INTRODUCTION

This document is aimed at focussing attention on the most important and complex aspects of safety: the risk of overpressure and negative pressure that may occur in silos and/or containers for powders and/or granules provided with filtration systems. In addition to the technical presentation of the phenomena, some experimental results are presented here, too. A calculation procedure enables engineers and technicians of the sector to estimate the risk of overpressure and negative pressure in the industrial filtration of dusts.

SILO SAFETY TECHNOLOGY

Solids in powder or grain form that are neither flammable nor toxic are stored in tanks (silos) that are in contact with the atmosphere through solid-gas separation systems. The silo design pressure is usually limited and the mechanical structure is not usually able to support conditions of excess or negative pressure. Generally, in order to avoid dust emissions into the atmosphere that are higher than the levels permitted by law, contact of the silo with the atmosphere passes through suitable dust collector systems, such as cyclones separators or filter systems.

Material loading into a silo may be carried out in one of the following ways:

- by mechanical handling system;
- by pneumatic positive-pressure system (in dense or dilute phase pneumatic conveying systems);
- by pneumatic negative-pressure system.

While mechanical product loading does not usually affect the pressure conditions inside the silo, during pneumatic loading – bearing in mind the gas involved – there may be dangerous pressure conditions inside the silo, caused by:

- malfunction in the machine that generates the gas flow (compressor or vacuum pump);
- wrong set-up of loading conditions or human error, particularly in loading systems placed on vehicles;
- cleaning of the pneumatic loading system under high gas flow rate or pressure;
- malfunction of the dust collector system (e.g. obstruction of filter elements).

Unloading a silo can be done by:

- mechanical handling system;
- pneumatic negative-pressure system.

In this case, too, abnormal internal pressure conditions may be caused by:

- wrong use of aeration pads to assist off-loading;
- malfunction in the dust collector system (e.g. obstruction of filter elements);
- malfunction in the vacuum system, which provokes a higher depression than that designed for the equipment;
- sudden discharge of the stored material from the silo.
These abnormalities cause an increase or decrease in pressure inside the silo, which may damage the silo structure. According to the international ISO 8456 standards concerning storage equipment for large quantities of bulk solid materials, it is necessary to use suitable pressure re-establishing devices for silos and hoppers, which, due to their loading and unloading methods, are subject to internal pressure variation. These devices, usually known as pressure relief valves, basically are valves that allow air into and out of the silo and, therefore, guarantee the safety of the silo if there is a change in internal pressure. The factors to be considered when choosing a relief valve are:
- design pressure of the silo range;
- type of solids stored, in order to choose a material suitable for the construction of the valve body, casing, plug and seals.

PRESSURE RELIEF VALVE: OPERATING PRINCIPLES

In designing a plant that pneumatically handles any type of fluid, it is very important to take into consideration the safeguarding of silos from possible danger of excess pressure and negative pressure (fig.1). The silo is pressurised during filling and set in negative pressure during emptying. When air does not flow in or out correctly possibly due to clogging of the filter, the pressure or depression caused inside may be so excessive as to lead to explosion or implosion, thereby resulting in serious danger to people and the environment. To avoid such problems, one of the solutions consists in fitting a pressure relief valve. In applications where powders and granules are handled, a "direct action" pressure relief valve is used, which may be of the lever weighted, spring loaded (Fig.2) or diaphragm type. Of these, the systems with spring-loaded valve are the most popular, thanks to their excellent performance/price ratio.

CRITICAL CONFIGURATIONS OF THE PRESSURE RELIEF VALVE

A spring-loaded pressure relief must be capable of satisfying the following requisites:

1) Operation

The pressure relief valve must operate in excess pressure (a) and in negative pressure (b);

a) During the pneumatic loading phase of the silo, when the pressure inside increases, exceeding the calibration value of the pressure relief valve, the valve plate (calibrated by three external springs) rises, to let out pressurised air (Fig.3).

b) During silo emptying, when negative pressure created inside the silo exceeds the valve calibration value, the plate (regulated by the central spring) lowers itself,
allowing air to enter the silo and thus balancing the negative pressure created inside (Fig. 4).

![Figure 4 Pressure Relief Valve in a Vacuum application](image)

**Figure 4 Pressure Relief Valve in a Vacuum application**

Figure 5 represents a correct device.

![Figure 5 Correct Device](image)

**Figure 5 Correct Device**

Figure 6 represents an incorrect device, as it does not provide protection from the risk of excessive negative pressure.

![Figure 6 Incorrect Device](image)

**Figure 6 Incorrect Device**

### 2) Sizing

**2.1) To allow correct inflow and outflow of air from the container as regards time/capacity, the ratio between the useful outlet surface “Y” between the valve and cover and silo filling pipe diameter “X” (std. condition $\phi=4^\prime$) must be greater than a minimum value. Experimental considerations and constructional experience indicate that:**

![Figure 7 Ratio Y/X > 4](image)

**Figure 7 represents the ratio between the Y and X**

If the ratio given above is not respected, the isokinetics of the airflow at the pressure control valve are interrupted prematurely, leading to incorrect operation of the safety device. In Fig. 8a) it can be clearly observed that the cover is too close to the valve body; the elbows are
broken up prematurely and do not allow correct backflow of air; the backflow of air is too slow to allow proper lowering of pressure inside the silo. Fig 8b) shows the correct diagram of the isokinetics ensuring correct working of the pressure control valve.

2.2) The valve diameter must be such as to eliminate all risk of explosion of the container. Taking into consideration a fully loaded 700 cu.ft silo, observe the difference in behaviour of a \( \phi = 10'' \) valve and a \( \phi = 10'' \) valve as described below:

The diagram in Fig. 9 represents operation of the two pressure relief valves of different diameters, calibrated at 16” H₂O. Elbow c1 (\( \phi = 10'' \)) indicates correct backflow of air from the silo; elbow c2 (\( \phi = 10'' \)) shows a dangerous situation because, for a certain amount of time, the pressure inside continues to increase. (Fig. 9)

Figure 9 shows the curve representing the proper functioning of the Pressure Relief Valve
The presence of diagrams of the type shown in Fig. 10 thus assumes particular significance for the design engineer, where it is possible to evaluate and compare the actual outflow capacity of the valve.

### 3) Constructional features

#### 3.1) The activating springs must be protected to ensure proper operation over time;

#### 3.2) The contact between the seal (closed-cell rubber recommended) and body valve to ensure proper working must be minimum, to avoid encrustation, and thus gluing; (Fig. 11)

#### 3.3) The parts must be made of stainless steel or powder-coated carbon steel; it is advisable to avoid galvanised carbon steel as it causes rusting, thus contaminating the product and damaging the seal.

The topics described at item 1 and 2 are binding for correct sizing and choice of the safety device to be fitted on top of the silo for operating in excess and negative pressure conditions.

An example of a correct safety device is shown below.

### CONCLUSIONS

On the basis of what has been described above, it is clear that the pressure relief valve to be fitted on top of the silo is not easy to choose, and since there is a number of factors that determines correct design (pressure, material handled, etc.) it is advisable to consult a specialist of the sector.

Making the correct choice/use of the pressure relief valve on top of the silo is the responsibility of the designer and the user, with all the practical and legal consequences.

For any further question please do not hesitate to contact our experts at info@waminc.com or by calling 1-817-232-2678 or visit us at www.waminc.com.

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### STANDARDS

Standards and laws are already in force that govern the various technical and functional aspects of safety devices to be used for the plant. The main standards are described below:
1) **UNI / ISO 8456:**

5 Special safety regulations
- 5.1.1.2.2 Every time the type of material or the feeding or unloading method is modified, causing unbalanced pressure inside hoppers or silos, a device must be provided to balance the pressure;
- 5.1.1.4.3 If feeding is performed using a system in negative pressure, a suitable safety device must be provided on the system to protect it from negative pressure exceeding the permitted limit;
- 5.1.1.4.2 If feeding is performed using a pressurised system, a pressure relief valve must be provided to protect the system from excess operating pressure higher than permitted.

2) **DIN 4119**

Chapter “Tanks over ground”

6 Loading hypothesis
6.1.2.2 Internal pressure and negative pressure

a) The buyer must communicate the calibration pressure value (kg/m²) of the valves in excess pressure and negative pressure to the manufacturer in a binding manner.

b) The calibration value of the valve can be introduced in the statistic checks as load, provided that the number and size of these are suitable for the size of the tanks and power of the pumps.

3) **EN 617**

See attachment in the original language (text is published in the original language to avoid misunderstandings).
REFERENCES

- UNI ISO 8456 Standards.
  DIN 4119 Standards.
- Raffaella Ocone and Gianni Astarita: Pressure shocks and pressure waves in granular systems.
- FOCUS: Quando le polveri esplodono. 1996/No.3.
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