Fluidising Apparatus for Transfer of Particulate Material

Abstract: A product fluidising apparatus comprising a chamber having at least one product inlet controlled by a first valve and adapted to receive a product supply, at least one gas inlet controlled by a second valve and adapted to receive a pressurised gas supply, and at least one product outlet which is connectable to a pressurisable product delivery pipe and which is controlled by a third valve. The first, second and third valves are provided with actuators capable of cycling each valve from a substantially open position to a substantially closed position. And, the apparatus includes a controller capable of controlling and cycling the operation of each valve in sequence, in such a manner that while the first valve is substantially open the second and third valves are substantially closed, and while the first valve is substantially closed the second and third valves are substantially open.
FLUIDISING APPARATUS FOR TRANSFER OF PARTICULATE MATERIAL

FIELD OF THE INVENTION

This invention relates to a fluidising apparatus and method, and in particular, but not exclusively, to a fluidising apparatus and method for use in the conveying of particulate material.

BACKGROUND

Particulate materials are often transported by trucks and stored in large silos. The transfer of the particulate material from a truck to a silo, or vice versa, is usually carried out by fluidising the material and then pumping it through large pipes. Air is separated from the material at its destination.

Two main methods are used to convey the material from one vessel to another, these being "dense phase" and "light phase" conveying. "Light phase" conveying is sometimes also referred to as "lean phase" or "dilute phase" conveying.

In the case of dense phase, a pressure vessel, for example a road tanker or a ground silo, is filled with product and then sealed and pressurised to approximately 22 pounds per square inch (psi). During this process, air is pumped into the product through aerators, fluidising the product. Once the operating pressure has been reached, the discharge valves are opened and the product is forced, under pressure, from the vessel and into the silo. An operating pressure of at least 75% of the initial vessel pressure must be maintained for effective operation.

The light phase method is one in which the product is typically introduced into a "live air Stream" via a rotary style valve. Operating pressures vary according to the application but are typically within the range of 5 to 12 psi. This method works on the principle that a head of product in a vessel above the valve will provide the necessary back pressure to overcome the pressure of the air stream within a delivery line, to enable effective transfer of the product from the vessel into the delivery line. However, in practice, this only works while a sufficient niags of product remains in the vessel. For example, when conveying say 1300 tons of cement from a silo, the system will work well for about an hour, but then "blow by" will occur. This is where pressurised air from the delivery line blows past the rotary
valve and up into the silo, causing the transfer rate to drop. The excessive aeration of the product can also cause both operational and environmental problems - this action can accelerate the wear on the rotary valve, and it can cause the release of dust if the silo or vessel is open to the surrounding atmosphere.

The fluidising beds, the pressure vessels or the associated valves and pipework can be expensive and can require a significant amount of maintenance. The systems are also prone to blockages and other malfunctions. And where the particulate material is abrasive, the maintenance requirements can be more burdensome. In situations where the vessel is pressurised, the vessels have additional structural and manufacturing requirements, as well as maintenance and inspection requirements.

Spills of the particulate material inevitably occur and it can be difficult to collect the material and pump it into a storage vessel again. Systems which are essentially closed, and which require an internal pressure, to operate, are not suitable for recovering material that has spilled from the system.

OBJECT

It is therefore an object of the present invention to provide a fluidising apparatus and method which will at least go some way towards overcoming the above mentioned problems, or at least provide the public with a useful choice.

STATEMENTS OF THE INVENTION

Accordingly, in a first aspect, the invention may be said to consist in a product fluidising apparatus comprising a chamber having at least one product inlet controlled by a first valve means and adapted to receive a product supply, at least one gas inlet controlled by a second valve means and adapted to receive a pressurised gas supply, and at least one product outlet which is connectable to a pressurisable product delivery pipe and which is controlled by a third valve means, the first, second and third valve means being provided with adaptation means capable of cycling, each valve means from a substantially open position to a substantially closed position, and wherein the apparatus includes control means capable of controlling and cycling the operation of each valve means in sequence in such a manner that
while the first valve means is substantially open the second and third valve means are substantially closed and while the first valve means is substantially closed the second and third valve means are substantially open.

Such an apparatus is advantageous in that it can be used to fluidise a particulate material without the need to pressurise the particulate material storage vessel, or without the need to use a rotary valve with its associated operational and maintenance problems.

Preferably the third valve means is sequenced to begin opening a short time after the second valve means begins to open.

Preferably the apparatus further includes a fourth valve means adapted to control the flow of a pressurised gas flow "which can pass directly into the pressurisable product delivery pipe at a location immediately downstream of the third valve means."

Preferably the fourth valve means includes actuation means and the control means is capable of cycling the fourth valve means in sequence with the other valve means.

Preferably, the fourth valve means is sequenced to be in an at least partially closed configuration during at least part of the time that the second valve means is substantially open.

Preferably the fourth valve means is sequenced to be in a substantially open configuration during at least part of the time that the second valve means is substantially closed.

Preferably least one of the valve means is a butterfly valve;

In a second aspect, the invention may be said to consist in a particulate material storage facility or transporter incorporating at least one fluidising apparatus substantially as specified herein.

In a third aspect, the invention may be said to consist in a method of fluidising a product including the steps of:
substantially opening a first valve means associated with a first inlet opening of a
chamber to allow a quantity of product to be deposited into the chamber via the first inlet,
substantially closing the first valve means,

substantially opening a second valve means associated with a second inlet of the
chamber, and substantially opening a third valve means associated with an outlet of the
chamber, to allow a compressed gas to flow into the chamber via the second inlet
and to carry the deposited product out of the outlet of the chamber and into a product
delivery pipe,

substantially closing the second and the third valve means, and

then repeating the above cycle as desired.

Preferably the opening of the third valve means is timed to occur a short time after the
opening of the second valve means.

Preferably the method further includes the at least partial closing of a fourth valve means in a
pressurised gas, supply line which is connected directly to the product delivery pipe, when
the second valve means is opened, and then moving the fourth valve to a more open position
when the second valve means is substantially closed.

The invention may also be said to consist in the parts, elements and features referred to or
indicated in the specification of the application, individually or collectively, and any or all
combinations of any two or more of the parts, elements or features, and where specific
integers are mentioned herein which have known equivalents, such equivalents are
incorporated herein as if they were individually set forth.

DESCRIPTION

Further aspects of the present invention will become apparent from the following description
which is given by way of example only and with reference to the accompanying drawings in
which:
FIGURE 1 is a schematic view of a fluidising apparatus,

FIGURE 2 is an electrical diagram showing a control system for use with the fluidising apparatus, and

FIGURE 3 is an electrical diagram showing an alternate control system for use with the fluidising apparatus.

With reference to Figure 1, a fluidising apparatus (10) is shown comprising a cylindrical chamber (11) having three openings, a product inlet (13), a pressurised air inlet (15) and a product outlet (17). The product inlet (13) is situated at a high point on the chamber (11) which allows product to be dropped into the chamber through the inlet (13). Alternatively, the product inlet (13) can "take a lower position on the chamber (11) if, for example, the product is to be augered into the chamber (11). The product outlet (17) is adapted to be connected to a product delivery pipe (19) which can guide the product to another location, for example into a transporter, or into a storage silo. The apparatus (10) is designed primarily to fluidise product in the form of particulate material, for example cement.

While the apparatus (10) could comprise a number of pressurised air supply configurations, a simple and effective configuration is shown comprising a single pressurised air source (not shown), from a 'blower for example', which is supplied via a non return valve (21) and which then divides into two flow paths, a first flow path (23) which supplies pressurised air to the air inlet (15) of the chamber (41), and a second flow path (25) which by-passes the chamber (11) and supplies air directly into the product delivery pipe (19).

A system of four valves is used to control the flow of product and compressed air to allow the apparatus to operate effectively. A first valve (27) controls the opening of the product inlet (13), a second valve (29) controls the opening of the air inlet (15), a third valve (31) controls the opening of the product outlet (17) and an optional fourth valve (33) controls the flow of pressurised air in the second flow path (25) which is supplied directly to the product delivery pipe (19). The second flow path (25) connects to the product delivery pipe (19) at a location immediately downstream of the third valve (31). A suitable valve type for use in this application is a butterfly valve. Other valves type can be used, for example gate valves
or ball valves, however the relatively rapid control possible using a butterfly valve is considered advantageous.

The apparatus (10) operates to fluidise a product and to supply the fluidised product into the delivery pipe (19). This is achieved by operating the second and third valves (29 and 31) to restrict the flow of the pressurised air into and through the chamber (11) and then allowing a particulate product to enter the chamber (11) via the product inlet (13) by opening the first valve (27). The product can be presented to the product inlet (13) by a number of means for example by gravity from a storage vessel above the chamber (11), or by augering the product to the product inlet (13), or even by manually shovelling the product, or emptying bags of the product, into the product inlet (13).

The first valve (27) then closes and the second and third valves (29 and 31) open allowing pressurised air to enter the chamber (11) and fluidise the product and carry it into the delivery pipe (19). Then the second and third valves (29 and 31) close and the cycle is repeated. The timing of the opening of the third valve (31) can be slightly out of phase with the opening of the second Valve (29), as will be explained below, to improve the efficiency of the apparatus (10).

Air flowing through the second flow path (25) ensures that the product continues to move along the delivery pipe (19). The apparatus (10) is shown having the second flow path (25) meeting the product delivery pipe (19) at an angle (35) of about 45 degrees. Angles (35) of between 30 and 60 degrees are considered suitable.

With reference to both Figures 1 and 2, the operation and control of an embodiment of the apparatus (10) is explained in further detail. Figure 2 is an electrical diagram showing wiring connections of a control system (37), the components being powered by an electrical power supply having a phase line (39) and a neutral line (41).

Each valve (27), (29), (31) and (33) can be actuated by its own pneumatic actuator, and can be controlled by its own solenoid operated valve (not shown), and a cam operated switch (not shown) is located on the actuator of the first, second and third valves (27), (29) and (31).
In this example, the first valve (27) is actuated by a first actuator (43), has a first cam operated switch (Cl) and is controlled by a first solenoid (Sl), the second valve (29) is actuated by a second actuator (45), has a second cam operated switch (C2) and is controlled by a second solenoid (S2), the third valve (31) is actuated by a third actuator (47), has a third cam operated switch (C3) and is controlled by a third solenoid (S3), and the fourth valve (33) is actuated by a fourth actuator (49) and is controlled by a fourth solenoid (S4).

The solenoids (Sl to S4) are single coil, or self return, style solenoids and operate a pneumatic valve, and when power is applied to the coil of the solenoid its associated pneumatic valve allows air to be exhausted from one side of the respective actuator (43 to 49) as air is applied to the opposing side.

A first timer (Tl), controls the filling time, that is, the time that the first valve (27) is open and allowing product to enter the chamber (11). A second timer (T2) controls the chamber (11) emptying time, that is, the time that the second and third valves (29 and 31) are open.

In the "power off" state, the third switch (C3) is closed; the first switch (Cl) is closed, the second switch (C2) is open; and all the valves except the fourth valve (33) are in the closed position. The fourth valve (33) is normally open and is powered towards the closed position.

In the "power on" state, a Sequence of valve actuations is achieved by the operation of the control system (37). When power is applied the sequence will normally begin with the third switch (C3) configured to allow power to flow to the first timer (Tl) and to the first solenoid (S1). The first valve (27) will open, taking approximately one second. The first valve (27) opens for the preset time of the first timer (Tl), allowing product to enter the chamber (11) via the product inlet (13). The action of the first valve (27) beginning to open causes the first switch (Cl) to open, resetting the second timer (T2).

When the first timer (Tl) reaches its preset time a pair of first timer contacts (Tl a) opens, cutting power to the first solenoid (S1). The first valve (27) will then close.

When the first valve (27) is fully closed the first switch (Cl) follows power to flow to the second solenoid (S2) and to the second timer (T2). The second valve (29) will then begin to open.
When the second valve (29) reaches 25% of its opening travel, the second switch (C2) closes momentarily, by the action of its associated cam, and this latches a first relay (R3), and this closes two pairs of contacts, a first pair of contacts of the first relay (R3a) and a second pair of contacts of the first relay (R3b), to allow power to flow to both the third solenoid (S3) and to the fourth solenoid (S4).

The third valve (31) will then begin to open and the fourth valve (33) will begin to close to 75% closed. The slight lag of the third valve (31) opening, generally less than a second after the second valve (29) begins to open, can be important, because the initial rush of air that is let into the chamber (11) via the pressurised air inlet (15) by the second valve (29) can lift and fluidise the product within the chamber (11) momentarily before the third valve (31) opens.

It is envisaged that for products like cement that it would be preferable to limit the filling of the chamber (11) to a depth of not more than 100 millimetres (mm) to ensure that fluidisation of the product will occur rapidly. It is also desirable to configure the second valve (29) so that the initial air that passes the valve as it begins to open will be directed towards the bottom of the chamber (H) so that the air will tend to get under the product. The chamber (11) could be enhanced to include ducting, and optionally a fluidising bed to help the inconli ng air to get under the product.

The fourth valve (33) is configured to stop closing at 75% closed, by a mechanical stop in the fourth actuator (49). This partial closing of the fourth valve (33) means that the pressurised air flow is directed mainly through the chamber (11) to clear the product from the chadiber (11) and to move it out through the product outlet (17) and into the product delivery pipe (19). The flow of airy bpth via the chamber (11) and via the second flow path (25) combine to move the product via the product delivery pipe (19) to its destination.

When the third valve (31), has moved from the closed position, the circuit to the first timer (T1) is broken by the third switch (C3) opening causing the first timer (T1) to reset.

The second and third valves, (29) and (31), remain open for the preset time of the second timer (T2).
When the second timer (T2) reaches its preset time a pair of contacts, a first pair of contacts of the second timer (T2a) and a second pair of contacts of the second timer (T2b), will open. This opens the circuit to the second, third and fourth solenoids (S2), (S3) and (S4). The fourth valve (33) will fully open, and the second and third valves (29) and (31) will fully close.

The first relay (R3) is required to latch because of the action of the second cam switch (C2), as it momentarily closes during both the opening and the closing of the second valve (29). The second pair of contacts of the second timer (T2b) prevent the first relay (R3) re-latching while the second valve (29) is closing.

When the third valve (31) is fully closed, the third switch (C3) will be closed again, allowing power to flow to the first timer (T1) and to the first solenoid (S1). The first valve (27) will open, resetting the second timer (T2), allowing the cycle to begin again.

Note! the contacts labelled (T1a) (T2a), (T2b) and (Pla) are normally closed, and are powered to open.

If an over pressure is sensed by a pressure sensor (51), its associated pressure switch (PS) is triggered and its associated pressure switch relay (P1) energises the first and second contacts of the pressure switch relay (Pla) and (Plb) causing each to change state. This interrupts the cycle described above by resetting the second timer (T2) and holding the first relay (R3) in the on statp, thereby applying power to the second and third solenoids (S2) and (S3) until the pressure drops, at which time the cycle can begin again.

Throughout the above sequence the fourth valve (33), maintains air flow in the delivery pipe while the chamber (11) is filling and this ensures that there is a constant flow of air in the delivery pipe (19) up to a silo or tanker. Otherwise the product may not transfer, it would likely block the delivery pipe (19) on horizontal sections or simply fall back down in any Vertical sections if constant airflow was not maintained.

By closing the fourth valve (33) to 75% closed and redirecting the air through the chamber (11) it ensures that all product in the chamber (11) is removed and it prevents any back
pressure from blocking the second flow path (25) between the fourth valve (33) and where it joins the product delivery pipe (19).

The fourth valve (33) operates in reverse to the other valves, it requires power to close, all other valves require power to open. This is a safety feature, should the power supply to the valves become interrupted the fourth valve (33) will remain open allowing the pressurised air to bypass the chamber (11).

The timing of the sequencing of the valves (29 to 33) of the apparatus (10) is adjustable from both the cam switches (C1 to C3) on the actuators and the first and second timers, (T1) and (T2), to suit the product and the application.

Initial testing by the inventor, using an apparatus (10) as described above, having a 100 nitri diameter pressurised air supply line and a 200 mm diameter chamber with a 200 mm diameter first valve, and operating at 5 to 12 psi and at a rate of 1800 cycles per hour, will fluidise up to 15 tonnes of cement per hour.

With reference to Figure 3 an electrical diagram showing the wiring connections of an alternate control system (53) is provided. The control system (53) is similar to the previously described control system (37) except for the addition of an optional switch (S5) which allows the closing of the fourth valve (33) to be timed to coincide with the opening of first valve (27) or with the second valve (29). In the previous control system (37) described with reference to figure 2 above, the closing of the fourth valve (33) can only be timed to coincide with the opening of the second valve (29).

With the alternate control system (53), when a connection is made through a first contact (S5a) of the switch (S5), the fourth valve (33) is sequenced to move towards closed when the first valve (27) closes. This means that when the second valve (29) is subsequently opened a greater air pressure can be initially available to enter the chamber (H) to fluidise the material in the chamber (H). This configuration and operating sequence is more suitable to move heavier particulate material such as cement, which can be relatively difficult to move.

When a connection is made through a second contact (S5b) of the switch (S5), the apparatus will operate as described with reference to figure 2, that is, fourth valve (33) is sequenced to
move towards closed when the second valve (29) reaches 25% of its opening travel. This gives a smoother or gentler transition of air flow between the first flow path (23) and the second flow path (25). This configuration and operating sequence is more suitable when the fluidising apparatus (10) is to be used to fluidise softer particulate material, for example coffee beans or barley, which may otherwise be damaged.

VARIATIONS

To those skilled in the art to which the invention relates, many changes in construction and widely differing embodiments and applicatibhs of the invention will suggest themselves without departing from the scope of the invention as defined in the appended claims. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

The above example uses a third valve (31) having an actuator. An alternative configuration of the apparatus (10) could use a non-return valve in this location, however the use of a non-return valve could give rise to reliability problems as the valve may not close positively when it becomes dirty.

The above example uses a control system comprising earned operated switches, timers, relays, contacts, and solenoid operated valves. A range of alternative control systems could be used, for example microprocessor based systems, or purely mechanical systems. However it is considered that the control system described is suited to the operating environment found in many fluidised product conveying applications and is cost effective and simple to maintain and adjust.

The above example uses pressurised air to fluidise and carry the product, but it is envisaged that in some applications a specialised gas, for example an inert gas, may be used.

The fluidising apparatus (10) has primarily been described with reference to fluidising cement, however the apparatus can be used to fluidise a range of products, for example including cement, ash, beans, grain, flour, sugar, etc.
DEFINITIONS

Throughout this specification the word "comprise" and variations of that word, such as "comprises" and "comprising", are not intended to exclude other additives, components, integers or steps.
CLAIMS

1. A product fluidising apparatus comprising a chamber having at least one product inlet
controlled by a first valve means and adapted to receive a product supply, at least one
gas inlet controlled by a second valve means and adapted to receive a pressurised gas
supply, and at least one product outlet which is connectable to a pressurisable product
delivery pipe and which is controlled by a third valve means, the first, second and
third valve means being provided with actuation means capable of cycling each valve
means from a substantially open position to a substantially closed position, and
wherein the apparatus includes control means capable of controlling and cycling the
operation of each valve means in sequence in such a manner that while the first valve
means is substantially open the second and third valve means are substantially closed
and while the first valve means is substantially closed the second and third valve
means are substantially open.

2. A product fluidising apparatus as claimed in claim 1, wherein the third valve means
is sequenced to begin opening a short time after the second valve means begins to
open.

3. A product fluidising apparatus as claimed in any preceding claim, wherein the
apparatus further includes a fourth valve means adapted to control the flow of a
pressurised gas flow which can pass directly into the pressurisable product delivery
pipe at a location immediately downstream of the third valve means.

4. A product fluidising apparatus as claimed in claim 3, wherein the fourth valve means
includes actuation means and the control means is capable of cycling the fourth valve
means in sequence with the other valve means.

5. A product fluidising apparatus as claimed in any one of claims 3 or 4, wherein the
fourth valve means is sequenced to be in an at least partially closed configuration
during at least part of the time that the second valve means is substantially open.
6. A product fluidising apparatus as claimed in any one of claims 3 to 5, wherein the fourth valve means is sequenced to be in a substantially open configuration during at least part of the time that the second valve means is substantially closed.

7. A particulate material storage facility, or a particulate material transporter, incorporating at least one fluidising apparatus substantially as claimed herein.

8. A method of fluidising a product including the steps of:

   substantially opening a first valve means associated with a first inlet opening of a chamber to allow a quantity of product to be deposited into the chamber via the first inlet,

   substantially closing the first valve means,

   substantially opening a second valve means associated with a second inlet of the chamber, and substantially opening a third valve means associated with an outlet of the chamber, to allow a compressed gas to flow into the chamber via the second inlet and to carry the deposited product out of the outlet of the chamber and into a product delivery pipe,

   substantially closing the second and the third valve means, and

   then repeating the above steps as desired.

9. A method of fluidising a product as claimed in claim 8, wherein the opening of the third valve means is timed to occur a short time after the opening of the second valve means.

10. A method of fluidising a product as claimed in any of claims 8 or 9, wherein the method further includes the at least partial closing of a fourth valve means in a pressurised gas supply line which is connected directly to the product delivery pipe, when the second valve means is opened, and then moving the fourth valve to a more open position when the second valve means is substantially closed.
INTERNATIONAL SEARCH REPORT

International application No. PCT/NZ2006/000167

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.
B65G 53/16 (2006.01) B65G 53/04 (2006.01) B65G 53/66 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

AU: IPC B65G 53/16, B65G 53/22, B65G 53/04, B65G 53/12

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI: IPC B65G 53/-. B65D 88/-. BOU 05/-. B05C 07/-. AOIF 25/-. and keywords: VALVE, FLUIDISE, GRANULES, PARTICULATE, CEMENT, GAS, AIR, PNEUMATIC and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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[X] Further documents are listed in the continuation of Box C  [X] See patent family annex

* Special categories of cited documents:

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

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“R” document member of the same patent family

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Form PCT/ISA/210 (second sheet) (April 2005)
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT7NZ2006/000167

**DOCUMENTS CONSIDERED TO BE RELEVANT**

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Note:
For Y citations, GB 2125358 or US 5494381 can be combined together with US 6648558 or GB 1216506 for the claims indicated.

Form PCT/ISA/210 (continuation of second sheet) (April 2005)
This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.