes aligned over a grate and storage area **47** (FIG. **10**), which is usually located in the ground.

[0124] In another embodiment, some trailers TK, such as the six-door trailer hopper offered by Hensley Fabricating & Equipment Co., Inc. located in Tippecanoe, Indiana, may be positioned and remain stationary during the unloading of the contents of the hoppers H**1**-H**5**. In this type of embodiment, the conventionally known trailer TK comprises an auger that transports the contents in the hoppers H**1**-H**5** to the chute, pit, conveyor or storage area **47**. In this embodiment, the trailer TK remains stationary over the storage area **47** and the auger delivers the contents from each of the hoppers H**1**-H**5** to the storage area **47** in a manner conventionally known. FIGS. **15**A and **15**B illustrate such an embodiment.

[0125] In one embodiment, the sequential opening is induced automatically, without human intervention, once a human operator initiates the sequence, as will now be explained.

[0126] FIG. **4** shows a spool valve **41** connected to a solenoid **42**. Pressurized air through a line **44** is supplied by a compressor (not shown) enters the spool valve **41** as shown and is diverted into line **44** at this time causing the piston **40** to move rightward (as viewed in FIG. **4**), thereby causing air in a chamber **46** to be expelled through line **48** and exit from the spool valve **41** to the atmosphere as indicated. A spring **37** biases a spool **51** in the spool valve **41** into the condition shown, which will be called a rest position for illustration.

[0127] FIGS. **4**-**4**A illustrate a general operation of the at least one driver **39**. In FIG. **4**A, solenoid **42**, when energized, overcomes the bias of the spring **37** and pulls the spool **51** of the spool valve **41** leftward (as viewed in FIG. **4**A) into the position shown in FIG. **4**A. This causes compressed air

to enter through line **48**, thereby causing the piston **40** to extend leftward into an actuated position and to displace air from the solenoid **42** through line **48**. The piston **40** of the at least one driver **39** is coupled to a bracket **131** (FIG. **6**) which is coupled to at least one slide door or gate **30**-**38** shown and the at least one driver **39** drives at least one slide door or gate **30**-**38** between open and closed positions and in a predetermined order or in sequence as controlled by a controller **50**.

[0128] FIG. **5** shows the controller **50** for controlling an operation of the system **100** and the at least one driver **39** which is implemented in a software computer (not shown) which may comprise one or more non-transient computer programs or instructions resident in a performance database or a memory and utilize a processor algorithm or procedure resident in the memory. The controller **50** can take the form of a PIC™ microcontroller available from Microchip Corporation, or a Basic Stamp™, available from Parallax Inc. The controller **50** has four output lines **52**-**58** in the illustration of FIG. **5**, one for each of the at least one driver **39**. When the controller **50** receives a start signal **60**, which is initiated by the operator, it issues the sequence of pulses shown on the output lines **52**-**58**.

[0129] FIG. **10** illustrates a plurality of slide doors or gates **30**-**38**. For ease of description, FIG. **5** shows only four drivers **39** and four slide doors or gates **30**-**36**. Thus, the embodiments being described can be used with as few as one door, such as slide door or gate **30**, or multiple slide doors or gates such as gates **30**-**38** in FIGS. **10** and **12**. The first pulse begins at time T**1** and has a duration of D**1**. The second pulse begins at T**2** and has a duration of D**2**. The third pulse begins at T**3** with duration of D**3**. The fourth pulse begins at T**4** with a duration of D**4**. At least one buffer or amplifier **62** may optionally be provided to supply a sufficient current level to the solenoids **42**. The events induced by the pulse will now be explained.

[0130] Prior to time T**1** in FIG. **5**, the spring **37** in FIGS. **4**, **4**A and **5** biases the spool valve **41** (as viewed to the right in FIG. **5**) into a rest position. The piston **40** is also in its rest position. When time T**1** arrives in FIG. **5**, a voltage on line **52** goes high, initiating the pulse of duration D**1** and delivering current to the solenoid **42**, thereby causing it to pull spool **51** to the left, as shown in FIG. **6**. The spool **51** drives air or causes air to pass through line **48**, thereby causing or urging the piston **40** to move leftward (as viewed in FIG. **5**) thereby driving the at least one slide door or gate **30** (FIG. **10**) associated with the slide door or gate **30** (FIG. **7**A) of the first hopper H**1** to an open position. FIG. **7**A illustrates the four hoppers H**1**-H**4** and then the associated slide doors or gates **30**-**36**. This results in any materials M in hopper H**1** (FIG. **10**) being unloaded or dumped into the grate and storage area **47**.

[0131] The piston **40** remains in the left most position (as in FIG. **4**A) for the duration D**1** in FIG. **5**. In one embodiment, all slide doors or gates **30**-**38** remain open until all hoppers H**1**-H**5** are unloaded and all solenoids **42** are de-energized at the same time. When D**1** in FIG. **5** terminates, the voltage on line **52** terminates, thereby de-energizing solenoid **42**, thereby allowing spring **37** in FIG. **4** to push the spool valve **41** to the right, thereby applying compressed air to line **44**, which drives the piston **40** to the right to its rest position, as in FIGS. **4** and **5**.

[0132] In FIG. **5**, the pulses on lines **52**, **54** and **56** and opening of the slide doors or gates **32**-**36** perform similarly with respect to the pistons **40** and spool valves **41** and are controlled by those lines **52**, **54** and **56**.

[0133] After the duration D**1**, the controller **50** generates another pulse at T**2** for duration D**2** which energizes solenoid **42** via line **52**. The general process repeats at each time T**1**-T**4** to separately and independently open each one of the plurality of slide doors or gates **30**-**38**. The apparatus of FIG. **5** can be used to control the plurality of slide doors or gates **30**-**38** on a bulk materials trailer TK, such as trailers TK**1**-TK**10** shown in FIGS. **10** and **12**. It should be understood that the trailer TK could have more or fewer slide doors or gates **30**-**38** and associated hoppers H**1**-H**5** associated at least one driver **39**. Some significant features of the operation are the following.

[0134] First, the slide doors or gates **30**-**38** open in sequence. The slide door or gate **30** is opened, then slide door or gate **32**, then slide door or gate **34**, then slide door or gate **36**, then slide door or

gate **38**. That is, the opening of slide door or gate **30** precedes the opening of slide doors or gates **32**-**38** in FIGS. **10** and **12**. The opening of slide door or gate **32** precedes the opening of slide door or gate **34**. The opening of slide door or gate **34** precedes opening of slide door or gate **36** and so on.

[0135] Second, a time duration is assigned to each pulse, namely, D**1** through D**4** in FIG. **5**. Each duration D**1**-D**4** includes a minimum duration expected and generally corresponds to the time required by its respective hopper H**1**-H**4** in the example of FIG. **5** to fully discharge its materials M or cargo. For example, D**1** may be sixty (60) seconds, but the time for the discharge of the corresponding hopper H**1** may be only twenty (20) seconds. The unloading time for each hopper H**1**-H**4** in FIG. **5** or H**1**-H**5** in FIGS. **10** and **12** may change, depending on the type of materials M carried in hoppers H**1**-H**5**. In this example, D**1** is longer than the discharge time in order to provide a generalized margin for error.

[0136] Third, a more specific reason for D**1** being much longer than the discharge time of twenty (20) seconds can exist. The remaining forty (40) seconds above can be used by the driver of the trailer TK to move the trailer TK into the correct position to accommodate the opening of the next slide door or gate **30**-**38**. This is explained more fully below.

[0137] Four times T**1**, T**2**, T**3**, and T**4** in FIG. **5** can be called initiation times for slide door or gate **30**-**36** openings. No initiation of a slide door or gate **30**-**36** (FIG. **5** or slide doors or gates **30**-**38** in FIGS. **10** and **12**) opening can occur before full discharge of a prior slide door or gate **30**-**36**. For example, if hopper H**1** takes fifteen (15) seconds to discharge, then the next slide door or gate **32** in the sequence cannot be initiated earlier than fifteen (15) seconds after the initiation of the prior slide door or gate **30**. Stated in other words, no slide door or gate **30**-**38** can be opened while another slide door or gate **30**-**38** is open and still discharging its associated hopper H**1**-H**5**.

Setting Delay Times T and Durations D

[0138] FIG. **7** illustrates how the times T**1**-T**4** and the durations D**1**-D**4** can be established or programmed into the controller **50**. Potentiometers P**1**-P**4** are connected to individual input pins of the processor. In the case of a Basic Stamp, the processor measures the voltage of the potentiometer by measuring the RC time constant of a resistor—capacitor pair (capacitor is not shown). The processor then computes the effective resistance of the potentiometer based on RC and thus ascertains the voltage of the potentiometer tap. That is, the potentiometer in effect delivers a number (a voltage) to the processor, which is interpreted as a time, such as T**1**.

[0139] Potentiometers P**5**-P**8** deliver voltages in the same way to indicate the time delays D**1**-D**4**. In practice, each potentiometer will be actuated by the switch **70** (FIG. **9**B) which is labeled with the parameter which it controls, namely T**1** or D**2**, for example. The potentiometers P**1**-P**8** eliminate any need to establish the times T**1**-T**4** and the delays D**1**-D**4** by declaring variables within the code (not shown) running on the controller **50**. Initially establishing the variables and also changing the variables at a later time to suit different materials M, different hoppers H**1**-H**5** and different cargos, for example, would require the ability to write computer code, but simply adjusting the potentiometers P**1**-P**8** in FIG. **7** does not and can be performed by the operator. Nevertheless, establishing the variables as parameters in code is possible.

[0140] FIG. **8** illustrates another control circuit. Resistors SOL**1**-SOL**6** represent individual solenoids **42**, like those shown in FIG. **4** (although FIGS. **4** and **4**A show only two solenoids **42** by comparison). In this illustration, six solenoids SOL**1**-SOL**6** driving at least one slide door or gate, such as slide doors or gates **30**-**38** (FIGS. **10** and **12**), respectively, are shown. In FIG. **8**, items TR**1**-TR**6** are relays, which are controlled by corresponding timers TR**1**T-TR**6**T which energize them. Relay TR**1** is physically contained within a single housing with its timer TR**1**T, as illustrated in FIG. **8**A and both together form a time-delay relay, although they are shown as separate units TR**1**T and TR**1** in FIG. **8** for ease of illustration. This comment on pairing applies to the other relays TR**2**-TR**6** and timers TR**2**T-TR**6**T, respectively, in FIG. **8**.

[0141] FIGS. **9**A, **9**C, and **9**D generally and schematically illustrate an operation of the components

within the dashed box B of FIG. **9**B. FIG. **9**B illustrates a section of FIG. **8**, namely, that above arrows A-A in FIG. **8**. In FIG. **9**A, a timer TR**1**T is represented as a clock face CF. A contact C rides in a circular track **55**, and an operator selects a position for the contact C to thereby select a time delay. The hollow circles C**1**, C**2** in FIGS. **9**B and **9**C represent other possible positions. When the timer TR**1**T is initiated, a hand H rotates clockwise and eventually reaches contact C (as shown in phantom).

[0142] FIG. **9**C generally and schematically illustrates timer TR**1**T and relay TR**1** connected together to further illustrate and simplify the description. In FIG. **9**C, a timer TR**1**T is labeled for ease of illustration and description and is coupled to the relay TR**1**. FIG. **9**C shows that hand H has reached contact C, which connects V+ across the coil of relay TR**1**, which creates a MAGNETIC FIELD MF, which draws iron bar **67** upward (as viewed in FIG. **9**C) which connects SOL**1** to 12 volts, thereby creating CURRENT through SOL**1** as shown. SOL**1** represents one of the solenoids **42** in FIG. **5** described earlier and is also shown in FIG. **8**. To repeat, in FIG. **9**B, element TR**1**T is a timer and when TR**1**T is actuated, it counts down from a predetermined value selected or predetermined by the operator. One such value corresponds to the time delay T**1** in FIG. **5**. When the count of TR**1**T reaches zero, relay TR**1** closes, thereby driving current through solenoid SOL **1**.

[0143] This countdown is initiated by momentary closure of a start switch **70** in FIGS. **9**B and **9**C. Timer TR**1**T introduces a delay in closure of timed relay TR**1** after the momentary closure of switch **70**, which is analogous to delay T**1** in FIG. **5**. In practice, the time delay of TR**1**T may be short because timed relay TR**1** controls the first slide door or gate **30** and there may be no reason for a significant delay in opening that first slide door or gate **30**.

[0144] The opening of one of the slide doors or gates **30**-**36** in FIG. **5** or **30**-**38** in FIGS. **10** and **12** in a series was just described. FIG. **8** shows apparatus which continues with the opening of subsequent slide doors or gates **30**-**36**. The Inventor repeats that (1) elements TR**1**T through TR**6**T are, in concept, countdown timers which are triggered by incoming voltages, as at points **92**-**100** in FIG. **8**. These timers TR**1**T to TR**6**T close their corresponding relays TR**1**-TR**6**, respectively, when they time out. That is, TR**2**T closes TR**2**, TR**3**T closes TR**3**, and so on, as indicated by arrows A**1**-A**6**. It should be understood that these timers TR**1**T to TR**6**T are not individual, discrete parts (although they could be). Instead, they are physically parts of overall time-delay relay apparatus or module **102**, as indicated in FIG. **8**A. Each such module **102** includes (1) a timer such as TR**1**T, and (2) the relay itself, such as TR**1**. The use of modules **102** provides various benefits, as this discussion will later be explained, in connection with FIGS. **11**A-**11**D.

[0145] In FIGS. **8**-**8**C, when TR**1** closes and solenoid SOL**1** (FIG. **8**) is actuated, 12 volts is applied to line **92** as mentioned earlier. This triggers timer TR**2**T into beginning counting down. When it times out, it closes relay TR**2**, as indicated by arrow A**2**. When TR**2** closes, solenoid SOL**2** is actuated, and at that moment, 12 volts is applied to point **94**, which triggers timer TR**3**T into counting down. When it times out, it closes relay TR**3**, as indicated by arrow A**3**.

[0146] When TR**3** closes, solenoid SOL**3** is actuated and 12 volts is applied at that moment to point or line **96**, which triggers timer TR**4**T into counting down. When it times out, it closes relay TR**4**, as indicated by arrow A**4**.

[0147] When TR**4** closes and solenoid SOL**4** is actuated 12 volts is applied at that moment to point **98**. That triggers timer TR**5**T into counting down. When it times out, it closes relay TR**5**, as indicated by arrow A**5**.

[0148] When TR**5** closes, and solenoid SOL**5** is actuated, 12 volts is applied at that moment to point **101**, which triggers timer TR**6**T into counting down. When it times out, it closes relay TR**6**, as indicated by arrow A**6**, which actuates solenoid SOL**6**.

[0149] The inventors repeat that when TRT**1** times out, it closes relay TR**1**. Closure of TR**1** triggers TR**2**T, which closes relay TR**2** when TR**2**T times out. Closure of TR**2** triggers TR**3**T, which closes relay TR**3** when TR**3**T times out. Closure of TR**3** triggers TR**4**T, which closes relay TR**4** when TR**4**T times out, and so on.

[0150] In general, the slide doors or gates **30**-**36** in FIG. **5** or **30**-**38** in FIGS. **10** and **12** form a sequence and associated solenoids form a parallel sequence, together with their associated relays, such as solenoids SOL**1**-SOL**4** and relays TR**1**-TR**4** in FIG. **8**. The following TABLE I shows several illustrative parallel sequences:
TABLE-US-00001 TABLE I Gate Sequence Relay/Solenoid Sequence 30 TR1/SOL1 32 TR2/SOL2 34 TR3/SOL3 36 TR4/SOL4
[0151] Thus, when one relay closes, such as TR**1** in FIG. **8**, it does two things. It (1) immediately actuates its own solenoid, such as SOL**1** in this example, and (2) causes actuation of the next solenoid in the sequence, SOL**2**, but after a predetermined time delay D**1**, which will be determined by timer TR**2**T in the illustration being described.
[0152] This process repeats until all slide doors or gates **30**-**38** are opened and their associated hoppers H**1**-H**5**, respectively, are emptied and unloaded in sequence as described earlier with respect to FIGS. **8**-**8**C.
[0153] During operation, the operator aligns one slide door or gate **30**-**38** over the grate or storage area **47** (FIG. **10**). For example, the operator aligns slide door or gate **30** over grate or storage area **47** and unloads the hopper H**1** by utilizing the switch **70** (FIG. **8**). After the hopper H**1** is unloaded, the operator advances or moves the trailer TK to align the second door or gate **32** over the grate or storage area **47**, preferably before the start of the next slide door or gate **32**-**38** opening. That slide door or gate **32** opens in accordance with the procedure described herein to unload the contents of hopper H**2**, thereafter the operator advances the trailer TK to align the next slide door or gate **34** over the grate or storage area **47** to unload the next hopper H**3** and so on. This process repeats until all hoppers H**1**-H**5** are unloaded. Thereafter, the system **100** causes the slide doors or gates **30**-**38** to close at the same time or after each hopper H**1**-H**5** is unloaded.
[0154] Several variations or alternate embodiments will be described. Different types of timed relays can produce different results. For example, if a time-delay relay merely closes a relay after a delay, then the relay may remain closed thereafter. If such relays were used in the circuit of FIG. **8** (for example, as the combination of timer TR**1**T and timed relay TR**1**, as in module **102** in FIG. **8**C), then after a hopper H**1**-H**5** had been discharged, its associated slide door or gate **30**-**38** would remain open. The reason is that the solenoid **42** in FIG. **4**A would remain energized because its relay remains actuated, which may be a desirable mode of operation.
[0155] On the other hand, another type of relay may be used, such as time-delayed one-shot. Such a relay (1) waits for an actuation signal, (2) imposes a delay after the signal is received, and then (3) actuates a one-shot relay. A one-shot relay remains closed for a predetermined duration and then opens. Module **102**A in FIG. **8**B illustrates such a one-shot relay apparatus. For example, in FIG. **5**, line **52**, nothing happens until time T**1**. That absence of events prior to T**1** represents the delay in a time-delayed one-shot. Then, in FIG. **5**, a pulse of duration D**1** arises, which is the “shot” of a “one-shot.” After delay D**1** expires, the pulse terminates, which de-activates solenoid **42**. Termination of the signal when duration D**1** expires would then remove actuation of the solenoid **42** in FIG. **4**, thereby closing its associated slide door or gate **30**-**38** after its hopper H**1**-H**5** had discharged.
[0156] Another embodiment of the invention comprises a kit **110** (FIG. **11**A) of components which are installed or retrofitted on the hopper vehicle, such as a semi-truck, semi-trailer TK, or a railroad car. FIG. **11**A shows a flat plate **112** having a top side **112***a* and a bottom side **112***b*. The bottom side **112***b* contains electrical wiring, which may take the form of a printed circuit board in which the wiring corresponds in layout to that of FIG. **8**. On the top side **112***a*, the time-relay and timer modules labeled TR**1**T/TR**1** are the time-delay relays described earlier which implement the functioning described herein and in FIG. **8**. This comment applies to the other modules in FIGS. **11**A-**11**D which begin with the symbols TR.
[0157] The modules SOL**1**-SOL**6** (FIG. **8**) are solenoid valves, corresponding to solenoids **42** in FIG. **4**, and the associated spool valve **41**. For example, when module TR**1**T/TR**1** in FIG. **8** or **11**A

actuates solenoid valve SOL**1**, the latter delivers pressure to the piston **40** in FIG. **4**A through line **48**, as described earlier, thereby controlling movement of its associated gate **30**-**38**.
[0158] In FIG. **11**B, connectors (not shown) extend through the board or plate **112** to deliver electrical signals and power to the solenoid and relay modules on the top side **112***a* (FIG. **11**A). For example, points P**10**, P**11**, P**12**, and P**13** on the bottom side **112***b* are connected to respective points P**10**, P**11**, P**12**, and P**13** on the top side **112***a* (FIG. **11**A). The plate **112** is installed in a weather-tight electrical housing or box **120** (FIG. **11**C), which is not drawn to scale which can be mounted or retro-fitted on the vehicle.
[0159] The kit **110** also includes one pneumatic piston or solenoid **42** (FIGS. **4** and **4**A) for each slide door or gate **30**-**38** to be mechanized on the vehicle as explained earlier, plus any necessary conventional plumbing (not shown) for delivering compressed air to the pneumatic piston or solenoid **42**. Each solenoid SOL comprises at least one relay TR and one timer TRT. Brackets **131** in FIG. **6** may be included for coupling the solenoid **42** to its associated slide door or gate **30**-**38**.
[0160] It should be understood that the time-delay relays comprising of TR**1**T and TR**1** as in FIG. **8** and represented as module **102** in FIG. **8**C are commercially available. The part numbers and availability are listed in the table below.
[0161] The following components are available from Electro Controls of Sidney, Ohio: [0162] CHD2PA6, RELAY, SOCKET 4 POLE RELAYS D2PR2 AND D2PR4 [0163] CHD2RR4R1ICE CUBE RELAY, 4PDT, 6 A, 12 VDC COIL [0164] CHFAZC51SPBREAKER, SUPP 1P C CURVE 5 A (REPLACE WMZS1C05) [0165] CHM22DG PB OPERATOR, NON-ILLUM, GREEN, FLUSH, MOMENTARY, SILVER BEZE [0166] CHM22DR PB OPERATOR, NON-ILLUM, RED, FLUSH, MOMENTARY [0167] CHM22K01 CONTACT BLOCK, N.C., SCREW TERM, REPLACED E22B1 [0168] CHM22K10 CONTACT BLOCK, N.O., SCREW TERM, REPLACED E22B2 [0169] HOFCP1616 PANEL ONLY [0170] HOFCSD16168SS ENCLOSURE, 16×16×8SS [0171] HTMSOCN11808PARL4 18 MM INDUCTIVE PROX, 10-30 VDC M12 QUICK CONNECT [0172] HTMSRFS4TZT665 M12 FEMALE STRAIGHT TPE WELDING CABLE [0173] MMC5679K55 RARE EARTH MAGNET 10-24 THREDED [0174] RSP1026123 MULITFUNCTION TIMING RELAY, 12-230V
[0175] The following components are available from Dickman Industrial & Electrical Supplies of Sidney, Ohio. [0176] CHEASYE4UC12RC1; EASYE4 NPLC 12/24DC, 24AC RLY DISP SCWTRM; Catalog #EASY-E4-UC-1 2RC1; 39 PCS SIDNEY STOCK [0177] CHEASYE4UC16RE1; EASYE4 ACCY DIO 12/24DC, 24AC 8DI 8RO STM; Catalog #EASY-E4-UC-1 6RE1; EXPANDER MODULE; FACTORY STOCK
[0178] A 12 vdc solenoid valve is available from Atlantic Valve & Supply Company of Baltimore, Maryland.
[0179] A 12 vdc **5** position air valve **6** bank is available from Baomain Electric located in Wenzhou City, Zhejiang Province, China
[0180] In one form of the invention, only air lines **122** in FIG. **11**D will run to the solenoids **42** when installed or retrofitted on the vehicle or trailer TK. No electrical lines **124** will run to the solenoids **42**. Electrical lines **124** (FIG. **11**D) such as power lines and those running from the start switch **70** and stop switch **70***a* in FIG. **8** do enter the box **120** as shown. These switches **70** and **70***a* are preferably located on the exterior of the box **120** itself or nearby for easy access.
ADDITIONAL CONSIDERATIONS AND FURTHER EMBODIMENTS
[0181] 1. One definition of a predetermined time. In FIG. **8**, current will reach SOL**2** when the timed relay TR**2** closes. TR**2** will close when timer TR**2**T times out after counting down. The countdown of timer TR**2**T begins when timer TR**1**T times out and closes relay TR**1**. That is, application of a voltage at line or point **92** (FIG. **8**) acts as a trigger signal for timer TR**2**T. Therefore, once the START signal is given in FIG. **8**, the current will reach SOL**2** after both timers TR**2**T and TR**1**T time out. TR**1**T is required to time out in order for current to reach SOL**1** because TR**1** is open prior to that time out. TR**2**T is required to time out for current to reach SOL**2** because

TR**2** is open prior to that time out.
[0182] The total time for both those timers TR**1**T and TR**2**T to count down and thus close relay TR**2** is considered to be a predetermined time. One reason is that both times are selected by the user. Another reason is that the count down time of TR**1**T may be some nominal value, a short time, or even zero. However, a sum of that time, whatever it is, plus TR**2**T time, will still be a predetermined time.
[0183] 2. In FIG. **8**, timer TR**2**T begins counting down when solenoid SOL**1** begins passing current, but that timer finishes counting down based on the position of its own contact C in FIG. **9**A (FIG. **9**A shows the contact C for timer TR**1**T). That is, the countdown interval of timer TR**2**T, as well as of all the other timers TRXT, is determined or programmed by the operator. Similarly, the times T**1**-T**4** and D**1**-D**4** in FIG. **5** are also determined and set by the operator.
[0184] It should be understood that these times T**1**-T**4** and associated durations D**1**-D**4**, respectively, are selected by (a) experiment, (b) observation or experience, (c) calculation, or by a combination of (a), (b), and (c). Once the times and intervals have been successfully ascertained, the invention will operate with the following characteristics.
[0185] Case **1**. A first slide door or gate **30** associated with the first hopper H**1** will open. The next or adjacent slide door or gate **32** associated with the next hopper H**2**, does not open until the first hopper H**1** has fully discharged its contents to a predetermined location, such as the grate and storage area **47**. All later slide doors or gates **32**-**38** in the sequence do not open until all preceding hoppers have fully discharged their contents to a predetermined location such as a grain or bulk material storage area **47** (FIG. **10**). These features are a result of the selection of the times T**1**-T**4** and delays D**1**-D**4**.
[0186] Case **2**. In another form of the invention, at least one multi-hopper trailer TK**1**-TK**5** (FIG. **12**) and TK**1**-TK**10** (FIG. **10**) delivers materials, such as gravel, grain or corn, to the chute, pit, conveyor or a storage area **47** which leads to the grate and collection or storage area **47***a* at a grain elevator, for example, as shown in FIG. **7**A. Typically, the collection or storage area **47***a* is below road level and has an inlet **47***a***1** (FIG. **10**) positioned at road level, through which grain passes en route to the grate and collection or storage area **47***a*. A conventional conveyor **130** conveys the unloaded materials to a desired location (not shown).
[0187] In this embodiment of the invention, the slide doors or gates **30**-**38** in FIGS. **10** and **12** of each hopper H**1**-H**6** open after their selected time delay, as in Case **1**, above. Specifically, for the multi-hopper trailer TK in FIGS. **10** and **12**, having hoppers H**1**, H**2**, H**3**, and H**4**, slide door or gate **30** opens first, then slide door or gate **32**, then slide door or gate **34**, and finally slide door or gate **36**. The first slide door or gate **30** is ordinarily the most forward slide door or gate, although it is possible to begin with the rearmost slide door or gate or even a middle slide door or gate if desired.
[0188] After slide door or gate **30** discharges hopper H**1**, the delay of opening slide door or gate **32** allows the truck driver sufficient time to move slide door or gate **32** over the area **47** (FIGS. **10** and **12**) or over another grate and storage area **47**. Similarly, sufficient time is allowed to move the trailer TK until slide door or gate **34** opens to the area **47** after hopper H**2** has discharged its load, and so on.
[0189] 3. These embodiments may be used with trailers TK that have one or more hoppers H**1**-H**5**. FIGS. **10** and **12** show a hopper trailer TK**1** through TK**10** with five hoppers H**1**-H**5**. They are all the same trailer TK, but at different positions or in different conditions or both. Time runs vertically, as indicated by the arrow labeled TIME in FIG. **10**.
[0190] Trailer TK**1** is brought to a position shown at a grain elevator (not shown). The slide door or gate **30** now stands over grate and storage area **47** so that when slide door or gate **30** is opened, the contents of the corresponding hopper will fall through the grate and storage area **47** and onto the conveyor **130**. The conveyor **130** will then remove the contents to another location.
[0191] Thereafter, slide door or gate **32** is opened, as indicated in TK**2**, its associated hopper H**2**, discharges its contents.

[0192] In TK**3**, the hopper H**1** is now empty, so the trailer TK**3** is moved to TK**4**, thereby placing the slide door or gate **32** in proper position over the grate and storage area **47**. The slide door or gate **32** is opened in trailer TK**5** and its hopper H**2** discharges its load. After the discharge, the hoppers H**1** and H**2** are empty and the trailer TK**5** is moved to TK**7**, thereby positioning slide door or gate **34** over the grate and storage area **47** and then slide door or gate **34** is opened as described herein and its hopper H**3** discharges as shown in TK**8**. When its hopper H**3** is empty, as in TK**9**, the truck or trailer TK is moved so that slide door or gate **36** is moved to the grate and storage area **47**, as in TK**10**, and the process just outlined continues.

[0193] The slide doors or gates **30**-**36** (FIG. **5**) and **30**-**38** (FIGS. **10** and **12**) are opened in the predetermined order or sequence established by the user. The time delay between opening of the slide doors or gates **30**-**36** is such that the driver of the truck pulling the trailer TK has time to move the trailer TK so that the slide doors or gates **30**-**36** about to be opened will be stationed above the grate and storage area **47** at the proper time. This reduces or completely eliminates a requirement of manual operation of the gates **30**-**36**, for example. For example, assume in FIG. **10** that the delay between gate-openings is sixty (60) seconds. When slide door or gate **30** is positioned over the grate and storage area **47**, the start switch **70** in FIG. **8** may be actuated by an operator. Assume the hopper H**1** associated with slide door or gate **30** takes twenty (20) seconds to empty. The driver ascertains the time when the hopper H**1** completes its discharge as by (1) detecting the termination of noise from the hopper H**1**, (2) visually observing a lack of flow, (3) timing twenty (20) seconds using a stopwatch, or (4) some other means.

[0194] Now, after discharge of hopper H**1**, the driver or operator has forty (40) seconds to move the trailer TK into position TK**4** in FIG. **10**. The driver does so and awaits slide door or gate **32** to open and unload hopper H**2**. Thereafter, the driver ascertains the time when discharge of hopper H**2** has completed and moves the trailer TK into the next position, such as position TK**5**-TK**10**, TK**7**, and so on.

[0195] In some situations, it may be possible for the driver to move the trailer TK at a continuous slow speed or crawl in order to position each slide door or gate **30**-**38** over the grate and storage area **47** at the proper time.

[0196] Two types of movement of the trailer TK have just been described. One is interrupted movement, where the trailer TK: [0197] (1) moves to position slide door or gate **30** over the grate and storage area **47** and stops while hopper H**1** discharges, then [0198] (2) moves to position slide door or gate **32** over the grate and storage area **47** and stops while hopper H**2** discharges, then [0199] (3) moves to position slide door or gate **34** over the grate and storage area **47** and stops while hopper H**3** discharges, and so on.

[0200] Another type of movement is a continuous slow crawl of the trailer TK, which keeps the slide doors or gates **30**-**36** over the grate and storage area **47** for sufficient time to discharge their contents or materials. Both types of movement are considered to follow a predetermined path, whether the movement be interrupted or continuous.

[0201] 4. In another form of the invention, the trailer TK (multi-hopper vehicle, semi-trailer or railroad car, for example) is never moved while a hopper H**1**-H**5** is discharged.

[0202] 5. The time-sequence of opening the slide doors or gates **30**-**38** in FIGS. **10** and **12** corresponds to the spatial-sequence of the slide doors or gates **30**-**38**. For example, if the spatial sequence is slide door or gate **30**, slide door or gate **32**, slide door or gate **34**, slide door or gate **36**, and slide door or gate **38** counting from the front of the trailer TK, the corresponding time-sequence is slide door or gate **30**, slide door or gate **32**, slide door or gate **34**, slide door or gate **36**, and slide door or gate **38**. Similarly, if the spatial sequence counting from the rear of the trailer is slide door or gate **38**, slide door or gate **36**, slide door or gate **34**, slide door or gate **32**, and slide door or gate **30**, then the corresponding time-sequence is slide door or gate **38**, slide door or gate **36**, slide door or gate **34**, slide door or gate **32**, and slide door or gate **30**. This latter sequence would be particularly relevant to a multi-hopper railroad car, which may not have a standardized

front and rear, as opposed to the trailer shown, which by convention, does have a forward end.
[0203] 6. It was stated above that one embodiment of the invention schedules opening of the slide door or gate **30**-**38**, such that (1) the first slide door or gate **30**-**38** to be opened is located at one end of a row of slide door or gate **30**-**38** and (2) after a discharging hopper H**1**-H**5** finishes discharging, the adjacent slide door or gate **30**-**38** is opened. This scheduling has implications. One is that, in the example of FIG. **10**, the row of gates contains slide door or gate **30**, slide door or gate **32**, slide door or gate **34**, and slide door or gate **36**. A second implication is that the first gate to be opened will be either slide door or gate **30** or slide door or gate **36** because these slide doors or gates are the end gates or the first and last slide doors or gates **30**-**36**.
[0204] A third implication is that the next gate to be opened will be (1) slide door or gate **32** if slide door or gate **30** was opened first, or (2) slide door or gate **34** if slide door or gate **36** was opened first.
[0205] A fourth implication is that no slide door or gate **30**-**38** will be opened while another slide door or gate **30**-**38** is discharging, which allows the trailer TK to move a closed gate **32** over the grate and storage area **47**, without causing a discharging hopper H**1**-H**5** to spill its contents outside the grate and storage area **47**. The fourth implication follows from the rule that an adjacent slide door or gate **30**-**38** is opened after discharging completes of the predecessor or prior hopper H**1**-H**6**.
[0206] 7. One definition of “row”.” A person walking in snow will leave footprints. The footprints are commonly called a “row” of footprints, but they actually form two rows: one produced by the left foot, and one produced by the right foot. The slide doors or gates **30**-**38** of FIG. **10** can be similarly positioned into a left row and a right row. However, one definition of “row” in this case is determined by the sequence of slide doors or gates **30**-**38** which cross the grate and storage area **47** as the trailer TK moves either forward or backward. That sequence will be either (i) slide door or gate **30**, slide door or gate **32**, slide door or gate **34**, slide door or gate **36** and slide door or gate **38**; or (ii) slide door or gate **38**, slide door or gate **36**, slide door or gate **34**, slide door or gate **32**, and slide door or gate **30**.
[0207] These two sequences can be termed “spatial sequences”. After a slide door or gate **30**-**38** opens, the next slide door or gate **30**-**38** to open must be adjacent physically to the just-discharged slide door or gate **30**-**38**, but because the first slide door or gate **30**-**38** to discharge will be either slide door or gate **30** or slide door or gate **38**, as stated above, then the next slide door or gate **30**-**38** to open will be that adjacent, which will be either slide door or gate **32** or slide door or gate **36**, respectively.
[0208] A situation where two slide doors or gates **30**-**38** simultaneously cross the grate and storage area **47** is typically not preferred. However, if such a situation arises, such as when the hoppers H**1**-H**5** are carrying the same materials M, then both slide doors or gates **30**-**38** may be opened at the same time or otherwise opened serially as described herein to discharge their respective hoppers H**1**-H**5** into the grate and storage area **47**.
[0209] 8. When the invention is installed on a hopper trailer, semi-truck, semi-trailer, grain carrier or other vehicle, for example as shown in FIG. **10**, pressurized air **44** in FIG. **4** is delivered to spool valve **41**. The pressurized air **44** can be provided by a pre-existing compressor on a truck (not shown) which pulls trailer TK, such as a truck compressor (not shown) that provides compressed air for air brakes. If the invention is installed on a railroad hopper car for example, a pre-existing source of compressed air can also be used.
[0210] 9. In a row of slide doors or gates **30**-**38** which are controlled by the invention, there will necessarily be a leading or forwardmost slide door or gate **30**-**38**. The slide door or gate **30** in FIG. **10** is such a slide door or gate. The slide door or gate **30** will be the first slide door or gate to cross over the grate and storage area **47**, when the trailer TK**1** moves forward, that is, to the left in FIG. **10**. One characteristic of the leading and trailing slide doors or gates, such as slide doors or gates **30** and **38**, is that they have only a single adjacent slide door or gate, which is associated with another hopper. Leading slide door or gate **30** in FIG. **10** has a single adjacent slide door or gate **32**,

for example. If the trailer TK is driven in reverse, then slide door or gate **38** would be the leading slide door or gate. It has a single adjacent slide door or gate **36**. All other slide doors or gates have two adjacent gate slide doors or gates as shown in FIG. **10**. For example, the slide door or gate **34** has two neighbors, for example: slide door or gate **32** and slide door or gate **36**.

[0211] 10. In another embodiment of the invention, a solenoid is actuated (1) by the actuation of the prior solenoid, but after a time delay, and (2) the time delay was established prior to the actuation of either solenoid. For example, in FIG. **8**, actuation of solenoid SOL**1** is accompanied by a voltage at point **92** (which is the cause of current running through SOL**1**). That voltage triggers timer TR**2**T into countdown and after the delay of that countdown, TR**2**T closes relay TR**2**, thereby actuating solenoid SOL**2**.

[0212] The length of the time delay is controlled by a knob **104** or setscrew contained in the timer module **102** (FIG. **8**C). If the module contains a time-delay one-shot, a second knob **106** or setscrew, shown in phantom, can control the duration of the one-shot.

[0213] 11. One definition of "proper operation" of the multi-hopper vehicle TK is that no significant amount of cargo fails to reach the grate and storage area **47** in FIG. **10**. This failure can occur if the trailer TK fails to advance after slide door or gate **30** has discharged the cargo of its hopper H**1**, thereby spilling the materials held by slide door or gate **32** onto the ground when slide door or gate **32** opens. One definition of "significant" is the amount of materials M which an ordinary workman can clean up and shovel into the grate and storage area **47** within a few minutes.

[0214] 12. FIG. **12** can define two terms, namely, dwell time DT and transit time TT, which are illustrated in FIG. **12**. Trailer TK**1**, at the top of FIG. **12**, remains stationary while slide door or gate **30** is opened and discharges hopper H**1**. This can be termed dwell time DT. Dwell time DT can be extended to allow for error. For example, if ordinary discharge time is twenty (20) seconds, DT may be made thirty (30) seconds. Assume, for simplicity of description, that all dwell times are the same, but they could be different or even some the same while others are different.

[0215] After slide door or gate **30** has completed discharging hopper H**1**, the trailer TK**1** is moved to position TK**2**. The time allowed for this is transit time TT. Then slide door or gate **32** is opened, and the trailer TK**3** remains stationary for dwell time DT, while slide door or gate **32** discharges hopper H**2**. So, the first event was that slide door or gate **30** is opened. Then, (DT+TT) seconds later, slide door or gate **32** is opened. Trailer TK**3** remains stationary during opening of slide door or gate **32** and discharge of hopper H**2** and then it moves to position TK**4**, which movement required transit time TT. Then, trailer TK opens slide door or gate **34**, which opens (2DT+2TT) seconds after slide door or gate **30**. Trailer TK remains stationary for a dwell time DT. This sequence repeats, for the remaining gates.

[0216] Stated another way, the trailer TK is positioned with the first slide door or gate **30** over the grate and storage area **47**. The operator or driver presses the start switch **70** in FIGS. **8** and **9**D. A delay may or may not occur before slide door or gate **30** opens. After slide door or slide door or gate **30** opens and hopper H**1** is unloaded, the next slide door or slide door or gate **32** opens (DT+TT) seconds after **30**. This DT is the dwell time for slide door or gate **30** to discharge. This TT is transit time for the trailer to get into position to discharge slide door or gate **32**.

[0217] Next, slide door or gate **34** opens (2DT+2TT) seconds after slider door or gate **30**.

[0218] Then, slider door or gate **36** opens (3DT+3TT) seconds after slider door or gate **30**.

[0219] Then, slider door or gate **38** opens (4DT+4TT) seconds after slider door or gate **30**.

[0220] The preceding processes or sequences assume that all dwell times DT are the same, but as stated earlier they can be different and selected by the user, as can be the transit times TT.

[0221] 13. Different materials flow from a given hopper H**1**-H**5** at different rates. Further, a given material will probably flow from two different hoppers H**1**-H**5** at two different rates. One reason is that the angles of the side walls will affect overall discharge rate. Another is that the size of the slide door or gate **30**-**38** will affect discharge rate. Still another example is the weight of the material itself.

[0222] The adjustability of the times T**1**-T**4** in FIG. **5**, as by using potentiometers P**1**-P**4** in FIG. **7**, and adjustability of the delay times D**1**-D**4**, as by using potentiometers P**5**-P**8**, allows a human operator to tune the operation of the hopper—gate—control the system **100** to suit the hoppers in a given vehicle TK. Such tuning may not be necessary or even suitable for another vehicle having hoppers of similar capacity, at least for the reasons given in the preceding paragraph.
[0223] Several of the preceding embodiments describe the serial sequence in which the slide doors or gates **30**-**38** may be opened. It should be understood, however, that the controller **50** may be a programmable logic controller (PLC) that is capable of or adapted to be programmed such that each sliding door or gate **30**-**38** is individually controlled and timed. This also means that the sequence of opening the slide doors or gates **30**-**38** can be random and non-serial. For example, if the driver wanted to empty hopper H**3**, then hopper H**5**, then hopper H**1**, etc. the controller **50** can be programmed by manually adjusting the knobs described earlier herein for each driver **39**.
[0224] 14. The controller **50** in FIG. **5** controls compressed air delivered to piston **40** in FIGS. **6** and **6**A, by way of modulating the spool valve **41**. The compressed air is provided by a conventional air supply associated with the vehicle carrying the hoppers. For example, both railroad cars and semi-trailers use air brakes which are energized by compressed air provided to them by the same source.
[0225] 15. A programmable digital controller, PDL, can be used to control the sequential actuation of the pistons **40** described above. FIGS. **13**A, **13**B and **13**C symbolically explain one operation of one type of PDL. It actuates the relays L**1**-L**4** in FIG. **13**A, which correspond to relays such as TR**1**T/TR**1** in FIGS. **11**A and **11**B.
[0226] It is common for a PDL to receive input signals from sensors, and issue output signals in response. For example, a PDL may receive input signals from two temperature sensors in two rooms in a building. When a sensor indicates that the temperature is below a limit, the PDL then issues a signal to a heater in the room to begin operation. When the sensor indicates that the temperature has reached a certain level, the PDL then shuts down the heater.
[0227] In one form of the invention, a PDL is used to issue the signals analogous to those on lines **52**-**58** in FIG. **5**, but this PDL receives only one, and possibly two input signals and no others, namely, a start signal **60** in FIG. **5**, and possibly a termination signal. For ease of understanding, an operation of one type of PDL will be illustrated.
[0228] Regarding FIG. **13**B, when latching relay L receives a trigger signal, the latching relay L closes, and remains closed, as indicated.
[0229] When a one-shot relay OS receives a trigger signal, the one-shot relay OS closes, and then opens after a delay D.
[0230] When a time delayed latching relay TDL receives a trigger signal, the time delayed latching relay TDL closes after a delay dd and then remains closed.
[0231] When a time delayed one-shot relay TDOS receives a trigger signal, the time delayed one-shot relay TDOS closes after a delay dd and then opens after a delay D. As explained above, these types of relay can be used in various forms of the invention.
[0232] FIG. **13**A illustrates a control which can actuate these types of relays. Four latching relays L**1**-L**4** are shown. A symbolic rotary switch RSW is shown that is used by the operator. It is rotated to successively occupy the phantom positions shown, to thereby successively apply twelve (12) volts to lines **116**, **118**, **120**, **122** in that order in the illustration. Twelve (12) volts are supplied by the vehicle's power supply (not shown). Rotary switch RSW can be rotated by the driver of the vehicle pulling the hopper trailer TK of FIG. **10**. This rotation will cause opening of hopper gates, as explained immediately below and herein. Rotary switch RSW in FIG. **13**A can be operated by an electric motor (not shown), which eliminates the need for the driver to rotate it.
[0233] It should be understood that the function of the rotary switch RSW can be replaced by digital circuitry, as shown in FIG. **13**B. For example, in response to actuation of the input switch **70** in FIG. **8**A, a 555 timer **111** in FIG. **13**B can generate a sequence of pulses, which are fed to a

counter **113** which counts up on two wires W**1** and W**2**, from zero (i.e., 00 binary) to three (3) (i.e., eleven (11) binary). The count advances on each pulse from the 555 timer.
[0234] The count is applied to a data selector/decoder **114**, which causes a pulse to appear on one of four output lines **116**-**122** in sequence as indicated. The output lines **116**-**122** correspond to lines **116**, **118**, **120**, **122**, respectively, in FIG. **13**A. If the circuitry shown relies on TTL logic (Transistor-Transistor Logic, which produces signals in the range of 5 volts), buffers/amplifiers **124** can raise the voltage to 12 volts, thereby applying 12 volts, in sequence to lines **116**, **118**, **120**, **122** as discussed above.
[0235] The speed of rotation of the rotary switch RSW (FIG. **13**A), and the timing of the pulses on lines **116**-**122** in FIGS. **13**A and **13**B, are adjusted by the operator to give the proper timing of the hopper gates H**1**, H**2** and so on.
[0236] FIG. **13**A shows four rows R**1**-R**4** of switches SW, which are analogous to ordinary snap-action wall switches used in a home. When the rotary switch RSW applies 12 volts to line **116**, the switches which are closed in row R**1** determine which relay L**1**-L**4** is closed and thus determine which hopper gates (not shown in FIG. **13**A) are opened. The same operation occurs when the rotary switch RSW applies twelve (12) volts to lines **120**-**122**.
[0237] Similarly, when the rotary switch RSW applies 12 volts to line **118**, the switches SW in row R**2** determine which relays L**1**-L**4** are actuated at that time and thus which hopper gates ae opened. The switches SW in effect act as memory of the PDL.
[0238] FIGS. **14**A-**14**D illustrate operation of the switches SW. In FIG. **14**A, the switches enclosed in dashed boxes are closed. The others are open.
[0239] Application of twelve (12) volts to lines **116**, **118**, **120** and **122** in FIG. **14**A will be described as follows.
[0240] When the rotary switch RSW of FIG. **13**A applies 12 volts to line **116** in FIG. **14**A, the closed switch **116***a* delivers twelve (12) volts to relay L**1** in FIG. **13**A.
[0241] When the rotary switch RSW of FIG. **13**A applies twelve (12) volts to line **118** in FIG. **14**A, the closed switch **118***a* delivers twelve (12) volts to relay L**2** in FIG. **13**A.
[0242] When the rotary switch RSW of FIG. **13**A applies twelve (12) volts to line **120** in FIG. **14**A, the closed switch **120***a* delivers twelve (12) volts to relay L**3** in FIG. **13**A.
[0243] When the rotary switch RSW of FIG. **13**A applies twelve (12) volts to line **122** in FIG. **14**A, the closed switch **122***a* delivers twelve (12) volts to relay L**4** in FIG. **13**A.
[0244] The open switches have no effect, or it could be said that the open switches keep their respective gates open.
[0245] It should be understood that this sequential application of twelve (12) volts to lines **116**, **118**, **120** and then 122 actuates relays L**1**, L**2**, L**3**, and L**4** in FIG. **13**A, in that order, to open their respective gates. The closed switches of FIG. **14**B cause relays L**4**, L**3**, L**2**, and L**1** in FIG. **13**A to be actuated, in that order, as twelve (12) volts are applied to lines **116**, **118**, **120** and then 122.
[0246] The closed switches of FIG. **14**C cause relays L**2**, L**1**, L**4**, and L**3** in FIG. **13**A to be actuated, in that order.
[0247] As to FIG. **14**D, the open switches SW in row **1** cause nothing to happen when 12 volts are applied to line **116** in FIG. **13**A and then relays L**1** and L**3** are actuated simultaneously, when row R**2** is connected to 12 volts, and then relay L**4**, when row R**3** is connected. Finally, nothing happens, when row R**4** is connected.
[0248] FIG. **14**D shows that switches SW can be programmed so that, sometimes, more than one gate is opened, as in row **2**.
[0249] The apparatus of FIGS. **13**A-**13**B represent the operation of a simple PDL controller. One advantage of using the switches SW of FIG. **13**A is that the type of programming is visibly evident to the operator or user based upon the position (i.e., open or closed) of the switches' handles (handles are not explicitly shown). A a truck driver can discern from viewing the arrangement of switches SW in FIG. **14**C, for example, that relays L**2**, L**1**, L**4**, and L**3** will be actuated, in that

order.
[0250] This has the benefit of eliminating any need to instruct the driver in the intricacies of programming a PDL. Further, it eliminates the expense of any computer-type display required for programming a PDL, and for displaying the sequence of gates which the PDL will open.
[0251] 16. The sixteen switches SW of FIG. **13**A can be replaced by ordinary or conventional automotive fuses of the type shown in FIG. **13**C. Specifically, the sixteen switches SW shown are replaced by sixteen respective sockets. Insertion of a fuse into a socket converts the socket into a closed switch SW; otherwise, the socket acts like an open switch SW.
[0252] 17. A significant feature of one form of the invention is that one or more of the hoppers H**1**-H**5** may be equipped with multiple modes of opening its respective gate **30**-**38**. One mode is the type described in connection with the prior art as shown in FIGS. **1**, **2**, and **3**, where a person manually operates a crank to open a gate as in the prior art. The second mode is the system which includes piston **40** of FIG. **6**, which implements one form of the invention. In one form of the invention, the driver has the option of using either mode.
[0253] 18. Another significant feature is that the controller **50** is timed such that the gate **30**-**36** of each hopper H**1**-H**4** is opened when the gate is engaged with the grate **47** in FIG. **7**A. Before that time, the gate remains closed.
[0254] 19. Assume that, at time T=0, a driver presses the start switch **70** in FIG. **8**. That causes solenoid SOL**1** to open its gate after time delay T**1**, which is the delay imposed by TR**1**T. At that moment when solenoid SOL**1** is actuated, countdown of time T**2** begins in timer TR**2**T. When the count of T**2** reaches zero, solenoid SOL**2** opens its gate, which occurs at time 0+T**1**+T**2**. This timing must be known to the driver because it constrains the path along which the vehicle is to be moved. In one form of the invention, the positions of dials or knobs **104** and **106** in FIG. **8**C indicate the timing by indicating the respective delays at which each SOL in FIG. **8** is actuated.
[0255] 20. Times T**1** and T**2** of the preceding paragraph each specify both a time and a place. Each time is the time at which a gate opens, measured from a reference time. For example. If the reference is noon and T**1** specifies forty (40) seconds, then the gate controlled by T**1** will open at noon plus forth (40) seconds.
[0256] Time T**1** also specifies a place. That is, T**1** is set in a specific relay or timer TR**1**T in FIG. **8**. That relay/timer TRIT is associated with a specific hopper H**1**-H**5**. Because the driver necessarily knows the contents of the hopper H**1**-H**5**, then T**1** by its association with a specific hopper H**1**-H**5**, specifies a location where the hopper H**1**-H**5** is to be discharged. Restated, the driver knows that T**1** is associated with one specific hopper H**1**-H**5**, and time T**2** is associated with another hopper H**1**-H**5**, and so on. Thus, in one embodiment each hopper H**1**-H**5** has a known destination.
[0257] From another point of view, each relay TR**2**-TR**6** in FIG. **8** has its own time (T**1**, T**2**, T**3**, etc.) and is associated with its own hopper H**1**-H**5**. Those two pieces of information are sufficient for the driver to know where each hopper H**1**-H**5** is to be discharged and at what time.
[0258] From yet another point of view, because of the design of the system, a driver knows that:
[0259] (1) time T**1** controls gate **30**, [0260] (2) gate **30** discharges hopper H**1**, [0261] (3) hopper H**1** contains a first discharge material, and [0262] (4) the first discharge material is to be discharged at location Y.
[0263] Therefore, T**1** tells the driver where to discharge hopper H**1**.
[0264] It is probably most common that all hoppers H**1**-H**5** will be discharged into a common location, namely the storage area **47** in FIG. **10**, but discharge at different locations is possible or the discharge may be spread.
[0265] 21. It is emphasized that knowledge by the driver of the various times, such as T**1**, T**2**, etc., does not amount to mere knowledge of a set of numbers or time intervals. The driver also has knowledge of the system **10**, so that he knows that time T**1** is associated with hopper H**1**, T**2** is associated with H**2**, and so on. Restated as to time T**1**, the driver does not merely know some time T, which can be viewed as an abstract number. Instead, he knows a time T for Hopper H**1**. That is

why this specific time is labeled T**1**, and not merely time T. T**1** refers to hopper H**1**.
[0266] 22. In FIG. **8**C, the knob **104** sets a timing delay, and the knob **104** itself is an indicator of the timing delay. The delay is actually set by the internal mechanism of the relay, as symbolically shown in FIGS. **9**A-**9**D. The combination of the knob **104** and that mechanism controls the timing delay.
[0267] In one form of the invention, the indicator must be visible to the driver. Consequently, if the timing apparatus of invention is contained within the weatherproof box **120** of FIG. **11**C, a window or display may be provided in the weatherproof box **120**, for viewing the timing indicators. Other provision can be made for viewing the indicators, such as a camera which views the indicators, and a display on the box **120** which presents what the camera sees.
[0268] 23. The PLC design can be programmed to acuate slide doors or gates **30**-**38** in any order that the customer wants to program them too.
[0269] 24. The PLC design allows the customer to select all or individual slide doors or gates **30**-**38** as needed.
[0270] 25. The PLC design also allows the customer to use wireless access to remotely operate the system.
[0271] 26. The mechanical timer design can unload hoppers H**1**-H**5** in numerical sequences according to wiring.
[0272] 27. It should be understood that that slide doors or gates **30**-**38** may be opened according to a plan, or convention, or specification, which resides outside the doors and their control system. The slide doors or gates **30**-**38** cannot be opened at random, unless this is desired by the user and a given slide door or gate **30**-**38** may be opened when it is in the correct position. The user may set out the required opening sequence in an instruction sheet or the user generate the instruction sheet in real-time, while he watches the trailer TK.
[0273] 28. The system **10** could also comprise the stop switch **70***a* that stops the operation of the system **10**. The stop switch **70***a* could be automatic or immediate or the sequence of operation may continue until the last hopper H**1**-H**5** is emptied. When the system **10** stops, all slide doors or gates **30**-**38** are closed automatically. Alternatively, the system **10** could be programmed so that the slide doors or gates **30**-**38** close one at a time after each hopper H**1**-H**5** is unloaded.
ADDITIONAL EMBODIMENT
[0274] 29. FIG. **6** shows the controller **50** which issues the signal of duration D**1** on line **52** which actuates the solenoid **42** as described earlier herein, which moves the spool **51** to admit air through line **48** which moves the pneumatic piston **40** leftward (as viewed in the figure), to actuate the gate **30** of the hopper H**1**.
[0275] FIG. **5** shows the controller **50** applying similar signals on lines **52**-**58** to thereby actuate four similar pistons **40**, to actuate their associated pneumatic pistons. The controller **50** causes the first piston **40** to open its slide door or gate **30**-**38**, and then closes that slide door or gate **30**-**38**. Then a second slide door or gate **30**-**38** and then closes, then a third slide door or gate **30**-**38**, and so on, as described earlier.
[0276] The controller **50** can take the form of a Programmable Logic Controller, PLC **107**, shown in FIG. **11**E, such as the controller manufactured by Eaton Industries GmbH. Such controllers are also called relay controllers. PLC **107** receives electric power from the twelve (12) volt system of the vehicle, as indicated. SOLENOID **1**, SOLENOID **2**, SOLENOID **3**, and SOLENOID **4** correspond, for example, to solenoids **22** in FIG. **5**.
[0277] When a START switch in FIG. **11**E is pressed, twelve (12) volts are applied to the pin and the PLC **107** begins operation. It first closes switch Q**1**, thereby connecting SOLENOID **1** between 12 volts and ground, thereby actuating the spool valve (not shown) controlled by SOLENOID **1**. SOLENOID **1** is analogous to the solenoid **42** in FIG. **5** which is fed by line **52**. After SOLENOID **1** in FIG. **11**E has been actuated for a time duration, analogous to duration D**1** in FIG. **5**, the PLC **107** may or may not de-energize SOLENOID **1**, depending on the programming of PLC **107**.

[0278] PLC **107** in FIG. **11**E then closes switch Q**2**, thereby connecting SOLENOID **2** between twelve (12) volts and ground, thereby actuating the spool valve (not shown) controlled by SOLENOID **2**. SOLENOID **2** is analogous to the solenoid **42** in FIG. **5** which is fed by line **54**. After SOLENOID **2** in FIG. **11**E has been actuated for a time duration, analogous to duration D**2** in FIG. **5**, the PLC **107** may or may not de-energize SOLENOID **2**, depending on the programming of PLC **107**.
[0279] PLC **107** in FIG. **11**E then closes switch Q**3**, thereby connecting SOLENOID **3** between twelve (12) volts and ground, thereby actuating the spool valve (not shown) controlled by SOLENOID **3**. SOLENOID **3** is analogous to the solenoid **42** in FIG. **5** which is fed by line **56**. After SOLENOID **3** in FIG. **11**E has been actuated for a time duration, analogous to duration D**3** in FIG. **5**, the PLC **107** may or may not de-energize SOLENOID **3**, depending on the programming of PLC **107**.
[0280] PLC **107** in FIG. **11**E then closes switch Q**4**, thereby connecting SOLENOID **4** between twelve (12) volts and ground, thereby actuating the spool valve (not shown) controlled by SOLENOID **4**. SOLENOID **4** is analogous to the solenoid **42** in FIG. **5** which is fed by line **58**. After SOLENOID **4** in FIG. **11**E has been actuated for a time duration, analogous to duration D**4** in FIG. **5**, the PLC **107** may or may not de-energize SOLENOID **4**, depending on the programming of PLC **107**.
[0281] This type of PLC **107** can be cascaded with similar PLCs, as shown in FIG. **11**F, following the manufacturer's instructions. In FIG. **11**F, PLC **130** is cascaded with PLC **107** of FIG. **11**E. PLC **130** can take the form of a controller manufactured by Eaton Industries GmbH.
[0282] PLC **130** then actuates SOLENOID **5** after PLC **107** actuates SOLENOID **4** in FIG. **11**E. PLC **130** then actuates SOLENOID **6** after SOLENOID **5**.
[0283] This cascading allows a manufacturer to, for example, initially implement a PLC as in FIG. **11**E, which controls a hopper system having four gates. But then the PLC can be expanded to handle, for example, six gates, as in FIG. **11**F. This type of expansion can be economical because while a PLC may be available which will control six gates and could be used initially for a four-gate system, such a PLC tends to be more expensive than one which is limited to controlling four gates.
[0284] The particular PLCs shown in FIGS. **11**E and **11**F use solid state electronics, whose electrical properties are temperature-dependent. Specifications published by Eaton Industries GmbH state that, depending on temperature, the PLCs may gain, or lose, up to 5 seconds per day, or (equivalently) one-half hour per year. Thus, for example, if a given PLC is powered by a vehicle and is stored outdoors in winter for one month, the timing may change by 5×30, or 150 seconds, over than month.
[0285] Therefore, the programming of the PLC should accommodate those possible time losses. For example, if a hopper is to be held open for 30 seconds, then the programming must impose a correspondingly longer opening time. Alternatively, the time-of-day which the PLC computes could be set to 12:00 am every day at midnight. That would limit the time error to 5 seconds, because the error which accumulated in the previous 24 hours would be erased at midnight every day.
[0286] Eaton Industries GmbH offers software called “EasySoft8” which facilitates generation of code for the PLC **107** and PLC **130** in FIG. **11**F. This allows a manufacturer of the controller **50** in FIG. **5** or PLC **107** in FIG. **11**E to generate a single program and load it into multiple controllers, as opposed to manually programming each individual controller by keying in symbols.
[0287] The presence of program code within the PLC points to a difference between use of a PLC and the embodiment of FIG. **8**. In FIG. **8**, relay TR**1** closes after timer TR**1**T times out. The TR**1**T is a physical device that is present in the circuit shown. When relay TR**1** closes, voltage is applied across solenoid SOL**1**, which opens a gate, and also causing timer TR**2**T to begin counting down. In FIG. **8**, the timing is established by physical count-down timers, but in the case of the PLC

shown in FIGS. **11**E and **11**F, any corresponding time intervals are determined by program code, or digital data.
[0288] 30. FIG. **15**A shows a protective container **88** which contains a panel which supports the solenoid valves SOL and the timers TR. Air lines **95** extend from the container **88** and run to the pistons **40**. In FIG. **15**A, each gate **30**-**38** is operated by one piston **40**, which is not shown in FIG. **15**A.
[0289] 31. FIG. **15**A shows the container **88** mounted on trailer TK**1**. The air lines **95** of FIG. **11** run through a protective pipe PP which is attached to the trailer TK**1**. FIG. **15**B is a rear view of the trailer TK**1**. The pipe PP is located at a position which is protected by the lateral edge E of the trailer TK**1**. The pipe PP is located inboard of edge E as well as being inboard of the outer edge OE of the TIRES. As to the latter, the pipe PP is inboard of the outer edge OE by distance D.
[0290] Numerous modifications can be made to the embodiments herein described, without departing from the true spirit and scope of the invention.
[0291] This invention, including all embodiments shown and described herein, could be used alone or together and/or in combination with one or more of the features covered by one or more of the claims set forth herein, including but not limited to one or more of the features or steps mentioned in the Summary of the Invention and the claims.
[0292] While the system, apparatus and method herein described constitute preferred embodiments of this invention, it is to be understood that the invention is not limited to this precise system, apparatus and method, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

Claims

1. An apparatus for use in a vehicle containing multiple hoppers, each having a discharge gate comprising: a) a plurality of actuators, each for opening a respective discharge gate; and b) a control system which induces the actuators to open the gates in sequence.
2. The apparatus according to claim 1, in which the control system opens each gate after its preceding gate has fully discharged its hopper.
3. The apparatus according to claim 2, in which each gate is opened at a predetermined time after its preceding gate has opened.
4. The apparatus according to claim 1, in which timing of the sequence of gate openings is adjustable by a human.
5. The apparatus according to claim 4, in which the timing is adjusted by a human to suit said vehicle.
6. The apparatus according to claim 1, in which a human initiates operation of the control system, which operates without human intervention after initiation.
7. The apparatus according to claim 1, wherein the vehicle comprises a) hopper H**1** having a leading gate G**1**, b) hopper H**2**, having a gate G**2** which is adjacent gate G**1**, c) hopper H**3** having a gate G**3** which is adjacent gate G**2**, d) hopper H**4**, having a gate G**4** which is adjacent gate G**3**, wherein the control system e) opens gate G**1** at time T**1** in response to a start signal issued by a human, f) opens gate G**2** after a time delay following opening of gate G**1**, g) opens gate G**3** after a time delay following opening of gate G**2**, h) opens gate G**4** after a time delay following opening of gate G**3**.
8. The apparatus according to claim 7, in which the time delays are programmable by said human.
9. The apparatus according to claim 1, in which the sequence begins with a leading gate.
10. The apparatus according to claim 1, in which the vehicle contains a source of compressed air, and a) the vehicle contains an input for receiving a start signal; b) the control system, in response to the start signal, delivers compressed air which (i) opens a first discharge gate and then (ii) opens a second discharge gate.

11. The apparatus according to claim 10, in which, during operation, the control system opens a gate only when the gate is engaged with a discharge chute.
12. The apparatus according to claim 10, in which, during operation, the control system opens a gate only when the gate is positioned above a grate which leads to a collection pit at a grain elevator.
13. A method of operating a vehicle containing multiple cargo hoppers, each having a gate, comprising: a) initiating a control which opens the gates, one-at-a-time, at predetermined intervals, and b) moving the vehicle so that every gate discharges its cargo into a stationary chute located below the vehicle.
14. The method according to claim 13 in which the vehicle does not change direction during said intervals.
15. The method according to claim 13, in which the vehicle changes direction during said intervals.
16. The apparatus according to claim 1, in which each hopper has a respective gate, the hoppers being numbered **1** through N, in which: a) the actuators comprise i) a plurality of pneumatic valves, numbered **1** through N, ii) a plurality of pneumatic pistons, numbered **1** through N, each 1) actuated by a respective valve, and 2) connected to a respective gate; b) the control system comprises a group of time-delay relays, numbered **1** through N, each associated with a respective valve, wherein i) relay **1** closes in response to a signal from a human, and actuates valve **1**, to thereby actuate piston **1**, to thereby open the gate of hopper **1**; ii) in response to the closure of relay **1**, a time delay occurs, after which relay **2** closes and actuates valve **2** to thereby actuate piston **2**, to thereby open the gate of hopper **2**; and iii) in response to the closure of relay **2**, a time delay occurs, after which relay **3** closes and actuates valve **3** to thereby actuate piston **3**, to thereby open the gate of hopper **3**.
17. The apparatus according to claim 1, in which a) the plurality of actuators comprising i) a first pneumatic piston which opens a first gate; ii) a second pneumatic piston which opens a second gate; b) the control system induces i) a first actuator to actuate the first piston after it receives a start signal; and ii) a second actuator to actuate the second piston at a predetermined time after the start signal.
18. The apparatus according to claim 17, and further comprising: d) a third pneumatic piston, which opens a third gate; e) a third actuator which actuates the third piston at a predetermined time after actuation of the second piston.
19. The apparatus according to claim 1, in which the vehicle empties the hoppers into a stationary chute, and a) the discharge gates are manually operable by a person, and b) the control system responds to a start signal issued by a person by (i) opening a first discharge chute when it is engaged with a stationary chute, and (ii) opening a second discharge chute when it is engaged with the stationary chute.
20. The apparatus according to claim 19, in which each gate is held open for a sufficient time to allow discharge of the contents of its hopper.
21. The apparatus according to claim 20, in which the controller is of the Programmable Digital Logic type, PDL.
22. The apparatus according to claim 1, further comprising: a) a start switch; and b) the control system comprises a Programmable Digital Controller, PDL, which responds to the start switch by opening gates in sequence.
23. The apparatus according to claim 22, in which the PDL receives no input signals other than the start signal and possibly a termination signal.
24. The apparatus according to claim 23, in which the PDL (i) opens a first discharge gate when it is engaged with a stationary chute, and (ii) opens a second discharge gate when it is engaged with the stationary chute.
25. The apparatus according to claim 24, in which c) the vehicle occupies a first position when the first discharge gate is engaged with the stationary chute, d) the vehicle occupies a second position

when the second discharge gate is engaged with the stationary chute, and e) the PDL imposes a time delay between opening of the first discharge gate and opening of the second discharge gate, and that delay is selectable by a human operator.

26. The apparatus according to claim 25, in which a transit time occurs while the vehicle moves from the first position to the second position, and the time delay is greater than the transit time.

27. The apparatus according to claim 26, in which f) the vehicle spends a first dwell time D**1** at the first position, g) the PDL holds the first discharge gate open for at least a first open time T**1**, and h) the first dwell time D**1** is greater than first open time T**1**.

28. The apparatus according to claim 27, in which f) the vehicle spends a second dwell time D**2** at the second position, g) the PDL holds the second discharge gate open for at least a second open time T**2**, and h) the second dwell time D**2** is greater than second open time T**2**.

29. A control system for opening gates of hoppers in a vehicle, which: a) applies a first voltage to a first solenoid which opens a first valve which delivers air pressure to a first piston which opens a first gate; and b) detects the first voltage and, in response, pauses for a delay and then applies a second voltage to a second solenoid which opens a second valve which delivers air pressure to a second piston which opens a second gate.

30. A kit for modifying a vehicle which contains a number N hoppers, each having a gate, comprising: a) N pneumatic actuators; b) N brackets, each for connecting an actuator to a respective gate, to allow an actuator to open its gate; and c) a control which actuates a first actuator, and then actuates the remaining actuators, one-at-a-time, at predetermined intervals.

31. An apparatus for controlling discharge doors of hoppers in a vehicle, comprising: a) a first pneumatic piston, which opens a first door of a first hopper; b) a second pneumatic piston, which opens a second door of a second hopper; c) a programmable logic controller, which contains program code, which receives a start signal and, in response, i) actuates the first piston to open the first door, in accordance with the program code, and ii) actuates the second piston to open the second door, after the first hopper has discharged fully, in accordance with the program code.