SHAPA TECHNICAL PAPER 11

The Protection of Silos From Over Pressurisation During Filling

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Abstract

Within the construction industry there have been a number of serious accidents involving silos, which have been over-pressurised by tankers, this has resulted in the Health & Safety Executive (HSE) issuing a guidance note on this subject. These recommendations have largely been reflected in the process guidance note for bulk Cement silos, PG 3/1 (2001), issued by the Secretary of State.

Although directed at the Cement, Concrete and Quarrying industries, these guidelines have obvious implications for all other industries, which utilise tanker filled silos.

This paper will discuss the five key recommendations made by the HSE and identify the test work undertaken by Portasilo to support these recommendations – with some alarming results.

The paper will also look at the implications of the guidance notes with regards to the design and operation of tanker filled silos. Whilst tackling these five key points to ensure that all silos, new and existing, can be supplied or modified to meet the current standards by putting into place measures to prevent the over pressurisation of silos and by providing an ultimate basis of safety... a pressure/vacuum relief valve (PRV).

Background to the Guidance Notes

In the case of each of these accidents, the silos became pressurised during pneumatic filling by a road tanker. The connection between the reverse jet filter and the silo roof was found to be the weak link and resulted in the 250kg filter unit being dislodged from the silo roof. In at least one case, this filter seriously injured the tanker driver.

The underlying problem in each case was found to be the pressure relief valve, which was undersized for the maximum airflow entering the silo. The problem was also exacerbated by a significant lack of maintenance and by the overfilling of the silo.

Fig 1: Background to Guidance notes

The guidance note makes recommendations for overall management control at the offloading point, together with a requirement for a documented maintenance regime for the filter unit and safety pressure relief valve. These recommendations are not particularly contentious; however, there is also a requirement to select a suitably sized vent filter and pressure relief valve for the anticipated peak airflow rate. It is the quantification of this flow rate, which was contentious, together with the requirement for an automatic shut-off system in the silo fill line.

Validation of the Air Flow Rate

The peak airflow occurs when the tanker is allowed to depressurise in an uncontrolled manner at the end of the delivery. The higher the tanker pressure or the shorter the delivery line, the higher the air flow.

This uncontrolled depressurisation of a road tanker is considered to be bad practice and management controls should be in place to prevent it; but its accidental occurrence is inevitable and must be taken into account.

In the HSE guidance note, the peak flow is calculated using a formula for conventional fluid dynamics. A 2 bar g road tanker depressurising through a 10m long inlet pipe with one 90º bend would give rise to an airflow of up 13,000m^3/hr. This figure is significantly higher than the 2000m^3/hr conventionally allowed for by the industry; so it was widely disbelieved resulting in a slow adoption of the HSE's recommendations.

Portasilo undertook a series of tests to try and understand what was really happening whilst a road tanker was discharging. The test work undertaken was designed to measure the airflow and the surge at the end of the conveying cycle. Although the measured results are less than those calculated, the differences can largely be accounted for by friction losses caused by an unpolished inlet pipe, plus losses through the onboard pipework and the flexible connecting hose.

Given that a highly polished pipe can be expected after some months' service and that the other losses are likely to be vehicle dependant, these calculated figures appear to present a conservative, but realistic basis for sizing equipment

The surge in flow experienced at the end of the cycle is clearly not a transient peak; therefore, it cannot be disregarded due to its short duration. Flow rates in excess of 2000m^3/hr, the figure conventionally used for design, are sustained for many minutes. The results of these tests and a comparison with calculated figures are shown in Fig 2.

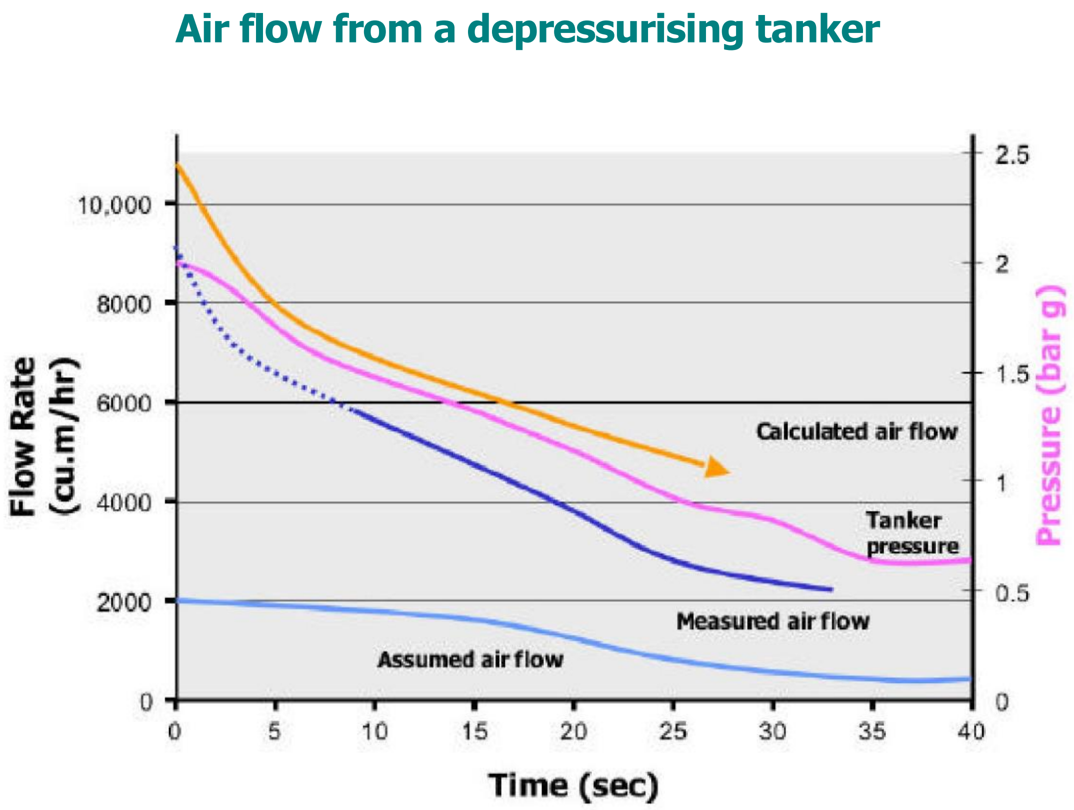

Fig 2: Airflow rate from a depressurising tanker

Implications on silo design and operation

Silo vent filter

The implications for filter sizing are not as onerous as might be expected, despite this large airflow – because... nothing has changed! Filters are conventionally sized on empirical rules that take into account the large surge in airflow on completion of the tanker's discharge. Although the numbers have changed, they have changed on both sides of the equation.

Portasilo surveyed a large number of OPC silo installations and the results indicated that filter size was not so important as might be first thought. Bag filters as small as 10m^2 were giving excellent performance after 20 years service, whilst much larger filters less than a year old were performing badly. Filter media area is obviously important, but the filter must also be well engineered, well maintained and installed on a generously sized silo.

Pressure/vacuum relief valve

Unlike a silo filter, pressure relief valves are typically sized by calculation. If the maximum airflow is under estimated, then even the best quality valve will be undersized and will fail to provide adequate protection for the silo to which it is fitted.

As part of the tests undertaken by Portasilo, direct tests were conducted on a number of pressure relief valves.

These trials consisted of a road tanker with a pressure relief valve coupled directly to the end of the filling pipe. The tanker was depressurised and the pressure accumulation was measured. Although this was an extreme test, this scenario is similar to a full silo with a blocked filter; which was a common factor on all the damaged silos.

It quickly became evident from these tests that the valves' capacities were significantly less than those claimed by the manufacturer. Further investigations revealed that both calculation errors and an effect known as pressure piling were to blame. The shape of the valve seat and proximity of the weather cover are critical and can give rise to a very significant reduction in valve capacity. These test results are shown in Fig 3 along with the manufacturer's claimed capacity.

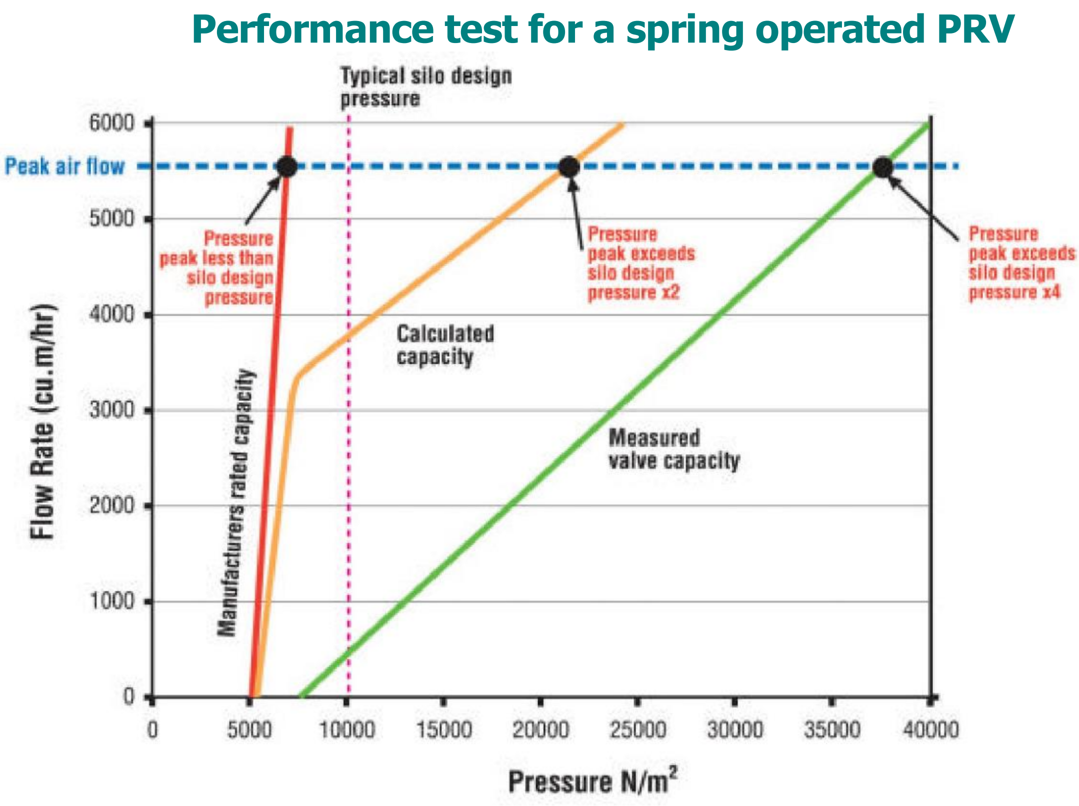

Fig 3: Performance test for a spring operated pressure relief valve

It was also evident that the spring loaded valves have a limited opening, due to short springs; which severely restricts the out breathing capacity and gives them a poor tolerance to powder build up. At first the dead weight valves seemed to fare better as pressure relief valves, but as their name suggests they use dead weight to provide the correct pressure relief setting. Therefore, the inertia required to lift the weight is great, resulting in transient pressure peaks greater that the silo's design pressure, which can be potentially damaging. They also suffer a similar problem of powder build up when utilised for vacuum relief.

From the results obtained, it was concluded that an ideal valve should be spring-loaded for both pressure and vacuum relief with long travel springs to maximise the valve's opening. A weather cover should be designed to prevent powder build up, which should also minimise the effects of 'isokinetic' crashing and facilitate the weekly test required by the HSE. Therefore, It should also be fitted and easily removed without tools.

Most importantly, the valve must be tested at peak flow rates and certified to confirm this! Certificates should be carefully scrutinised to ensure that tests were conducted at the peak flow rate and at specified pressure set points. Finally the pressure accumulation of the valve must be taken into account. The valve must relief the maximum flow rate whilst ensuring that the pressure build up within the silo is less than that of the silo's design pressure.

Automatic shut off system

The automatic shut-off system stipulated by the guidance note comprises of an actuated valve in the fill pipe, operated by both pressure and level sensors. In addition, to preventing damage to the silo filter, such a system can prevent nuisance operation of the pressure relief valve and hence, emission of dust to the atmosphere.

It is conceivable that such a system could be used as the basis of safety for the silo, instead of the relief valve. However, all components and circuitry need to be arranged to fail-safe and the level of risk involved would justify duplicate instrumentation with cross checking safety circuitry.

It is therefore, more realistic to use a suitably sized pressure relief valve for protection of the silo, and to provide a simpler version of this shut-off system to protect the silo filter from the damaging surges and to prevent dust release to atmosphere. In order to give the tanker driver a chance to carry out a controlled shutdown prior to the automatic closing of the shut off valve, a two-stage alarm system for both silo level and pressure should be provided.

Management Control at the unloading point

It is important that clear instructions are provided for the tanker driver at the offloading point. These should prohibit uncontrolled venting of the tanker through the silo and instruct the driver to carry out a controlled shut down in the event of an alarm prior to the automatic closing of the shut off valve.

Documented maintenance

Weekly maintenance checks should include the operation of the pressure relief valve and to confirm the operation of the reverse jet filter. The condition of the filter bags is easily monitored by measuring the differential pressure across the filter; however, the reading must be taken during the silo filling operation. An analogue gauge or digital display of silo filter's differential pressure is therefore, best mounted adjacent to the filling point rather than located on the silo roof.

Summary

1) A reverse jet filter in the order of $20m^2$ should be considered for new projects. Exact area and filter media choice will depend on the dust being handled. Of equal importance is the number of cleaning valves and a generously sized casing to allow separation of the dust and air.

2) A combination pressure/vacuum relief valve sized for the peak flow rate needs to be provided. The set pressure must be high enough to prevent accidental dust leakage (typically around 500m WG) and the pressure accumulation must be less than the silo design pressure. (Typically in the order of 1000mm WG). The valve must be certified for this maximum airflow (13,000m^3/hr) and must be tolerant of dusty air.

3) An automatic shut-off system should be provided, comprising of a control unit and an actuated valve in the silo fill line. This is operated by both pressure and level transducers installed in the silo. A digital/analogue display for the filter's differential pressure will indicate the condition of the reverse jet filter and facilitate its maintenance. If this is supplied in addition to the pressure relief valve, fail-safe circuits are not required.

4) Clear instructions should be provided at the offloading point for the tanker driver.

5) A documented maintenance regime should be introduced to ensure regular inspection of the relief valve, the filter and the automatic shut-off system.

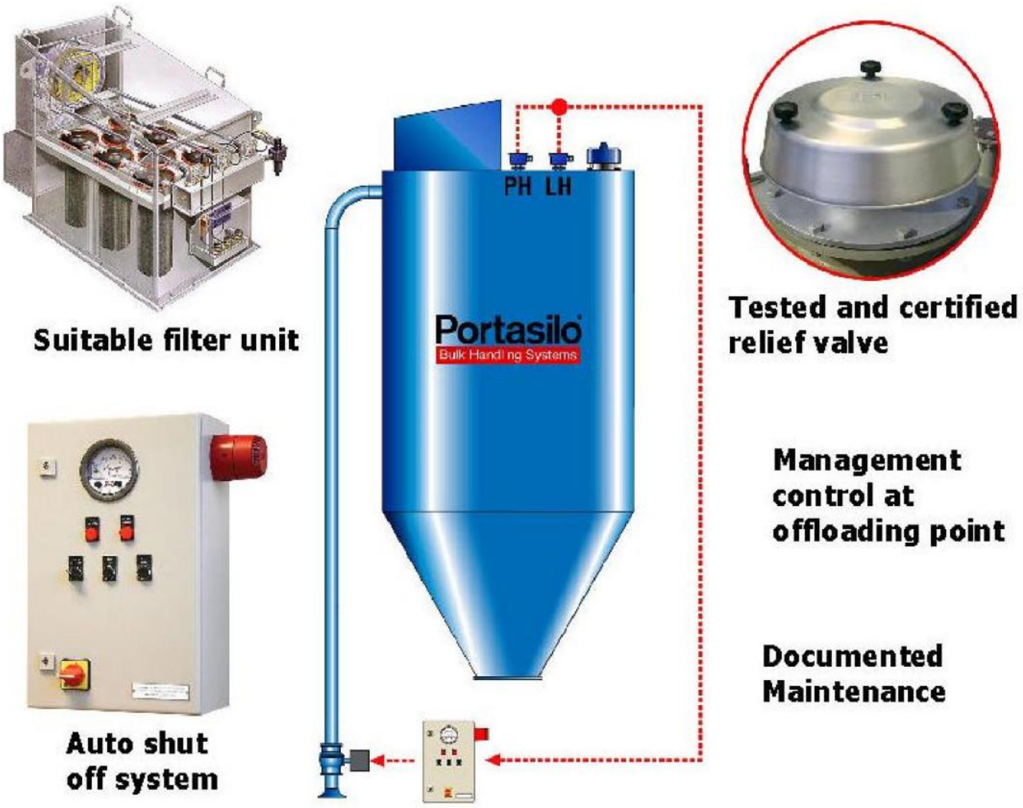

Fig 4: Summary