Explosion Protection System Selection Guide

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Selecting the right explosion protection system for your combustible dust handling process can be a daunting task considering the availability of many explosion protection technologies. Over the past decade with the introduction of new suppressor and detection technologies with smarter features along with new passive protection products, the number of available explosion protection options has increased[1]. Combined with increased emphasis on combustible dust hazards by OSHA[2] due to recent high profile combustible dust explosions[3,4] , understanding the available explosion mitigation options has become even more important. Process owners, corporate risk managers and process engineers need to understand the available protection options and applicable regulations in order to address combustible dust hazards within their processes using the most applicable and cost effective mitigation technology.

This paper provides a brief introduction to the explosion protection methods including suppression, isolation and venting. Other protection options such as pressure containment, combustible concentration reduction and inerting are also available, however not within the scope of this paper.

Overview of Explosion Protection Options

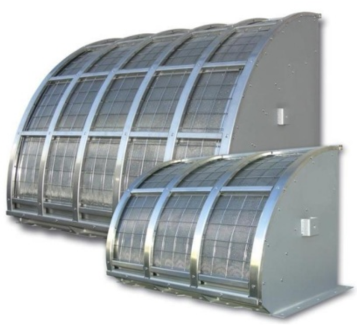
Before proceeding with the selection process, let's briefly look at the various explosion protection options:

Explosion Venting. It is one of the most widely used techniques for mitigating dust explosions. It is based on the opening of a specifically designed weaker membrane installed on a vessel to open and direct the flame, burned/unburned material, overpressure and other combustion byproducts to a safe location during the incipient stages of an explosion. According to NFPA 68, section 8.8, in the case of dust deflagrations, the vented fireball size can be estimated using the following equation; $\mathbf{D = K*[V/n]^{1/3}}$, where D is the axial fireball distance (m) from the vent, K is the flame length factor (8 for chemical or agri dusts, 10 for metal dusts), V is the volume of the enclosure (m^3), and n is the number of vents. Additionally the width of the fireball is estimated as one-half of D. For example for a vented enclosure with a volume of $1m^3$ handling agricultural dust, and protected by a single vent, fireball dimension becomes approximately 8 meters with a width of 4 meters. Thus a safety distance in front of the vented vessel is required to protect against the ejecting fireball. Explosion relief vents are designed to ensure that the pressure rise due to explosion does not exceed the pressure shock resistance of the protected equipment. In the US, explosion relief vents are designed in accordance with the procedures given in NFPA 68[5].

Picture 1 – Various sizes and shapes of explosion relief panels


Picture 2 – Vented and isolated explosion

Flameless Venting. This relatively new technology is finding niche applications in the process industries for protection of indoor process equipment against dust explosions. Flameless vents combine the proven explosion relief venting technology with flame arresting and controlled particle retention. Similar to explosion relief venting, its operation relies on the rupture of a weak membrane during a deflagration event where the overpressure, flame and particulate material discharges through a flame and particulate trap material, thus eliminating the flame and material discharge to surrounding areas. Only hot gas and pressure are discharged to ambient. For safety purposes, a safety perimeter around the flameless vent is required in order ensure employee safety. The ratio of the room volume to vented vessel volume has to be kept below the manufacturer's specifications for successful implementation of the flameless venting technology. Additionally, it is critical to regularly clean[6] the "mesh" layer in order to ensure that it is free of dust accumulation or dirt on its surface at all times, which otherwise may block the mesh openings and compromise the operation of the flameless vent. Low inertia, fire resistant fabric covers are available by some vent manufacturers to help keep flameless vents free of dirt.


Picture 3 –Flameless Vent

According to NFPA 654, vented equipment needs to be isolated in order to prevent flame propagation between connected vessels. Further information on isolation methods is provided in the following sections of this paper.

Picture 4 – Flameless vent protecting an indoor receiver

Explosion Suppression. As a well proven technology, explosion suppression systems have been employed in the industry since late 1950s. It is often used where it is not possible to vent the contents of process equipment to a safe place, and where the material being handled is toxic or is a harmful material to people and environment. Deflagration suppression requires that the incipient explosion be detected very soon after ignition, and a sufficient amount of suppressant is discharged into the developing fire ball in the enclosure at a fast enough rate to extinguish all flame before a destructive overpressure develops[7]. Figure 1 below shows the basic steps in deflagration suppression. In the US, NFPA 69[8] governs the standards on explosion protection systems.

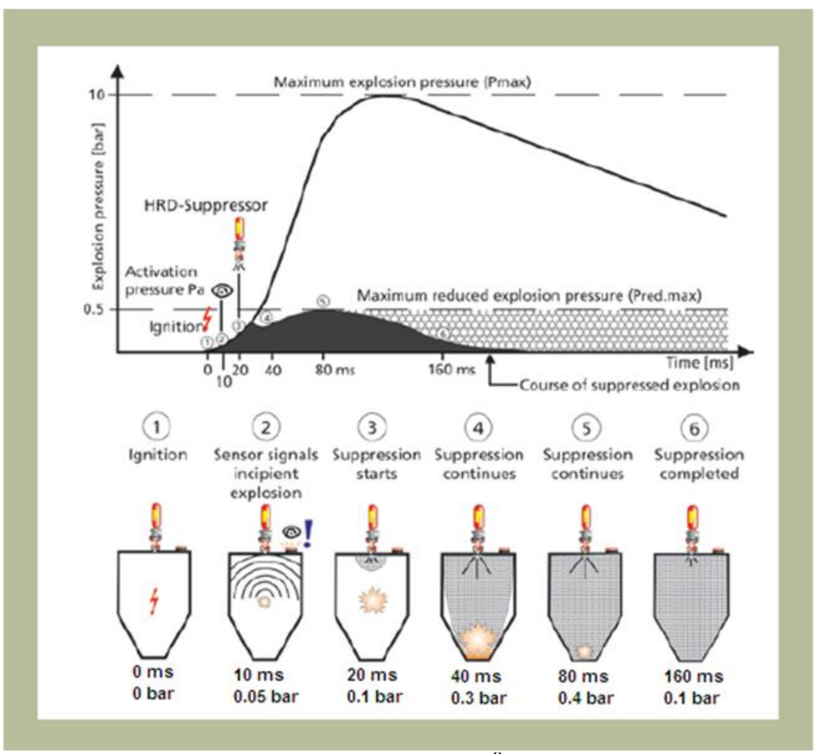


Figure 1 – Steps in explosion suppression[9]

Picture 5 – Explosion Suppressor

Picture 6 – Explosion protection (suppression and isolation) of an indoor dust collector

Explosion Isolation. Very often process equipment handling particulate solids are connected to each other by ductwork, chutes and conveyors. A deflagration in a vessel can propagate through these connections to upstream or downstream equipment and cause subsequent explosions in the adjacent equipment. Explosion isolation systems are employed to mitigate the flame propagation and pressure piling between connected equipment. The objective of explosion isolation is to prevent dust explosions from spreading from the primary explosion site to other interconnected processes[10]. According to NFPA 654 Section 7.1.4, where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between pieces of equipment connected by duct work[11]. Some of the commonly used explosion isolation systems are:

1. **Chemical isolation**. It is achieved by rapid discharge of a chemical extinguishing agent (e.g. sodium bicarbonate) into interconnecting duct to mitigate flame propagation.

Picture 7 – Chemical isolation of a duct using a high rate discharge suppressor

2. **Mechanical Isolation**. High-speed gate valves and flow-actuated valves are some of the examples of mechanical isolation products. Active isolation devices such as high speed gate valves close in milliseconds upon detecting an explosion, and mitigate flame and pressure propagation inside ductwork by rapidly deploying a mechanical barrier[12]. Passive isolation devices, such as flap or float type valves are self actuated by the air-flow created by deflagration event, thus require no detection or control components. Passive isolation devices are typically used to isolate nuisance dust handling equipment with relatively low dust loads.

Picture 8A – High-speed isolation gate valve

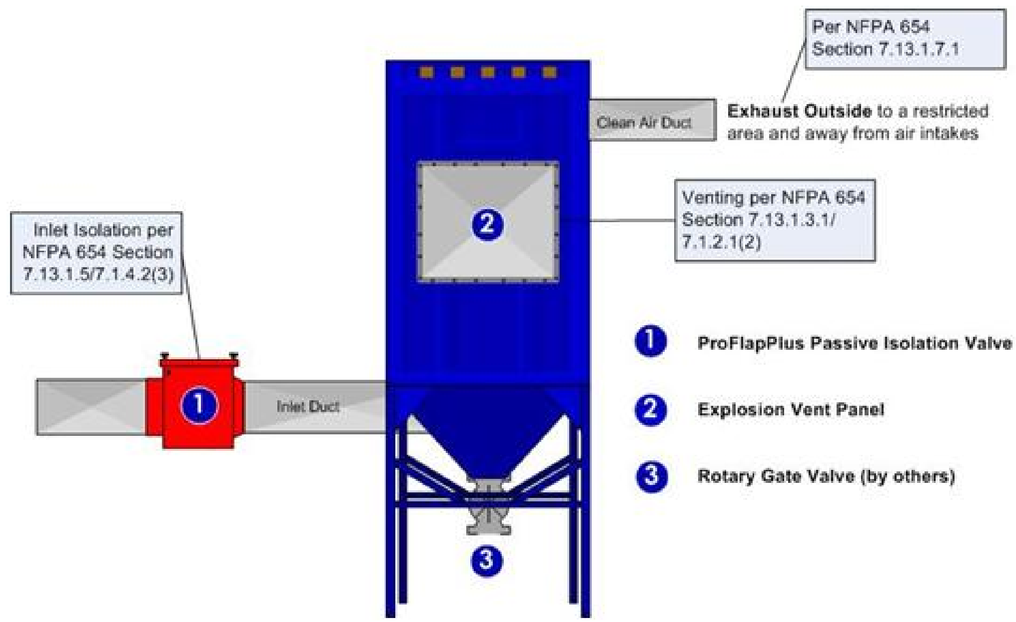
Picture 8B – Flap-type passive isolation valve (shown with maintenance hatch opened)

Picture 9 – Flap type valve isolating the inlet of a vented dust collector

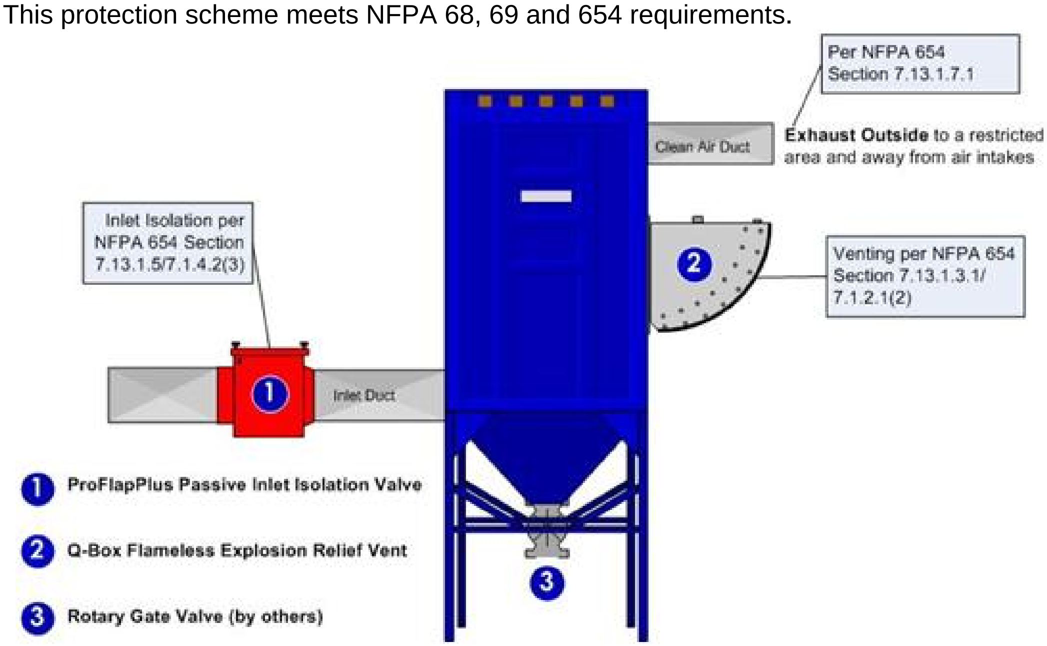
Explosion Protection System Selection[13]

Considering the large number of explosion protection options available, we developed the following selection guide to illustrate the commonly employed explosion protection options for process owners. Throughout this paper it is assumed that the process owner has already performed a risk assessment, and determined that an explosion protection system is required as one of the means to mitigate combustible dust hazards. Thus our focus in this paper is limited to explosion venting, suppression and isolation.

1) **Vented Dust Collector with Flap Type Passive Inlet Isolation**
   This is one of the most cost effective protection options, utilizing a complete passive protection method. In this case, dust collector is located outside, and does not handle any toxic or other harmful materials. Due to valve's design limits, the K_{ST}[14] of the dust is limited to maximum 300 bar.m/sec, the inlet duct diameter is maximum 22 inches, and the maximum reduced pressure[15] (P_{RED}) is limited to 7 psi. There will be flame and material release due to opening of the venting device during a deflagration event. The periodic maintenance of this system can be done by the system owner. This protection scheme meets NFPA 68, 69 and 654 requirements.

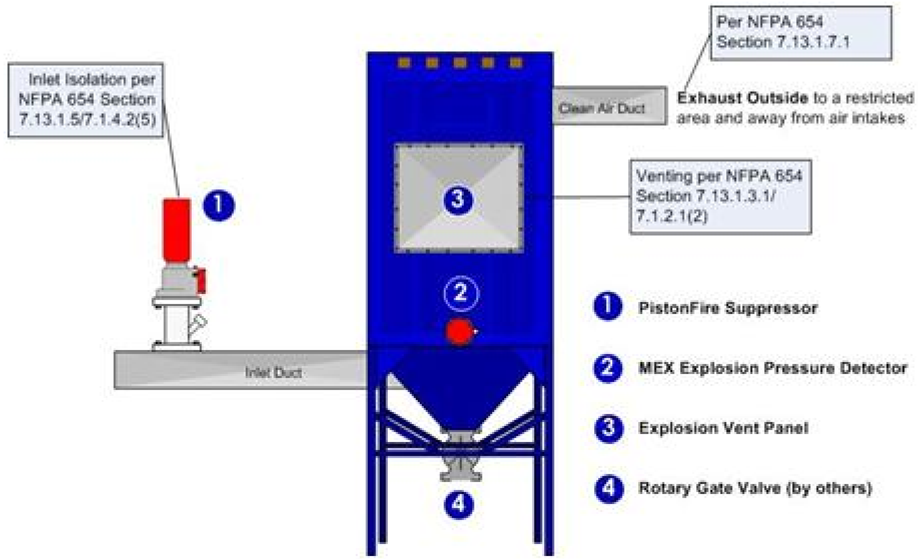


2) **Flameless Vented Dust Collector with Flap Type Passive Inlet Isolation**
In this case dust collector is located indoors, and it does not handle any toxic or other harmful materials. There is sufficient space around the vent area to allow 5 meters of safety perimeter. Due to flameless vent's design limits the maximum allowable K_{ST} of the dust is 250 bar.m/sec. And due to flap valve's design limits, the inlet duct diameter is maximum 22 inches, and the maximum reduced pressure (P_{RED}) is limited to 7 psig. The isolation distance is up to 4 meters from the protected vessel. There will be no flame release however some hot-gas will release due to opening of the venting device during deflagration. The periodic maintenance of this system can be done by the system owner. This protection scheme meets NFPA 68, 69 and 654 requirements.

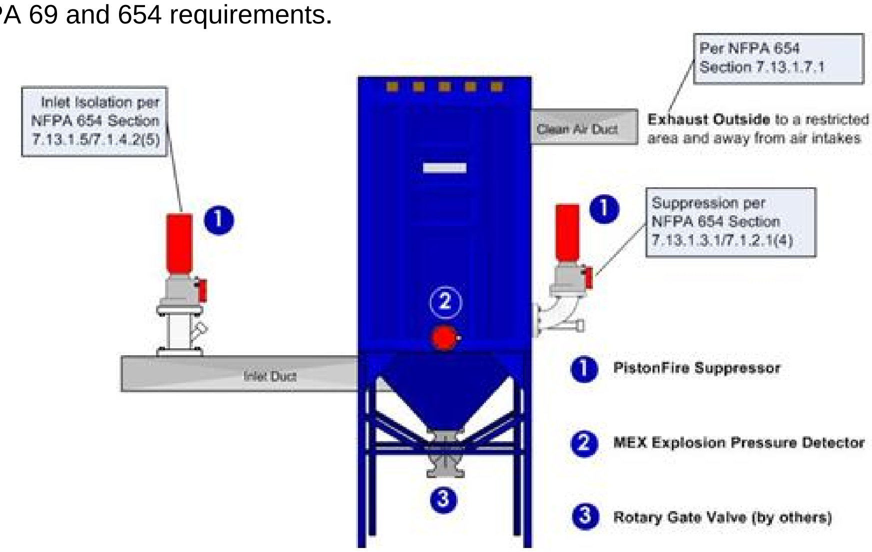


3) **Vented Dust Collector with Chemical Inlet Isolation**
In this case, dust collector is located outdoors, and it does not handle any toxic or other harmful materials. There is no restriction on the size of inlet duct diameter. The maximum reduced pressure (P_{RED}) can be higher than 7 psi. The maximum allowable K_{ST} for this system is 500 bar.m/sec. There will be flame and material release due to opening of the venting device during

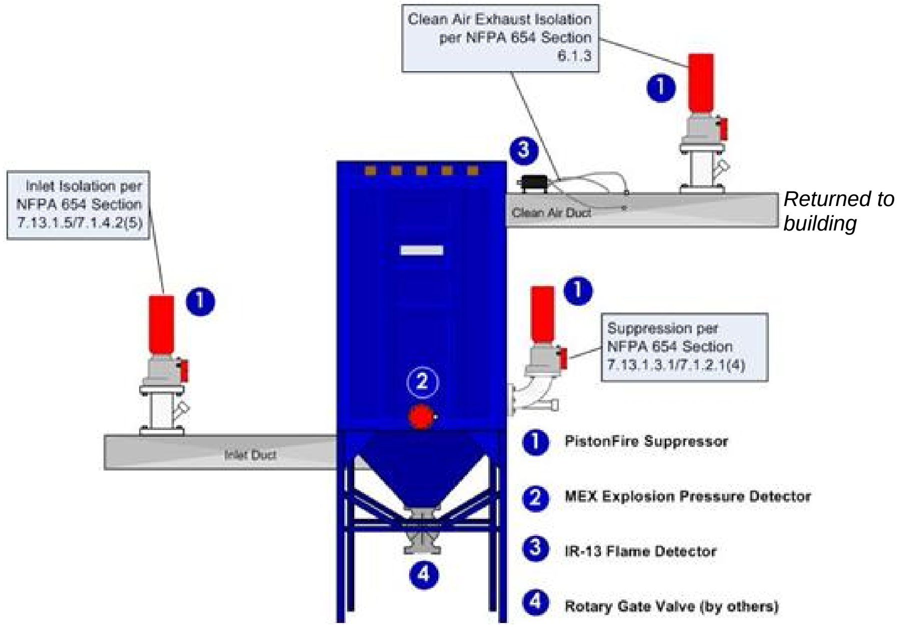
deflagration. The periodic maintenance of this system can be done by manufacturer or by manufacturer trained system owner. This protection scheme meets NFPA 68, 69 and 654 requirements.



4) **Suppressed Dust Collector with Chemical Inlet Isolation**
In this case, dust collector can be located indoors or outdoors. There is no restriction on the type of material being handled. Also there is no restriction on the size of inlet duct diameter. The maximum reduced pressure (P_{RED}) of the vessel can be higher than 7 psi. The maximum allowable K_{ST} for this system is 500 bar.m/sec. There will be no flame or material release after actuation of the system during a deflagration event. The periodic maintenance of this system can be done by the manufacturer or by manufacturer trained system owner. This protection scheme meets NFPA 69 and 654 requirements.

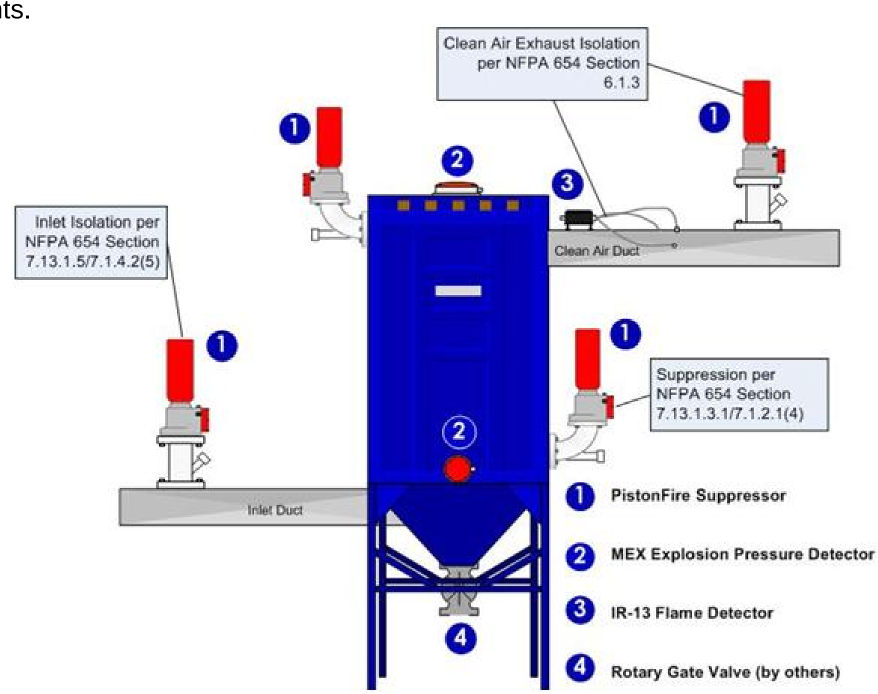


5) **Suppressed Dust Collector with Chemical Inlet and Outlet Isolation**
In this case, dust collector can be located indoors or outdoors. However the clean-air exhaust is re-circulated back into the building. There is no restriction on the type of material being handled. There is no restriction on the size of inlet or outlet duct diameter. The maximum reduced pressure (P_{RED}) of the vessel can be higher than 7 psi. The maximum allowable K_{ST} for this system is 500 bar.m/sec. There will be no flame or material release after actuation of the system during a deflagration event. The periodic maintenance of this system can be done by the manufacturer or by manufacturer trained system owner. This protection scheme meets NFPA 69 and 654 requirements.



6) Suppressed Dust Collector with Chemical Inlet and Outlet Isolation for Hybrid Material Applications

This is a case commonly seen in pharmaceutical or specialty chemical process applications. Dust collector can be located indoors or outdoors. There is no restriction on the type of material being handled. However the material is a mixture of flammable vapor/gas and combustible dust. There is no restriction on the size of inlet or outlet duct diameter. The maximum reduced pressure (P_{RED}) of the vessel can be higher than 7 psi. The maximum allowable K_{ST} for this system is 500 bar.m/sec. There will be no flame or material release after actuation of the system during a deflagration event. The periodic maintenance of this system can be done by manufacturer or by manufacturer trained system owner. This protection scheme meets NFPA 69 and 654 requirements.



Final Thoughts

This paper provides a brief introduction to the commonly employed explosion protection technologies and illustrates the system selection process. Using the process provided in this paper, process engineer or risk manager can make informed decision on their explosion protection requirements. However it is important to note that selection of explosion protection system is application specific, and system design expertise is required to select and size the most appropriate system. The number and size of suppressors, their installation locations and explosion detector settings should only be determined by the application engineer of the system manufacturer using computer aided design methods specific to the system being considered. Thus contact your explosion suppression system supplier for more information on the products and system design criteria.

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[9] http://www.incom-ag.ch/utcfs/ws-998/Assets/Explosion%20Protection_E.pdf

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[12] Siwek, R., Explosion Protection Systems Classification and Design

[13] A Tri-fold brochure illustrating the explosion protection options is available at www.fenwalprotection.com

[14] K_{ST} is the deflagration index of a dust, and is a measure of the relative explosivity of the material

[15] P_{RED} is the maximum pressure developed in a protected enclosure during a vented or suppressed deflagration.