EXPLOSION PROTECTION SYSTEMS

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1.0 SCOPE

This data sheet provides loss prevention recommendations for the use, review, design, testing and maintenance of explosion protection and isolation systems.

The information is applicable to deflagration explosions occurring in systems handling dusts, gases and dust-vapor mixtures.

The use of halons and possible replacements for systems already in service is discussed in this document.

Data sheets covering specific occupancies might supersede this document and should be reviewed prior to applying this data sheet.

NFPA 69, *Explosion Prevention Systems*, which also covers this subject, generally agrees with this data sheet.

This data sheet does not apply to detonations. Systems involving deflagration venting of dust and gas explosions are covered in Data Sheets 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*, and 7-32, *Ignitable Liquid Operations* (gases) respectively. Deflagrations in pipelines are also not covered.

Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*, provides explosion isolation recommendations applicable to dusts. The isolation and suppression systems described in Data Sheet 7-17, *Explosion Protection Systems*, apply to both dusts and gases.

1.1 Changes

January 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Protection

2.1.1 Explosion Suppression Systems

An explosion suppression system is comprised of explosion detectors, a suppressant delivery system, and a control and monitoring unit (see Fig. 1).

2.1.1.1 General

2.1.1.1.1 All components of the explosion suppression system should be FM Approved.

2.1.1.1.2 Use isolation devices to prevent fire or explosion from propagating to adjacent equipment or areas (such as ducts, etc.).

2.1.1.2 Application

The best way to prevent damage from a deflagration is to substitute, eliminate, or inert the materials that create the hazard (inherent safety approach). If this is not possible, the most reliable way to control the amount of explosion damage is to use properly designed damage-limiting construction (i.e., explosion venting or explosion resistant construction — passive safety approach). If Damage-Limiting Construction (DLC) cannot be provided or other protection issues must be addressed, an explosion suppression system may be chosen to control the damage from a deflagration. These systems are the least desirable form of explosion protection due to their complicated design and lack of testing that represents actual conditions in industrial environments. They are an active protection system and are less reliable than the passive protection provided by DLC.

Equipment and processes that can be protected by explosion suppression systems include but are not limited to the following:

- Processing Equipment: mixers, blenders, reactor vessels, pulverizers, mills, dryers, ovens, filters, separators, dust collectors, test cells, laboratory equipment and hoods, rooms handling flammable gases, etc.
- Storage Equipment: mobile facilities, atmospheric or low pressure tanks, silos, aircraft fuel tanks.

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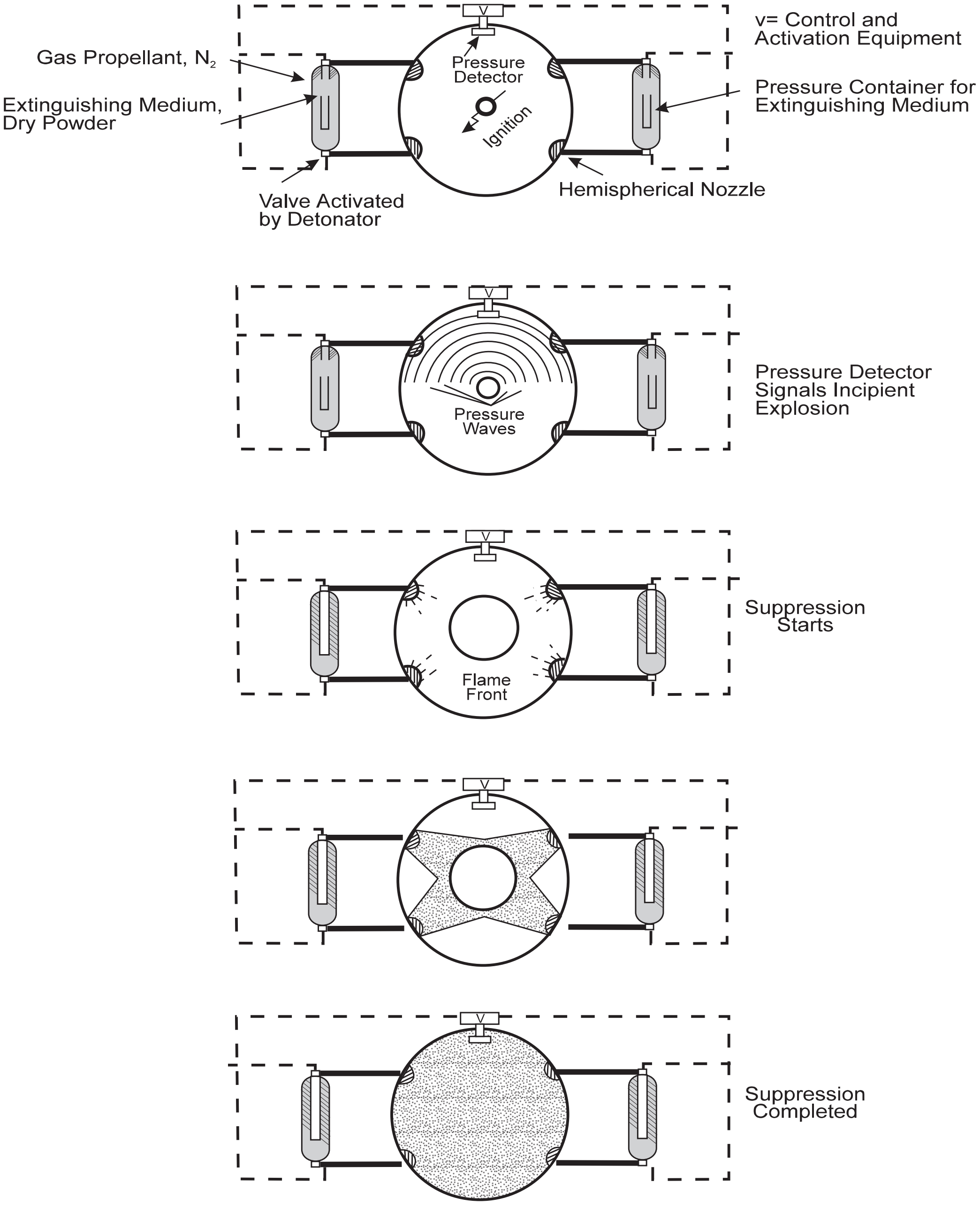

Fig. 1. Explosion suppression system example.

- Material Handling Equipment: pneumatic and screw conveyors; spray, rotary and tray dryers; bucket elevators, scrap and refuse shredders; grinding and blending equipment.

2.1.1.2.1 Provide explosion suppression for high value equipment, or equipment that exposes high value processes, or equipment with frequent explosions, when either explosion venting, pressure containment, or inerting cannot be provided.

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2.1.1.2.2 The process temperature, in general, should be limited to -20°F to 160°F Max. (-28°C to 71°C). The process temperature limits depend on the agent used, therefore the system designer should be consulted for specific limits.

2.1.1.2.3 Use caution when installing explosion suppression systems on enclosures/vessels larger than those used in the verification testing of the systems. It is technically possible to suppress explosions in vessels with volumes of up to 1000 m^3 (35,300 ft^3). In practice, dust and gas explosions have been successfully suppressed in vessel sizes of 0.2 m^3 (7.1 ft^3) up to 250 m^3 (8825 ft^3).

2.1.1.2.4 Do not install explosion suppression systems where ST3 dusts are used unless proven by full-scale tests. In general, ST3 dusts cannot be effectively suppressed due to their extremely fast rate of pressure rise.

2.1.1.2.5 Do not use combinations of suppression and inadequate explosion venting unless full scale tests prove the system is effective.

2.1.1.3 Aerosol Filling Rooms

2.1.1.3.1 Explosion suppression systems should not be used as an alternative to DLC in aerosol filling rooms. The only reliable form of worst case explosion protection for these rooms, at this time, is DLC. Explosion suppression systems may provide some level of protection for small (i.e., partial volume) explosion events.

2.1.2 System Components

2.1.2.1 Detectors: General

An explosion is not instantaneous but takes time to build up destructive pressures in a containing vessel. Typically it takes 30-100 ms before destructive pressures build. The detector chosen must be capable of recognizing the existence of an explosion very early after ignition. There are three types of detectors: thermoelectric, optical and pressure.

2.1.2.1.1 To minimize false trips of the suppression system, position two detectors in two planes i.e., cross-zoned). This is especially important for pressure detectors.

2.1.2.1.2 For dust explosion hazards, thermoelectric sensors (activated by direct heat transfer from hot gases), and optical detectors should not be used since they only work effectively if located close to the heat source.

2.1.2.1.3 Wire detectors actuating explosion suppression systems to a Class ‘‘A’’ initiating device circuit, as defined by NFPA.

2.1.2.2 Optical Detectors

Optical detectors give the earliest warning (typically actuating in less than 10 ms) because they detect ultraviolet or infrared emissions.

2.1.2.2.1 Use optical detectors in clean systems where the detector lens will not become obscured or the radiation diminished by the combustible medium. Also, do not use optical detectors where liquid hydrocarbons can coat the viewing window.

2.1.2.2.2 Use optical detectors in areas where there is a risk of flash fires (e.g., rooms containing ignitable liquids or liquefied flammable gases) or in low strength enclosures with pressure resistance 7 to 14 mbar (0.1 to 0.2 psi).

2.1.2.2.3 Arrange optical detectors to ensure they have an unobstructed view of the protected volume. Detection of an incipient explosion can be delayed if the detectors cannot ‘‘see’’ the flame.

2.1.2.3 Pressure Detectors

Pressure detectors continuously measure pressure and monitor the rate of pressure rise and threshold pressure.

2.1.2.3.1 Set the activation pressure above normal process pressure fluctuations, typically 27 to 35 mbar (0.4 to 0.5 psi).

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2.1.2.3.2 The detectors must not be sensitive to condensation. They must resist corrosion, shock and vibration, and must be unaffected by variations in temperature and by the material being handled.

2.1.2.3.3 In general, locate pressure detectors a maximum distance of 20 ft (6 m) from the suspected ignition source(s).

2.1.2.3.4 Use strain gauge or piezo-electric pressure sensors where there are large fluctuations in normal operating pressure.

2.1.2.4 Control Systems

Control systems detect changes in the explosion sensor output or mechanical condition; they determine whether a hazard exists, and activate the suppressors.

2.1.2.4.1 The control system should be interlocked to shut down the equipment involved safely upon detector activation and should prevent the process equipment from restarting without re-arming the suppression system.

2.1.2.4.2 Monitor the electrical system of the detector and suppressor activation circuits at a constantly attended location. Any component failure should sound an alarm and automatically shut down the process.

2.1.2.4.3 Provide a standby battery that engages automatically when the electrical power fails.

2.1.2.4.4 Install the control system in a safe, dust-free area or within enclosures Approved for explosive atmospheres (see Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*).

2.1.2.4.5 De-activate the control system, shut down the process and purge any combustible dusts or flammable gases before entering the vessel or doing any activity that could accidentally trip the suppressant system.

2.1.2.5 Suppressant Delivery Methods

2.1.2.5.1 High Rate Discharge (HRD) suppressors should be provided with a pressure gauge.

2.1.2.5.2 Do not use hemispherical suppressors in high temperature processes (> 60°C [140°F]).

2.1.2.6 Suppressant Materials

2.1.2.6.1 The suitability of a particular extinguishing agent for a given application should be determined by explosion suppression tests. The correlation between activation pressure of the suppression system and the reduced maximum explosion pressure has to be established. Also, the suppressant has to be insensitive to the temperature and vibration inherent to the protected system. Table 1 contains a comparison of the merits of common suppressants.

Table 1 - Relative Merits of Common Suppressants

Consideration	*Powder*	*Halon*	*Water*
Toxicity	No	Slight	No
Contamination	Yes	Slight	Wets Product
Decomposition	No	Yes	No
Dust Class	ST1 & ST2	Usually ST1 Only	Hydrophilic ST1 & ST2
Gases	Yes	Yes	No

2.1.2.6.2 When halon is the suppressant, an activation pressure of less than 0.1 bar (1.5 psi) should be used. (See Appendix C for possible restrictions on the use of halon.)

2.1.2.6.3 The halons should only be used to suppress ST1 dusts.

2.1.2.6.4 Water should not be used to suppress gas explosions.

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2.2 Operation and Maintenance

2.2.1 Design Procedures

2.2.1.1 The mathematical or computerized suppression model used to determine the suppression system design should be Approved.

2.2.1.2 The design model output should be submitted to the local FM office with the system proposal and should include all input parameters as well as the worst-case reduced pressure and a graphical display of mass versus time of the required and delivered suppressant quantities.

2.2.1.3 The system manufacturer should provide calculations and information detailing the scale-up of a small scale explosion suppression system to its actual size.

2.2.1.4 To prevent permanent equipment damage, the pressure experienced during a suppressed deflagration (P_{red}) should not exceed two-thirds of the equipment yield strength (stress).

2.2.1.5 The suppression system alone can produce pressures of 0.13-0.2 bar (2-3 psi), which may exceed the design strength of some equipment such as dust collectors. This must be considered in the design process.

2.2.2 Maintenance and Testing

2.2.2.1 Service and functionally test the explosion suppression system at least quarterly by a qualified individual to verify satisfactory operation of all detector signals, switch functions and indicators.

Inspection and cleaning frequency depend on the process being protected and may need to be increased to ensure that the system will perform properly. A fixed schedule should be determined and followed.

2.2.2.2 When explosion suppression systems are installed in equipment which make parts of the system prone to plugging (such as shredders), detector ports and discharge pipes should be checked and cleaned at least on a daily basis.

2.2.2.3 Pressure gauges on HRD suppressors should be visually verified on a monthly basis to ensure that the cylinder pressure is in the proper operating range. The HRD should be recharged if the pressure decreases below 90% of the original charged pressure.

The pressure in the HRD is temperature dependent, therefore the temperature/pressure relationship for the particular agent being used must be obtained from the system manufacturer or installer in order for a proper verification to be performed.

2.2.2.4 The standby battery voltage should be checked weekly or following a power failure. Voltage should be at least 90% of rated capacity. The battery pack should be replaced annually or whenever a low battery condition is indicated.

2.2.2.5 Replace explosive actuators and fuses annually.

2.3 Equipment and Processes

2.3.1 Explosion Isolation Systems

2.3.1.1 Explosion isolation systems should be provided between two pieces of connected equipment (e.g., connected via process piping or ductwork) whenever one or both of the interconnected pieces is protected against explosion damage using an explosion suppression system.

2.3.2 Chemical Explosion Blocking Systems

2.3.2.1 A chemical blocking system (see Fig. 2) should be activated by optical or pressure detectors at the same time as an explosion suppression system.

These systems are generally activated using the same control equipment as the explosion suppression system. They can also be installed and activated separately.

2.3.2.2 In general, gaseous clean agents and dry chemical powders based on ammonium phosphate should be used as suppressants. Gaseous suppressants have the additional advantage of remaining intimately mixed with the combustible after discharge.

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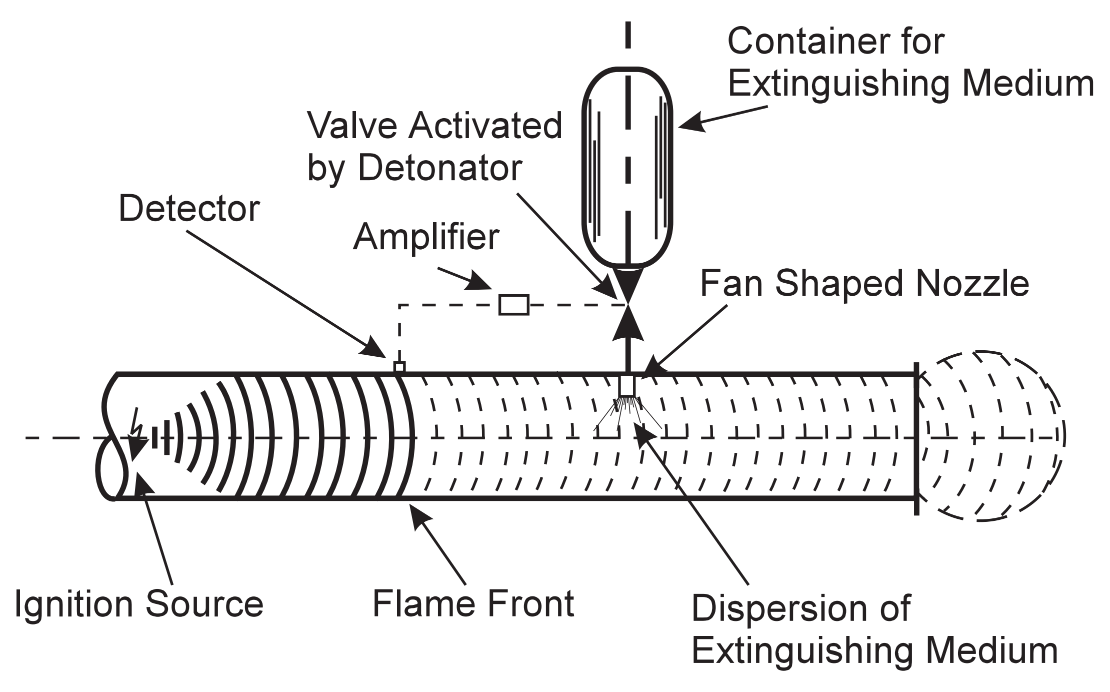

Fig. 2. Schematic representation of a chemical explosion blocking system.

2.3.2.3 The vessel or ductwork should be designed to withstand the expected local pressure which would result from the blocking system.

2.3.3 Flame Arrestors

2.3.3.1 The arrestors used should be Approved.

2.3.3.2 Deflagration and detonation arrestors should be used in accordance with their Approval. These types of arrestors are not interchangeable and must be used in the proper regime. The vendor or manufacturer should supply the necessary details regarding the arrestor.

2.3.3.3 Do not use in-line arrestors as end-of-line and vice versa. The arrestor must be placed in the flame path between the source of ignition and the system to be protected.

2.3.3.4 Inspect arrestors at least annually, and after each incident in which they have functioned. Replace all damaged components.

2.3.4 Flame Front Diverters (also known as explosion diverters, backblast dampers, backflash interrupters or backflow preventers)

2.3.4.1 Flame front diverters which are either commercially manufactured and distributed, or fabricated in-house according to design guidelines from VDI (Germany) are acceptable (see Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*, for the guidelines). Prefabricated rupture disks should be specified as having a release pressure equal to or less than 0.1 barg (1.5 psig).

2.3.4.2 The opening part of a flame front diverter fabricated in-house may be either a cover or rupture membrane. When providing a solid cover, make sure it is attached so it will quickly and easily release during an explosion. The connection methods shown in Data Sheet 1-42, *MFL Limiting Factors* , (or similar) are acceptable.

When providing a rupture membrane, use a weak, weather-resistant material such as aluminum foil or tar paper. Confirm the rupture pressure to be at or below 0.1 barg (1.5 psig) by calculations or pressure testing. Base this calculation on the ultimate tensile strength of the material. Using prefabricated rupture disks for the rupture membrane will eliminate the need to test or calculate the rupture pressure.

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2.3.4.3 Do not use explosion diverters for hybrid mixtures whose flammable vapors exceed the LEL.

2.3.4.4 When an air moving fan is located downstream of the explosion diverter, assume that an explosion originating upstream of the diverter will propagate past the diverter. The combustion zone from the upstream explosion can be drawn into the downstream side despite the open diverter cover.

2.3.4.5 Do not use explosion diverters in air streams which have a significant loading of abrasive dust. Such dust would eventually erode through the pressure relieving diverter cover.

2.3.5 Rapid-Action Valves

2.3.5.1 The distance between the valve and the explosion detection device should be long enough to allow the valve to fully close before the arrival of the flame front. See Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*, for an estimation method for the flame front travel time.

2.3.5.2 The valve should be activated simultaneously with an explosion suppression system, if provided, by using optical or pressure detection.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Explosion Suppression Systems

3.1.1 General

Explosion suppression is an active protection method which relies on sensing the start of an explosion and delivering an extinguishing agent as quickly as possible to quench the explosion and reduce the maximum explosion pressure to a substantially lower level (see Fig. 3). The lower pressure is called the reduced explosion pressure or suppressed pressure and must be lower than the vessel design strength for an explosion to be successfully suppressed.

Most (more than 90%) carbonaceous dusts fall into the explosion class ST1. Only a very small number of industrial dusts (e.g., aluminum) are classified ST3. An example of the explosibility data of several industrial gases and powders are given in Table 2. The K value of gases depends on the volume of the test enclosure and the ignition energy. The K values for gases shown in Table 2 are for 1 m^3 spherical vessels. The values shown for dusts are worst-case data. K_{st} values strongly depend on particle size distribution and other factors. The values in Table 2 should be used with care.

Table 2 - Explosibility Data of Industrial Gases and Dusts

Fuel	*P_{max}, bar*	*K, bar-m/s*
Methane gas	7.2	55
Pentane gas	8.7	345
Propane gas	8.6	205
Hydrogen gas	7.4	659
Milk Powder	8.6	130
Sugar (fine)	8.4	154
Coal dust	7.5	167
PET fines	9.2	150
Cellulose dust	9.7	229
Maize fines	10.3	195
Organic pigment	10.0	286
Aluminum dust	11.5	1100

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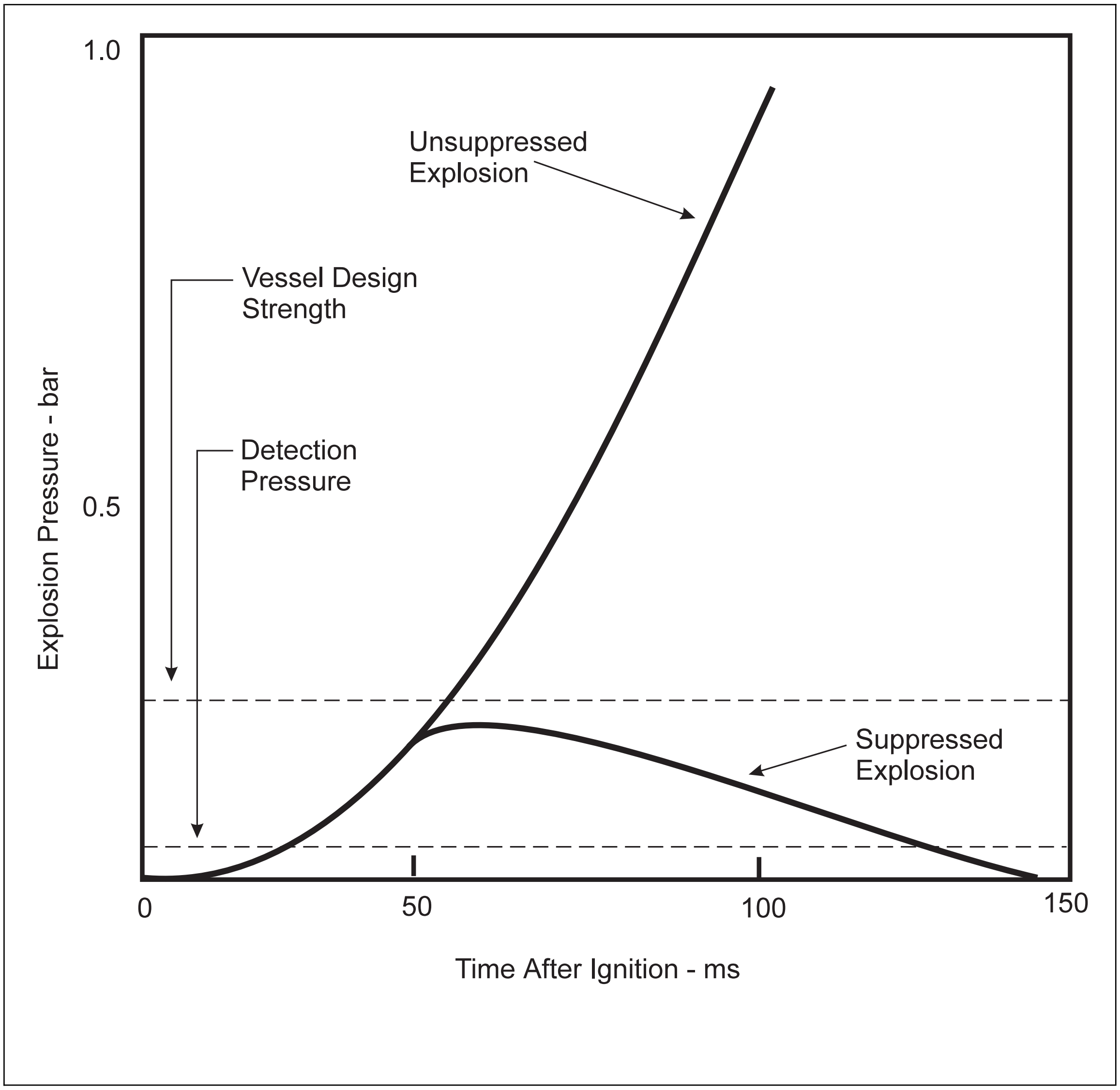

Fig. 3. Typical pressure/time curves for suppressed and unsuppressed explosions.

The advantages of explosion suppression systems are they:

- Stop the explosion before the developing pressure can damage the process equipment.
- Control any ensuing fire and reduce flame front propagation to other process equipment.
- Do not vent flame or other material, therefore are useful when toxic, radioactive or corrosive materials are being handled, equipment is located indoors, or venting exposes personnel to discharge of pressure and combustion products.
- Are maintained in an active condition with continuous electrical supervision of components.

The disadvantages of explosion suppression systems are:

- Design and installation of systems is expensive. Also re-filling and re-setting of the system after a discharge is expensive.
- Maintenance requirements are more severe than for conventional venting systems.

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- Use for low strength enclosures or equipment is limited because reduced explosion pressure or even system discharge pressure alone may exceed room or vessel strength. Vessels therefore may need to be constructed or reinforced to withstand the increased pressure resulting from a suppressed explosion and from the discharge of the suppression system.

3.1.2 Limitations

Explosion suppression systems are generally developed from a limited number of small scale tests. These tests do not cover all possible conditions that may be present in an enclosure/vessel during normal operation or in the event of a failure. Many factors can significantly affect the effectiveness of explosion suppression systems. They should only be installed in enclosures/vessels whose operating conditions and expected upset conditions fall within the tested conditions used to design the systems.

In some instances explosion suppression is used with venting to protect a vessel. Venting/suppression combinations are used mainly where enough vent area cannot be provided for venting alone to protect the vessel, or where the size of the fireball from a vented explosion must be minimized. The design of such vent/suppression protection system requires considerable knowledge. No such system should be accepted without supporting full scale test results.

The suppression of ST3 dusts is only possible in some exceptional cases. Any proposal outlining the suppression of such a dust must be accompanied by supporting full scale test results.

Explosion suppression is usually ineffective in interconnected vessels. Explosion isolation systems are needed for this reason.

Because of the cumulative response time (detection, actuation, agent discharge) involved in explosion suppression, small vessels or enclosures may not be protectable by this method. Destructive pressures may develop before the system can respond. Recent testing has indicated that the lower limit for suppression is 0.2 m^3 (7.1 ft^3).

3.1.3 Suppressant Delivery Methods

High Rate Discharge (HRD) bottles are available in a variety of sizes depending on the manufacturer. These sizes range from 3 liters to 45 liters with various outlet (nozzle) sizes. The bottles are usually pressurized with nitrogen to 20-120 bar (290-1740 psi). The bottles are capable of throwing their contents a maximum of approximately 10 m (33 ft).

Telescopic hemispherical nozzles, which are sometimes used, are installed on the outside of the protected vessel and are usually sealed from the vessel by blow off caps, rupture disks or some other membrane. Upon activation, an explosive charge propels the nozzle into the vessel and the suppressant is dispersed.

For hemispherical suppressors the suppressant is usually a halon and is discharged in 10 to 30 ms. These units typically contain small quantities of suppressant (1.3 U.S. gals [4.9 liters]) in liquid form only. They have a limited discharge distance (less than 2.5 m [8.2 ft]) and are mainly used to protect small volumes and ducting. The suppressors are not suitable for high temperature processes due to the possibility of weakening the pre-scored metal of the suppressor and/or losing the liquid suppressant through vaporization.

3.1.4 Suppressant Materials

The type of suppressants used are dry powders, halons and water. New systems also use carbon dioxide, HFC-227ea (i.e., FM-200), and tri-fluoromethane. In addition, other agents are currently being tested. Refer to Table 5 for a list of suppression agents. An agent is considered to be very effective if an increase in the activation pressure results in a minimal increase in the reduced maximum explosion pressure. Figure 4 compares a very effective agent versus a less effective agent.

Several test programs have provided data on the quantity of agent, activation times, pressures and agent dispersal method needed for effective suppression of a variety of flammable gases and dusts up to a maximum volume of 250 m^3 (8875 ft^3).

Suppression agents are effective by absorbing heat from the combustion process, interfering with the chemical (combustion) reaction by free radical scavenging or by inerting. In general, all three actions contribute to the effectiveness of a suppressant, although one aspect may have a more dominant effect than the others for a particular suppressant.

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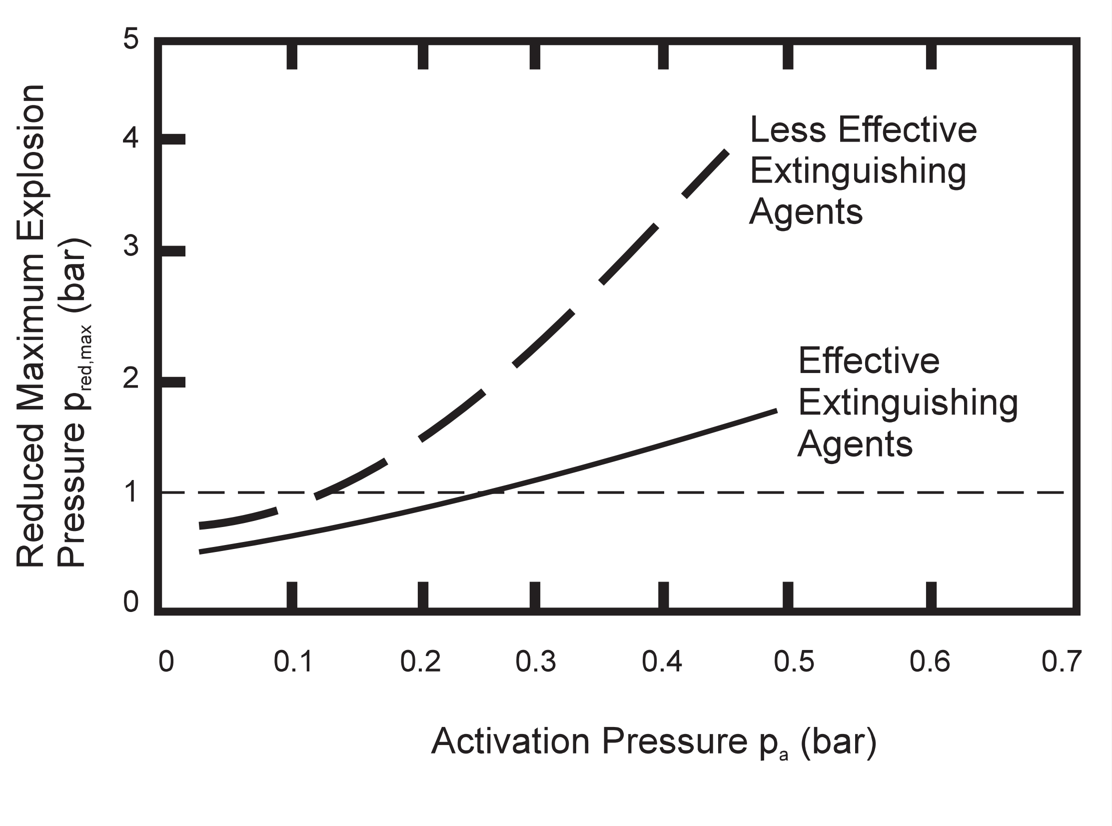

Fig. 4. Effectiveness of explosion suppression agents.

The halons in particular operate on the basis of free radical scavenging. In simple terms, when heated, the halon molecule breaks up and generates ions which deplete hydrogen ions necessary to continue combustion. The flame is literally snuffed out chemically. This type of suppressant is most effective when it is mixed with the fuel/air system prior to being heated by the flame. Research has shown that if halon is injected directly into the flame (i.e., late suppressant delivery), it will thermally decompose and generate a significant additional pressure increase without achieving suppression(1). The use of halon therefore calls for very low activation pressures (less than 0.1 bar) to ensure quick agent dispersion after ignition.

In general, extinguishing powders have a good suppression effectiveness if they are suitable for inerting once mixed with combustible dusts.

Hybrid suppressants consist of a particular halon mixed with a specific powder. Their advantage lies in the inerting effect halon takes once the explosion is successfully suppressed in the protected equipment.

The relative effectiveness of three test suppressants (halon, water, and a mono-ammonium phosphate based powder) were tested against propane, ST1 and ST2 explosions(3). The results of the tests, which were conducted in a 25 m^3 (888 ft^3) vessel, indicated that water was very effective against hydrophilic ST1 and ST2 type dusts. Water was not tested against propane as previous tests showed it to be ineffective against gas explosions.

Halon was effective against propane and ST1 dusts. The mono-ammonium phosphate based powder was the only agent effective against all three types of explosions. The powder, however, resulted in significantly higher reduced pressures than halon for ST1 dust explosions. Figure 5 compares the effectiveness of halon 1011, water and MAP (Furex 770 Powder) suppressants against propane, ST1 and ST2 explosions.

Systems potentially exposing personnel or contaminating food or high value products often use halon 1301 (CF_3 Br), because it is non-toxic. Replacement agents are being developed for halon 1301 due to its ozone-depleting characteristics (see Appendix C). A water soluble and food grade compatible sodium bicarbonate-based dry powder has been developed for some applications involving food.

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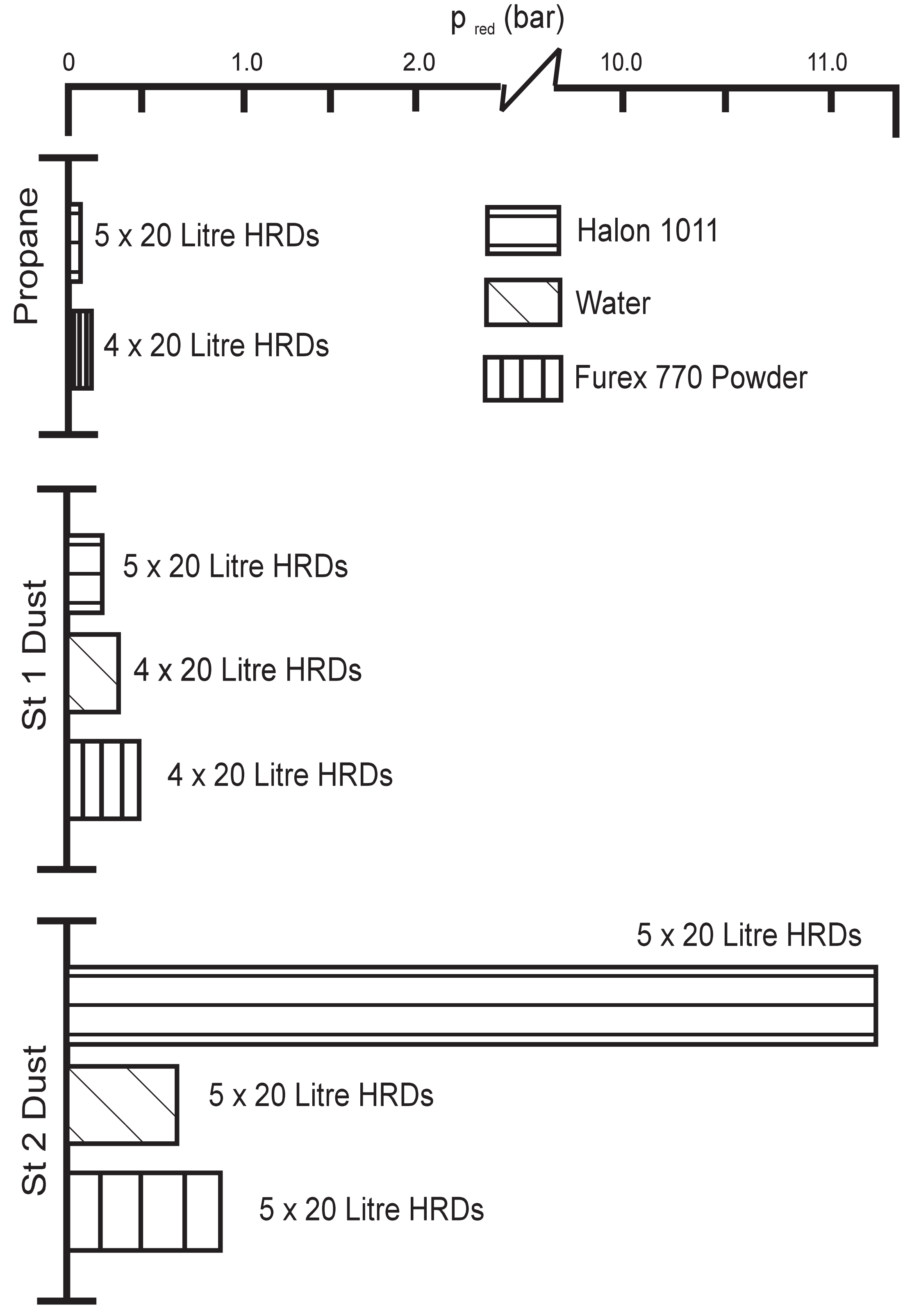

Fig. 5. Relative effectiveness of three suppressants.

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3.1.5 Design Procedures

Design of explosion suppression systems is based on the interpretation of experimental data obtained by conducting suppressed and unsuppressed explosions in test vessels.

Experimental procedures are required to determine the number of nozzles, type of suppressant, and the threshold level of the detector, which will start suppression early enough to prevent the pressure in the vessel from exceeding its design strength.

The first step in the design of an effective explosion suppression system for a specific industrial application is to quantify the potential explosion hazard. The following information is required:

1. Dust or vapor explosibility parameters — burning velocity, autoignition temperature, maximum explosion pressure and the maximum rate of pressure rise.
2. The vessel geometry and volume.
3. The maximum pressure that the vessel is designed to withstand.
4. Process parameters such as pressure and temperature.
5. Process conditions — in particular the amount of turbulence.

The initial level of turbulence in a vessel plays a major role in the rate of pressure rise. The level of turbulence in standard tests for dust explosibility represents the conditions found in most powder-handling equipment.

Explosion suppression system manufacturers have also begun using mathematical models with the aid of computer programs to design explosion suppression systems. Very little information is published as to how these programs determine the required amount of agent, delivery pressure, reduced pressure, etc. for a given deflagration. To date, no standardized methodology exists for the design of explosion suppression systems.

Research(1) has shown that for a particular dry extinguishing agent, assuming the agent is the most suitable as defined above (Section 2.1.2.6), the number of suppressors required to suppress a given volume is calculated as:

$$N = C\ V^{2/3}$$

where N = the number of suppressors
C = constant (see Table 3)
V = Vessel Volume (m^3)

Table 3 - Constants for Determining the Number of Suppressors

Material	*5 liter HRD 3 in. Outlet*	*20 liter HRD 3 in. Outlet*	*45 liter HRD 5 in. Outlet*
Propane	1.08	0.43	0.13
ST1 Dust	1.08	0.47	0.18
ST2 Dust	1.40	0.58	0.25

Note: The number of suppressors calculated must be rounded to the next highest number.

The suppressors should be distributed as evenly as possible on the protected vessel.

The activation pressure (P_a) should be chosen to meet the following criteria.

Table 4 - Criteria for Activation Pressure

Protected Material	*$P_{red,\ max}$ bar (psig)*	*P_a bar (psig)*
ST1 Dusts	0.5 (7)	<0.1 (1.5)
ST2 Dusts	1.0 (14.5)	<0.05 (0.75)
Gas with K_g equal to or less than Propane	1.0 (14.5)	<0.05 (0.75)

3.2 Aerosol Filling Rooms

Explosion suppression systems are not an acceptable alternative to DLC for the protection of aerosol filling rooms.

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For an aerosol filling room, there are three different probable propellant release scenarios. They are:

1. Rupture of 1 to 2 cans
2. Feeder jam (rupture of many cans)
3. Filling head failure or broken line

The third scenario would immediately result in the most destructive incident and is the worst case event (i.e., the entire room filled with a stoichiometric fuel-air mixture). This scenario was evaluated during an Factory Mutual Research program. The second case could also release enough propellant to fill the room to a worst case mixture, but, the turbulence created by the release will be significantly less than scenario number 3. The first scenario is expected to release enough propellant to fill only a partial volume of the aerosol filling room. The first and second scenarios were not investigated in the program.

The objective of the program was to generate experimental data on the effects of high ventilation flow rates and jet release of propellants on the explosion suppression requirements for aerosol filling rooms.

Although explosion suppression systems are usually designed to protect the worst case incident in other occupancies, the test program indicated that this is not the case for aerosol filling rooms. The test program demonstrated that halon 1301 explosion suppression systems, when installed per the manufacturer’s specifications, were generally incapable of satisfactorily suppressing a worst case liquefied flammable gas explosion where the flammable gas fills a significant portion of the protected volume. This means that an aerosol filling room, equipped only with an explosion suppression system, could be destroyed and create a significant exposure to surrounding occupancies.

3.3 Explosion Isolation Systems

3.3.1 General

The objective of explosion isolation systems is to block potential flame paths that lead to other process equipment or occupied areas. The detection and control functions are identical to explosion suppression, because system activation must be initiated within milliseconds of detection.

3.3.2 Chemical Explosion Blocking Systems

These systems are typically used with explosion suppression systems.

Duration of discharge, quantity of suppressant discharged, location of discharge point, flame propagation velocity and operating flow rates must all be considered in the design of a blocking system. Processes with high flow rates and/or large primary vessels may not be suitable for chemical explosion blocking systems.

3.3.3 Flame Front Diverters

The flame front diverter incorporates the need to vent deflagration pressures with the need to direct the flame front in such a way that it does not ignite material in the process downstream.

Advantages are low initial capital and maintenance costs.

3.3.4 Rapid-Action Valve

An explosion isolation valve such as a rapid-action valve provides a mechanical barrier against the flame front of an explosion. The intent is to isolate the explosion and protect the area beyond the valve. The valve must be activated upon detection of the explosion.

An explosion suppression system or explosion venting is required on the ignition side of the valve because, when the isolation valve closes, the ducting or vessels are subject to overpressurization.

The main advantage of this isolation method is the certainty of preventing flame propagation to other equipment or processes.

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4.0 REFERENCES

4.1 FM

Data Sheet 1-42, *MFL Limiting Factors*.

Data Sheet 1-44, *Damage-Limiting Construction*.

Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*.

Data Sheet 7-17, *Explosion Protection Systems*.

Data Sheet 7-32, *Ignitable Liquid Operations*.

Data Sheet 7-49, *Emergency Venting of Vessels*.

Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*.

Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*.

4.2 NFPA Standards

NFPA Standard No. 69, *“Explosion Prevention Systems,”* National Fire Protection Association, Quincy, Massachusetts, 1992.

APPENDIX A GLOSSARY OF TERMS

FM Approved: References to ″FM Approved″ in this data sheet mean a product or service has satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Chemical explosion blocking: the technique of using a chemical suppressant to extinguish a propagating flame front.

Deflagration: the propagation of a combustion zone at a lower velocity that is less than the speed of sound in the unreacted medium.

Detonation: the propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium.

Explosive actuators: electrically activated explosive devices used to release agent from suppressors.

Explosion: a rapid equilibration of a high pressure gas with the environment. The equilibration must take place so fast that the energy is dissipated in a shock wave.

Explosion isolation: the use of mechanical valves or chemical suppressants to block potential flame paths that lead to other process equipment through ducting or piping.

Explosion suppression: the technique of detecting and arresting combustion in a confined space while the combustion is in its incipient stage, thereby preventing the development of pressures that could result in structural damage.

Flame arrestor: a device which prevents a flame from progressing through a flammable gas/air mixture. The flame is quenched on the surfaces of a series of heat sinks through which the flame must pass. The emerging gases are sufficiently cooled to prevent re-ignition.

Hydrophilic: a substance which has a strong affinity to, is wetted by, or dissolves readily in water.

Ignitable Liquid: Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other reference to a liquid that will burn. An ignitable liquid must have a fire point.

K_g: gas explosibility constant (expressed in bar-m/s), defined as the maximum rate of pressure rise as tested in a 1 cubic meter (m^3) vessel.

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K_{st}: the dust explosibility constant, defined as the maximum rate of pressure rise as tested in a 1 meter^3 vessel. This rate is constant for a given dust. The hazard classes for dusts are as follows:

ST1	K_{st} 1-200 bar-m/s
ST2	K_{st} 201-300 bar-m/s
ST3	K_{st} > 300 bar-m/s

P_{red}: the reduced explosion pressure. It is the highest explosion pressure experienced by a *protected* vessel. Also called the suppressed or vented pressure.

P_{max}: the maximum pressure that can be developed by a gas or dust under confined test conditions.

Suppressant: the agent used in an explosion suppression system to extinguish the incipient explosion.

APPENDIX B DOCUMENT REVISION HISTORY

January 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

May 2001. Clarification regarding wiring of detectors was made in section 2.1.2.1, Detectors: General.

May 2000. This revision of the document was reorganized to provide a consistent format.

June 1997. This data sheet was completely rewritten. Major revisions are as follows:

1. A definition section has been added.

2. The recommendation section has been expanded and segmented to highlight recommendations dealing with all aspects of explosion suppression system application, installation, maintenance, testing and design.

3. Recommendations pertaining to explosion isolation devices for gas and dust explosions have been added.

4. The loss experience section has been updated and illustrative losses provided.

5. The support for recommendations section has been added. This section provides information regarding design procedures, explosion suppression and isolation system operation and general background information regarding these systems.

6. Guidance and information regarding the use of explosion suppression systems in aerosol filling rooms is provided.

APPENDIX C HALON IN EXPLOSION SUPPRESSION & ISOLATION SYSTEMS

C.1 Introduction

Many explosion suppression and isolation systems use halon, a chloro-fluorocarbon (CFC) as the suppressant or blocking agent. Halon 1301 was the principal agent used as a suppressant for food and pharmaceutical processes in North America.

Under the Montreal Protocol of 1987, 71 countries worldwide have pledged to eliminate ozone depleting chemicals including halons by the year 2000. The European Community committed to a deadline of July, 1997.

The United States has halted all production of CFCs as of December 31, 1995. Additionally, the Clean Air Act has labeled halon 1301 as a class 1 substance and added it to the list of CFCs that threaten the environment.

Halon 2401 is also subject to a production ban. This halon is used in very few systems in North America, but can be found in systems installed in Japan.

As manufacturers worldwide phase-out the production of halon, future supplies for recharge purposes will become progressively more difficult to obtain and consequently higher prices will result. Tighter regulations for usage and disposal in addition to harsher penalties for non-compliance will also result.

C.2 Retrofit

System manufacturers are presently evaluating the suitability of many new clean agents for use in explosion suppression systems.

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Sodium bicarbonate powder, water, and pentafluoroethane (HFC-125) are three agents being used as replacements for halon 1301. (See Table 5 for a full list of suppressants.)

The retrofit of existing explosion suppression systems can utilize existing detection and control equipment to lower the cost of the retrofit. The systems will require redesigning to ensure that the system will function properly.

Halon 1011 is an unrestricted agent which can be used and manufactured without penalty. It is used as a suppressant in many explosion suppression systems and is the predominant agent used in the woodworking industry.

Table 5 - Suppression Agents

Type	*Agents*
Gaseous	Halon 1301
	Halon 1211
	Carbon Dioxide
	HFC-227ea (FM-200)
	HFC-23
	HFC-125
Liquids	Halon 1011
	Water
	Salt-based antifreeze solutions
Powders	Mono-Ammonium Phosphate (MAP)
	Potassium Chloride
	Potassium Carbonate
	Sodium Bicarbonate
Hybrids	MAP/Halon

APPENDIX D CONFLICTS WITH NFPA STANDARDS

NFPA 69, *Explosion Protection Systems*, which also covers this subject, generally agrees with this data sheet.

APPENDIX E BIBLIOGRAPHY

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(4) Swift, I., *“Design of Deflagration Protection Systems,”* Butterworth & Co., 1988.

(5) Chaffee, J. L., *“The Venting and Suppression of Explosions in Aerosol Gas Filling Rooms,”* Factory Mutual Research, 1991.

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