Title: AUTOMATED TANKER UNLOADING SYSTEM

Abstract: A tanker vehicle (1) for transporting particulate material in bulk, said vehicle comprising: a tank having a discharge outlet and at least one compressed air inlet for pneumatic unloading of the tank; at least one valve to control the flow of the particulate material from the tank; at least one sensor for detecting when the level of particulate material in the tank falls below a predetermined level; and a controller programmed to actuate the valve or valves in response to an output from one or more of the sensors. Also provided is a system comprising a tanker vehicle according to the invention and a receiving vessel such as a silo (2). Also provided are methods of operation of such systems.
The present invention relates to a tanker delivery vehicle for delivery of bulk particulate materials, and to systems and methods for such delivery.

When powders or granules are delivered in bulk by vehicles, it is common practice for the load to be discharged from the delivery tank on the vehicle by blowing the material into a receiving vessel such as a hopper, silo or bin using pneumatic conveying. The air used to carry the material is vented through the top of the receiving vessel, often through a filter assembly to prevent release of the material into the environment. If the air entering the receiving vessel is not vented adequately, then the receiving vessel can become over-pressurised. This can result in rupture of the receiving vessel, ejection of lids, ejection of filter systems, rupture of explosion relief panel or activation of an explosion suppression system. Pressures as low as 6800 Pa (lpsi) gauge may be sufficient to damage a receiving vessel.

To ensure that the material is introduced into the transfer pipe, the delivery tank is pressurised, normally but not exclusively, with the same air supply that is utilised for pneumatic conveying. The pressure in the delivery tank during pneumatic unloading will vary dependant on the height of receiving vessel, length and size of pipe, complexity of routing, designed phase density, filter design, and other factors. For example, road tankers currently operate at air pressures up to 200kPa (29psi) gauge. As the product is transferred, more air is pumped into the delivery vessel to maintain the pressure. This volume of air, often referred to as residual air, will be released from the delivery vessel when the outlet into the delivery pipe is free of material. Subsequently a large volume of air at above atmospheric pressure is released through the transfer pipe into the receiving vessel, which can cause an abrupt increase in the pressure inside the receiving vessel.

During material transfer from the delivery vessel to the receiving vessel the operator controls the process by adjusting the pressure of the system by varying the air and material ratio, often basing their judgement solely upon the reading from a pressure gauge on the delivery tank and based on their experiences of when intervention will be required.
To prevent a pressure surge in the receiving vessel when unloading is completed, the operator has to be vigilant, have fast reactions, and be experienced as to what changing noise level and tones emitted from the delivery pipe indicate. Failure to respond to changing conditions results in the residual air being released at pressure into the receiving vessel, potentially causing damage. The changing conditions can be from material flow characteristics, changes in the properties of the conveying air, condition of the filter assembly, sticking pressure reducing valves, roughness of the transfer pipe from accumulated material, or other factors.

To ensure this does not happen the current practice is to operate at the minimum known transfer pressure, as subsequently the delivery tank pressure will be reduced and the material still introduced into the pneumatic conveying system. The effect of this is that a reduced transfer pressure equates to a reduced transfer air velocity and subsequently a reduced ratio of material to conveying air, resulting in increased delivery duration and less than optimum productivity.

The present invention seeks to overcome the above problems by providing for rapid, safe pneumatic transfer of particulate material from a delivery vehicle to a receiving vessel with minimum operator intervention.

In a first aspect, the present invention provides a tanker vehicle for transporting particulate material in bulk, said vehicle comprising: a tank having a discharge outlet and at least one compressed air inlet for pneumatic unloading of the tank; at least one valve to control the flow of the particulate material from the discharge outlet; at least one sensor for detecting when the level of particulate material in the tank falls below a predetermined level; and a controller programmed to actuate the valve or valves in response to an output from one or more of the sensors.

The invention works by sensing when the discharge outlet is suitably plugged with particulate material so that the residual air cannot escape from the delivery vessel. The automatic closing or restricting of the discharge outlet when the outlet is no longer plugged with the particulate material ensures that the residual air cannot escape from the
delivery vessel at a rate sufficient to damage the receiving vessel, thereby allowing the
delivery vessel to be unloaded faster. The automatic closing or restricting of the
discharge outlet allows the system to be operated by suitably trained, but inexperienced
operators.

The tanker vehicle may be of any type, for example a road tanker or a rail tanker. The
tanker may be of the tipping type with a single outlet at the rear end, or it may be of the
non-tipping (belly) type, in which case a single vehicle usually comprises a plurality of
tanks, each with a respective outlet at the bottom. Suitably, the capacity of the tanker
vehicle is at least about 1m³, preferably at least about 10m³, for example from about
20m³ to about 40m³. The tanker is typically equipped with a compressed air pump and
couplings in conventional fashion.

The particulate material may be any powdered or granular material that is suitable for
pneumatic unloading, including for example sugar, other particulate foodstuffs, chemical
powders or granulates, and cement powder.

In its simplest embodiments, the present invention comprises a single valve associated
with the discharge outlet, whereby the valve can be switched from an open configuration
to a closed configuration in response to a signal from the sensor(s) that the particulate
material has fallen below the predetermined level in the tank. Optionally, the controller
may allow a suitable delay between activation of the sensor and closing of the valve to
enable the residual particulate material to be transferred, so that the tank is substantially
empty when the valve is closed.

In other embodiments, the single valve associated with the discharge outlet may be
capable of being switched by the controller to provide a restricted flow rate intermediate
the normal unrestricted flow and complete shut-off. In these embodiments, the
controller may be programmed to switch the valve from the open configuration to the
restricted flow configuration in response to a signal from the sensor(s) that the
particulate material has fallen below the predetermined level in the tank. The residual
particulate material in the tank can then be conveyed at a reduced flow rate until the tank
is empty. The reduced flow rate through the valve in the restricted configuration results
in improved control in the final phase of the unloading, and reduced risk of a damaging blow-off of compressed air from the delivery tank into the receiving vessel.

It will be appreciated that when the vehicle comprises multiple tanks (e.g. a belly tanker), then there may be a control valve associated with each tank, or a single control valve controlling the manifold of tank outlets.

In certain embodiments, the vehicle comprises a first valve that can be actuated by the controller to block the flow of particulate material from the tank, and a second valve that can be actuated by the controller to permit restricted flow of particulate material from the tank. The second, restricting valve allows the remnants of particulate material remaining in the tank after the level has fallen to the predetermined level to be discharged in a controlled manner, so as to maximise the delivered payload, as discussed above.

The first and second valves may preferably be positioned in series in the discharge outlet of the tank, or in certain embodiments they may be positioned in parallel, that is to say they may be positioned in separate discharge outlets from the tank. Suitably, the separate outlet lines then merge into a single transfer line downstream from the valves.

In the case of vehicles with multiple tanks, such as belly tankers, there is suitably a respective first valve at the discharge outlet of each tank. The discharge outlets then merge into a single outlet pipe, and a single, second (flow restrictor) valve is suitably then positioned in the single outlet pipe downstream of all of the outlets. This enables the desired high degree of control to be achieved with a single flow restrictor valve.

In these embodiments, the controller is suitably programmed to switch the first and second valves to allow either unrestricted flow, restricted flow, or no flow of the particulate material from the tank in response to the output from the sensors. For example, when the valves are in series, the controller is programmed to set the valves as follows: (a) both valves fully open when the level of material in the tank is above the predetermined level, (b) first valve open and second valve in the flow restricting position when the level of material in the tank falls below the predetermined level, and (c) first valve and optionally also second valve closed during when the tank is empty. When the
valves are in parallel, the controller may be programmed to set the valves as follows: (a) first valve and optionally also second valve fully open when the level of material in the tank is above the predetermined level, (b) first valve closed and second valve open in the flow restricting position when the level of material in the tank falls below the predetermined level, and (c) both valves closed when the tank is empty.

The sensors can be of any type, including mechanical (paddle), electric, electronic or pneumatic. The sensors are selected dependent upon the properties of the material being conveyed. The sensors should be suitably positioned so as to allow enough time for other parts of the assembly to respond in time. The sensors are typically located such that the said predetermined level at which the sensors are activated is from about 50cm to about 1m above the outlet of the tank, typically about 75cm above the outlet, when the tank is being discharged.

In certain embodiments, the tanker vehicle according to the present invention comprises a plurality of sensors associated with a single discharge outlet. For example, the plurality of sensors may be distributed radially around the outlet. This permits the sensors to detect air channeling through the material, or other uneven flow of the particulate material, that could cause a pressure spike in the receiving vessel. The controller is suitably programmed to reduce or cut off the flow through the outlet line in response to an indication of such uneven flow from the plurality of sensors.

Suitably, the controller is further programmed to shut off the flow of particulate material from the tank in response to a signal output from a level sensor or a pressure sensor in a receiving vessel. This feature provides a back-up protection, for example if the receiving vessel is in danger of being over-filled or over-pressurised. It also allows the unloading of the particulate material to be conducted in a fully automated manner, without an operator in attendance. For example, the feedback from the pressure sensor in the receiving vessel can be monitored while the delivery vehicle is in the restricted-flow mode described above after the level of particulate material in the delivery tank has failed below the predetermined level for the sensors in the tank. The controller then shuts off the flow completely when the signal from the receiving vessel indicates a pressure rise characterising of blow-off from an empty tank. The relatively low rate of
blow-off in the restricted flow mode means that the shut-off can safely be achieved in fully automated fashion before an excessive pressure is reached in the receiving vessel.

The controller can further comprise a timers and programmed delays so that multiple outlets are emptied in a sequentially controlled manner, and/or it can be linked to the compressor to vary the pressure of the air within the delivery vessel and delivery pipe. The controller can also be connected to the receiving vessel or ancillaries to start and stop the transfer sequence so that the delivery vessel becomes a portable silo or production buffer.

In a second aspect, the present invention provides a bulk delivery system for particulate material comprising a tanker vehicle according to the present invention, a receiving vessel, and a transfer pipe for connecting an outlet of the tanker vehicle to the receiving vessel.

Suitably, the receiving vessel is a silo, a hopper, or a bin. Suitably, the bulk delivery system according to this aspect of the invention further comprises at least one level sensor and/or pressure sensor for detecting a pressure or fill level within the receiving vessel, wherein said level sensor and/or pressure sensor can be connected to the controller on the vehicle whereby at least one said valve can be actuated by the controller in response to the output of said level sensor and/or pressure sensor. The additional sensors may be permanently fitted to the receiving vessel, with suitable connectors for connection to the controller. In other embodiments, the additional sensors could be portable on the vehicle and fitted to the receiving vessel only during unloading of the vehicle.

Alternative and preferred features of the system according to the invention are as described above in relation to the first aspect of the invention.

In a further aspect, the present invention provides a method of delivering bulk particulate material from a tanker vehicle to a receiving vessel, wherein the tanker vehicle comprises: a tank having at least one discharge outlet and at least one compressed air inlet for pneumatic unloading of the tank; at least one valve to block or restrict the flow
of the particulate material from the tank; at least one sensor for detecting when the level of particulate material in the tank falls below a predetermined level; and a controller programmed to actuate the valve or valves in response to an output from one or more of the sensors, said method comprising the step of supplying compressed air to the air inlet of the tank to effect pneumatic transfer of the bulk particulate material from a discharge outlet of the tank to the receiving vessel through a transfer pipe, and wherein at least one said valve is automatically actuated by said controller to block or restrict flow of the particulate material from the tank in response to a signal from at least one said sensor that the level of particulate material in the tank has fallen below said predetermined level.

Alternative and preferred features of the method according to the invention are as described above in relation to the first aspect of the invention,

Specific embodiments of the present invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 shows a general schematic view of a system according to the present invention for unloading bulk particulate material;

FIG. 2 shows a schematic side elevation view of a road tanker in accordance with the present invention;

FIG. 3 shows a detail schematic side view partly in cross-section of the outlet region of the tanker of FIG. 2;

FIG. 4 shows a graph of silo pressure against time for tanker unloading according to the prior art; and

FIG. 5 shows a graph of silo pressure against time for unloading of a tanker as shown in figures 1 to 3.

Referring to FIG. 1, the system according to the present invention comprises a road tanker 1, a storage silo 2 and a transfer line 3. The road tanker 1 is of the non-tipping (belly) type with two tanks having respective outlets 4,5 at the bottoms thereof. The vehicle further comprises a compressed air pump 7 and a controller. The tanker 1 is connected by coupling 8 to transfer line 3, which feeds into the top of silo 2. The silo 2
is fitted with conventional filtered air vent 9 at the top. The silo 2 is further fitted with a conventional pressure relief device 10. The silo 2 is further equipped with a paddle sensor 12 to detect when the silo 2 is full of particulate material. The output of the paddle sensor 12 is connected to the controller 16 of the tanker vehicle 1. The silo 2 is further equipped with a pressure sensor 14 for measuring the gas pressure in the top of the silo. Again, the output from this pressure sensor is fed to the controller 16 of the tanker 1.

Referring to FIGS. 2 and 3, there is shown a further tanker delivery vehicle according to the present invention. The vehicle is of the non-tipping (belly) type. It comprises three tanks 21,23,25, each tapering at the bottom to respective cones 22,24,26 terminating in respective delivery outlets. Each delivery outlet is provided with a respective shut-off valve 28,30,32. The delivery outlets merge to common outlet line 34. A single flow restrictor valve 36 is situated the outlet line 34 downstream from the discharge outlets valves 28,30,32. A level sensor is provided in each of the tanks approximately 75cm above the level of the outlet valves, to detect when the level of particulate material 44 in that cone falls below a predetermined level. The vehicle is equipped with an air compressor 46 for delivering compressed air to suitable distribution means inside the tanks to fluidise the particulate material inside the tanks and propel it through the discharge outlets. The tanker vehicle is further provided with a controller 48 that is operatively connected to each of the valves 28,30,32 and 36 to sense the state of each valve, and to actuate each valve by conventional electrical, pneumatic or hydraulic drive means. The controller 48 is also operatively connected to the sensors 38,40 and 42 so that the output of the sensors can be read by the controller 48. Finally, the controller 48 has appropriate connector elements for connecting the controller to level sensors and/or pressure sensors in the receiving vessel, as hereinbefore described.

In this particular embodiment, the particulate material is sugar, the level sensors in the tanker are Endress-Hauser - Soliphant FTM-20-4G25A probes, the outlet valves are actuated Burgmer butterfly valves with a Kinetrol fail-safe spring actuator, the restricted flow valve is an actuated Burgmer butterfly valve modified so that restricted flow is still allowed when in the closed mode, and the controller is a Moeller "Easy" EASY719-DC-RC programmable logic controller.
Unloading of the vehicle tanker is conducted as follows. First, the outlet line 34 is connected through a suitable coupling to the inlet line of the silo. Air compressor 46 is activated to fluidise the particulate material in the tank and to pressurise the tank. Main valve 32 is opened, and restrictor valve 36 is set at the open (unrestricted) position by the controller 48. The particulate material flows out of the tank through valve 32 and 36 until the level of particulate material and discharge cone 26 drops below the level of sensor 42. Restrictor valve 36 is then set to the restricted flow position, and the remaining particulate material in cone 26 is expelled through the restrictor valve 36 at substantially reduced volumetric flow rate. When cone 26 is completely empty, the compressed air from tank 25 is able to blow off through the restrictor valve 36 into the silo. The pressure in the silo begins to rise, but only slowly because of the restricted flow rate of air through restrictor valve 36. The increase in silo pressure is detected by the pressure sensor inside the silo and communicated to the controller 48, which then closes valve 32, opens valve 30, and sets the restrictor valve 36 to the unrestricted (fully open) configuration. Tank 23 is then emptied in the same way as tank 25. The procedure is repeated once more for tank 21. All valves are then closed, and the remaining compressed air inside the tanks can be blown off through suitably filtered vents (not shown).

Referring to FIGS 4 and 5, the difference in the air pressure versus time graph within the silo achieved by the present invention is readily seen. FIG. 4 shows the air pressure inside the silo for a conventional pneumatic unloading procedure. Pressure spikes are seen at times corresponding to the first tank change 50, the second tank change 52, and the final blow off from the tank 54. In contrast, the pressure profile of the process according to the present invention shown in FIG. 5 shows almost no pressure peaks.

In addition to the additional safety of the unloading procedure according to the present invention, it is also quicker because higher pneumatic unloading pressures can be used, and furthermore it can be fully automated for application by unskilled (but suitably trained) operators.
The above embodiments have been described by way of example. Many other embodiments falling within the scope of the accompanying claims will be apparent to the skilled reader.
CLAIMS

1. A tanker vehicle for transporting particulate material in bulk, said vehicle comprising: a tank having at least one discharge outlet and at least one compressed air inlet for pneumatic unloading of the tank; at least one valve to control the flow of the particulate material from the tank; at least one sensor for detecting when the level of particulate material in the tank falls below a predetermined level; and a controller programmed to actuate the valve or valves in response to an output from one or more of the sensors.

2. A tanker vehicle according to claim 1, wherein the said at least one valve can be configured to allow a high flow rate of the particulate material from the tank, a restricted flow rate of the particulate material from the tank, or no flow of the particulate material from the tank.

3. A tanker vehicle according to claim 1, wherein the vehicle comprises a first valve that can be actuated by said controller to block the flow of particulate material from the tank, and a second valve that can be actuated by said controller to permit restricted flow of particulate material from the tank.

4. A tanker vehicle according to claim 2, wherein the first and second valves are positioned in series in a discharge outlet line.

5. A tanker vehicle according to claim 2 or 3, wherein the controller is programmed to switch the first and second valves to allow restricted flow of the particulate material from the tank when the output from the sensors indicates that the level of particulate material in the tank fallen below said predetermined level.

6. A tanker vehicle according to any preceding claim, comprising a plurality of said sensors associated with a single discharge outlet.
7. A tanker vehicle according to any preceding claim, wherein the controller is further programmed to shut off the flow of particulate material from the tank in response to a signal output from a level sensor or a pressure sensor in a receiving vessel.

8. A bulk delivery system for particulate material comprising a tanker vehicle according to any preceding claim, a receiving vessel, and a transfer pipe for connecting an outlet of the tanker vehicle to the receiving vessel.

9. A bulk delivery system according to claim 8, further comprising at least one level sensor and/or pressure sensor for detecting a pressure or fill level within the receiving vessel, wherein said level sensor and/or pressure sensor can be connected to the controller on the vehicle whereby at least one said valve can be actuated by the controller in response to the output of said level sensor and/or pressure sensor.

10. A method of delivering bulk particulate material from a tanker vehicle to a receiving vessel, wherein the tanker vehicle comprises: a tank having at least one discharge outlet and at least one compressed air inlet for pneumatic unloading of the tank; at least one valve to block or restrict the flow of the particulate material from the tank; at least one sensor for detecting when the level of particulate material in the tank falls below a predetermined level; and a controller programmed to actuate the valve or valves in response to an output from one or more of the sensors, said method comprising the step of supplying compressed air to the air inlet of the tank to effect pneumatic transfer of the bulk particulate material from a discharge outlet of the tank to the receiving vessel through a transfer pipe, and wherein at least one said valve is automatically actuated by said controller to block or restrict flow of the particulate material from the tank in response to a signal from at least one said sensor that the level of particulate material in the tank has fallen below said predetermined level.
INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/000899

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60P1/60 B60P3/22 B65G53/66

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

B. RELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
B60P B656 B65D

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Date of the actual completion of the international search: 5 June 2007
Date of mailing of the international search report: 14/06/2007

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