(54) Title: SYSTEM, DEVICE, AND METHOD FOR SHAKING DOWN BRIDGED LOOSE MATERIALS

(57) Abstract: Proposed are a system and a method for shaking down loose materials in distribution reservoirs, comprising a tank for compressed air, formed by a pipe, pneumatic impulse devices with loose material bridging sensors connected to the pressure tank, and a control unit receiving signals from the sensors and sending instructions to control the valves of the pneumatic impulse devices. The pneumatic impulse device includes a quick-acting valve and a discharge pipe whose length, with a specified inside diameter and a specified valve opening time, is selected so as to provide generation, in the discharge pipe, of a shock wave used for efficient shakedown of the bridged loose material.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
SYSTEM, DEVICE, AND METHOD FOR SHAKEING DOWN BRIDGED LOOSE MATERIALS

FIELD OF THE INVENTION

The present invention relates to using compressed gas and can be employed to induce shaking down the bridged loose material in bunkers.

BACKGROUND OF THE INVENTION

Many processes comprise the production, storage and transport of various loose materials such as flour, cement, and carbon black. These processes involve the use of different distribution reservoirs, namely: bunkers, silos, hoppers, metering devices wherefrom the loose material is transported to outlets by gravity. This is accompanied by some undesirable phenomena such as bridging the loose material in industrial distribution reservoirs, its sticking to the walls and clogging the outlets of these reservoirs. All this may lead to emergency situations and the necessity to stop the process and clean the equipment.

To stimulate the normal discharge of loose material from industrial bunkers, it is common practice to use vibrators, magnetic pulse devices and vibrating bottoms. These devices all have one common feature, namely: they act upon the outside wall of the bunker which is deformed, acting, in turn on the loose material.

The effect is reduced with increasing thickness and rigidity of the bunker wall, since the vibration energy is largely spent to deform the bunker walls rather than to shake up the loose material. Furthermore, the effect produced on the material adjoining to the bunker wall is known to be not so significant, particularly for large - size bunkers.

All the above methods are inefficient for bunkers with undeformable walls, e. g. concrete silos, therefore the action is only directed immediately at the loose material inside the bunker. Aeration systems have been extensively used on such equipment, which enable a large amount of compressed air to be pumped, through a special hole system, deep into the bulk of the loose material inside the bunker.
The properties of many loose materials, however, are far from those of an ideal continuum, so the air cavities resulting from the aeration process fail to provide the displacement of the bulk of material, leading to a poor efficiency of such systems. A large amount of air is generally required to disturb the equilibrium of the great mass of loose material.

Unlike the stationary effect of aeration, pneumatic shakedown systems based on pneumatic guns, allowing a direct impulse excitation of the loose material inside the bunker by compressed air, are free from the above disadvantages.

The state-of-the-art pneumatic guns comprise a pressure tank filled with compressed air and a pipe interconnected by a controlled pressure-operated valve. The pipe is fixedly secured in the bunker wall, such that the open end of the pipe is within the inner space of the bunker, e. g. in the bulk of the loose material. The pneumatic guns traditionally employ the so-called 'quick-exhaust' valve having one, closed, steady state. In response to a control signal, such valve opens and compressed air from the tank is supplied to the bunker through the pipe, generating an impulse designed to remove the bridged loose material. After the tank has been emptied, the quick-exhaust valve is closed and returned to be the steady, closed, state. Such designs are described in a number of patent specifications, e. g. US patents: US 4579138, US 4817821, US 5797582, US 6253784.

The quick-exhaust valves in devices described in the patents mentioned above provide the effect of an impulse jet on the loose material.

Such valves, however, contrary to their name, only allow a relatively slow opening and, consequently, an inadequate effect of loose material excitation, the operation time being at least 5 ms. An addition, the quick-exhaust valve by virtue of its operating principle, fails to provide an operation rate of the pneumatic gun high enough, since after opening, such valve cannot close until the pressure tank has been fully emptied. The tank must then be re-filled with compressed air, and only then is the pneumatic gun with a quick-exhaust valve ready for re-operation.
Furthermore, one tank may only feed a single quick-exhaust valve. This latter circumstance is due to the fact that it is impossible to ensure uniformity of the flow passages, and that both valves are operated in synchronism, so that the bulk of compressed air will be drained through one valve. Because of this, a separate tank will be required for each valve.

To shake down the loose material bridged in large-size bunkers, pneumatic guns are used which include pressure tanks shaped as large bottles, and valves of a large standard size.

Such a design, however, entails additional problems, since bottles of a capacity of 500 litres or more, which are under pressure of industrial compressed air, are dangerous objects necessitating, special operating conditions and periodic tests in accordance with specified norms.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system for shaking down bridged loose materials, that would ensure an efficient shakedown of bridged loose materials in a distribution reservoir, with a low consumption of compressed air, to provide a pneumatic impulse device ensuring a highly efficient shakedown of bridged loose materials, and to provide a method that ensures an automatic shakedown of bridged loose materials in a distribution reservoir, with a low consumption of compressed air.

With this object in view, in a system for shaking down bridged loose materials in a distribution reservoir, comprising a pressure tank, at least one pneumatic impulse device, and a control unit, the pneumatic impulse device includes a valve, a discharge pipe, and a loose-material bridging sensor, the control unit is connected to the sensor to receive signals therefrom, and to the valve to apply control instructions thereto, the inlet duct of the valve is connected with the tank, and the outlet duct of the valve is connected with the input end of the discharge pipe so positioned that the open output end of the discharge pipe penetrates the distribution reservoir, the valve is capable of opening and closing the duct from the tank to the input end of the discharge pipe in response to instructions received from the control unit, the loose-
material bridging sensor being positioned so as to indicate the bridged loose material at the location of the discharge pipe. The use of the valve made capable of not only opening, but also closing in response to control instructions, allows the pneumatic impulse devices to be fed from the same tank. The presence of a loose-material bridging sensor in each pneumatic impulse device of the system enables an action to be brought upon the bridged loose material directly at the time and at the spot where the bridging has occurred, also allowing an automatic operation of the system.

It is advisable that the valve opening time be within 2 ms, preferably no greater than 1 ms, the length of the discharge pipe of the pneumatic impulse device relative to its inside diameter being at least such as to provide, with a specified valve opening time, generation of a shock wave in the discharge pipe.

It is preferred that, with a specified diameter of the discharge pipe of the pneumatic impulse device, its length be such as to provide generation of the shock wave at the output end of the discharge pipe. Such construction of the discharge pipe enables the unproductive loss of the shock wave energy, in the area extending from the generation point to the output end of the discharge pipe, to be avoided.

It is expedient that the system includes at least two pneumatic impulse devices with their discharge pipe locations distributed across the area of probable bridging of loose material in the distribution reservoir, and with the tank made of a pipe of a specified diameter laid along the outside surface of the distribution reservoir in the vicinity of the discharge pipe location points. This ensures the safety of the pressure tank and makes it possible to feed the widely spaced pneumatic impulse devices from the same tank.

It is reasonable that the tank include at least one ring of a pipe adapted to be positioned so that the ring encircles the distribution reservoir. In an extended tank made of a pipe looped to form a ring local pressure differentials of compressed gas, arising from operation of the pneumatic impulse devices connected thereto, are levelled.
The object of the invention is also achieved by providing that in a pneumatic impulse device for shaking down the bridged loose materials in distribution reservoirs, comprising a valve and a discharge pipe, the valve includes an inlet duct to connect it to the external pressure tank and an outlet duct serving to connect it with the input end of the discharge pipe, the valve is made capable of opening the duct running from the tank to the input end of the discharge pipe within a time interval not exceeding 2ms, the discharge pipe length being chosen at least such that the ratio of the discharge pipe length to its inside diameter allows generation of a shock wave within the discharge pipe as a result of the valve opening, when the valve is connected to the pressure tank.

It is preferred that the opening time of the valve of the pneumatic impulse device should not exceed 1ms.

The object is further attained by providing that in a method of shaking down the bridged loose material in a distribution reservoir by means of impulses of compressed gas generated by at least one pneumatic impulse device comprising a valve, a discharge pipe and a loose-material bridging sensor, the outlet of the valve is connected with the input end of the discharge pipe, the inlet of the valve is connected to the source of compressed gas, the valve being adapted to open and close the duct between the compressed-gas source and the discharge pipe in response to instructions formed by electric control signals, the loose-material bridging sensor is set so that an indication of bridged loose material in the distribution reservoir, at the location of the discharge pipe, may be received, the valve is left closed as long as there is no indication of bridged loose material, and appropriately spaced successive instructions to open and close the valve are applied, which are repeated, provided that the loose-material bridging signal keeps coming.

It is expedient that the sensor signals be applied to the electronic control unit generating the valve opening and closing instructions in accordance with the sensor signals.

A detailed description of the present invention now follows. It will be illustrated by its embodiments, using compressed air as the pressure gas and referring to the accompanying drawing.
BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a diagram of the system in accordance with the present invention;

Fig. 2 represents a cutaway side view of the distribution reservoir with the components of the system of Fig. 1 mounted thereon;

Fig. 3 is a view along the line 3-3 of the distribution reservoir and the system components shown in Fig. 2;

Fig. 4 is a side sectional view of a valve of the pneumatic impulse device according to the present intention;

Fig. 5 is a view along the line 5-5 of the valve shown in Fig. 4;

Fig. 6, 7 represent variants of mounting the pneumatic impulse device of the present invention on the distribution reservoir.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a schematic diagram of a system for shaking down loose material in a distribution reservoir 1. The system comprises a pressure tank 2 with compressed air, which is refilled from the external source (not shown), pneumatic impulse devices 3, and control unit 4.

The distribution reservoir 1 operates as follows.

The loose material supplied to the distribution reservoir 1 from above, in a standard mode of operation, moves down by gravity. The loose material is discharged from the lower part of the distribution reservoir 1. The standard mode of the distribution reservoir may be disturbed due to the bridging of loose material, which generally occurs in a probable bridging area characteristic of a specific distribution reservoir.

The pneumatic impulse device 3 comprises a valve 5, a discharge pipe 6, and a loose-material bridging sensor 7. The inlet duct of the valve 5 is connected with the pressure tank 2. The control unit 4 is connected with each pneumatic impulse device 3 and the sensor 7 through connections 8, 9, respectively, formed by electric cables. The connections 8, 9 may also be made wireless through radio communication. An electric control signal representing
instructions to open and close the valve 5 is supplied from the control unit 4 to the pneumatic impulse device 3 over the connection 8. A signal carrying information about the state (i.e. moving or bridging) of the loose material in the distribution reservoir 1 is applied to the control unit 4 from the sensor 7 over the connection 9. The bridged loose material provided with a reference number 10 is indicated schematically by a hatched area.

In the preferred embodiment, the control unit includes a computer.

The discharge pipe 6 is made of a steel pipe employed for gas communications. The discharge pipe 6 is so positioned within a hole in the wall of the distribution reservoir 1 that its output end 11 penetrates the distribution reservoir 1.

Figs 2, 3 show a vertically extending cylinder-shaped distributing reservoir 1 for discharging the loose material, with a tank 2 and pneumatic impulse devices 3 mounted thereon. The pneumatic impulse device 3 are spaced around the surface of the distribution reservoir 1 in a probable bridging area 20 schematically isolated by a dashed line in Fig. 2.

The tank 2 for compressed air is located outside the distribution reservoir 1. In the preferred embodiment, the tank is made of a pipe of desired diameter such as a steel pipe for gas communications.

In the present embodiment, the tank 2 includes two rings 22, 23 encircling the distribution reservoir 1, which are made of a pipe. In other embodiments of the present invention, the tank may have a single ring, or else, more than two rings. The inner spaces of the rings 21, 22 communicate with each other through connection ducts 23 made of a pipe of the same diameter as the rings 21, 22. The levels of the rings 21, 22 on the distribution reservoir 1 are chosen to be within the area 20 of probable bridging of the loose material. The probable bridging area is generally known from the experience of handling the distribution reservoir, or else it is determined by experiment. The inside diameter of the tank pipe is selected so as to provide, on one hand, the desired volume of the tank, and on the other hand, a multiple safety margin with the operating pressure of compressed air, accounting for the fact that
the internal pressure force applied to break the tank is inversely proportional to its inside diameter squared.

When using compressed air from industrial compressors developing pressure ranging from 0.6 to 1.0 MPa, both of the above conditions are met provided the tank is made of a steel pipe with an inside diameter not exceeding 209 mm. The aforementioned design of the tank offers the advantages of its safe operation.

The pneumatic impulse devices 3 are equally spaced over the periphery of the side wall of the distribution reservoir 1 as shown in Fig. 3. However, in case the inner space of the distribution reservoir has special features making the area probable bridging of loose material occupy only part of the periphery of the side wall, the pneumatic impulse devices may be concentrated in this part of the periphery. The number of pneumatic impulse devices required for an efficient shakedown of bridged loose material is dependent on the size of the distribution reservoir and on the properties of the materials.

Figs 4, 5 illustrate the design of the valve 5 such as that described in International Application PCT/RU002/00225. The valve 5 includes a control valve 40. The control valve 40 is designed as a bistable electromagnetic distributor 3/2. The control valve 40 has three ducts, namely: a feed duct 41, an outlet duct 42, and an exhaust duct 43 enabling the duct 42 to communicate with the environment. In one end position of the control valve 40, the feed duct 41 is connected with the outlet duct 42, and the exhaust duct 43 is closed. In the other end position, the outlet duct 42 is connected with the exhaust duct 43, and the feed duct 41 is closed. The change in the position of the control valve 40 is made by switching on/off the specified d.c. voltage applied to its electromagnetic coil (not shown).

The valve 5 comprises a hollow body 44, wherein provided are an inlet duct 45 connected with the tank 2 and an outlet duct 46 connected with the input end of the discharge pipe 6 (Fig. 2). A seat 47 is mounted within the outlet duct 46.

Inside the body 44, there are provided a movable dome-shaped shutoff device 48 with its apex facing the outlet duct 46, and a cylindrical guide 49 of the shutoff device. The shutoff device 48
consists of integral dome-shaped portion 50 and cylindrical portion 51.

The seat 47 is composed of an elastic material, the shutoff device 48 being made of a hard, shock-resistant material such as carbon-filled plastic.

The guide 49 is secured inside the body 44 by radial ribs 52 (Fig. 5). Provided within the guide 49 are cavities 53, 54 communicating with the ducts 41, 42 of the control valve 40 through duct 55, 56, respectively. The ducts 55, 56 run along one of the ribs 52. The guide 49 includes an annular stop 57 of an elastic material, for the shutoff device 48.

Fig. 4 shows the shutoff device in a position corresponding to the open valve 5. When the shutoff device is in a position 58 represented by a dashed line, it cuts off the outlet duct 46, which corresponds to the closed position of the valve 5. The open or closed position of the valve 5 is determined by the position of the control valve 40. With the control valve 40 open, the cavities 53, 54 communicate along the following path: cavity 54 – duct 56 – ducts 41, 42 of valve 40 – duct 55 – cavity 53. Compressed air from the inlet 45 passes along this path, filling the cavity 53 and a space 59 beneath the shutoff device 48. The air pressure holds the dome shaped portion 50 of the shutoff device tightly against the seat 47, and the valve 5 is closed.

When the closing instruction, in terms of a specified d. c. voltage, is applied to the control valve 40, its position is changed to closed. The supply duct 51 is closed, and the outlet duct 42 communicates with the environment through the exhaust duct 43. The duct 56 of the cavity 54 is now cut off, and the cavity 53 is isolated from the pressure tank 2 (Fig. 1).

The cavity 53 is connected with the environment along the path: cavity 53 – duct 55 – ducts 42, 43 of control valve 40. This results in a pressure drop within the cavity 53 and under the dome-shaped part 50 of the shutoff device 48. Compressed air supplied from the pressure tank 2 along the duct 45 exerts a pressure on the outside surface of the dome shaped part of the shutoff device. Due to an unbalance of pressures acting on the outside and the inside surface of the dome-shared part of the shutoff device 48, the
latter is displaced along the cylindrical guide 49 away from the seat 47, until it contacts the annular stop 57. So the valve 5 comes to be open.

The streamlined form of the radial ribs 52 provides minimum air flow separation zones. The rounded-off joint between the dome shaped and cylindrical portions of the shutoff device 48 causes resistance to the resultant supersonic air flow to be reduced, and the domed shape of the shutoff device 48 allows a smooth flow around it. The design features result in high-speed valve 5.

It has been experimentally found that the valve 5, with the flow area of the outlet 46 not exceeding 20 cm², is opened within 1 ms.

As the control valve 40 is subsequently switched, the duct 41 is connected with the duct 42. In this case, the cavities 54 and 53 communicated along the path: cavity 54 - duct 56 - ducts 41, 42 of valve 40 - duct 55 - cavity 53.

Compressed air is supplied from the tank 2 to the cavity 53 through the duct 45.

Owing to the smooth flow around the outside surface of the dome-shaped part 50 of the shutoff device, the pressure exerted thereon is equal to the static pressure which is below the overall pressure in the cavity 53 by an amount of velocity head of air flow throw the open valve 5 outside the shutoff device 48. Due to pressure unbalance the shutoff device 48 is displaced against the stop into the seat 47. Acted upon by the air pressure under the dome shapes portion 50 of the shutoff device, the latter is pressed hard against the annular stop 57, cutting off the outlet duct 46 whereby the closed position of the valve 5 is ensured.

It has been experimentally found that, with the flow area of the outlet 46 not in excess of 20 cm², the valve 5 is closed within 1 ms.

Thus the opening and the closure of the valve 5, with the flow area of the outlet duct 46 no greater than 20 cm² is accomplished essentially within the same time not exceeding 1 ms.

The control valve 40 in the valve 5 may be, e.g., an electrically controlled pneumatic distributor 3/2, MHA2-MSIH-3/2G-
2-K available from FESTO AG (Germany), which provided a switching time of 2ms.

Considering the operating time of the known control valve, the time interval from the arrival of the control instruction to the completion of opening (closure) of valve 5, with the flow area of the duct equal to 20cm², does not exceed 3ms.

The opening time of the valve 5 is the shorter, the less is the mass of the shutoff device 48. It has been found by experiment that the opening and closing time of the above valve, with its outlet cross-sectional area not exceeding 10cm², is within the range of 0.5 to 0.8ms depending on the specimen.

The use of the valve with a short opening time provides a pneumatic impulse device for shaking down the bridged loose material in an industrial reservoir, which is more efficient than those known in the art, owing to the effect produced on the loose material by a shock wave generated in the discharge pipe of the pneumatic impulse device, with an appropriate choice of the pipe length - to - cross-section ratio.

Generation of the shock wave within the discharge pipe of the pneumatic impulse device runs as follows. At an initial point of valve opening, a small hole is formed, through which an air jet gushes out of the high-pressure area connected with the pressure tank. This hole is enlarged throughout the valve opening time with the consequently increasing cross-sectional area of the air jet supplied to the discharge pipe.

The air jet from the valve is a perturbation source generating compression waves in the air within the pipe, so that during the entire valve opening time, a compression wave packet is formed. The slope of the curve defining distribution of pressures in the compression wave, as it is propagated along the pipe, increases, since those phases of the compression wave, where the pressure is higher (and the sound velocity greater) propagate at a higher rate and catch up with the preceding ones. As a consequence, at a certain distance from the valve, the wave front is made so steep that it represents a shock wave. The shock-wave velocity exceeds the sound velocity, the more so as the shock intensity is greater.
As the valve opening time decreases, the distance at which the shock wave is generated is reduced and its intensity increased.

The phenomenon of generating the shock wave in the pipe is known from experiments with the so-called "shock wave tunnels".

The experimental results are described, for example, in: P. S. Shtemenko, "Generation of shock wave at an initial stage of the current adjacent the diaphragm in a shock wave tunnel", Vestnik MGU, 1968, 22, No. 1. The experiments were conducted on a pipe wherein a diaphragm dividing the pipe into two chambers (a high and a low pressure chamber) was used instead of a valve. The low-pressure chamber communicated with the outside. Gas was forced into the high-pressure chamber, followed by destruction of the diaphragm within different time spaces, to open the flow section of the pipe. The following experimental data was obtained, concerning the gas velocity after the shock wave, as a function of the pipe flow section opening time. With an opening time $T$ equal to 0.42ms, the maximum gas velocity $V$ of 750m/s was achieved at a distance $L$ equal to 50 times the internal diameter of the pipe. With $T = 0.680\text{ms}$, $V = 700\text{m/s}$, $L = 80$, and with $T = 0.75\text{ms}$, $V = 600\text{ m/s}$, $L = 100$. As the shock wave is further propagated along the pipe, an energy loss occurs, accompanied by a gradual drop in the gas velocity. If the pipe flow section opening time is much in excess of the sound propagation time in the gas at rest throughout the pipe length, no shock wave arises.

A simple calculation as applied to the discharge pipe of the pneumatic impulse device with an internal diameter of 32mm, shows that with a valve opening time of 0.42ms, the shock wave is generated at a distance of 1.6m from the valve, while with a valve opening time of 0.75ms, the shock wave is generated at twice the distance i.e. 3.2m from the valve. Extrapolation of the above experimental data leads to a conclusion that, with a valve opening time exceeding 2ms, only a very low-intensity shock wave may be obtained, and a discharge pipe with its length beyond the reasonable limits will be required.

The optimum length of the discharge pipe 6 of the pneumatic impulse device 3 (Fig. 1) is derived, given the opening time of valve 5, from the condition of generating the shock wave within the
discharge pipe 6 in close proximity to its output end 11. This eliminates the shock wave energy loss in the discharge pipe as compared to the case of a longer discharge pipe.

Fig. 6 illustrates a pneumatic impulse device with a loose material bridging sensor 7. The sensor is positioned so that it indicates the bridging of loose material at the discharge pipe location point. It is most convenient to place the sensing element of sensor 7 inside the distribution reservoir 1 immediately beneath the discharge pipe 6.

In this embodiment, the sensor 7 comprises a commercially available rotary level indicator for the material contained in industrial reservoirs model RP30A, manufactured by Fine Automation Co, Ltd. (Taiwan). Operation of the rotary meter is based on braking the rotation of a blade mounted on the rotor of the electric motor, when the blade penetrates deep into the bulk of the material.

The signal to stop the rotation of the blade a change in the motor feed current. In case the loose material is bridged in the location area of this pneumatic impulse device, the blade rotation is stopped, and a signal is applied to the control unit 4, which has a logical level, say, "1", indicating the loose material bridging. With the material normally moving inside the distribution reservoir, the blade rotates, a signal with a logical level, say, "0" is applied to the control unit 4. Discrimination between the signals of the rotary indicator is carried out in the control unit 4, using know signal processing means.

The loose-material bridging sensor 7 may also be a capacitive sensor such as "Kompact SU 500" based on the effect of increasing the electric capacitance of the sensing element, when the material gets into the sensitive zone. These sensors are offered by ZAO "Contact-1" (based at Ryazan town, Russia) and designed to indicate the level of granular and liquid materials in industrial reservoirs. If loose material is bridged at the sensor locations, the fixed material comes to be in the sensitive area of the capacitive element, which corresponds to the expected operating conditions of the sensor. In this case, the sensor signal has a constant level, e.g., logic level - 1, indicating the contact with
the fixed material. With the distribution reservoir normally
operated, loose material is essentially left outside the sensitive
area of the capacitive element and a signal having, e.g., a logic
level – 0 level is received by the control unit 4. The capacitive
sensor signals corresponding to the two conditions are
discriminated by the control unit 4, using a known signal
processing means.

Fig. 6 represents an embodiment of mounting the pneumatic
impulse device 3 on the distribution reservoir 1, in which the
discharge pipe 6 is horizontally secured, perpendicular to the wall
of the distribution reservoir 1. The output end 11 of the discharge
pipe 6 is inside the distribution reservoir 1.

The sensing element of the loose material bridging sensor 7 is
located immediately below the end 11 of the discharge pipe, in
order to warn about the hang-up of loose material inside the
distribution reservoir 1 at the location of the discharge pipe 6,
and to protect the sensitive element of the sensor 7 from being hit
by lumps of loose material falling down from a great height, inside
the distribution reservoir 1.

Fig.7 shows another embodiment of mounting the pneumatic
impulse device 3 on the distribution reservoir 1, in which the
discharge pipe 6 is secured to the wall of distribution reservoir
1, slantwise, with its output end 11 pointing downwards. Such
arrangement of the discharge pipe 6 may provide better conditions
for shaking down the hang-up of part of the loose material, as
compared to the embodiment of Fig.6. Similarly to the embodiment of
Fig. 6, the sensing element of the loose material bridging sensor 7
is positioned directly below the end 11 of the discharge pipe, to
give warning about the hang-up of loose material within the
distribution reservoir 1, at the point where the discharge pipe 6
is located.

Implementation of the loose material shakedown system in the
distribution reservoir and its operation is illustrated by the
example as follows.

The pressure tank 2 (Fig.2) is made of welded sections of a
steel gas pipe with an internal diameter of 209mm, an overall
length of 40mm, and a volume of 1,4m3. The ends of two pipe
sections of the tank 2 are interconnected so as to form rings. The pipes combined to form the tank 2 extend along the outside surface of the distribution reservoir 1 so that they pass near the selected locations of the discharge pipes 6 of the pneumatic impulse devices 3. The pressure tank 2 is connected with the external compressed-air supply line (not shown). The volume of the tank 2 is sufficient to provide simultaneous operation of thirty pneumatic impulse devices 3 distributed over the entire area 20 of probable bridging of loose material. The valves 5 (Fig.1) of the pneumatic impulse devices 3 have outlet duct 35mm in diameter, the inside diameter of the discharge pipes 6 being 32 mm. The valve opening time is within 1ms, the pipe lengths ranging from 3 to 4.5m. For each pneumatic impulse device, a pair of holes lying one below the other are provided in the concrete wall of the distribution reservoir. In the upper hole, the discharge pipe 6 is mounted, while the lower hole is used to insert the rotary loose-material bridging sensor 7 into the inner space of the distribution reservoir 1. The outputs of the sensors 7 are applied to the control unit 4. The control unit 4 sends equally spaced (every 100ms) instructions for opening and closing the valve of that pneumatic impulse device from whose sensor the loose-material bridging signal is received. Thus impulses of compressed air are fed into the discharge pipe of the pneumatic impulse device, producing each a shock wave generated in the discharge pipe, which acts upon the bridged loose material. The compressed-gas impulses are applied as long as the loose material bridging signal is received from the sensor of this pneumatic impulse device.

Such algorithm of operating the bridged material shakedown system ensures a cost effective shakedown regime, since compressed air is only spent at the time when the bridging occurs, and only at those points of the distribution reservoir where it has occurred.

The effect of the shock wave on the bridged loose material, which is provided by the pneumatic impulse devices of the present invention, results in a highly efficient shakedown of bridged loose material.
CLAIMS

1. A system for shaking down the bridged loose materials in a distribution reservoir, comprising a pressure tank, at least one pneumatic impulse device, and a control unit, the pneumatic impulse device including a valve, a discharge pipe and a loose material bridging sensor, the control unit is connected with the sensor to receive signals therefrom, and with the valve to apply control instructions thereto, the inlet port of the valve is connected with the tank, and the outlet port of the valve is connected with the input end of the discharge pipe so positioned that the open output end of the discharge pipe penetrates into the distribution reservoir, the valve is adapted to open and close the duct from the tank to the input end of the discharge pipe in response to the control instructions, the loose material bridging sensor being positioned so as to indicate the bridging of loose material at the discharge pipe location.

2. A system of Claim 1 in which the valve opening time is within 2 ms, and the length of the discharge pipe is at least such that the ratio of the discharge pipe length to its inside diameter provides generation of a shock wave in the discharge pipe, as a result of the valve opening during operation of the system.

3. A system of Claim 2 in which the valve opening time does not exceed 1 ms.

4. A system of Claims 2, 3 in which, with a specified inside diameter of the discharge pipe, its length is selected such as to provide generation of a shock wave at the output end of the discharge pipe.

5. A system of Claim 1 comprising at least two pneumatic impulsive devices whose discharge pipe locations are distributed over the area of probable bridging of loose material in the distribution reservoir, the pressure tank being made of a pipe of a specified diameter extending along the outside surface of the distribution reservoir adjacent the discharge pipe locations.

6. A system of Claim 5 in which the tank includes at least one pipe ring adapted to be positioned so as to encircle the distribution reservoir.
7. A pneumatic impulse device for shaking down the bridged loose materials in a distribution reservoir, comprising a valve and a discharge pipe, wherein the valve has an inlet port for connection to the external compressed gas tank and an outlet port for connection to the input end of the discharge pipe, the valve being adapted to open the duct from the tank to the input end of the discharge pipe within 2 ms, in response to instructions represented by electric control signals, the length of the discharge pipe being selected at least such that the pipe length-to-internal diameter ratio provides generation of a shock wave in the discharge pipe, as the valve is opened, when the valve is connected to the pressure tank.

8. A pneumatic impulse device of Claim 7, in which the valve opening time does not exceed 1 ms.

9. A pneumatic impulse device of Claims 7, 8 in which the length of the discharge pipe is selected such as to provide generation of a shock wave at the output end of the discharge pipe.

10. A pneumatic impulse device of Claim 7, further including a control unit connected with the loose material bridging sensor to receive signals therefrom, and with the valve to send instructions to open and close the valve.

11. A method of shaking down the bridged loose material in a distribution reservoir by compressed-gas impulses generated by at least one pneumatic impulse device, comprising a valve, a discharge pipe, and a loose material bridging sensor, wherein the outlet of the valve is connected with the input end of the discharge pipe, the inlet of the valve is connected to the source of compressed gas, the discharge pipe being positioned so that its open output end penetrates into the distribution reservoir in the area of probable bridging of the loose material, the valve being adapted to open and close the duct between the source of compressed gas and the discharge pipe, in response to instructions in the form of electric control signals, the loose material bridging sensor being positioned so as to receive therefrom a signal indicating the presence of the bridged loose material in the distribution reservoir at the discharge pipe location, the valve being left closed as long as there is no loose material bridging signal,
following one after another succeeding instructions to open and close the valve being applied, and repeated provided the bridging indication signal keeps coming.

12. A method of Claim 11 in which the sensor signals are applied to the electronic control unit generating instructions to open and close the valve according to the sensor signals.

13. A method of Claim 11 in which the valve opening time does not exceed 2ms, and the length of the discharge pipe of the pneumatic impulse device is selected at least such that the pipe length-to-inside diameter ratio provides generation of a shock wave in the discharge pipe as the valve is opened.

14. A method of Claim 13 in which the valve opening time is within 1ms.

15. A method of Claims 13, 14 in which, with a specified inside diameter of the discharge pipe, its length is made such as to provide generation of a shock wave at the output end of the discharge pipe.

16. A method of Claim 11 which employs at least two pneumatic impulse devices whose discharge pipe locations are distributed over the area of probable bridging of loose material in the distribution reservoir, the source of compressed gas being a pipe lying in the vicinity of the discharge pipe locations.

17. A method of Claim 16 in which the pressure tank includes at least one pipe ring encircling the distribution reservoir adjacent the probable bridging of loose material.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. B65D88/70
ADD. F16K1/12

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)

B65D B65G F16K

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

Electronic database 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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Further documents are listed in the continuation of Box C.

See patent family annex.

**Date of the actual completion of the international search**

4 August 2006

**Date of mailing of the international search report**

14/08/2006

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epic nl, Fac. (+31-70) 340-3016

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Garlati, T

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