SAFETY SYSTEMS ENGINEERING IN CHEMICAL ENGINEERING

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Abstract

Explosion protection is the object of various national and international documents, that are focused on the functions, the intended uses or the dimensioning rules for specific systems. However, despite a few application examples are described in the usual guidelines, they are limited to the description of a protection that can be added on a single piece of equipment while it is not the case in industrial processes. Furthermore, in an ATEX explosion there is a strong coupling between the explosion and its environment. Because of this the guidelines recommendations cannot be transposed on an industrial site without due consideration. In this paper, a way to take into account the real explosion conditions is given allowing a choice and dimensioning of a set of safety systems. An example is shown based on a real installation. The functional properties of the safety system are extracted from the certification tests whereas the explosion characteristics are extracted both from the standard combustion properties of the dust and from the latest knowledge about flame propagation.

Keywords: Safety barriers, dust explosion

1. Introduction

ATEX directives introduce everywhere in Europe the obligation to take dispositions to protect the workers in industry from the explosion risk. In many situations, and especially when dust explosions are identified, prevention measures are insufficient and protection should be ensured. Explosion protection is the object of various national and international guidelines and standards, that are focused on the functions, the intended uses or the dimensioning rules for specific systems: NFPA68:2012, EN14797:2007 (testing) and EN14991:2014 (dimensioning) for dust explosion venting techniques. Despite a few application examples are described in the usual guidelines, they are limited to the description of a protection that can be added on a single piece of equipment in which an explosion may occur, in quite an ideal configuration with fully known turbulence conditions, combustible reactivity, repartition or concentration. Such observation is general to most of the safety barrier used in the industry. However, in real installations, the device to be protected is rarely isolated but often connected to various ducts and vessels in which the explosion may propagate. This is a critical point as in an ATEX explosion there is a strong coupling between the explosion and its environment. As a consequence the guidelines recommendations cannot be transposed on an industrial site without due consideration.

An example is shown based on a real installation. The example of a painting installation is considered, and is schematized in Figure 1. It consists of a paint booth and a dust collecting system made of a filter and a cyclone connected by pipes. The supply circuit is excluded from the present study. The major objective is to protect the paint booth from the explosion effects as well as to limit the explosion effects in the medium range from the installation.

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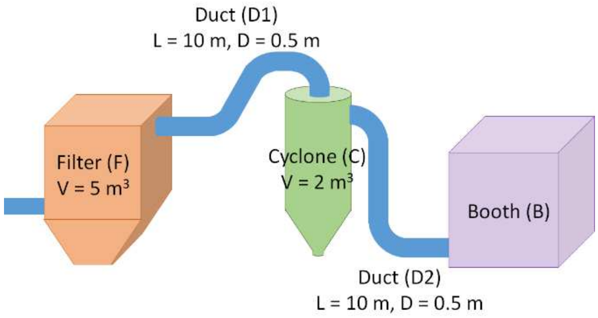

Figure 1. Schematized painting installation

2. Modelling the development of the explosion in a process

In practice, industrial sites can be of a tremendous complexity and make it impossible or too costly to perform extensive fluid dynamics computations to simulate complex flame propagation throughout the whole structure. To model such explosion phenomena and keep a satisfying understanding on the course of the events, INERIS developed the EFFEX code (Proust, 2005), a phenomenological software consisting of interlinked models each dedicated to a single aspect such as flame propagation in a volume, turbulence characteristics prediction, combustion rates, mechanical resistance, pressure effects… Most of the physics is derived from fundamental research. Each model is qualified separately and the overall consistency can be compared to realistic full scale experimentation or actual accidents. In a first approach an isolated and partially confined cell in which an explosion is generated is considered: the filter. The pressure rise due to the dust explosion is directly linked to the quantity of gases produced by the combustion minus the gases lost by the various openings on the filter (ducts, opened vents). Thus, the pressure rise curve as function of time can be estimated with a model such as that of Lewis and Von Elbe (1987):

$$\frac{1}{P}\frac{dP}{dt} = \gamma \cdot \frac{Q_{produced} - Q_{lost}}{V} \qquad (1)$$

where P, V and γ are the filter pressure, its volume and the specific heat ratio of the gaseous species. $Q_{produced}$ and Q_{lost} are respectively the volumetric fluxes produced by the combustion and lost through the vent. Such model clearly indicates that the effect of the explosion will be directly linked to the reacting products, which will determine the rate of the gases production and the environment through the action of the vents in the Q_{lost} parameter. Q_{lost} can be estimated through some various models derived from the generalized Bernoulli's laws. In practice whether the flow is subsonic or supersonic it is possible to estimate the Q_{lost} term through equation (2) or (3) respectively for the subsonic and supersonic cases:

$$Q_{lost} = C_d \cdot S \cdot \left(\frac{P_2}{P_1}\right)^{1/\gamma} \cdot \sqrt{\frac{2\cdot\gamma}{\gamma-1} \cdot \frac{P_1}{\rho_1} \cdot \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right)} \qquad (2)$$

$$Q_{lost} = C_d \cdot S \cdot \sqrt{\gamma \cdot \frac{P_1}{\rho_1} \cdot \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}} \qquad (3)$$

However, the problem of the estimation of the produced gases flux $Q_{produced}$ is more challenging as it depends both on the products that are reacting but also on their environment which will influence the flame surface or impose concentration or turbulence gradients. Gas production through combustion can be approximated as follows in our model: the fresh combustible mixture is instantaneously transformed in hot burnt products through the passage of the flame whose thickness is zero. Thus, it is a function of the area of the reacting surface Af, its velocity St and an expansion ratio α:

$$Q_{produced} = St.Af.(\propto -1) \qquad (4)$$

Firstly, the expansion ratio α is a thermodynamic data which depends only on the heat released by the combustion and can be expressed through the first principle of thermodynamics:

$$\propto = \frac{\rho_{fresh}}{\rho_{burnt}} \approx \frac{T_{burnt}}{T_{fresh}} = \frac{\Delta H_{Comb}}{C_P . T_{fresh}} + 1 \quad (5)$$

With ΔH_{Comb} the reaction enthalpy T_{fresh} and T_{burnt} the temperatures of the reactants and the burnt products, ρ_{fresh} and ρ_{burnt} are the densities of the reactants and the burnt gases, and C_P the specific heat of the burnt products. The expansion ratio α is a fundamental parameter which depends strongly on the combustible mixture composition and is poorly influenced by the propagation. For most common mixtures found in the process industries it is comprised between 6 and 8 (Eckoff, 2003).

Alternatively, the shape of the confined structure suffering the explosion can have an influence on the flame surface Af and so is the case for the local flow velocities, or when obstacles are present. Even in a medium initially at rest, the flame grows spherically until the spherical front reaches the closest wall. When contacting the wall the flame front is stopped then reversed. During this phase the flame front surface can become cellular or be curved toward the combustion products most likely because of local perturbations such as Landeau-Darrieus instabilities (Darrieus, 1944). In all case the maximal flame area is linked to the dimensions of the volume and its cross section. Extensive comparisons of EFFEX calculations with experiments indicate that a decent agreement can be achieved when the flame surface is roughly equivalent to the largest inscribed sphere in the enclosure (Proust, 1999).

Finally, the flame velocity in a mixture attached referential is also expected to be an intrinsic property of the mixture. The fundamental combustion velocity S_{lad} obeys to the laws of thermokinetics (thermodynamic equilibrium, Arrhenius law) and can be described as the volume of reactants consumed by a square meter of the flame surface. However, this definition corresponds to a configuration in which the reactive mixture is at rest in which case the effect of an explosion would be limited to the maximum. For a more realistic approach, it is necessary to consider a turbulent flame velocity S_t that can be determined for industrial applications based on the empirical definition of K_{st}:

$$K_{St} = \left(\frac{dP}{dt}\right)_{max} \cdot V^{1/3} \quad (6)$$

Replacing this in equation (1) (and assuming no openings on the vessel), we obtain:

$$\frac{1}{P_{max}} K_{St} = \gamma \cdot \frac{St \cdot Af_{max} \cdot (\alpha - 1)}{V^{2/3}} \Rightarrow \quad St \approx \frac{K_{st}}{\gamma \cdot P_{max} \cdot (\alpha - 1)} \quad (7)$$

As a summary, even in the isolated enclosure the effects of a dust explosion are strongly dependent not only on the nature of the reactants but also on the specificities of their environment such as the geometry or local turbulence effect.

All these results assume enclosures in which the pressure can be considered uniform, which is not the case as soon as the length over diameter ratio is larger than 5 (Proust, 1996), that is in the case of ducts. In this last situation, the flow velocity is driven by the pressure difference between both ends of the pipe, and so is the flame. In practice, there would be an explosion at one end, here the filter and the atmospheric pressure at the other end. A direct consequence of this is that the flame velocity in such situation quickly reaches hundreds of meters per second. Empirical data show that the flame velocity in a duct downstream an enclosure is well correlated with the square-root of the overpressure P_{red} (stands for “reduced explosion pressure” a term often use to design the maximal overpressure in a vented vessel) in the enclosure (analogy to a Bernoulli model):

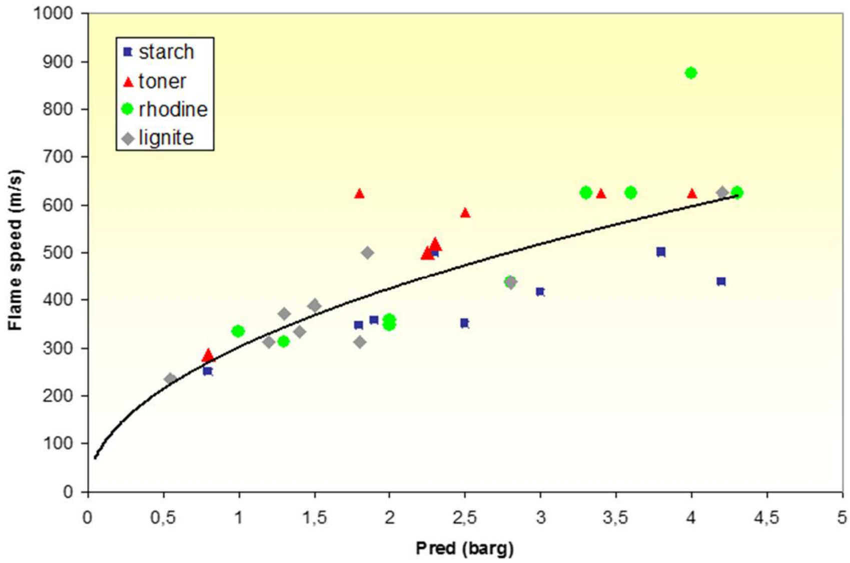

Figure 2 Correlation between vessel overpressure and maximal flame velocity in a connected in a duct (Grégoire, 2014)

When an explosion occurs in a structure made of interconnected enclosures the explosion can be transmitted from one vessel to its neighbors and the flame propagation can become of an extreme complexity (Phylaktou et Andrews, 1999). In such case a schematic of a possible course of events is presented in Figure 3: the dust ignition in the primary enclosure induces a first explosion (3a) and generates a significant turbulence and flow velocity in the connected pipe (3b). Then large quantities of the combustible mixture will be pushed in the downstream enclosure and pressurize it. After its significant acceleration in the duct, the flame will enter the pressurized and highly turbulent combustible mixture in the secondary volume. A secondary explosion, of much greater violence can then happen (3c). It can also reverse the flow completely and push the reactive front back in the primary vessel where the combustion is not terminated (3d).

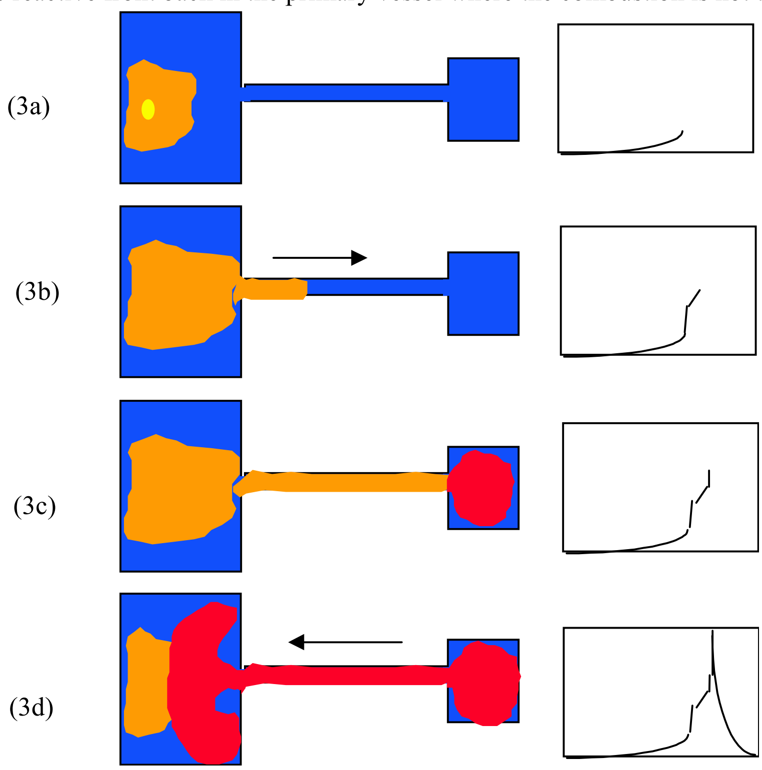

Figure 3: Schematic representation of explosion development in interconnected enclosures

Under certain conditions, phenomenological models are also available to estimate the pressure effects due to the flame arrival in the turbulent mixture of the secondary volume. In most situations, the turbulent flow will be induced by jets which characteristics are relatively well known (see Ruffin (1994) for further details on jet theory). A prediction tool was elaborated at INERIS from this knowledge database. Analytic models used to estimate the local turbulence velocity u' and the characteristic sizes of the turbulent structures L_t were proposed by Hinze (1975). The two flow turbulence parameters u' and L_t can then be used to estimate the turbulent flame velocity with a Gülder empirical model (Gülder, 1990). Further details on the application of this model have been published by Proust (2005). The main interest here is the order of magnitude to the flame velocities enhancement due to the turbulence effect that can be on the order of 5 to 20 times that observed in the same mixture at rest.

3. The explosion scenario

Because of the specific phenomenology of flame development in the complex structure made of interconnected enclosures it is necessary to define first an explosion scenario which is the baseline for the comprehensive analysis of the explosion effects in the structure. In the present case, the explosible dust is painting powder which is known to have a K_{St} value close to 200 bar.m/s and a P_{max} on the order of 7,5 bar. Filters are prime causes of dust explosion. The conventional situation occurs during a declogging operation, when the fall of an agglomerate of powder produces an electrostatic spark which ignites the dust cloud in suspension. Then the flame will propagate towards the cyclone and the paint booth. If it is assumed that the filter is well closed and resistant, the explosion overpressure can reach 5 bar. In practice, calculations show that the filter should rupture for an overpressure lower than 500 mbar. The flame then propagates to the cyclone, pushed by the overpressure in the filter at a speed of 300 to 500 m/s (see Figure 2). Under these conditions, the flame arrives supersonic in the cyclone, so that combustion is likely to occur at a speed comparable to that of the expansion waves. This implies that a combustion at a quasi-constant volume inside the cyclone will occur (despite the exhaust ducts). An overpressure of the order of the dust P_{max}, 7,5 bars seems possible but again a complete failure of the cyclone will happen before reaching this value (we assume a resistance of the cyclone of 1 bar in this case study). Such scenario was simulated with the EFFEX code and the results support this summary of events: Figure 4 presents the pressure in the filter, the duct and the cyclone assuming an explosion initiated in the filter (5 m^3, pressure resistance of 1 bar), transmitted to the duct (L =10 m, D= 0,5 m) and to the cyclone (2 m^3, pressure resistance of 2 bar).

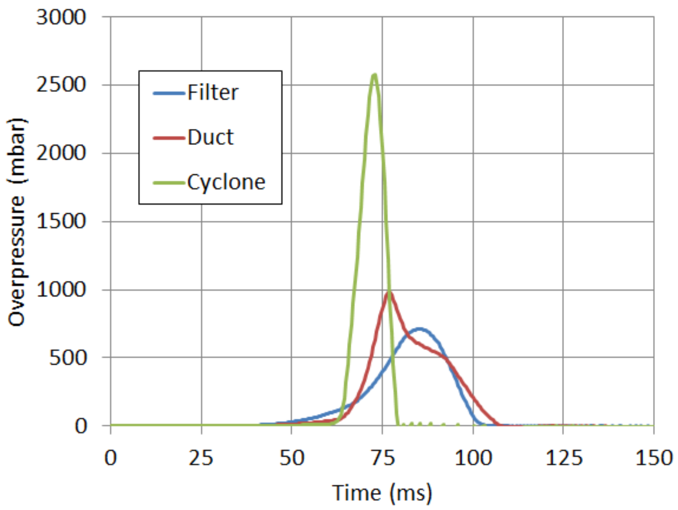

Figure 4: Overpressure calculated in the filter, duct and cyclone; explosion ignition in the filter

The flame should continue to the paint booth at speeds in excess of 500 m/s. The consequences of such scenario are the bursting of enclosures with the projection of fragments up to several tens of meters and the emission of a pressure wave corresponding to that induced by the detonation of 1 to 3 kg of TNT, the effects of which are known to be dangerous for humans from 20 to 30 m in open field. Secondly, the blast induced by the propagation of the flame in the pipes is largely sufficient to blow all available dust, especially inside the paint booths. This could result, depending on the configuration of the cabins, either a flash, ie. a large ball of fire without noticeable pressure effect, or an explosion if the confinement offered by the cabins is sufficient. It is also possible that the ignition occurs in a small explosive volume in contact with a gun in the paint booth. Consequences of such scenario would be very similar to the previous one: each exploding volume supports flow and flame acceleration in the connected pipes not only propagating but also intensifying the explosion in the next volumes, thus enhancing the rate of combustion and associated the damaging effects.

4. Implementing the explosion protection strategy

The potential effects of an explosion within such installation are not acceptable and make it absolutely essential to equip it with explosion protection devices. As the most fundamental principle is the safety of people who are working in the painting booth, the risk of having a flame reaching a combustible cloud in the painting booth in unacceptable. Consequently, one would look in a way to isolate the cyclone form the painting booth which needs the use of an isolation device on the duct. The essential parameter is the closing delay that is usually close to a dozen of milliseconds. This delay must be compared to the duct length and the flame velocity which is directly dependent on the overpressure in the cyclone. As a result, the cyclone protection is a requirement for a successful isolation of the painting booth. Different techniques may be used such as deflagration venting which consists in discharging the explosion through an orifice (the vent) cut in a wall of the protected enclosure, which is sealed in normal operation and opens as soon as there is an accidental pressure rise in the enclosure. The vent area must be calculated so that the maximum pressure reached in the protected vessel, P_{red} remains significantly lower than the mechanical pressure resistance of the enclosure.

A mistake would be to consider each volume separately: knowing the dust reactivity parameters (K_{St} = 200 bar.m/s, Pmax = 7,5 bar) in each "independent" volume, one would estimate vent areas on the order of 0,65 m^2 for the filter and 0,15 m^2 for the cyclone (calculations based on EN14991:2014). However, proceeding such way completely occults the flow and flame acceleration effects in the pipes (supported by the upstream exploding enclosure) and the significantly enhanced combustion effects downstream the pipes, thus rendering the protective equipment completely inefficient. The simulation of this scenario in EFFEX (Figure 5) shows that despite the filter was initially protected by the vent opening, the flame acceleration in the pipe led to a severe explosion in the cyclone and to its destruction (from a 1 bar overpressure). One can also note that an overpressure of 400 mbar is calculated in the filter while the vent was dimensioned to prevent reaching more than 250 mbar in the filter. This is a side effect of the major explosion in the cyclone that could have been worse if a more resistant cyclone had been selected.

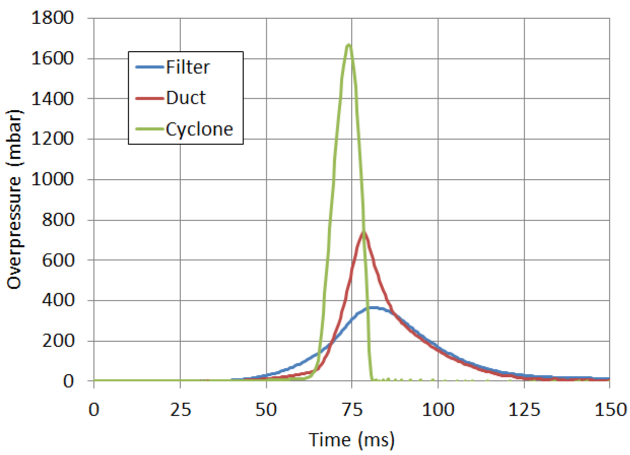

Figure 5: Overpressure calculated in the filter, duct and cyclone; explosion ignition in the filter; 0,65 m^2 vent on the filter and 0.15 m^2 on the cyclone.

A critical aspect in this example scenario is the coupling between the two enclosures, that need to be accounted for when choosing and dimensioning an explosion mitigation technique. Several options exist, a few are presented in the subsequent paragraphs:

- vents protection of the cyclone and filter,
- vents protection in addition to a decoupling system between the two enclosures,
- isolation of the duct and vent protection of each volume,
- explosion suppression in the filter and the cyclone,
- mixed systems protection.

4.1 Vents protection of the cyclone and filter

In the normative document EN14491:2014, a dimensioning method is proposed to limit the violence of the explosion in an assembly "enclosure 1 – duct – enclosure 2". The vent areas to install are often much wider as those predicted by the usual method in the same document. In such situation, the purpose of the vents is not only to unload the explosion but also to reduce the flame acceleration in the duct. The EN14491:2014 document indicates an order of magnitudes for these vent areas, which imply typically a coefficient ($Av/V^{0,753}$) of 0,4. It can be highlighted that inconsistencies exist between such recommendations and the calculations that can be made with the formulas concerning the vents connected to ducts. Nonetheless the use of such technique is feasible in the present case but it is necessary to perform some calculations. Knowing the available vent area on the cyclone and the acceptable reduced explosion pressure P_{red}, one can estimate a maximal flame velocity acceptable in the duct. Then the vent area to install on the filter will be calculated in view of discharging the explosion but also limiting the flame velocity in the duct to the maximal acceptable value. In the present example EFFEX calculations indicate that with a 2 m^2 vent on the cyclone, the device can be protected provided the flame velocity in the duct remains lower than 150 m/s that is when the P_{red} in the filter is lower than 200 mbar and the vent area is 1,5 m^2.

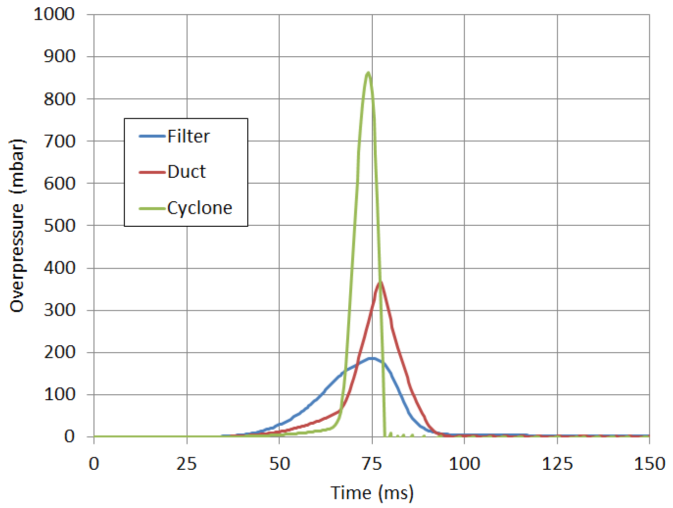

Figure 6: Overpressure calculated in the filter, duct and cyclone; explosion ignition in the filter; 1,5 m^2 vent on the filter and 2 m^2 on the cyclone.

In this example the structure is protected. However, it is important to point out that these calculations rely on the hypothesis of an ignition in the filter. If the explosion starts in the cyclone or the painting booth it will be necessary to perform new, yet similar, calculations. Also note that the environment around the enclosures (a road, workers, a wall, …) may impose to have vent ducts, deflectors or flame arrestors at the exhaust of the vents. All of these systems impede the explosion discharge and induce a lower vent efficiency, thus the necessity to install larger vent areas.

4.2 Vents protection in addition to a decoupling system between the two enclosures

The previous mitigation solution requires large vent areas on each device, which may not be feasible for practical reasons. The smallest possible vent areas A_v for the filter and for the cyclone corresponding to this scenario are those predicted by the standard formula:

$$\frac{A_v}{V^{0,753}} = \left[3{,}264 \cdot 10^{-5} \cdot P_{max} \cdot Kst \cdot p_{red}^{-0{,}569} + 0{,}27 \cdot (P_{stat} - 0{,}1) \cdot p_{red}^{-0{,}5}\right] \cdot \left(1 - 4{,}305 \cdot log(p_{red}) + 0{,}758 \cdot \log\left(\frac{L}{D}\right)\right) \quad (8)$$

with A_v the vent area to be installed, V the enclosure volume, P_{max} and K_{St} the dust reactivity parameters, P_{red} the maximal accepted pressure in the enclosure, P_{stat} the vents opening pressure, L the maximal flame length and D the enclosure diameter (further details on this formula applications can be accessed in the original standard EN14491:2014). For the present case the values calculated by this formula were used in the first simulation in paragraph 4: we calculated vent areas of 0.65 m^2 for the filter and 0.15 m^2 for the cyclone. Note that large variations can be observed on these values, depending on the L/D ratio and maximal flame length (farthest distance between the vent and the ignition origin) of each enclosure. In the case of isolated enclosures, this is expected a conservative approach as the P_{max} and K_{St} terms are measured in more critical conditions (dust concentration, turbulence) than they are supposed to exist in the industrial process. However, for this model to be valid for connected enclosures, the violence of the explosion must correspond to the limitations defined in the standard, which implies that the turbulence level must remain in the range of the tests that were performed to establish this formula. In the present case, this typically means that the flow velocity in the duct between the filter and the cyclone should not exceed 30 m/s. A direct consequence of this is that these lower venting areas may be used provided the duct effect can be neglected, which can be done when the explosion is either decoupled or isolated. Firstly, we will consider the option of the explosion decoupling.

Explosion decoupling devices are designed to limit the flame velocity in a duct. It can be achieved by adding vents on the duct that are designed to open before the flame arrival and slow down the flow in the event of an explosion. Such systems may also be constructed in view of forcing the flame to change directions, to prevent excessive accelerations. Those decoupling systems can be dimensioned so that the turbulence induced in the downstream enclosure remain at an acceptable level, however they will not stop the flame but only slow it down. Experiments performed at INERIS showed that an explosion generating a 2 bar overpressure in an enclosure can induce a flame velocity on the order of 400 m/s in the connected duct without any protection while having vents on the duct close to the exploding vessel can limit significantly the pressure effects and reduce the flame velocity by a factor 2 to 4 (Roux et Proust, 2003). In the present case this would not be sufficient but reducing the flame velocity level between the two enclosures can make it possible to use smaller vent areas than those presented in paragraph 4.1.

4.3 Isolation of the duct and vent protection of each volume

If an isolation system is present on the duct, the flame will not propagate from one enclosure to the other one and then standard venting protection rules for isolated enclosures may be applied. These isolating devices can be of several types and based on very different technologies, for example: active (electronic detection of the explosion) or passive (purely inertial) flap valves, gate valves, pinch valves or chemical flame extinguishers. However, as any explosion mitigation device, they have their own limits that need to be accounted for. Firstly, some of those, such as the flap valves can only function in one direction, to stop a flame traveling in a direction opposed to the usual flow observed during the functioning of the process. Secondly some of these systems rely on the mechanical closing of the duct, which imply there are not efficient before a certain amount of time. From past experience on systems tested at INERIS, sometimes in the scope of ATEX certification, this delay is typically ranging around a few ms for active devices (with actual explosion detection and non-passive closing system such as in the case of gate valves or pinch valves) to a several dozens of ms when the device is fully passive and actuated by the explosion generated flow. Depending on the flame velocity (which can hardly be lower than 150 m/s in the present configuration) and the duct length (10 m here) it is necessary to ensure that the chosen system is really able to stop the flame. Also, quite regularly singularities, such as bends or a restriction generating a Venturi effect, are present on the ducts of industrial processes, they may alter the flow significantly. This needs to be taken into account when installing the isolation devices. Finally, there is also an upper limit in time (chemical isolation) or installation distance (mechanical isolation) after which the extinguishing cloud has settled down or the duct pressure has become too high and the isolating system will fail mechanically.

4.4 Explosion suppression in the filter and the cyclone

Alternatively, it is possible to use explosion suppressors on the filter and the cyclone. Those are based on the active and early detection of explosions coupled with a chemical agent that is injected at a sufficient rate so that the explosion can be quenched before it becomes too damaging for the structure. Typical delays for flame quenching are on the order of a few dozen of ms. As it is intended to extinguish the flame in each of the capacities, there should not be any transmission effect through the pipe between the cyclone and the filter, so that it is not necessary to install an isolation device. However, if an explosion is quenched in the cyclone, the residual overpressure (typically a few hundred mbar) would be sufficient to propel the hot combustion products present in the cyclone-cabin pipe to the cab at a few hundred meters per second. Under these conditions, the risk of dust explosion in the cabin persists. It is therefore a fundamental requirement to maintain an isolation valve between the cyclone and the cabin as indicated at the beginning of paragraph 4. It is reminded that such isolation valve is likely to function correctly only under certain distances conditions as described in paragraph 4.3.

4.5 Mixed systems protection

The solutions presented in the previous paragraphs can be combined, but again without losing the perspective that the enclosures are connected by a duct. For example, if the filter is outside of the building and the cyclone is located inside, the former can be protected by a vent while the later cannot (it is assumed that people are working in the same building). It would be possible in such case to protect the cyclone with explosion suppressor. Again, it cannot be done without a due consideration of flame velocity / acceleration in the duct. Explosion suppressors are certified within limits in terms of dust reactivity (among other limits such as the throw of the extinguishing cloud or the activation delay) that are applicable to the case of isolated enclosures. This is not the case if the flame has been significantly accelerated in a duct before reaching an enclosure in which the turbulence has been significantly increased compared to the standard process conditions. Consequently, in order for the suppression technique to remain effective in this situation a larger vent area might be needed on the filter (as in paragraph 4.1) or a decoupling device (paragraph 4.2) or an isolation valve (paragraph 4.3) should be placed between the filter and the cyclone. The limitations referred to in the preceding paragraphs for the different explosion mitigation devices apply.

5. Conclusion

A strategy to implement an explosion mitigation solution has been presented around the example of an industrial painting process made of a filter, a duct, a cyclone, a second duct and a painting booth (where workers are present). A phenomenological analysis of explosion development and propagation in dual enclosure-duct systems was presented. The scenario of an explosion starting from the filter was selected as a reference to highlight the critical mechanisms involved when explosions propagate between interconnected enclosures. In the fourth part a way to account for the real explosion conditions is given, allowing a choice and dimensioning of a set of safety systems. Vent area calculations were presented together with the order of magnitudes of the characteristic functioning parameters of the other safety systems that may be implemented. Beyond that an important focus is given on the actual strategy of protection to implement, which aims at protecting firstly the people working close by then the structure and must always rely on a physical understanding of the dust flame propagation (in enclosures and in ducts) as well as its interaction with its environment (turbulence generation, pressure effects). A specific focus can thus be made on two fundamental aspects: on the one hand, it is of critical importance to understand how the flame propagates in a given complex system. On the other hand, the behavior of the protection systems that might be used must also be carefully studied as it cannot be dissociated form the previous analysis, those systems will indeed systematically have an effect on the explosion driven flow.

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Titre français : Ingénierie des systèmes de sécurité

Mots clefs : barrières de sécurité, explosion de poussière

Résumé
La protection contre les explosions fait l'objet de plusieurs documents, nationaux et internationaux, qui décrivent la fonction, les applications et les règles de dimensionnement de systèmes de protection spécifiques. Toutefois, bien que des exemples d'application figurent dans les guides de bonne pratique, ils sont limités à la description de solutions de protection pour des équipements considérés isolément, ce qui n'est pas représentatif des situations industrielles réelles. En pratique, le dimensionnement correct d'un système de protection doit tenir compte des fortes interactions qui existent entre une explosion et l'environnement dans lequel elle se développe.
Dans cet article, une manière de tenir compte des conditions réelles de développement des explosions est présentée, qui permet de sélectionner et dimensionner des systèmes de protection adaptés à l'application industrielle. Un exemple est donné sur la base d'une installation réelle. Les paramètres fonctionnels des systèmes proposés sont issus d'essais d'explosion, tandis que les caractéristiques des explosions sont calculées à partir des propriétés de combustion des poussières et des connaissances les plus récentes sur la propagation des flammes.

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