Protection Technology

How new technological breakthroughs are affecting explosion protection

Before the HRD Suppressor…

The pressurized HRD suppressors of today are a far cry from the first suppressors used in explosion protection. Referred to as a hemispherical suppressor (pictured below), these devices were actually installed *inside* the protected equipment. They contained bromochloromethane, a liquid halogenated hydrocarbon. Unlike today's suppressors, these devices were not pressurized, nor was the suppressant distributed through a nozzle. So how did they work?
Three explosives were mounted inside the suppressor. Upon receipt of the firing signal from the control panel, the explosives detonated, blowing the hemisphere to pieces and releasing the agent into the protected vessel. Only the force resulting from the detonation of the explosives distributed the suppressant.
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ABSTRACT

Over the last half&#151century, technological breakthroughs in electronics, pyrotechnics, and computers have had a positive affect on the explosion protection industry. Explosion protection system manufacturers have embraced these technologies, incorporating their benefits into system design modeling and new product development. As a result, explosions are better understood and products are more sophisticated, reliable, and user-friendly.

INTRODUCTION

Processes handling combustible dusts and vapors are vulnerable to the devastating effects of an explosion. Introduction of an ignition source in a confined process enclosure could result in an explosion if the air and product mixture inside the enclosure is within explosive limits. Proper implementation of explosion prevention methods, such as control of static discharge, process inerting, spark detection, and good housekeeping provide a means of reducing the likelihood of an explosion. However, factors including, but not limited to, unpredictable process disruptions, equipment malfunction, process control failure, and human error can circumvent explosion prevention means.
Explosion protection begins where explosion prevention ends. A surprising fact about industrial process explosions is that they are not instantaneous. There is a measurable amount of time between ignition within a process enclosure and when

the pressure within the process enclosure reaches destructive levels. Within this timeframe, explosion protection systems can rapidly detect and suppress incipient explosions (deflagration), mitigating the damage resulting from an explosion. The total elapsed time from ignition of the deflagration to suppression is measured in milliseconds. Explosion suppression systems are comprised of four major components: explosion detectors, a control panel, high rate discharge (HRD) suppressors, and discharge nozzles. Explosion detectors sense incipient explosions and provide an input signal to the control unit. The control unit, which provides annunciation and control for the entire system, including process interlocks, processes the input signal and sends an actuation signal to high rate discharge (HRD) suppressors mounted on the protected enclosure. The HRD suppressors contain a suppressant and are pressurized with nitrogen or other inert gases. Figure 1 illustrates a simple explosion protection system protecting a dust collector. The use of explosion protection systems dates back to the late 1950's. Over the last half&#151century, continuous improvements in the control of material processing systems and related technologies, along with changes in regulatory requirements, have necessitated advances in explosion protection technology. These advances have made these vital protection systems more compatible with today's processing environment and more reliable. Furthermore, these new systems provide features that facilitate their use by reducing maintenance and associated process downtime.

SYSTEM DESIGN MODELS

In explosion protection's infancy, suppression system designs were greatly dependent on suppression tests. A combustible mixture of air and the material being handled would be injected into a pressure&#151rated vessel, ignited, and subsequently suppressed by the designer's "best guess" at the required suppressant quantity. As one could imagine, this method of design validation was expensive, and took the suppression system's reaction time and scalability for granted. As time passed, scientists studied actual test data and were able to correlate results with measured and calculated deflagration parameters. These studies revealed a correlation between the quantity of suppressant and the time that suppressant had to be delivered to suppress the deflagration. Today, some manufacturers design systems using computer models of varying degrees of sophistication. The most sophisticated computer model requires detailed process information such as operating pressure, process enclosure volume, and explosive parameters of the material being processed along with detailed specifications of the proposed explosion protection hardware, such as suppressor quantity and the amount of suppressant in each suppressor. The computer model calculates the growth of the explosion and the

suppressant discharge characteristics of the proposed system. A successful suppression system is one that delivers enough suppressant in a timely manner to extract heat from the deflagration before destructive pressures within the protected enclosure are reached. Computer modeling has made system design calculations more precise and consistent with a higher level of safety.

EXPLOSION DETECTION

Technological advances in electronics have had a dramatic effect on the design of explosion detectors. Explosion detectors have evolved from simple, electro&#151mechanical devices into microprocessor&#151based products with discrete software. The software provides rapid processing of input data to determine if a deflagration is present, and then reports the alarm condition to the control panel. There are two major types of explosion detectors, explosion pressure detectors and explosion flame detectors. Explosion pressure detectors sense pressure increases caused by a deflagration in a protected enclosure, and explosion flame detectors sense the ultraviolet and/or infrared radiation emitted by the deflagration.

Pressure Detectors

Early explosion pressure detector designs use a fast&#151response pressure switch that closes when the pressure in the protected enclosure reaches a threshold value or static setting. Simple and robust in design, these static detectors are still used today in certain applications. The drawback to static detectors is that they cannot differentiate between a deflagration and an increase in pressure due to process disruption.
Newer explosion pressure detectors use a dynamic pressure principle to address the shortcoming of the static detector. Using microprocessor&#151based electronics, pressure readings are taken at a rapid rate, on the order of every 0.125ms. Current readings are then compared to previous values. If the pressure increase is occurring at a rate similar to that of a deflagration, the system is activated. Dynamic detectors first used a stainless steel, oil&#151filled diaphragm as the sensing element. Newer dynamic detectors utilize more

stable, ceramic sensing elements. Some dynamic detectors incorporate two sensing elements within a common detector housing. This detector can be configured such that both cells need to sense an incipient explosion, minimizing the likelihood of an inadvertent discharge. Figure 2 shows a tried and true static detector and a new dynamic pressure detector with two sensing elements. The electronics used in dynamic detectors allow the recording of pressure values just prior to, during, and shortly after a system discharge in a history buffer. Using software available from the manufacturer, the data can be downloaded to a computer, and used to determine the severity of the deflagration, or the possible cause of an inadvertent discharge. Figure 3 shows a pressure versus time graph downloaded from a dynamic pressure detector.

Flame Detectors

Explosion flame detectors are the sensors of choice in processes involving combustible vapors in occupied volumes, such as an aerosol filling room or chemistry laboratory. These devices are used in applications where a partial volume deflagration is possible. A partial volume deflagration occurs when a small, localized combustible fuel/air mixture ignites. In the example of an aerosol filling operation, a localized combustible fuel/air mixture could result from a failed valve crimping operation.
Early flame detector designs sense the presence of ultraviolet (UV) radiation emitted by a deflagration. The detectors are blind to solar radiation, but they are unable to differentiate between UV emitted from a deflagration and other UV sources such as welding, static discharge, and lightning. Although UV flame detectors are still in use today, systems installed in locations where the presence other UV sources is likely utilize UVIR (ultraviolet&#151infrared) flame detectors. UVIR flame detectors incorporate two sensors in a common housing. One sensor detects UV radiation, while the other sensor detects IR radiation. The detector logic is normally configured such that both sensors need to detect a deflagration for the system to discharge. Thus, the UVIR detector is less likely to alarm without the presence of a real deflagration, minimizing the likelihood of inadvertent discharge. Figure 4 shows a superseded UV detector design of the early 1970’s and a

modern UVIR detector.

HIGH RATE DISCHARGE (HRD) SUPPRESSORS

Explosion HRD suppressors have changed substantially over the last 50 years. Advancements in technology and changes in regulatory requirements necessitated new HRD suppressor development. In particular, technological advances of pyrotechnic devices have revolutionized HRD suppressor actuation methods. The signing of the Montreal Protocol in 1987 significantly impacted the selection of suppressant used in explosion protection systems. Other regulatory requirements and customer demands have prompted suppressor manufacturers to incorporate other features such as an OSHA lockout/tagout provision, and the ability to continuously monitor the internal pressure of the suppressor into new suppressor designs.

Suppressants

From the early years of explosion protection to the late 1980's, systems used halogenated hydrocarbons almost exclusively as a suppressant. Among the most popular were bromochloromethane, CH2BrCl, used primarily in unoccupied areas, and trifluorobromomethane, CBrF3, used in occupied areas. Although effective suppressants, these and other halogenated hydrocarbons are ozone&#151depleting substances. The passing of the Montreal Protocol in 1987 prohibited the further production of such substances and their use in most applications, including explosion protection systems.
As a result, newer systems use a dry chemical suppressant for unoccupied volumes and water for occupied volumes. The most commonly used dry chemical agent is sodium bicarbonate, NaHCO3, with monoammonium phosphate, (NH4)3PO4, a distant second. Although chemically similar to the dry chemical agents used in fire protection, explosion protection dry chemical suppressants have a much finer particle size distribution. The finer particle size is required to effectively and quickly absorb heat from the deflagration. A smaller percentage of systems use ozone&#151friendly gases, such as pentafluoroethane (C2HF3), and an even smaller percentage

use water mist.

Suppressor Actuation Methods

Ironically, most explosion HRD suppressors use an explosive or other pyrotechnic device to actuate. Until recently, a pyrotechnic device was the only method known to provide the response time necessary to successfully suppress an explosion. In the late 1990's, an HRD suppressor using a high&#151speed motor was introduced. Though packed with features, this suppressor has its shortcomings, including cost and a difficult reconditioning process requiring special tools.
Older pyrotechnically operated suppressor designs use line cutting charges and detonators as initiating devices. Yearly replacement of these devices is required to maintain system reliability. The devices are classified such that they cannot be transported on passenger aircraft. This complicates shipping logistics. Later, gas generators were introduced. These devices provide a longer service life and can be transported on a passenger aircraft. Until recently, all of these explosives were exempt from the storage and handling requirements stipulated by the US Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATFE). The terrorist attacks of 9/11, and the subsequent passing of the Safe Explosives Act, have prompted the ATFE to reexamine existing exemptions. The ATFE has since revoked at least one exemption, and it is likely to revoke others as they continue to work at limiting unmonitored commerce of explosive material. In recent years, a protracting actuator was introduced. This device is classified as a non&#151explosive, as it does not emit flame or pressure when actuated. Upon actuation, the only energy released to the surrounding environment is mechanical energy in the form of a piston being projected from the device. Figure 5 shows a protracting actuator before and after actuation.

Suppressor Features

Early suppressor technology was focused almost exclusively on the timeliness of its operation. As a result, all suppressors were essentially the same in design, using a pyrotechnic device as an initiator, and high&#151pressure nitrogen to disperse the agent into the protected enclosure. The subtle differences in

design were mostly marketed as lowering installation costs, such as providing suppressors that were factory&#151pressurized; or lowering maintenance cost, such as providing an initiating device with a longer service life. Today, there are vast differences between suppressors. With the exception of using nitrogen as a propellant, suppressors differ on almost every front; materials vary from mild steel to stainless steel, agents vary from water to dry chemical, and even suppressor pressures vary from 360 to 900 psig. Initiating devices vary from pyrotechnic devices to non-explosive initiators to high-speed motors.
Suppressors also vary substantially in the features they provide. Some include a pressure switch to constantly monitor suppressor pressure, ensuring that it can properly operate upon demand. Some suppressor designs incorporate an OSHA lockout/tagout provision, enabling an explosion protection system owner to execute the OSHA recommended procedure for confined space entry without having to spend the time and money to remove suppressors from their mounted positions. To prevent the inadvertent arming of a suppression system while a suppressor is locked out, the OSHA lockout/tagout provision may be supervised and interlocked with the explosion protection system control panel. Figure 6 illustrates an early HRD suppressor, and a newer version that incorporates many of the aforementioned features.

AGENT DISTRIBUTION NOZZLES

The quick release of suppressant stored in HRD suppressors is not the final step in the operation of an explosion protection system. The suppressant must now be properly distributed within the protected enclosure. Suppressant distribution is achieved by discharging the agent through a nozzle or spreader that is mounted in close proximity to the enclosure wall. Spreader technology has evolved with process requirements. The early spreaders were fixed nozzles that extended into the protected enclosure. These spreaders, which are still in wide use today, work well in distributing the agent, but are undesirable in processes that are adversely affected by the spreader's projection into the enclosure. The projection could adversely affect process equipment efficiency, like in the case of a cyclone. The projection into the enclosure could adversely

affect the product being manufactured because product can accumulate atop the spreader. The accumulated product can then be “over&#151processed,” or cause product contamination. These design deficiencies led to the development of telescopic spreaders.
Telescopic spreaders were designed to project into the protected enclosure only upon system activation. Similar to fixed spreaders, the product was blocked from entering the spreader using a polymer cap. Although more costly than fixed spreaders, telescopic spreaders solve the inherent problems of fixed spreaders. Design improvements of telescopic spreaders incorporated the use of a stainless steel disc situated in front of the polymer cap. This mitigated the growth of bacteria within the polymer. The relatively high cost, size, and weight of telescopic spreaders hampered its applicability. The most recent spreader on the market offers the simplicity of the fixed spreader and the benefits of the telescopic spreader at an affordable price. This flush mounted spreader effectively distributes suppressant through a spreader insert. The spreader insert is a flat plate with angular slots that homogenously discharge agent into the protected enclosure. This spreader operates without projecting into the enclosure, even during operation. This allows use of the spreader in protecting process equipment with moving parts in close proximity to its walls, such as mills and blenders. Since the nozzle remains exterior to the process equipment at all times, the discharge of the system cannot damage the protected enclosure, nor can moving parts near the enclosure wall prevent the discharge of the suppressant. Partially sectioned, exploded views of the spreaders described are shown in Figure 7.

CONTROL PANELS

As was the case with explosion detectors, designs of explosion protection control panels have greatly improved, thanks to breakthroughs in the electronics field. Early control panels were limited to providing control and annunciation of the explosion protection system. They utilized through&#151hole electronic components, fuses, transistors, and electro&#151mechanical relays. Today, surface mount electronic components dominate the industry, as they lower

manufacturing costs and minimize control panel size. Circuit breakers and thermistors, where applicable, provide reliable protection and facilitate reset in the case of an overload. Solid&#151state relays provide faster response as compared to electro&#151mechanical relays.
The breakthrough that had the greatest impact on control panel design was the introduction of the microprocessor. The microprocessor allows the incorporation of safeguards to prevent inadvertent discharge. For example, if a malfunctioned detector is in an alarm condition on start&#151up, the microprocessor can discount this signal and not discharge the system, but rather provide a trouble signal. The microprocessor continuously performs built&#151in tests to ensure the integrity of the explosion protection system. The ability to program the microprocessor to execute specific functions in optimum order all but eliminated the need for transistor&#151based circuitry. Many control panels today utilize LEDs in conjunction with the microprocessor to identify where the system trouble is located. This level of annunciation simplifies troubleshooting, which reduces downtime. Control panel capabilities continue to expand as detectors and suppressors become more sophisticated. For example, modern control panels provide specific terminals to accommodate pressure switches and OSHA lockout supervisory switches equipped with new suppressors. A wide variety of control panels are available from single zone wall&#151mounted enclosures to two&#151zone rack mounted enclosures to multi&#151zone control systems using a high&#151speed bus network. All of these panels provide the necessary supervisory circuitry, battery backup, annunciation, control, and interlocking capabilities.

CONCLUSION

Technological advancements in electronics, pyrotechnics, and suppressant distribution have dramatically changed the designs of explosion protection components. Explosion detectors, HRD suppressors, spreaders, and control panels have become more sophisticated and user&#151friendly. Scientific research in the field of explosion protection has ensured that today’s designs provide a higher level of safety and reliability as compared to their predecessors. Explosion protection system manufacturers

offer a wide range of products with equally varying prices and feature sets. With such a range of products, a solution to meet the specific requirements of the process to be protected is merely a phone call away.

Richard Z. Karadizian has nearly 10 years experience in the design of explosion protection systems and equipment, and has 5+ years experience in process equipment design including dryers, boilers, cyclones, and conveyors. He has a Bachelor's Degree in Mechanical Engineering and a Master's Degree in Fire Protection Engineering, both from Worcester Polytechnic Institute, Worcester, Massachusetts. He was the lead inventor on Fenwal's flush spreader (Patent No. US 6,732,809 B2,) and has three patents pending on Fenwal's PistonFire™ HRD Suppressor. He is a member of NFPA and holds an EIT License in the Commonwealth of Massachusetts. For nearly 50 years, Fenwal Protection Systems, 400 Main Street, Ashland, MA 01721, has been a global leader specializing in the design, manufacture, and service of explosion protection systems. Additional information is available by calling (508)881-2000, or visiting www.fenwalprotection.com.

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