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A REVIEW OF EXPLOSION ISOLATION TECHNIQUES FOR DUSTS

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SESSION 2

PROTECTION FROM EXPLOSION INITIATED IN THE PROCESS

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A REVIEW OF EXPLOSION ISOLATING TECHNIQUES

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Abstract: *The paper present the "explosion isolation techniques", the aim of which is to prevent the propagation of explosions from a vessel to other vessels via pipelines. This technology has also been appreciably extended. Explosion isolation systems for explosions of combustible dusts can in general be effected by rotary air locks, extinguishing barriers, explosion protection slide valves, explosion protection float valves, or diverters. Explosions in pipelines can be interrupted by flame barriers, such as mechanical flame barriers (rotary air locks) and extinguishing barriers. Explosion protection slide valves or explosion protection float valves prevent excessive pressure loads in enclosures interconnected by pipelines, or prevent an explosion propagating from protected equipment into the non-protected parts of an installation. Containers containing flammable or explosible gas or vapors mixtures must be protected against ignition originating outside the container. This can be achieved by end-line flame arresters in the attached pipelines. The installation of such elements prevents the propagation of a fire, an explosion or a detonation to the container under protection. The same explosion protection technology applies analogously to containers connected by pipes in which the formation of gas/air or vapor/air mixtures can present a hazard. In this case in-line flame arresters are used.*

1 Combustible Dusts

To prevent an explosion occurring in e.g., a constructional protected installation, from spreading through a pipeline (l > 6 m) to part of the installation fitted with preventive explosion protection, explosion isolation measures (Fig. 1) must be implemented /1/.

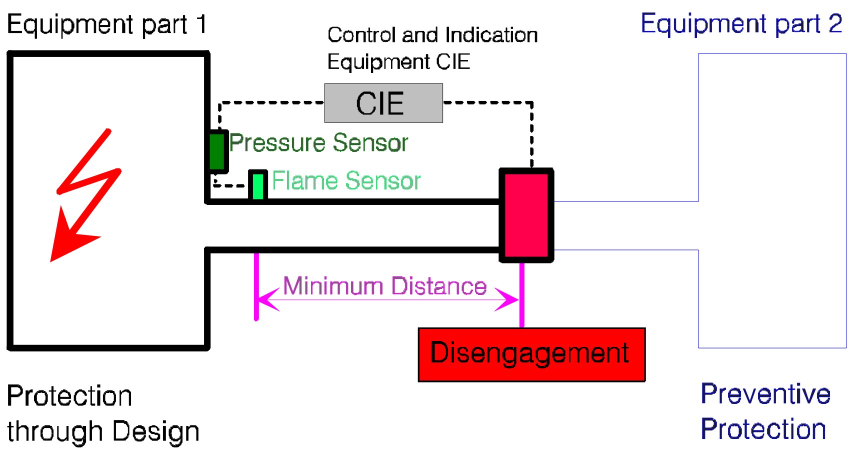


Figure 1. Principle of the constructional measure explosion isolation

As explosions are generally propagated by *flames* and not by the pressure waves, it is especially important to detect, extinguish or block this flame front at an early stage, i.e. to isolate or disengage the explosion. If there is no explosion isolation the flame issuing from the equipment e.g. from the equipment protected through design (Equipment part 1), through the connecting pipeline comes into contact with a highly turbulent pre-compressed mixture in the equipment with preventive protection (Equipment part 2). The mixture will ignite in an instant and explode; a large increases in the rate of combustion reaction and, naturally, in the reduced explosion overpressure is the result. The equipment in question may be destroyed.

The following explosion isolation systems for explosions of combustible dusts in general can be effected by ***rotary air locks, extinguishing barriers, explosion protection slide valves, explosion protection float valves ,*** or ***diverters*** /1..3/.

1.1 Rotary Valve

The mechanical flame arresters (see Fig. 30) which are used for explosion isolation of flammable gas and solvent vapor explosions are very susceptible to the action of dirt and, with one exception, are thus *not suitable for dust-carrying* pipelines. The exception involves the *rotary valve* which is based on the flame quenching effect through narrow gaps and is mainly used at product charging and discharging points (Fig. 2).

As a rule of thumb, it was found for normal organic dusts that the ignition cutout of rotary air locks is effective when 3 rotor blades on each side are diametrically opposed, provided that the blades are made of metal and the gap between the tip of the rotor blade and the housing is $w \leq 0.2$ mm. For aluminum powder the gap between the tip of the rotor blade and the housing is $w \leq 0.1$ mm /2,3/.

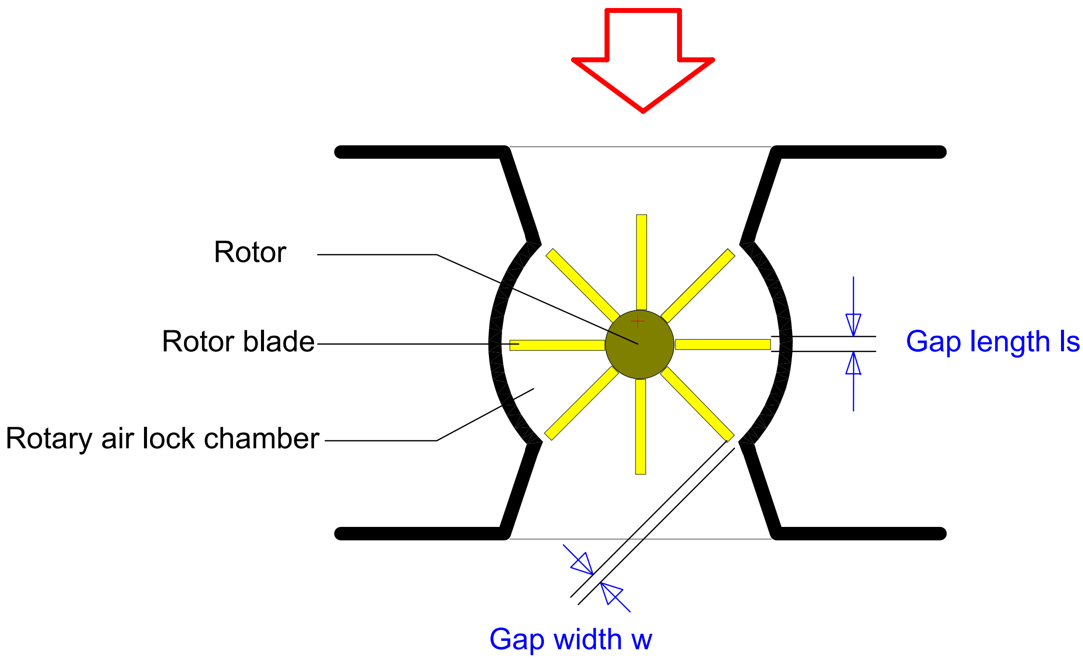


Figure 2. Design features of a rotary air lock

The size of the gap between the rotor blades and the housing depends on the design and is important for the ignition breakthrough protection of the rotary air lock since the limiting gap width for combustible dusts like that for flammable gases lies in the mm range. With the aid of a nomogram /2..5/ and knowledge of the **minimum ignition energy MIE** and the **minimum ignition temperature MIT** of a dust, the gap length **ls** and the number of rotor blades always diametrically opposed ns, the minimum admissible gap width **w** between the blade tips and the inside wall of the rotary air lock can be determined (Fig. 3).

As Figure 3 shows, the product of the MIE and the reduced MIT (1+MIT/273), the so called **reduced ignition product**, has been used in order to take the two influencing factors MIE and MIT into account. The MIT values were measured in the BAM furnace. The relation shown in the Figure 3 can also be described by the following equation /6/:

$$\mathbf{w = 3\cdot10^{-7} + 7.55\cdot10^{-3}\cdot\log MIE\,\{1+(MIT/273)\} + 1.92\cdot10^{-2}\,[MIE\{1+(MIT/273)\}\,]^{0.06182}\; ns^{2.224 + 5.167\cdot10^{-2}\cdot \log MIE\{1+(MIT/273)\}}\cdot ls} \qquad \mathbf{(1)}$$

Where:
ls is the gap length in mm: 0 mm ≤ ls ≤ 10 mm
MIE is the minimum ignition energy in J
MIT is the minimum ignition temperature in °C measured in the BAM oven

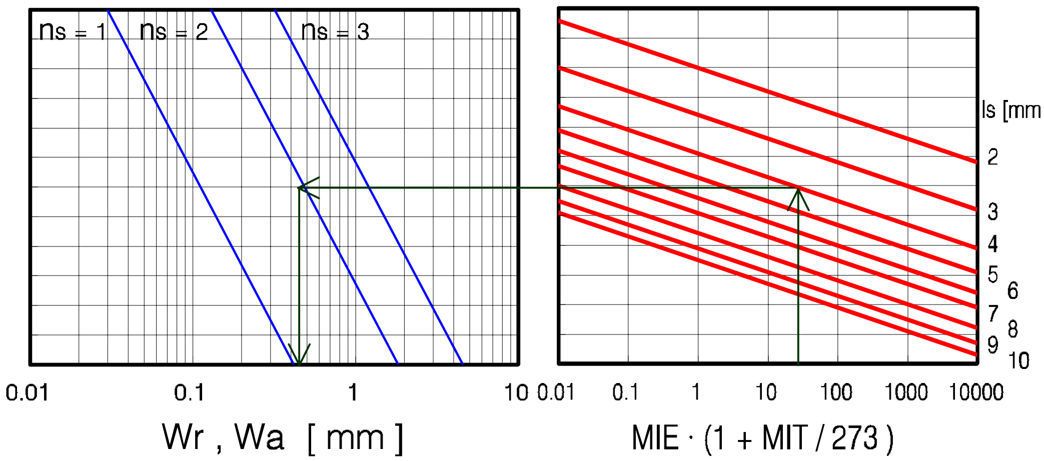


Figure 3. Nomogram for the determination of the radial (Wr), axial (Wa) dust-ignition proof gap dimensions of rotary air locks

The nomogram in Figure 3 and the equation (1) applies to rotary air locks with both open and closed rotor. Further, the following points must be noted to assure the ignition breakthrough protection of rotary air locks:

- The rotary air lock blades must be made of metallic materials and have a thickness of at least 3 mm.
- The rotor must have a strong enough construction to ensure no displacement in the radial or axial direction if an explosion occurs.
- The housing and the housing cover must be explosion resistant for the corresponding explosion overpressure.
- In the event of an explosion, the lock must be shut down automatically to prevent a secondary fire or secondary explosion resulting from the transport of lumps of smoldering material.
- The nomogram in Figure 3 and the equation (1) may be used only for organic dusts and wettable sulfur.

In the event of an explosion, the valve must be automatically stopped to prevent any subsequent upstream fire or explosion due to through passage of smoldering material or burning product through the valve.

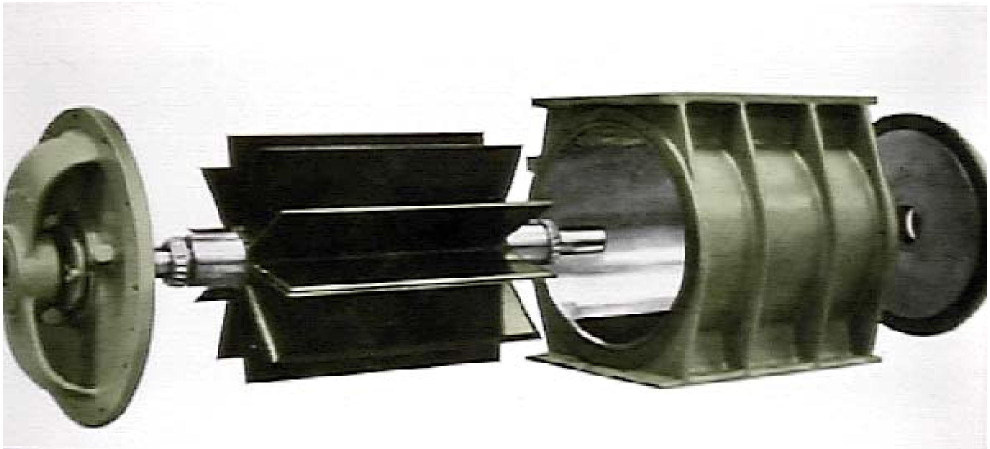


Figure 4. Example of a type tested rotary air lock /7/

1.2 Extinguishing Barrier

An extinguishing barrier comprises an optical flame sensor and a HRD-Suppressor located downstream of the detected flame front. The effectiveness of an extinguishing barrier is based on its ability to detect an explosion in a pipeline by means of an optical flame detector whose tripping signal is amplified and then very quickly actuates the detonator-actuated valves of the pressurized HRD-Suppressors (Fig. 5). In case an equipment is protected by a design measure e.g., containment, suppression or venting, the usual explosion pressure sensor with a corresponding low activation pressure can also be used to initiated the triggering mechanism for the extinguishing barrier. The extinguishing agent - preferably extinguishing powder - is discharged into the pipeline and forms a thick blanket, which extinguishes the incipient flame. This type of barrier does not impede product throughput down the pipeline.

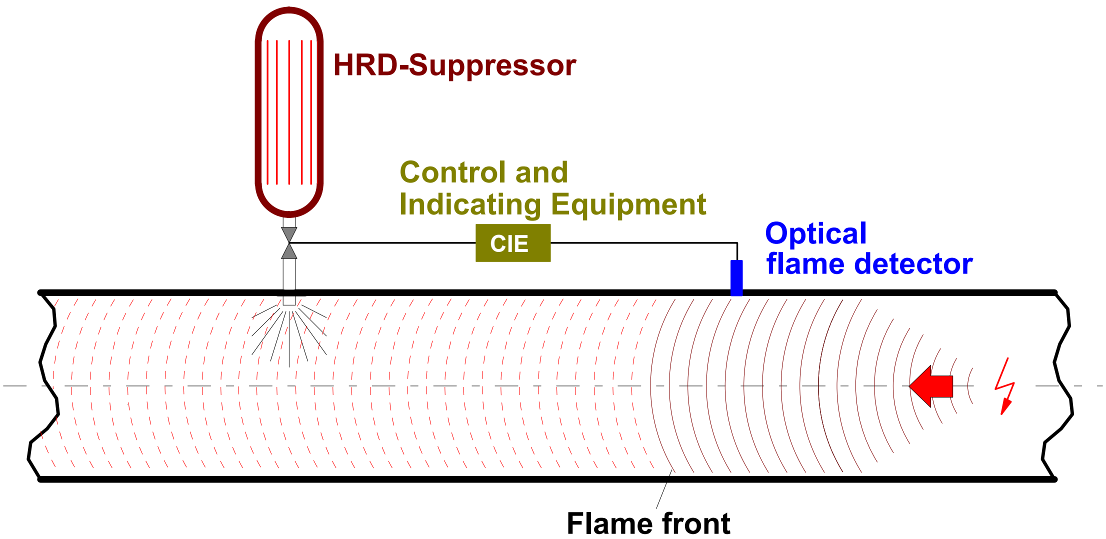


Figure 5. Automatic extinguishing barrier

Figure 6 shows a typically used IR-photoconductor sensor having three photo sensor symmetrically installed in the pipe. Depending upon the pipe diameter at least two photo sensor must be installed. These type of sensor contains a manually or automatically controlled operational test system for checking the photo sensor and a gas (air or nitrogen) flush system for cleaning the optical lens to keep it dust-free.

Pressure detectors or pressure sensors are not suited for the case on hand because there is no distinct separation between the pressure and flame fronts for explosions in pipelines. Since, with explosions in pipelines, the detection and quenching of the explosion flames is important, optical IR-sensors (Fig. 6), which have a relative low sensitivity to daylight, are chosen for the activation of the barrier system. Therefore daylight into the pipe in the vicinity of the sensor must be avoided.

There is a definite distance between the installation sites of the optical detector and the extinguishing barrier to ensure that the extinguishing agent acts directly on the flame. The amount of extinguishing agent required depends on the nature of the combustible dusts, the nominal diameter of the protected pipeline, the flame velocity and the maximum reduced explosion overpressure in the vessel.

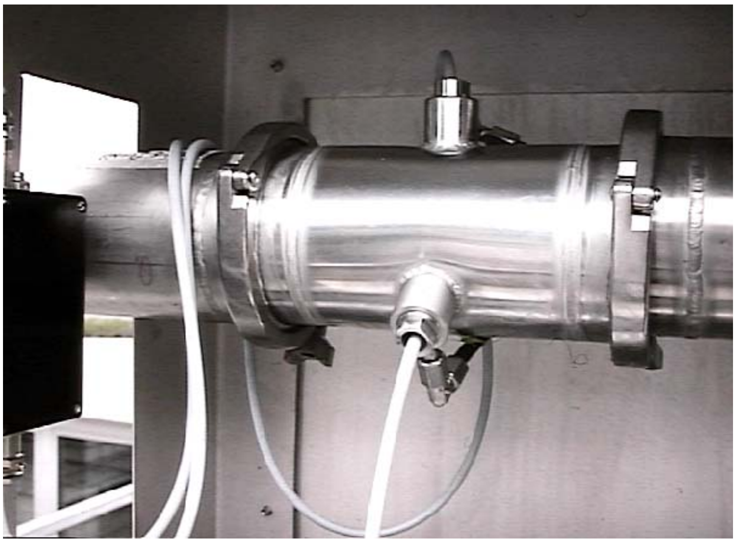


Figure 6. Infrared photoconductor sensor /8/

The basis for the design of extinguishing barriers is established from experimental trials /2/. The K_{max} of the dusts was varied and the flame velocity at the 10-m mark was measured, which is the location of the extinguishing barrier. Figure 7 shows the correlation between the maximum explosion constant, K_{max}, of a dust and the explosion velocity, v_{ex}, at the 10-m mark with the flame detector at the 1-m mark. The values were determined in a 20-m long pipeline having nominal diameter between DN 200 to DN 400. For larger pipe areas, the values for the explosion velocity move downwards.

The relationship between the explosion velocity, v_{ex}, at the 10-m mark - which is the location of the extinguishing barrier - and the maximum explosion constant, K_{max}, can be described according to the following empirical equation (2):

$$\mathbf{v_{ex} = 29 \cdot K_{max}^{0.45}} \qquad \textbf{(2)}$$

Where:
v_{ex} is the explosion velocity in m/s.

Intensive studies /2/ have shown (Fig. 8) that the suppressant requirement at the barrier location must be adjusted linearly with the explosion velocity. Especially at high explosion velocities the HRD-Suppressors with 4 kg content are more effective than the ones with 2 kg. For a given explosion velocity (4 kg up to 150 m/s and for 2 kg up to 300 m/s), the extinguishant sectional density is constant in order to force the disruption of the explosion, independent of the pipe diameter.

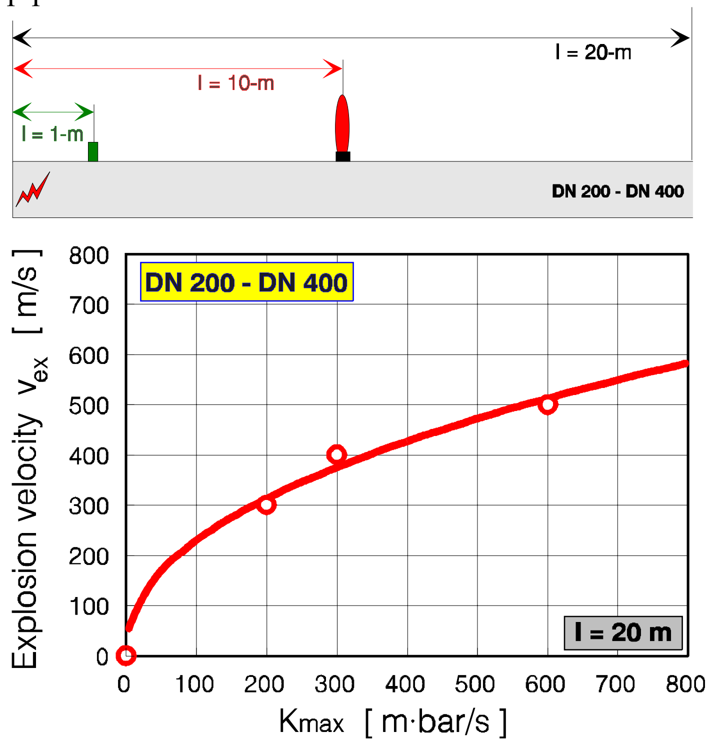


Figure 7. Correlation of maximum explosion constant, Kmax, with explosion velocity, vex /2/

The correlation shown in Figure 8 is limited to pipelines having a nominal diameter of 150 ≤ DN ≤ 700-mm.

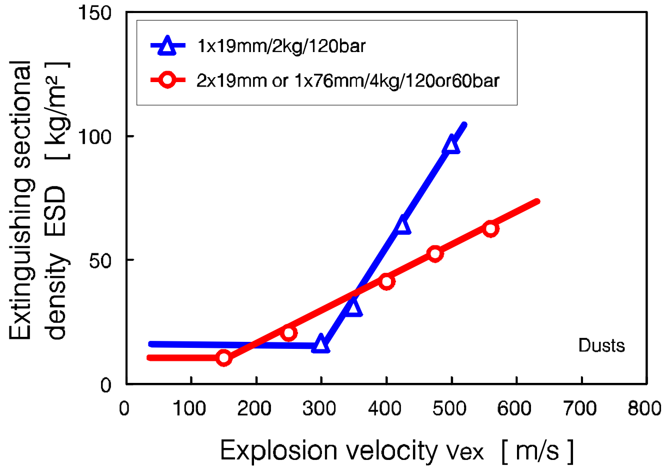


Figure 8. Correlation of explosion velocity at location of extinguishing barrier with extinguishing sectional density (Pipeline DN 200-400, length 20-m, flame detector at 1-m mark, flame barrier at 10-m mark) /2/

The empirical equations (3 and 4) developed from Figure 8 present the experimentally derived extinguishant sectional density, ESD, needed across the duct as a function of the explosion velocity respectively K_{max}:

<u>5-ℓ-HRD-Suppressors with 1x19mm outlet, Ps = 120 bar and 2 kg suppressant</u>

$$\mathbf{ESD = (0.4 \cdot v_{ex}) - 104 = (11.6 \cdot K_{max}^{0.45}) - 104} \qquad \mathbf{(3)}$$

<u>5-ℓ-HRD-Suppressors with 2x19-mm outlets or 1x76-mm outlet, Ps = 120 bar or 60 bar and 4 kg suppressant each</u>

$$\mathbf{ESD = (0.13 \cdot v_{ex}) - 10 = (3.77 \cdot K_{max}^{0.45}) - 10} \qquad \mathbf{(4)}$$

Thus the minimum suppressant charge, Ms, can be calculated from the empirical equation (5):

$$\mathbf{M_s = ESD \cdot DSA} \qquad \mathbf{(5)}$$

Where
Ms is minimum suppressant charge in kg,
ESD is the extinguishant sectional density in kg/m²,
DSA is the duct sectional area in m².

Based on the minimum suppressant charge the minimum number of HRD-Suppressors, N_s, required to effectively suppress an explosion of a defined intensity in a given pipe, can be determined from the following equations (6) and (7):

<u>5-ℓ-HRD-Suppressors with 1x19mm outlet, Ps = 120 bar and 2 kg suppressant</u>

$$\mathbf{N_s = M_s : 2\ kg} \qquad \mathbf{(6)}$$

<u>5-ℓ-HRD-Suppressors with 2x19-mm or 76-mm outlets, Ps = 120 bar or 60 bar and 4 kg suppressant each</u>

$$\mathbf{N_s = M_s : 4\ kg} \qquad \mathbf{(7)}$$

> ***Note:*** *The calculated minimum number, Ns, must be rounded up to the next higher integer value.*

Having determined the minimum suppressant charge, Ms, that is to be deployed across the duct section or the minimum number of HRD-Suppressors, N_s, it is necessary to locate the barrier with respect to the expected point of ignition. Extinguishing barrier location is determined from the mean flame velocity, v_m, and not from the worse case accelerated explosion velocity. Tests in a vented or suppressed 2.4-m³-vessel connected to a pipe having a nominal diameter of DN 400 and a length of 15 m /9a/ and in a 1-m³-vessel connected to a pipe having a nominal diameter of DN 200 and a length of 10 m /9b/ show the relationship in Figure 9. In this case the maximum reduced explosion overpressure in both vessels was $P_{red,max} < 2$ bar.

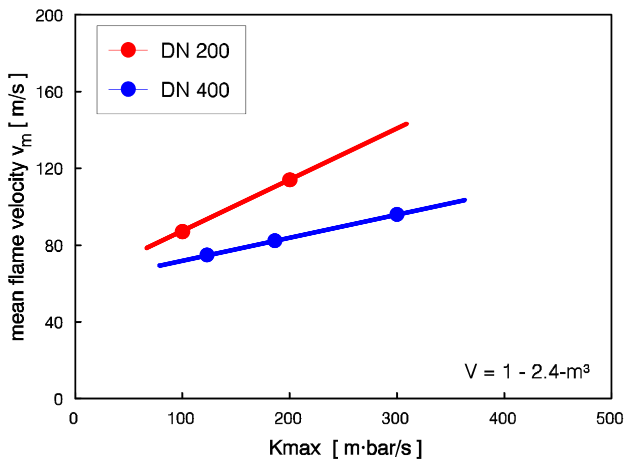


Figure 9. Correlation of nominal diameter, DN, of a pipe and the maximum explosion constant, K_{max}, with mean flame velocity, v_m, expected at 10-m mark ($P_{red,max}$ < 2 bar in the connected vessel)

The data are estimated values, which indicate that at a constant pipe nominal diameter, DN, the values for the mean flame velocity increases with increasing K_{max}. At a constant value of K_{max} the values for the mean flame velocity increases with decreasing nominal pipe diameter. As an orientation aid for the estimation of the mean flame velocity, v_m, Figure 9 can be used. At the 10-m mark of the pipeline from a protected vessel (venting or suppression) with a $P_{red,max}$ less than 2 bar overpressure, the mean flame velocity, v_m, can be estimated according to the following equation (8):

$$v_m = \{(0.42 - 7.5 \cdot 10^{-4} \cdot DN) \cdot K_{max}\} + 60 \quad (8)$$

Where :
v_m is the mean flame velocity in m/s,
K_{max} is the maximum explosion constant in m·bar/s,
DN is the nominal diameter of the pipe in mm,
$P_{red,max}$ in the protected vessel is less than 2 bar overpressure.

> ***Note:*** *For DN < 200 the estimated mean flame velocity for DN 200 and for DN > 400 the one of the DN 400 must be used.*

Taking into account the forward air velocity, v_{air}, - if existing in the praxis - the equation (8) changes to equation (9):

$$v_m = \{(0.42 - 7.5 \cdot 10^{-4} \cdot DN) \cdot K_{max}\} + 60 + v_{air} \quad (9)$$

Where:
v_{air} is the forward air velocity in m/s,
v_{air} is 0 m/s for an upstream placement of the extinguishing barrier.

For the estimation of the minimum distance, d_{min}, of the extinguishing barrier from the flame sensor installed in a pipe, the extinguishing barrier establishment time, t_b, has to be known. The time t_b is the time between the activation of the fast acting valve of the suppressor and a blanket of suppressant is formed in the pipe. This time includes also the electronical delay time of the used sensor and the control and indication equipment. From a knowledge of this extinguishing barrier establishment time, t_b, the mentioned minimum distance of the extinguishing barrier from the flame sensor installed in a pipe can be determined as:

$$\mathbf{d_{min} = v_m \cdot t_b = (\{(0.42 - 7.5{\cdot}10^{-4}{\cdot}DN) \cdot K_{max}\} + 60 + v_{air}) \cdot t_b} \qquad \textbf{(10)}$$

Where:
d_{min} is the minimum distance in m,
t_b is the extinguishing barrier establishment time in s.

The extinguishing barrier establishment time is depending upon the type of HRD-Suppressors and lies normally between 0.025 s and 0.1 s.

If a pressure sensor is installed in an equipment and is the selected means of triggering, allowance must be made for propagation of the flame beyond the location of the detector before the barrier is triggered. This results in an additional delay and therefore in an additional increased distance. The calculation of this time is not that ease and must be done by experts. As a rule of thumb - for vessels between 1 and 10 m³ - this additional distance, d_a, lies between 1 m and 5 m. Thus, the minimum distance, d_{min}, from the extinguishing barrier to the connection point equipment/pipe can be estimated as follows:

$$\mathbf{d_{min} = v_m \cdot t_b + d_a = (\{(0.42 - 7.5{\cdot}10^{-4}{\cdot}DN) \cdot K_{max}\} + 60 + v_{air})\ t_b + d_a} \qquad \textbf{(11)}$$

Where:
d_a is an additional increased distance due to the pressure sensor in m.

Figure 10 shows schematically the arrangement of the minimum distance for the extinguishing barrier as a function of the type of sensor.

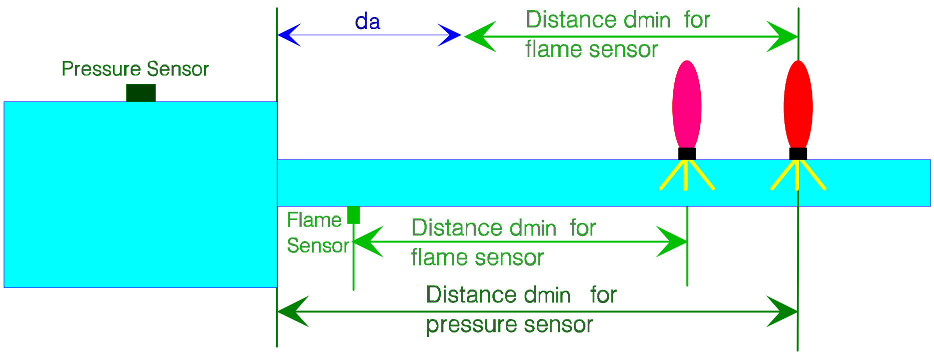


Figure 10. Schematic presentation of the distance d_{min} for pressure and flame sensors using extinguishing barriers

In difficult situations it is recommended to install both sensors - flame and pressure - and they must be switched in a OR-logic to activate the extinguishing barrier. In this case the minimum distance from the extinguishing barrier to the connection point equipment/pipe must be estimated from the equation (11).

Finally, Figure 11 shows the actual installation of three extinguishing barriers in connecting pipes. The cross section of the pipe determines the number of 5-ℓ-HRD-Suppressors.

The pipe on the right hand side of Figure 11 has 3-HRD-Suppressors (only two are visible) and the other two pipelines have 2-HRD-Suppressors.

Figure 11. Extinguishing barrier in connecting pipes

The use of extinguishing barriers is by no means limited to pipes with small cross sections (DN ≤ 700). New results (Fig. 12) from a pipeline DN 1000, length 20-m, flame detector at 5-m mark, flame barrier at 15-m mark, using 5-ℓ- or 20-ℓ-HRD-Suppressors with 76-mm outlets, Ps = 60 bar and 4 kg respectively 16 kg suppressant have shown that there are no problems in fighting dust explosions with the dust explosion classes St 1 and St 2.

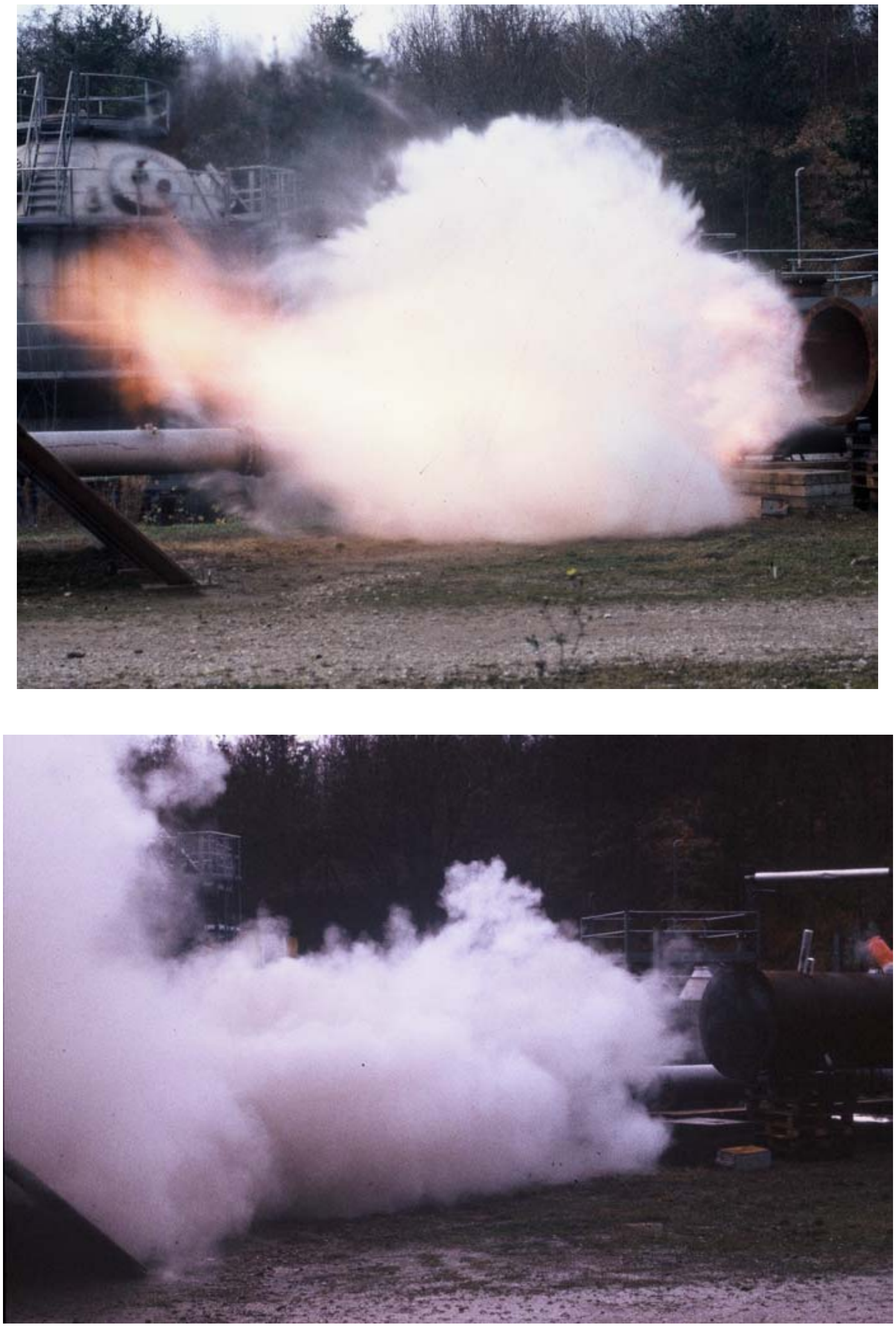


Figure 12. Dust explosion (St 1) in a pipeline DN 1000 (above without, below with extinguishing barrier

The test results (Fig. 13) are compared with the ones shown in Figure 8 using 5-ℓ-HRD-Suppressors with 2x19-mm outlets, Ps = 120 bar and 4 kg suppressant.

Figure 13 correlates the explosion velocity with extinguishing sectional density in different pipelines. Again the suppressant requirement at the barrier location must be adjusted linearly with the explosion velocity. For a given explosion velocity: $v_{ex} \leq 150$ m/s for the smallest pipe and $v_{ex} \leq 200$ m/s for the other pipe, the extinguishant sectional density is constant.

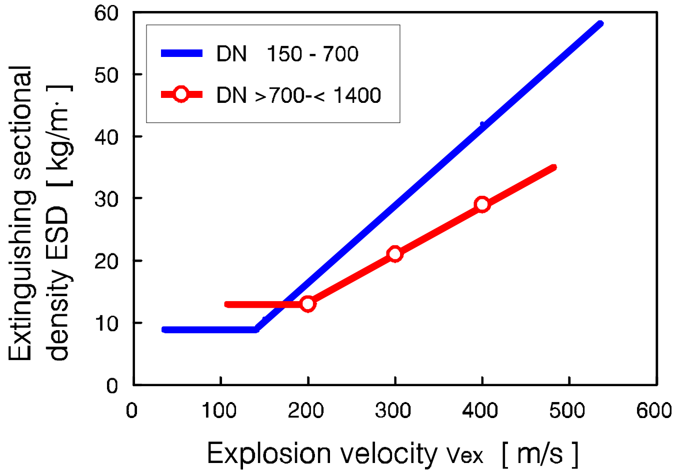


Figure 13. Correlation of explosion velocity at location of extinguishing barrier with extinguishing sectional density in different pipelines (distance flame detector to flame barrier 9-m to 10-m)

The empirical equations (12) developed from Figure 13 present the experimentally derived extinguishant sectional density, ESD, needed across the duct as a function of the explosion velocity respectively K_{max} if 5-ℓ-HRD-Suppressors with 1x76-mm outlet, Ps = 60 bar and 4 kg suppressant or 20-ℓ-HRD-Suppressors with 1x76-mm outlet, Ps = 60 bar and 16 kg suppressant are used:

700 < DN < 1400

$$\mathbf{ESD = 0.08 \cdot v_{ex} - 3 = 0.08 \cdot (29 \cdot K_{max}^{0.45}) - 3} \quad \textbf{(12)}$$

The minimum suppressant charge, Ms, can be calculated from the empirical equation (5).

Based on the minimum suppressant charge the minimum number of HRD-Suppressors, N_s, required to effectively suppress an explosion of a defined intensity in a given pipe, can be determined from the following equations (7) for 5-ℓ-HRD-Suppressors and (13) for:

20-ℓ-HRD-Suppressors with 1x76-mm outlet, Ps = 60 bar and 16 kg suppressant:

$$\mathbf{N_s = M_s : 16\ kg} \quad \textbf{(13)}$$

> ***Note:*** *The calculated minimum number, N_s, must be rounded up to the next higher integer value.*

At the moment not enough test results are available allowing a proper estimation of the minimum distance, d_{min}, of the extinguishing barrier from the sensor installed. This calculation must be left to experts.

1.3 Explosion Protection Slide Valve

Explosion protection slide valves have the advantage that the closing time device is normally out side the pipe cross section. Figure 13 shows an example of such a slide valve. The pipe area is completely open and can be built without pockets and dead corners, so that dust will not settle or accumulate. Special dampers have been developed in order to absorb the substantial shock forces from the closing device and to prevent the slide from springing back after closure. The damping elements are exchangeable.

Figure 14. Explosion Protection Slide Valve WEY Type SLX-SISTAG with test box (left) /10/

The valve is connected to the compressed nitrogen cylinder via high-pressure hose. In case of an explosion, again an impulse from a control and indicating equipment will activate a detonator, which opens the valve of the compressed nitrogen cylinder. The propellant (nitrogen pressure 10-40 bar), via a cylinder-piston system, closes the slide, which will be dampened through the plastic deformation of a braking device. The slide valve can be mounted in vertical, horizontal or slanting pipelines.

The function measuring of the normal closing time (no explosion) of the valve can be tested in place (using standard pressure) with the “Test box” (Fig. 14) in combination with a pneumatic control valve block.

These valves must be tested for ignition breakthrough protection and pressure rating in dust explosions. They can meet these requirements for dust explosions, and are effective at shorter distances against dust explosions than for gas explosions. When rapid action slide valves are used, a dust explosion approaching the installation site in the pipeline is detected by an optical sensor and the closing process initiated by an triggering mechanism (Fig. 14). In case an equipment is protected by a design measure e.g., containment, suppression or venting, the usual explosion pressure sensor with a corresponding low activation pressure can also be used to initiate the triggering mechanism for the explosion protection slide valve.

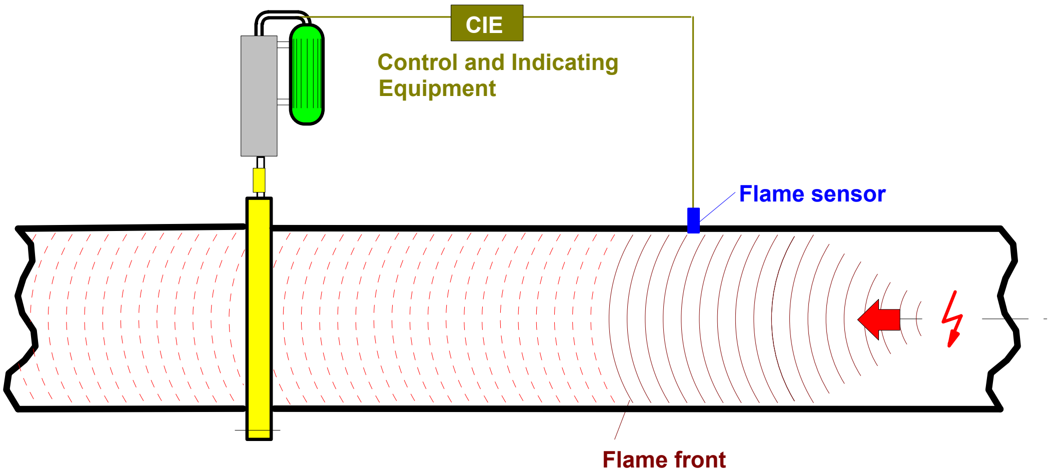


Figure 15. Arrangement for the performance testing of Explosion Protection Slide Valve

The basis for the design of explosion protection slide valves is established from experimental trials. Figure 16 presents the experimentally derived closing time ts of slide valves having different nominal diameter. The closing time, ts, is the time between the activation of the detonator for the closing mechanism and the complete closure of the valve.

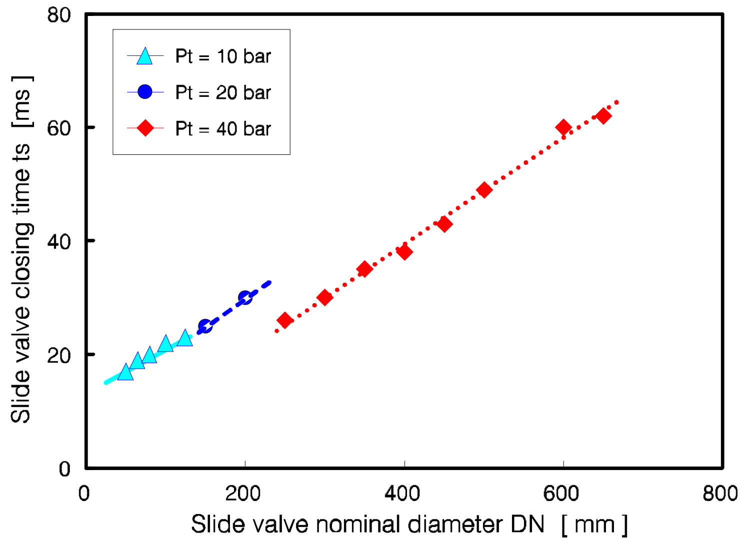


Figure 16. Closing time ts of explosion protection slide valves with nominal diameter DN 50 to 650 mm

Figures 16 shows clearly that the closing time, ts, depends not only on the propellant pressure Pt but also on the nominal width, DN, of the slide valve and is generally less than 50 ms. This closing time, ts, is the real closing time of the explosion protection slide valve and does not include the electronical delay time, te, of the used sensor including the control and indication equipment. Typically values for the electronical delay time, te, are for:

Explosion pressure sensor with a control and indicating equipment te $\leq$ 2 ms.
Flame(optical) sensor with a control and indicating equipment te $\leq$ 4 ms.

There is a definite distance between the protected vessel and the explosion protection slide valve to ensure that the valve is stopping the explosion. The minimum distance, d_{min}, required depends on the nature of the combustible dusts, the closing time of the explosion protection slide valve including the electronical delay time of the used sensor and the control and indication equipment, the flame velocity and the maximum (reduced) explosion overpressure in the protected vessel. The calculation of this minimum distance is relatively complex and should be done only by experts. The following Table 1 may serve as a guideline for the minimum distance. There, it is assumed, that an equipment is protected by a design measure containment, suppression or venting, and an explosion pressure sensor with a corresponding low activation overpressure ($P_a \leq 0.1$ bar) is used to initiated the triggering mechanism for the externally actuated explosion protection slide valve.

Table 1. Externally actuated explosion protection slide valve: Minimum distance, d_{min}, of the slide valve from the protected vessel

Type of explosion protection in the vessel	containment	venting with vent pipe	venting without pipe or suppression
P_{max}, $P_{red,max}$	9 bar	3-4 bar	1 bar
DN of the float valve in mm	minimum distance, d_{min} in m		
100	ca. 5	ca. 4	ca. 3
400	ca. 9	ca. 6	ca. 5

Figure 17 shows schematically the arrangement of the minimum distance for the explosion protection slide valve.

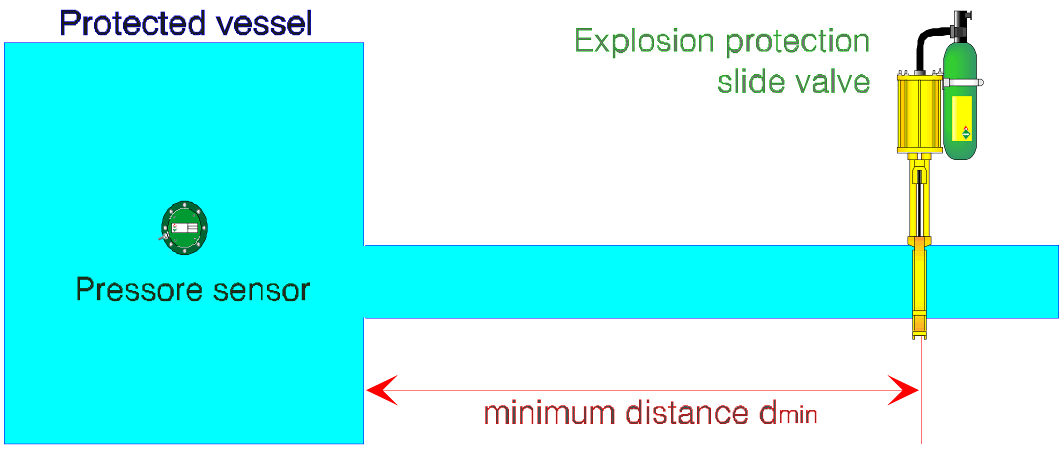


Figure 17. Schematic presentation of the distance dmin for explosion protection float valves

Finally Figure 18 shows a practical application of an explosion protection slide valve.

Figure 18. Explosion protection slide valve installations in a pipe

1.4 Explosion Protection Float Valve

Explosion isolation can also be effected by explosion protection float valves. They can be arranged in horizontal pipelines and if necessary also in vertical pipelines and are suitable in general only for streams with a small amount of dust. Such valves are thus frequently used to protect ventilation lines. As a certain explosion overpressure is necessary to close such valves, a distinction is made between **self-actuated** and **externally actuated** float valves. Both valves can withstand an explosion overpressure within the pipeline of at least 10 bar (DN 100-500) and at least 5 bar (DN 700). They have been tested, with satisfactory results, against propane-air and dust-air mixtures. The float valves provide adequate protection against the propagation of dust explosions ($P_{max} \leq 10$ bar, $K_{max} \leq 300$ m·bar·s^{-1}) and explosions of hybrid mixtures with a maximum concentration of flammable gas or vapor of 50% of the lover explosion limit.

1.4.1Self-Actuated Explosion Protection Float Valve

The interior of the barrier valve contains a valve cone mounted in spherical sockets and which can be moved axially in both directions; it is held in its middle position by springs. The spring tension is set for a maximum flow velocity of 24 m·s^{-1}, based on the pipeline cross-section. If an explosion occurs, the valve closes automatically owing to the kinetic energy of the pressure wave preceding the flame front. Here, either the explosion velocity must be > 24 m·s^{-1} or the pressure difference in front of and behind the valve ≥ 0.1 bar. The valve cone is pressed onto a rubberized valve seat on closing and held in place by a retaining device. In addition the closed position can be signaled by electrical impulse contacts (limit switch). The float valve remains closed until the manual reset device (reset knob) is operated. It is released from outside. The self-actuating barrier valve (Fig. 19) functions - with exception of the DN 700 - in both directions.

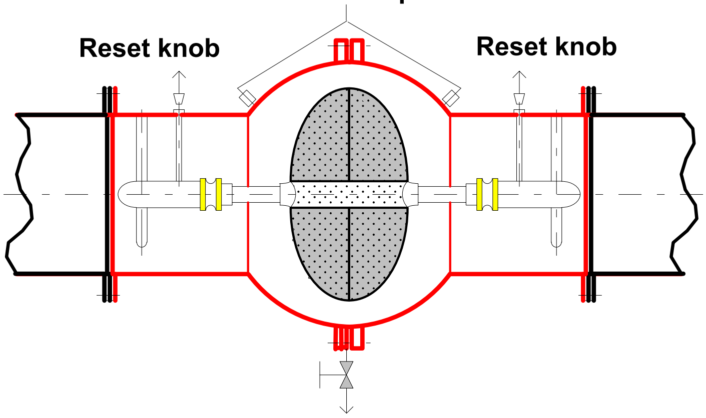


Figure 19. Self-actuated explosion protection float valve Type VENTEX /11/

Since a certain minimum explosion pressure is required to close the float valve, the propagation of an explosion through the pipe will not be interrupted if its pressure is lower than the minimum activation pressure of the float valve. To keep this range of uncertainty acceptably small, vessels which are protected by explosion venting or explosion suppression, it must be ensured, that the static activation overpressure of the venting device is $P_{stat} \geq 0.2$ bar or the activation overpressure of the suppression system is $P_a \geq 0.2$ bar. Otherwise reliable performance of the self-actuated explosion protection float valve cannot be expected.

The basis for the design of explosion protection float valves is established from experimental trials. A correlation exists between the dynamic activation pressure, P_{dyn}, of the slide valve and the momentum (action time of the explosion pressure). On the one hand with decreasing P_{dyn} the momentum also decreases and on the other hand only a high momentum results in a short closing time. Therefore self-actuated slide valves have not only one closing time. For the design of self-actuated explosion protection float valves minimum and maximum distances from the vessel being protected to the float valve exist (Table 2, Fig. 20). The maximum distance makes sure that no detonation develops in the vicinity of the float valve and the pressure effect is not increasing the design pressure of the float valve. The minimum distance makes sure that the float valve still closes properly and consequently no ignition breakthrough of an explosion through the float valve can occur.

Table 2. Minimum distance, ℓ_{min}, and maximum distance, ℓ_{max}, for self-actuated explosion protection float valves /2/

	Combustible Dust		Hybrid Mixtures	
DN [mm]	**ℓ_{min} [m]**	**ℓ_{max} [m]**	**ℓ_{min} [m]**	**ℓ_{max} [m]**
100	**5**	**12.5**	**3**	**5**
200 - 700	**5**	**12.5**	**5**	**8**

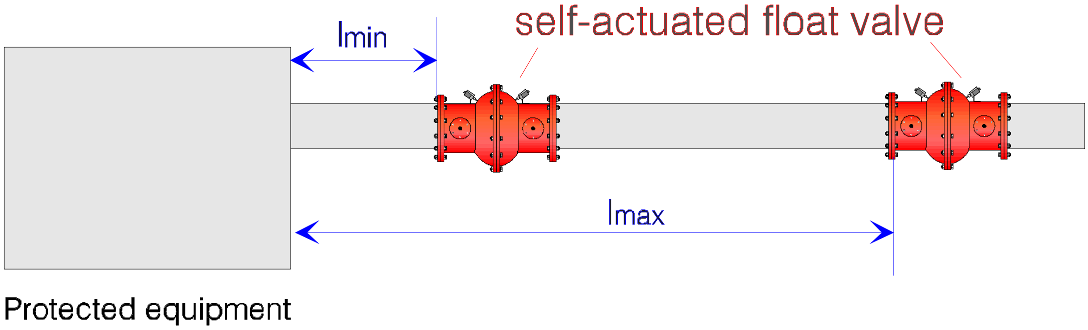


Figure 20. Minimum distance, ℓ_{min}, and maximum distance, ℓ_{max}, for self-actuated explosion protection float valves

The installation distance, di, of the float valve to the connection point equipment/pipe lies between the minimum and the maximum distance and is dependent upon the explosion overpressure (P_{max} or $P_{red,max}$) in the protected equipment. The installation distance depends also on the nominal diameter, DN, of the float valve and on the situation if combustible dusts or hybrid mixtures are present. If possible, always the maximum distance indicated in Table 2 should be used for the placement of the slide valve. If not the installation distance, di, can be calculated depending upon the expected explosion overpressure (P_{max}, $P_{red,max}$) in the vessel to be isolated, according to the equations (14) to (16). In case of doubt, externally actuated float valves (see section 1.4.2) must be used.

<u>Combustible dusts:</u>

DN 100 - 700 : $$d_i = 8.6 \cdot P^{-0.23} \quad (14)$$

<u>Hybrid mixtures:</u>

DN 100 : $$d_i = 4.05 \cdot P^{-0.13} \quad (15)$$

DN 200 - 700 : $$d_i = 6.6 \cdot P^{-0.12} \quad (16)$$

Where:
DN is the nominal diameter of the self-actuated float valve in mm,
d_i is the installation distance in m,
P is the maximum (P_{max}) or the maximum reduced ($P_{red,max}$) explosion overpressure in the equipment to be protected in bar.

An exception is given for the installation of the self-actuated explosion protection float valves regarding to the minimum length ℓ_{min}, respectively installation distance d_i. Dust separation filters with specific pocket filters or filter bags on cages, have a positive effect on the course of the explosion and, as a consequence, on the effectiveness of the self-actuated float valve. These type of filters act as a single flame barrier in case of an explosion, that means no flame will pass the filters and can travel on the clean side into the outlet duct. In case of doubt, satisfactory tests have to be carried out. Based on this characteristic the float valve can be installed directly after the filter ($\ell_{min} = d_i = 0$ m) on the clean side (Fig. 21). The reason for the distance of 0 m is, that in case of an explosion in the filter the flame will always keep back and guarantee that the explosion pressure will first reach the float valve and close it.

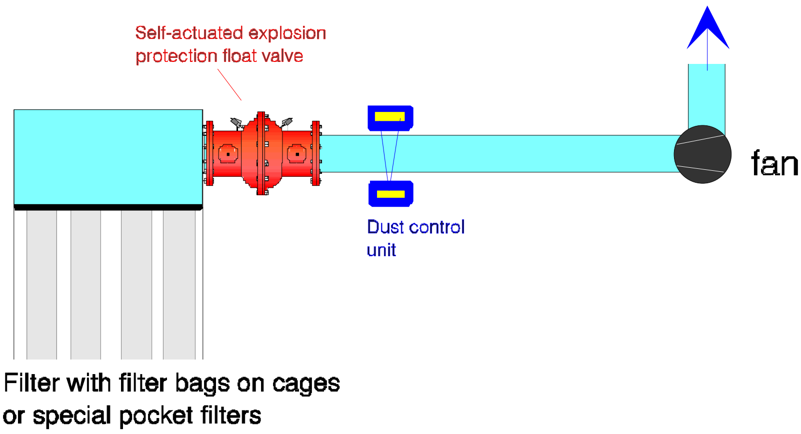


Figure 21. Exception of an installation of a self-actuated explosion protection float valve on a ventilation pipe of a filter with specific pocket filters or filter bags on cages

To control the proper function of the filter and therefore of the float valve a dust control unit must be installed after the float valve (Fig. 21). This measure makes sure that the dust in the pipe never reaches an explosible concentration and avoids an ignition by the fan, in case of a filter break-through. In addition this measure ensures that no product will leave uncontrolled the equipment and contaminate the surrounding of the building. Furthermore, the installation of built-in fire extinguishing devices e.g., water spray nozzles is recommended, in order to limit the duration of a possible fire following an explosion.

Finally Figure 22 shows a practical application of such self-actuated explosion protection float valve in a ventilation line.

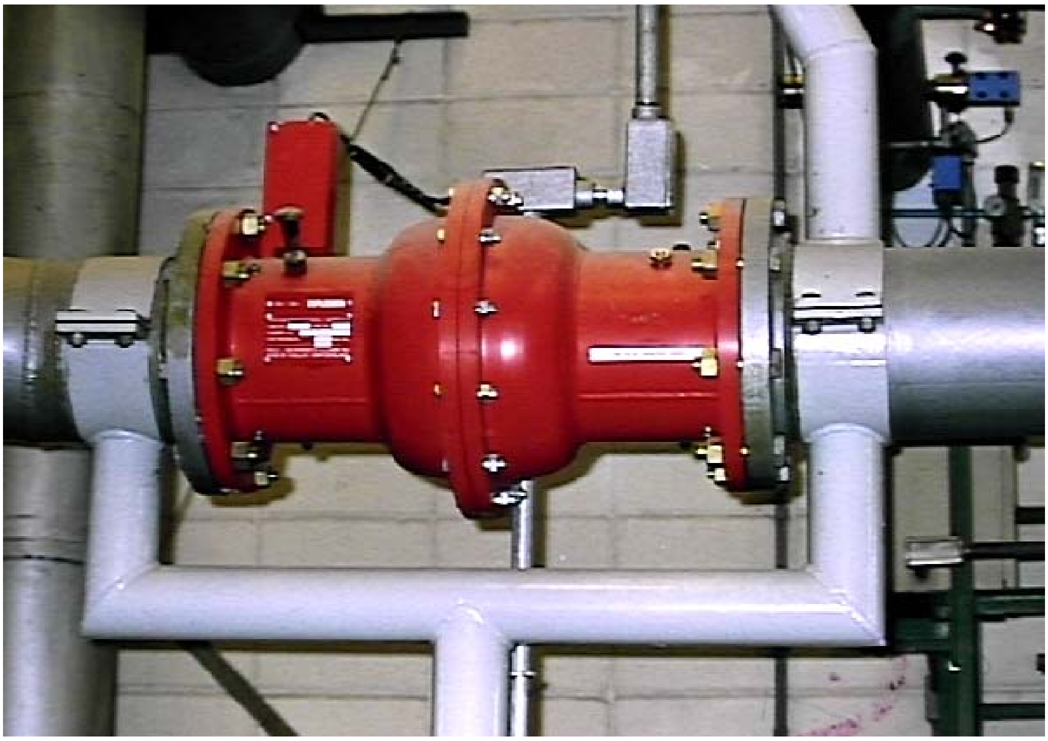


Figure 22. Self-actuated explosion protection float valve type VENTEX installed in a ventilation pipe

1.4.2Externally Actuated Explosion Protection Float Valve

Externally actuated explosion protection float valves are installed when low explosion overpressures are expected and consequently ignition breakthrough of an explosion through the installation site can occur with a self-actuated float valve. These operated by a sensor-controlled auxiliary gas flow (jets of 120 bar nitrogen from HRD-control containers onto the valve cone) in the direction of the pipe axis via a hemispherical nozzle (Fig. 23). When the externally actuated explosion protection float valves are used, a dust explosion approaching the installation site in the pipeline is detected by an optical sensor and the closing process initiated by an triggering mechanism. In case an equipment is protected by a design measure e.g., containment, suppression or venting, the usual explosion pressure sensor with a corresponding low activation pressure can also be used to initiated the triggering mechanism for the externally actuated explosion protection float valve.

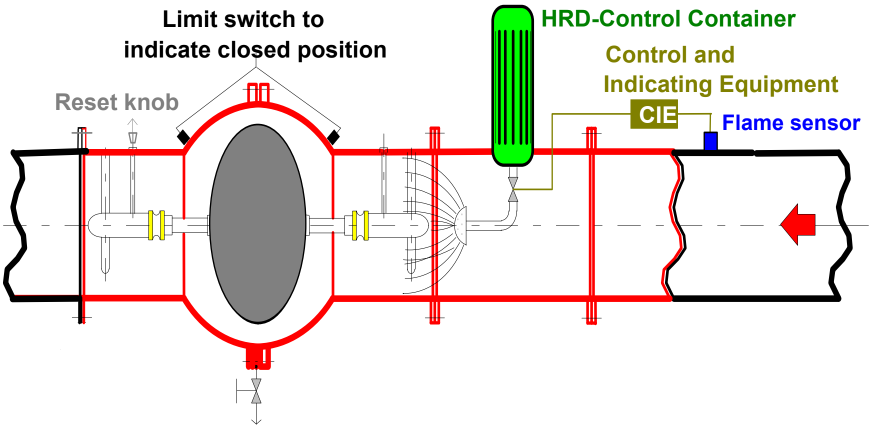


Figure 23. Externally actuated explosion protection float valve /11/

The valve cone is pressed onto a rubberized valve seat on closing and held in place by a retaining device. In addition the closed position can be signaled by electrical impulse contacts (limit switch). The float valve remains closed until the manual reset knob is operated. It is released from outside. The externally actuated float valve functions in one direction only.

The basis for the design of externally actuated explosion protection float valves is established from experimental trials. Figure 23 presents the experimentally derived closing time, ts, of float valves having different nominal diameter. The closing time, ts, is the time between the activation of the detonator for the closing mechanism and the valve is completely closed.

Figure 24 shows clearly that the closing time, ts, depends not only on the number of the HRD-control container (propellant pressure, P_t) but also on the nominal diameter, DN, of the float valve.

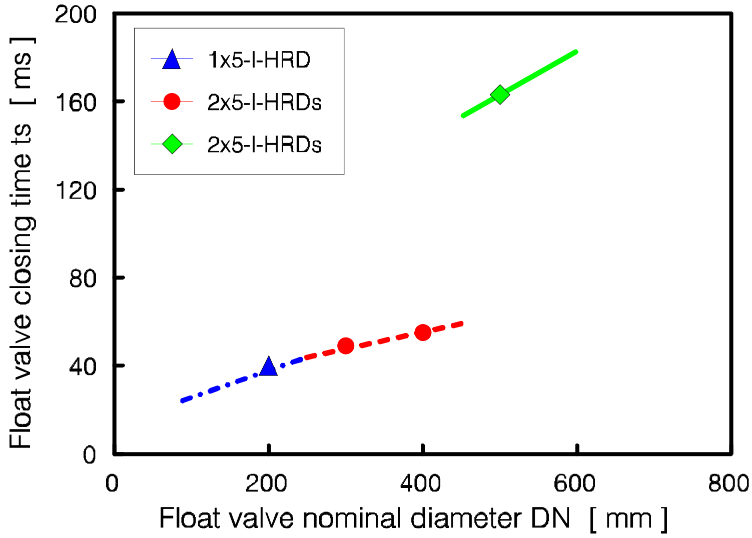


Figure 24. Closing time, ts, of externally actuated explosion protection float valves type VENTEX with nominal diameter DN 200 to 500 mm

This closing time, ts, is the real closing time of the explosion protection slide valve and does not include the electronical delay time, te, of the used sensor including the control and indication equipment. Typically values for the electronical delay time, te, are:

For explosion pressure sensor with a control and indicating equipment te ≤ 2 ms.
For flame(optical) sensor with a control and indicating equipment te ≤ 4 ms.

There is a definite distance between the protected vessel and the externally actuated explosion protection float valve to ensure that the valve is stopping the explosion. The minimum distance, d_{min}, required depends on the nature of the combustible dusts, the closing time of the float valve, the flame velocity and the maximum (reduced) explosion overpressure in the protected vessel. The calculation of this minimum distance is relatively complex and should be done only by experts. The following Table 3 may serve as a guideline for the minimum distance. There, it is assumed, that an equipment is protected by a design measure containment, suppression or venting, and an explosion pressure sensor with a corresponding low activation overpressure (P_a ≤0.1 bar) is used to initiated the triggering mechanism for the externally actuated explosion protection float valve. For the installation and definition of the minimum distance see Figure 20.

Table 3. Externally actuated explosion protection float valves: Minimum distance, d_{min}, from the protected vessel to the float valve

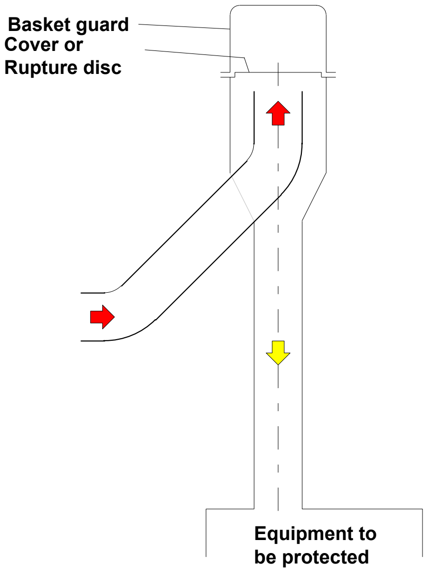
Type of explosion protection in the vessel	containment	venting with vent pipe	venting without pipe or suppression
P_{max}, $P_{red,max}$	9 bar	3-4 bar	1 bar
DN of the float valve in mm	**minimum distance, d_{min} in m**		
200	ca. 9	ca. 5	ca. 4
400	ca. 12	ca. 7	ca. 6

Finally Figure 25 shows a practical application of such externally actuated explosion protection float valve.

Figure 25. Externally actuated explosion protection float valve type VENTEX installed in a ventilation pipe

1.5 Diverter (Relief Pipe)

Particularly reasonably priced explosion isolation of systems involves the use of a *relief pipe* with which the flow direction can be diverted by 180° (Fig. 26). It prevents flame jet ignition with pre-compression in constructional protected equipment.



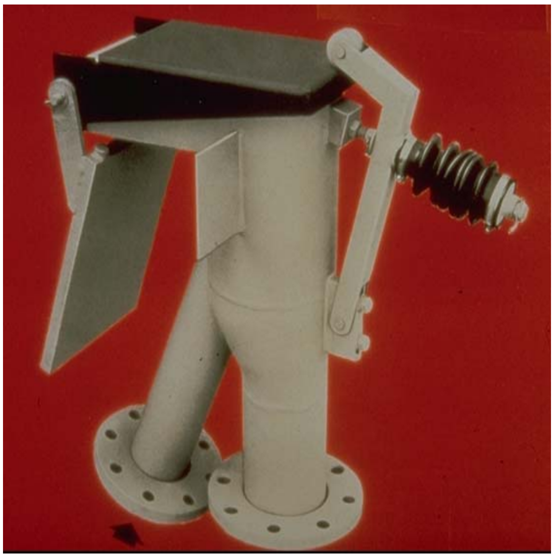


Figure 26. Diverter: schematic presentation (left), actual diverter (right) /12/

For a ideal design (Fig. 27, left), the area of the cross-section of the coming pipe A1 is equal to the ring area A2 of the downward pipe and the ring area A3, which is given by the periphery of the coming pipe and its distance H: A1 = A2 = A3. But due to the flow resistance and therefore the resulting pressure drop, only the real design of the diverter is suitable (Fig. 27, right), where: 2A1 = A2 = A3 /12/.

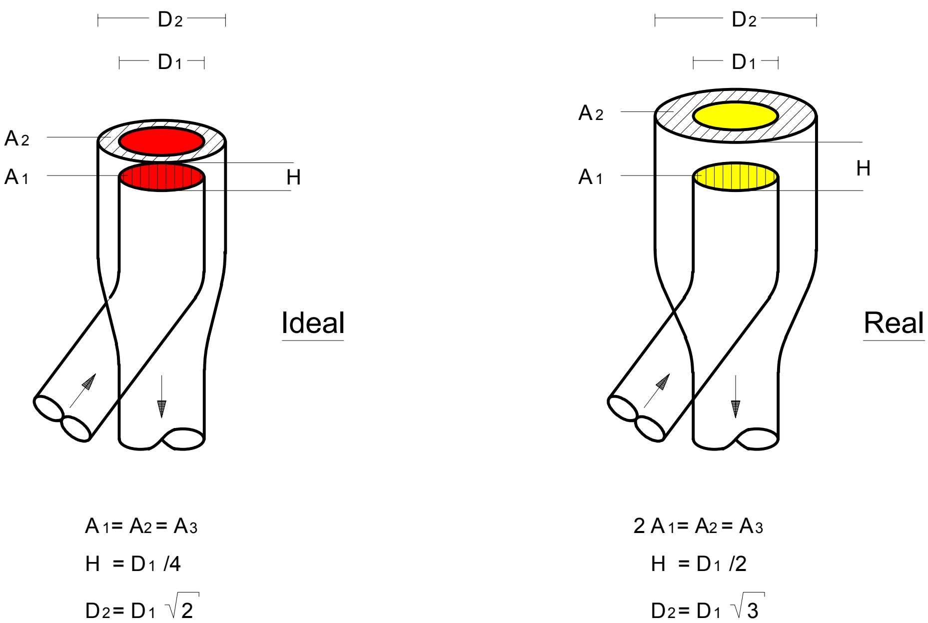


Figure 27. Design features of a diverter /13/

If a "real" designed diverter is installed were **pressure feed** is given, then the diverter is in general safe against an explosion propagation.

In case of **lifting by suction** a "real" designed diverter is only safe against an explosion propagation, if an additional extinguishing barrier or an explosion protection slide valve is installed (Fig. 28).

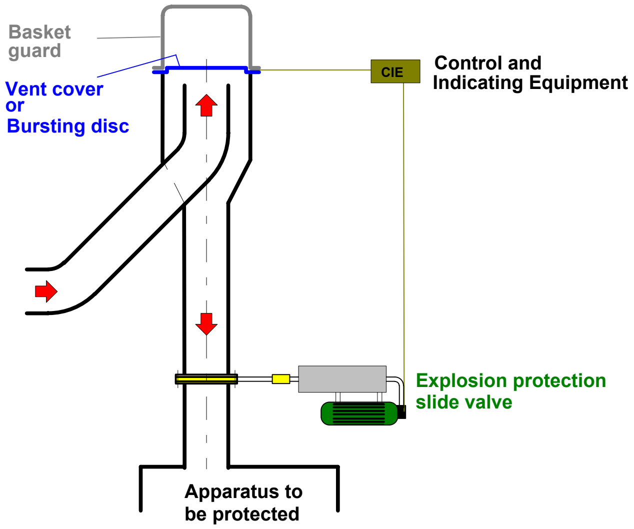


Figure 28. Explosion diverter with an additional explosion protection slide valve

1.6 Double-Slide System

Product removal mechanisms from apparatus that are explosion-resistant can be protected with a *double-slide* system (Fig. 29). Here, the slides must be at least as resistant as the apparatus. The slides may be used only when their pressure rating and ignition breakthrough protection and reliability have been proven in suitable investigations by competent bodies. By means of proper control, it must be assured that a slide is always closed /1/.

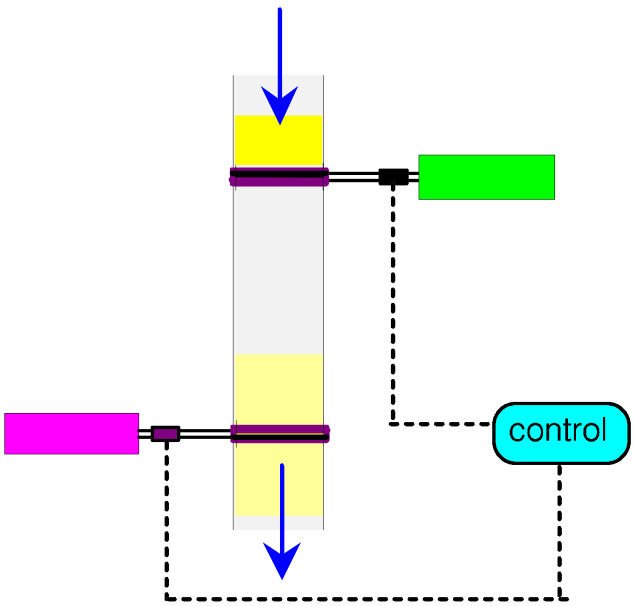


Figure 29. Schematical presentation of a double-side system

1.7 Product Receiver

In connection with the protective measure of explosion venting or suppression, a rotary air lock which does not fulfill the ignition breakthrough requirement or other product receivers (e.g., at the outlet of an silo or filter) having an adequate height of product pile, are suitable to separate parts of the system (Fig. 30). The product pile must always be so high - this must be ensured by a level indicator - that under the pressure stress of the explosion, no flames can shoot through the product /1/. At the moment there are no test results.

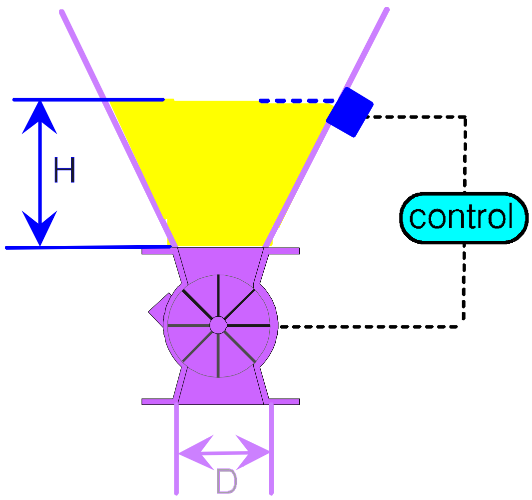


Figure 30. Schematical presentation of a product receiver

As a rule of thumb, the following numerical equation (17) and (18) can be used which describes the correlation between the height of the product pile and the outlet diameter for different bulk density of products

Bulk density BD ≥ 1 kg/ℓ:

H = D **(17)**

Bulk density BD < 1 kg/ℓ:

H = D / BD **(18)**

Where
H is the height of the product pile in m,
D is the outlet diameter in m,
BD is the bulk density of the product in kg/m^3.

1.8 Screw Conveyors

An other type of isolation can be achieved by judicious selection and design of powder conveying equipment /14/. Two of the designs are shown in Figure 31. They provide a “choke” of powder that would prevent passage of flaming material from one part of plant to another. The removal of part of the screw ensures that a plug of bulk powder will always remain as a choke. Experiments in which rice meal explosions in a $3.5\text{-}m^3$-vessel were vented through the choked screw conveyors and through a safety vent at the other end of the vessel. Dust clouds were ejected at the downstream end of the conveyors, but no flame /14/.

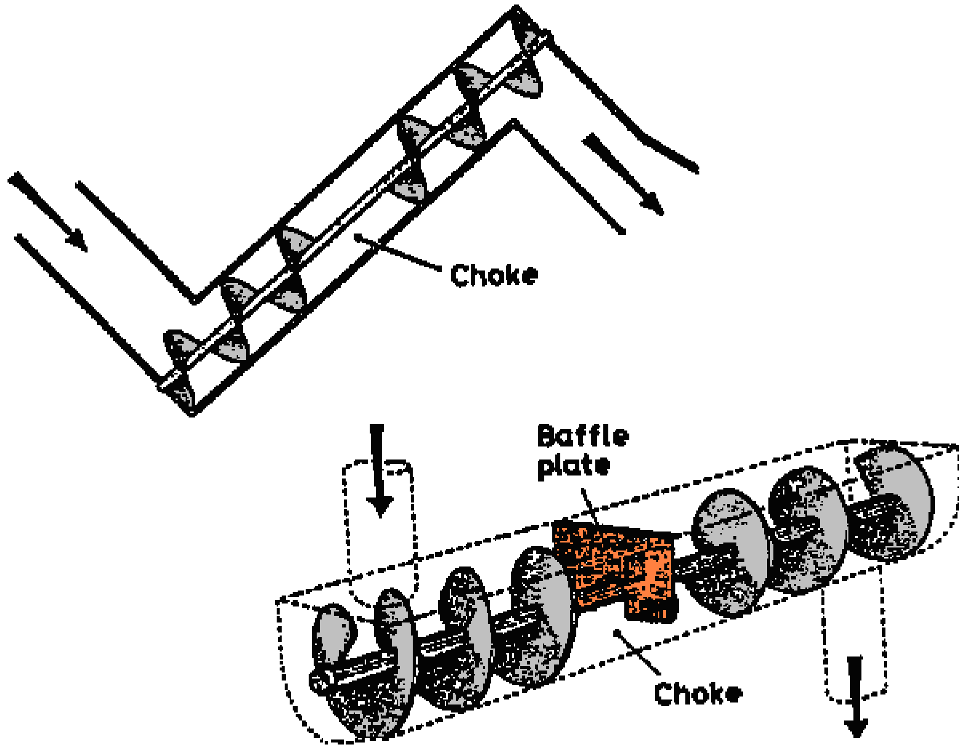


Figure 31. Schematical presentation of screw conveyors as chokes /14/

1.9 Conclusion

Finally, it must be pointed out that all devices suitable for use in explosion isolation or quite generally all explosion protection devices used in practice may be used only when their *pressure rating, ignition breakthrough protection* and *reliability* have been proven in suitable investigations by competent bodies.

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