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Process Safety eHandbook

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Product Release

Food-Grade Hoses Handle High-Static Applications

Hose design helps dissipate static charges to ground.

KURIYAMA OF America's new line of Tigerflex Voltbuster food-grade material-handling hoses have been designed for high-static applications such as the transfer of powders, pellets and other granular materials.

The hose's design helps dissipate static charges to ground, helping prevent static build-up and reducing the potential for dangerous electrostatic discharges. They have been constructed with static dissipative plastic materials, allowing for the free flow of static to the hose's embedded grounding wire. The light-weight design of the hoses can help reduce injuries related to heavier metal hoses.

The "Volt Series" hose-tube construction includes abrasion-resistant food-grade polyurethane to ensure the purity of transferred materials. In addition, the grounding wire has been encapsulated in a rigid PVC helix on the exterior of the hose, eliminating the risk of contaminating the transferred materials. The VLT-SD Series is constructed the same, but has an FDA polyester fabric reinforcement to handle both suction and higher pressure discharge applications. New 2- and 8-in. ID sizes have been recently added to this product line.

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Use Elegant Design to Bolster Inherent Safety

Embrace a variety of strategies that can eliminate hazards from operations

By Kelly K. Keim and Scott W. Ostrowski, ExxonMobil Research and Engineering

TREVOR KLETZ was able to simplify the concept of inherent safety in such a way that everyone "gets it." His mantra "What you don't have can't leak" is so clear and powerful that it has grabbed the attention of all stakeholders, including owner/operators, labor, community members and regulators, who have an interest in safer processing facilities of all types. It expresses a vision that we all seek, one where no harm comes from the operation of process facilities that manufacture the materials that make our lives better every day.

Of course, the concept of inherent safety goes beyond simply not having materials that potentially could damage the pipes, vessels and equipment that make up manufacturing facilities. We must understand all the ways those materials can be involved in incidents that harm people, the environment and our facilities. Without a thorough understanding of those scenarios and how they can occur, we can't properly evaluate the risks posed by different technological approaches and effectively apply inherently safer technologies.

For example, the lower annual corrosion rate of a stainless alloy compared to carbon steel in some processes may seem compelling. However, chloride exposure may cause stress corrosion cracking in the alloy; this damage is difficult to detect before a catastrophic component failure occurs. So, in fact, the inherently safer option may be to use carbon steel while implementing a strong inspection and replacement program that manages the hazard of corrosion effectively.

FUNDAMENTAL STRATEGIES

Kletz in his groundbreaking 1984 paper [1] described four basic strategies for achieving inherently safer processes:

- intensification;
- substitution;
- attenuation; and
- limitation of effects.

In its 2007 book, "Inherently Safer Chemical Processes: A Life Cycle Approach" [2], the Center for Chemical Process Safety translated those terms into simpler ones readily understood by a wider audience than just safety professionals:

- substitute — replace a material with a less hazardous one;
- minimize — reduce the quantities of hazardous substances;
- moderate — use less hazardous conditions, a less hazardous form of a material or facilities that minimize the impact of a release of

hazardous material or energy; and

- simplify — design facilities that eliminate unnecessary complexity and make operating errors less likely, and that accommodate errors that occur.

Let's consider their application to the use of a chlorine cylinder:

- substitute — change from chlorine to a bromine tablet;
- minimize — keep only one cylinder on the site;
- moderate — connect a vacuum inductor to the cylinder; and
- simplify — adopt a distinct design with unique connections for chlorine hoses.

Other strategies can complement these simple ones. Here, we introduce the phrase "elegant design" to represent the selection of process technology, equipment, design or layout that makes higher-potential-consequence scenarios non-credible. Elegant design may take advantage of a number of Kletz's strategies — and may even go beyond them to achieve risk reduction, minimization, or elimination.

Simply put, the concept of inherently safer design is: "What can't happen can't happen."

Any number of design features can contribute to preventing something from happening. Substitution and some elegant design solutions can provide absolute certainty against an occurrence. Minimization, moderation and other elegant designs can afford a reasonable certainty. Instructions and procedures can help but offer the least degree of certainty. All are desirable steps toward a safer processing facility.

Every strategy doesn't have to result in the complete elimination of the hazard or risk scenario. When we can make an incorrect action or assembly impossible (or at least very difficult) or design to accommodate the error without harm, we use the term "mistake proofing." Where doable at a reasonable cost, this may be

SULFONIC ACID PLANT

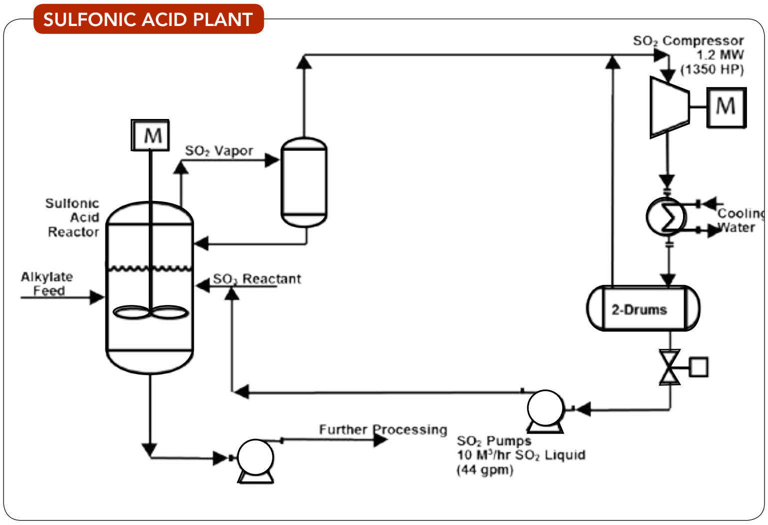

Figure 1. Traditional design includes a compressor and knockout drum.

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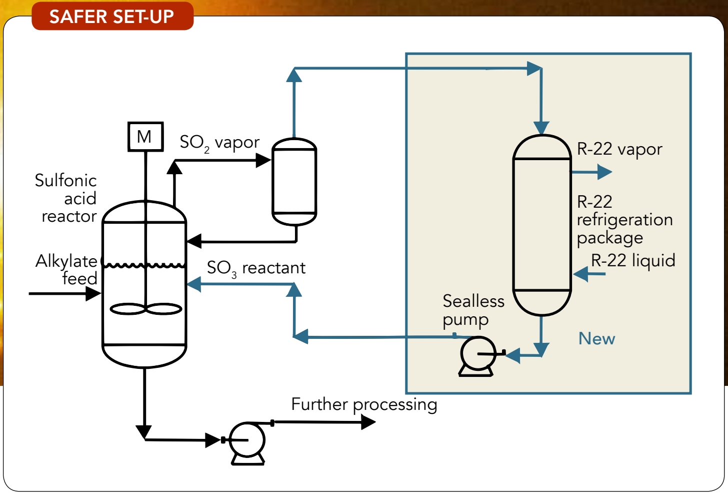
SAFER SET-UP

Figure 2. Modified design requires less inventory of SO2 and eliminates equipment that could leak toxic material.

an attractive strategy because it rarely introduces alternative scenarios. For our chlorine cylinder example, mistake proofing might include using unique connections for the hoses.

In contrast, mistake tolerant systems provide timely feedback when a mistake happens, the means (either before or after loss of containment) to correct the error before an undesirable outcome occurs, or, if not corrected, reduced consequences from the mistake. For the chlorine cylinder, a mistake tolerant strategy might involve isolating chlorine inside buildings that have a chlorine vapor recovery system.

APPLYING THE STRATEGIES

To illustrate the application of inherent safety strategies, let's look at several real-world situations: sulfonic acid plant design, aluminum chloride ($AlCl_3$) handling, a utility station and an electrical switchgear.

Sulfonic acid plant design. Reacting sulfur trioxide (SO_3) dissolved in sulfur dioxide (SO_2) with an alkylate feed produces sulfonic acid. This is an exothermic reaction that boils off SO_2 as its primary means of heat removal. The SO_2 performs the role of mutual solvent to allow intimate contacting between alkylate and SO_3, which otherwise would only react at their mutual surface. All of the materials are flammable. The SO_2 and SO_3 are both inhalation toxics.

The heat of reaction boils the SO_2 and SO_3 from the reactor. In the traditional plant design (Figure 1), two drums collect the boiled-off vapor and allow the return of SO_3 and any

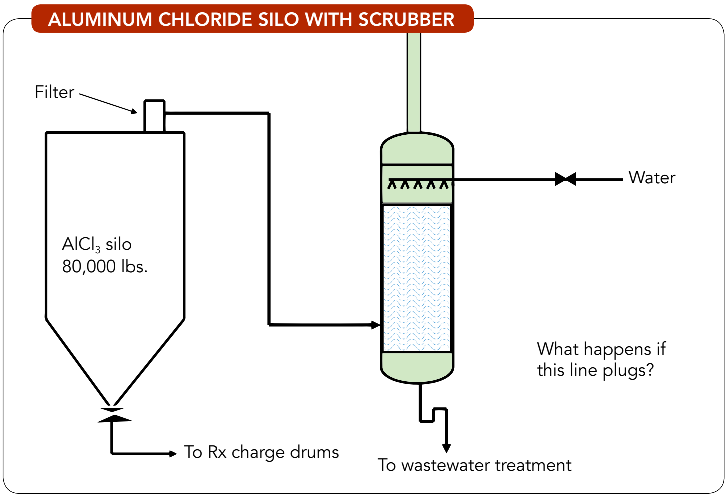
ALUMINUM CHLORIDE SILO WITH SCRUBBER

Figure 3. Plugging of line could lead to water getting into the silo — causing an exothermic reaction that creates HCl.

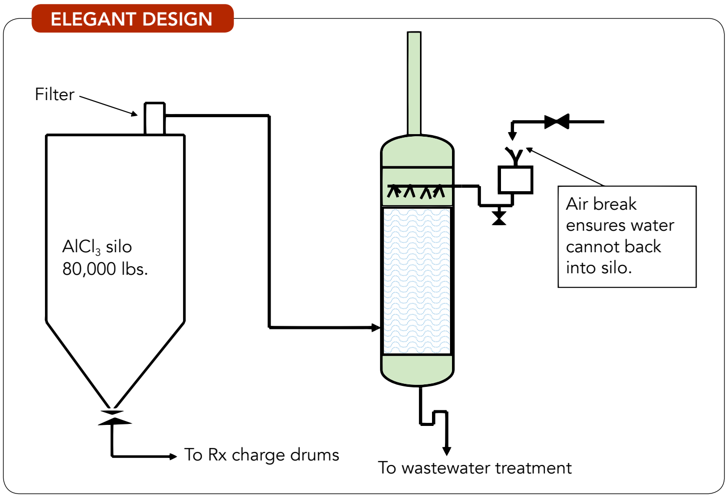
ELEGANT DESIGN

Figure 4. In the event of drain-line plugging, water will overflow at the air break rather than back up into the silo.

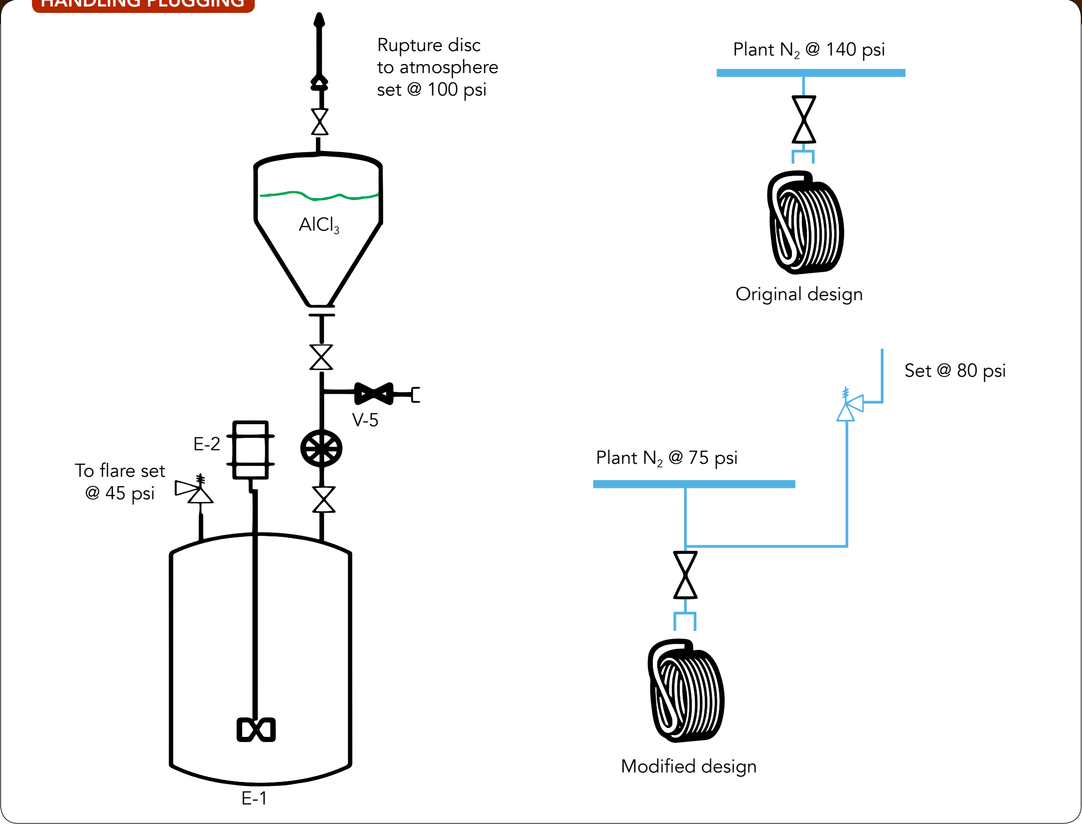

Figure 5. Original design had nitrogen at 140 psi, which posed risk of blowing rupture disk if operator used nitrogen to remove plug; changing to lower nitrogen pressure reduced risk.

knocked-out liquid to the reactor. A compressor and cooling water exchanger provide cooled, liquefied SO_2 for recycling to the reactor.

Following inherently safer design principles, the process was modified to eliminate the compressor and collector drums and replace the standard pumps with seal-less ones (Figure 2). This very significantly reduced the inventory of SO_2 required to operate the process and removed two pieces of rotating equipment, each of which had the potential to leak toxic material to the air. In addition, because a Freon refrigerant is used, the bulk of the SO_2 now is at a temperature not far from its boiling point, which minimizes vaporization in the event of a leak. However, these process safety improvements were achieved by using an ozone reactive material rather than cooling water.

The minimization and moderation strategies enhanced process safety — but opportunities exist to make the process even more inherently safe:

- Use the cooling exchanger as knockout pot and provide for gravity drain of cooled SO_2 back to the reactor, eliminating the pump. (This requires relocation of the SO_3 injection point.)
- Find a safer solvent than SO_2.

In addition, even greater inherent safety may be possible by avoiding the process altogether, such as by switching to sulfonic acid alternatives that are made via inherently safer processes.

Aluminum chloride handling, part 1. Figure 3 depicts part of a process that uses $AlCl_3$ as an ionic polymerization catalyst. $AlCl_3$ is a powder that reacts violently with water to form toxic hydrogen chloride (HCl) gas and aluminum hydroxide ($Al(OH)_3$). Its contact with skin results in burns. Low-pressure nitrogen is used to unload $AlCl_3$ from delivery trucks and transport the material to smaller vessels from which it is conveyed into the reactor. The $AlCl_3$ is a very fine powder, some of which will travel with the nitrogen. All conveying nitrogen is returned to a silo that can contain as much as 80,000 lb of $AlCl_3$. It then passes through a filter that returns most of the $AlCl_3$ to the silo. What passes through the filter is scrubbed from the nitrogen in a packed tower where water is sprinkled down through the bed as the nitrogen rises and is released from an elevated vent stack. The slightly acidic water drops through a "p-trap" and then goes to the wastewater sewer.

This is a fairly simple process — but what happens if the p-trap plugs? Water will flood the scrubbing tower and back up in the line towards the silo. Because the top of the vent from the scrubber is considerably higher than the filter on top of the silo, the water eventually will reach the silo, resulting in a highly exothermic reaction and generation of HCl gas that can't be contained within the silo.

The normal way to address this issue would have been to install level sensors in the packed tower with alarms and automated trip of the scrubbing water. An elegant and inherently safer design was to provide an air break in the water to the scrubbing tower (Figure 4). The top of the funnel is at an elevation considerably lower than that of the filter — thus, if a plug occurs in the drain line, the water runs out the top of the funnel. Little-to-no pressure head was required to get the water through the distributor inside the tower.

This modification was far less costly than installing the safety critical devices first considered.

It's difficult to put this inherent safety strategy into any of the four basic ones. It's simply an elegant design solution that works to make the scenario of water backing into the silo noncredible.

Aluminum chloride handling, part 2. Figure 5 shows the situation that existed at the reactor in the same plant with the $AlCl_3$ silo. The $AlCl_3$ passes at a controlled rate through a rotary feeder into the reactor. The $AlCl_3$ has a tendency to plug the standpipe between the feeder and the reactor. An operator's natural inclination is to blow

REFERENCES

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2. Center for Chemical Process Safety, "Inherently Safer Chemical Processes: A Life Cycle Approach," 2nd ed., Wiley, Hoboken, N.J. (2010).

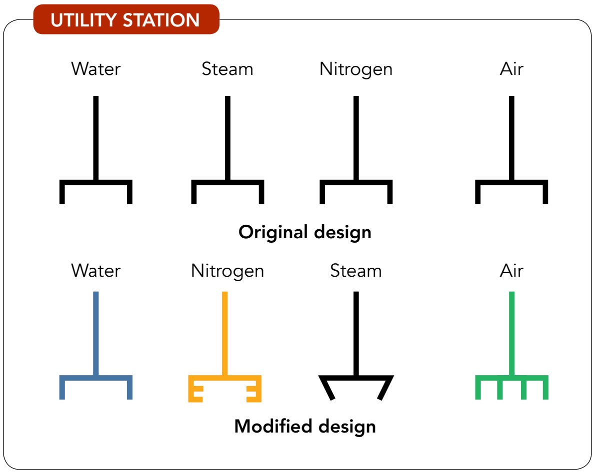

Figure 6. Use of similar types of connections makes it easy to connect a hose to the wrong utility; opting for distinct connections and color-coding makes hookup mistakes unlikely.

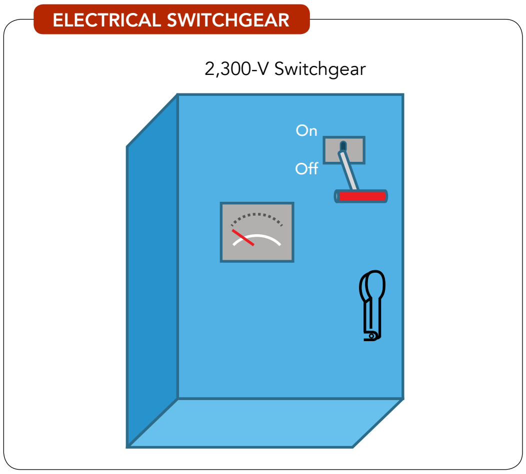

Figure 7. Operators mistakenly presume the lockout lock should go through hasp on cabinet door handle; sawing off the hasp eliminated the problem.

the plug free and into the reactor using 140-psi nitrogen available close by. Fortunately, there's never enough catalyst in the standpipe to cause a runaway reaction.

What can go wrong in this situation? If the valve between the bleeder where the nitrogen is injected and the day pot is left open or leaks, the nitrogen overpressures the day pot, blowing the rupture disk and sending fine $AlCl_3$ powder over several acres.

To make the situation more mistake tolerant, the nitrogen source within a hose length of the bleeder was reduced in pressure to 75 psi, well below the set pressure of the rupture disc on the $AlCl_3$ day pot. To prevent an operator from being tempted to adjust the pressure of that regulated nitrogen, a safety valve that relieves to an elevated location limits the pressure.

This didn't prevent one ambitious operator from stringing two nitrogen hoses together to bring 140-psi nitrogen to the day pot after working unsuccessfully for several hours to remove a clogged drop line using the 75-psi source.

Utility station. The use of a hose connected to a utility station is one of the most common ways that operators interact with process facilities. Figure 6 depicts a typical set-up for a utility station near the point of use that provides water, steam, nitrogen and air.

What could go wrong here? How could this set-up be improved?

In the modified utility station design, each utility was given a different type of connection. Each line not only was labeled but also color coded in a fashion that allowed even those suffering from color blindness to distinguish the utility based on the line's lightness or darkness. The distinct connector and color of each hose made mismatching, and therefore mistaking, the utility being connected to the process very unlikely. In addition, the arrangement of the utility station was modified to separate the air and nitrogen supply to provide one more barrier to mistakenly using nitrogen to drive a tool in a confined space.

It remains possible for some ambitious soul to prepare a crossover connection by appropriating the right set of fittings. Therefore, you must carefully control these utility station fittings.

This is an application of the mistake proofing form of inherently safer design.

Electrical switchgear. Figure 7 depicts an electrical switchgear in 2,300-V service. It serves as the primary electrical disconnect and lockout point for isolating a large pump when it needs service.

Where does the lock go to ensure that the equipment can't be re-energized while repairs are being made? There is a hasp conveniently placed in plain view on the handle that opens the cabinet door. However, the lock actually should go through a little tab above the disconnect switch that can be pulled out when the switch is in the off position.

You could try training your personnel on the proper location for the lock. You could put a sign on the cabinet to indicate where the lock goes. Then you could realize operators will hang the lock in the wrong location before they look for a sign that would tell them the right location — and put another sign on the wrong location that says: "Lockout lock does not go here!" However, eventually even that sign becomes just background noise.

We tried all these things before happening upon a solution that worked — cutting off the hasp on the door handle!

An operator knows a lock must be placed on the switchgear. Now, if the operator forgets exactly where the lock should go, the person will think about it and either come up with the right — and only — solution or ask. The possibility of making a mistake no longer exists.

Is this an inherently safer switchgear? Yes.

Does it fall into one of the four basic inherent safety strategies? Not really, although it may be a form of mistake proofing.

THE KEY TO SUCCESS

Application of inherent safety principles is just one aspect of making safety second nature. For each situation, other approaches may be equally effective as the basic four and may be economically feasible when none of the four are. Moreover, it's important to realize that mandating the use of inherent safety is like placing signs throughout the workplace that say: "Be Safe." Each has little benefit until you have translated the mindset into practical application.

You achieve expertise in the practical application of inherent safety principles through the diligent and repeated search for and application of inherently safer solutions. This experience is what makes a safety engineer effective and a process plant a safer place to earn a living. You train your brain to spot applications for solutions you've seen before and you apply principles you've used before to solve new problems. The end result is a mindset that makes safety second nature. ●

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PREVIOUS PAGE

Improve Alarm Management

Adopt a pragmatic approach to achieve significant benefits

By GC Shah, Wood Group

TODAY'S PROCESS control and safety systems provide massive amounts of valuable data that significantly enhance a plant's ability to manage operations and troubleshoot problems. The systems have fostered impressive gains in productivity and safety. These improvements stem to a certain degree from alarms that warn of variables deviating from appropriate ranges, enabling operators to take corrective actions. However, the ease and low cost of adding alarms too often lead to almost unchecked growth in their number, which, in turn, causes alarm "floods" that tax an operator's ability to identify and thus respond correctly to the key underlying issue. Some experts regard this as a problem of operators drowning in an ocean of data.

Dealing with this problem demands an effective alarm management (AM) system. Briefly put, such a system should provide an operator with actionable information and guidance for corrective action in a timely manner and should accommodate organizational and process changes over the lifespan of the alarm.

A number of standards — ISA-18.2 (IEC 62682) and EEMUA-191, API RP 1167 are the most frequently used — provide guidelines for implementing an effective AM system. These standards use a system's approach and consider the entire alarm lifecycle.

KEY CONSIDERATIONS

These standards offer an excellent roadmap for developing your AM plan. When working up your plan, keep the following key points in mind:

- Operators are the primary recipients of alarms; therefore, their input in developing an AM system is vital. In addition, engineers and maintenance personnel as well as safety and environmental professionals are important stakeholders.
- AM is not a one-time effort. It lasts for the entire lifecycle of the alarm system. The management system should be capable of handling changes in personnel, procedures and technology. As a corollary to this, well-designed operator training and change management will help ensure success of the AM system.
- Alarm system displays should be easy to grasp. Appropriate groupings of alarms, e.g., safety-critical alarms for an area or a piece of equipment or alarms related to environmental or other regulatory compliance, may enhance understanding.
- From a functional viewpoint, the alarm system should be robust (say, fault tolerant) and provide reliable and timely information so operators can take corrective action with confidence. Alarms representing scenarios with high consequence should be clearly visible.
- The importance of alarm records can't be overstated. Today, alarm system records generally are part of larger corporate systems. So, consider the alarms and AM in the broader context of data and information management for the organization.
- Evaluate the impact of power failure on alarm availability in the AM system.
- Some AM systems may require extensive development efforts. So, to augment in-house expertise, you may need to seek help from control and safety system vendors, consultants and database management professionals.

- Streamline the AM system. Where possible, avoid paperwork and bureaucracy. Some bureaucracy is necessary — e.g., to guard against uncontrolled modifications by imposing strict management-of-change (MOC) procedures — but strike a balance between bureaucracy and efficiency.

GAP ANALYSIS

For existing systems, it's important to determine how they compare to recommended guidelines from the standards. In the gap analysis, you can observe the alarm system for a representative period or do an offline analysis. Such an analysis often uses 10-hr segments. Consider:

- Alarm documentation and procedures for AM and their last updates;
- Alarm displays and whether operators easily understand them;
- Suppressed alarms and why they are suppressed or disabled;
- Frequency of alarms (average and maximum number of alarms in a 10-min period); and
- Duration of alarms.

Then, take a number of actions:

- Identify "bad actors" — e.g., alarms that keep going on and off (chatter), and ones that stay on too long (say, hours) — as well as stale and nuisance alarms.
- Determine the percentage of time that alarm rates fall outside acceptable limits. Standards note that an average of one alarm in a 10-min period is acceptable while an average of two alarms in a 10-min period, though manageable, would tend to stress out the operators.
- Pinpoint those alarms required for safe, efficient and regulatory-compliant operation. Operators, engineers and safety/environmental professionals should provide key inputs.
- Assign a priority — high, medium or low — to every alarm based on the consequence of a mishap associated with the alarm scenario and the response time available. Give alarms with high consequence and low response time high priority, and those with low consequence and longer response time low priority. For the system as a whole, the standards recommend the following distribution of alarms: high priority, ~5%; medium, ~15%; and low, ~80%.
- Find the causes of any high-frequency alarms; don't eliminate any such alarms without careful analysis of their underlying causes. Potential culprits include: poor controller tuning, incorrect installation of sensors/transmitters, improper setting for the alarms (too close to the normal operating range), faulty grounding and inadequate deadband in alarming. Removing the causes can reduce some frequencies considerably.
- Adopt the standards' suggested alarm frequency goal (an average of one alarm per 10-min period), and follow their guidelines for alarm delays:
  - — For any on/off delay, consider the impact on the process. Obviously, safety, productivity and compliance are the key criteria.
  - — For flow and pressure, aim for approximately 15 sec.
  - — For level and temperature, ~60 sec is acceptable.
  - — For analyzers, review your process and consider how an alarm delay can affect safety, quality and compliance.

SYSTEM DEVELOPMENT

Developing an AM system is a team-based activity that requires technical know-how as well as diplomacy in dealing with diverse groups of stakeholders. For new systems, follow the guidelines and requirements given by ISA-18.2, IEC 62682 or EEMUA-161:

Alarm philosophy. This is the umbrella document that specifies the processes to be used for each lifecycle stage (discussed below). The focus is to ensure operational or working definitions exist for,

e.g., alarm priorities, settings, performance metrics (such as frequencies), design of alarm displays (human/machine interface (HMI)) and MOC. A companion document called the alarm system requirement specification goes into greater detail on specifications.

Identification. Determine the alarms needed for safety, regulatory compliance and smooth plant operation. Some alarms also could be dictated by other activities such as hazard and operability studies, and process and instrumentation drawing reviews. The key questions to think about are: "Do I really need this alarm? What do I lose if this alarm is not there?"

Rationalization. Review each alarm and develop supporting documentation such as the basis for the alarm set point, corrective action necessary, consequence of inaction, alarm priority and alarm organization. Rationalization likely will enable elimination of many unnecessary or nuisance alarms. You possibly may find a need to add some other alarms. Results of rationalization typically are captured in a document called the master alarm database.

Detailed design. Broadly put, you must address three major areas in this stage: specifics of alarms (set point, deadband, associated control systems, etc.); particulars of the HMI; and advanced alarming, the need for which will depend upon your process.

Implementation. It's not uncommon to find that many alarms don't perform as designed because of poor installation. This stage of the AM lifecycle involves logical and physical installation — including location of the alarm as well as its testing and commissioning. Operator training also takes place during this step; it should focus on what the operator must know about the alarm and how to respond properly.

Operation. This is the stage in which the alarm system is functioning. You may consider refresher training for the stakeholders.

Maintenance. Periodic repairs and testing are part of the maintenance stage of the lifecycle. Lack of appropriate procedures could lead to alarms that end up shutting down the plant. The key is communication among the parties involved.

Monitoring and assessment. You regularly must check the performance of each alarm and the whole AM system, and compare performance metrics with the ISA-18.2 (IEC 62682; EEMUA 191) guidelines. Periodic reviews of the results will help you initiate appropriate troubleshooting.

Management of change. From time to time, you may need to add or remove alarms, modify their set points, deadbands or other parameters, or alter displays. Unless these changes are properly controlled and documented, the AM system will deteriorate. You must review a proposed change from the standpoint of each of the lifecycle stages.

Audits. Their purposes include, for instance, identifying deficiencies in the AM system against the alarm philosophy and potential areas of improvement. Audits are more comprehensive than periodic monitoring and assessment. Audits involve, e.g., man agement commitment, AM practices, comparison of performance indicators against the standards, MOC, operator's ability to respond to alarms, and training and documentation.

AM is a tool to enhance safety, productivity and regulatory compliance in a quantifiable manner. It is a multi-discipline activity. Teamwork and vigilance are the key to its success. ●

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Are You Overprotected?

A rational approach exists for combustible dust explosion protection

By Dr.-Ing. J. W. Lottermann, Rembe Inc./Rembe GmbH Safety + Control;
and Eric Finley and Helen Sztarkman, Rembe Inc.

IT IS a given that dust explosion protection is expensive. While combustible dust explosions are less likely to occur than fires, when they do occur, they often are catastrophic events. This raises the issue of how much investment is necessary for appropriate protection measures.

Because such protection legally is required [1], the issue is not *whether* to provide protection, but rather it is *defining* appropriate explosion protection measures to avoid over-engineering.

NFPA STANDARDS

According to National Fire Protection Association (NFPA) 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, 2013, the employer must (1) determine and assess the combustible dust explosion risk by conducting a process hazard analysis as part of its obligation to ensure life safety, and (2) implement the "necessary and appropriate" safety measures [2].

Looking at NFPA 654, chapter 5.2.1.2, the life safety objectives with respect to an explosion hazard shall be achieved if either of the following criteria is met:

1) Ignition has been prevented, or

2) Under all explosion scenarios, no person [...] is exposed to untenable conditions [...] and no critical structural element of the building is damaged [...].

Regardless of this performance-based design option, massive over-engineering is seen in practice. Simply stated, once companies are aware of the need for explosion safety, the "or" frequently is taken as an "and" so that the combination of both explosion prevention and explosion protection measures lead to expensive and excessive safety designs.

EXPLOSION PREVENTION VERSUS PROTECTION

In the first stages of any process hazard analysis, operators must determine the presence of combustible materials and whether they should anticipate the formation of explosive atmospheres in hazardous quantities. Although regulations and standards show preference to *avoiding* hazardous explosive atmospheres through substitute combustible materials [3], instead of using preventive safety measures, experienced operators know the practical relevance of this preferred preventive measure. For instance, a baker needs flour and sugar to bake, a power station burns coal, and wood dust is a natural by-product in chipboard factories. All these materials can cause explosive atmospheres. As

a result, the explosion hazard is a given in all of these examples when no real substitute would be safer.

If hazardous explosive atmospheres can't be prevented safely, the employer must assess the probability and duration of hazardous explosive atmospheres occurrences and the probability of the existence or the introduction of effective ignition sources. This assessment stage commonly is known as "classification" in the United States or "zoning" in the European Union (EU). [4]

But what frequently is forgotten when implementing these explosion safety measures in manufacturing processes is that the classification of hazardous locations into zones or classes also helps in providing protection priorities.

RISK-BASED, PROBABILISTIC APPROACH

Regardless of which global classification or zoning approach is used, the scope of explosion prevention measures depends on the probability of the occurrence of hazardous explosive atmospheres (zone, class and division). This probabilistic concept is based on the comparative assessment of the generally accepted residual risk (RR_{Ex}), which arises from a combination of the severity (A_S) and the probability of an explosion (P_{Ex}): [5]

$$RR_{Ex} = A_S \times P_{Ex} \quad (1)$$

Because the probability of an explosion is characterized by the probability of a hazardous explosive atmosphere's existence ($P_{g.e.A.}$) and the probability of the occurrence of an effective ignition source ($P_{w.Z.}$),

$$P_{Ex} = P_{g.e.A.} \times \sum P_{w.Z.} \quad (2)$$

this central requirement results:

$$RR_{Ex} = A_S \times [P_{g.e.A.} \times \sum P_{w.Z.}] \quad (3)$$

To determine the appropriate protection, operators first must identify the hazardous locations and ignition sources in the process area. Many factors come into play, which is why a process hazard analysis is crucial when equipping a facility with explosion protection equipment. A comprehensive analysis will examine the entire facility and determine which prevention or protection techniques are required for each process instead of applying *everything* available. This is the first step in properly and efficiently controlling the combustible dust hazard present.

Next, operators should analyze the risk's severity because the severity can fluctuate depending on the situation. For instance, the explosion severity in a dust collector located in the middle of a facility is greater than the explosion severity in a dust collector located outside in an isolated area. It may be hard to determine the actual severity of an explosion taking place, so some type of protection will be required in all cases. This risk analysis provides only a way to prioritize which areas to protect first.

Taking the example of a dust collector system (Figure 1) that is protected with a flameless venting device and an explosion isolation device, operators need only to implement measures to *avoid* ignition sources, not *prevent* ignition sources. In the filter's raw gas and dirty air section, which normally is classified as hazardous Zone 20, Class II, Division 1, a rotary air lock classified in equipment category 3D (or equivalent) [6] also could be used if this rotary air lock was certified or approved to be pressure shock-resistant and flameproof.

However, a look into processing systems that

DUST COLLECTOR SYSTEM

Figure 1: This type of dust collector system requires only that operators avoid ignition source, not prevent them.

are, in practice, protected shows that all stops frequently are pulled out to apply preventive measures, such as eliminating ignition sources, despite the existence of consequence-limiting measures.

With regard to the comparably low probability of ignition within the design parameters of working equipment (see, for example, EN 13463-1 introduction), such concepts become absurd. For example, a manufacturer recently applied for his equipment category 1D [6] silo discharge screws to be considered a unique selling point, even though most silos *already are protected with explosion-venting devices*. In light of the escalating costs of equipping a plant in such a manner, it is no wonder that the high cost vs. benefit of explosion safety is the first topic of discussion whenever a need is identified.

Rather, an appropriate mix of preventive and protective measures can lead to a consistent explosion safety concept. The freedom to design such an appropriate explosion protection mix already is provided in the German Technische Regeln für Gefahrstoffe (TRGS) 720/Technische Regeln für Betriebssicherheit (TRBS) 2152, [7] where the legislative authority speaks of "suitable combinations of preventative and constructive measures in accordance with expert judgement." This interpretation is supported in the more precise definition from the European Directives 94/9/EC (ATEX 114) and 1999/92/EC (ATEX 153) [6], as well as NFPA 654, chapter 5.2.1.2. According to these regulations and standards, all necessary measures must be taken to ensure that the workplace, the work equipment and the relevant connection devices are designed, constructed, assembled, installed, maintained and operated in a way to minimize the *risk of explosions*.

In view of equation (1), above, if an explosion's effects are limited to a nonsevere level using explosion protective measures, an acceptable residual risk arises almost independently of the probability of occurrence, with reference to the risk matrix, from the Verein Deutscher Ingenieure (VDI) series of guidelines 2263 "Dust fires and dust explosions: Hazards, assessment, protective measures; inerting" (Figure 2). This risk matrix is recognized by the professional engineering industry and tried-and-tested in operational practice. [5]

EXPLOSION PROTECTION MEASURES

Although an explosion could lead to catastrophe and death in any zone, class and division,” the question of requiring a risk-oriented approach also is raised for *protective* explosion measures.

This risk-oriented approach for protective explosion measures would be the same as for preventive explosion measures in which the measures’ scope, degree and reliability are aligned to the probability (frequency and duration) of a hazardous explosive atmosphere’s occurrence.

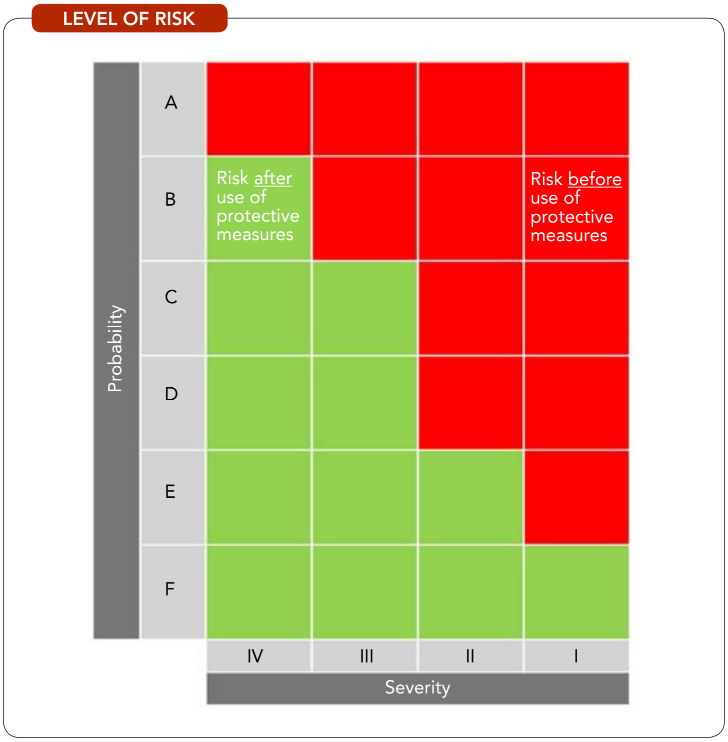
Take the example of a system protected using explosion suppression but whose protective system was deactivated at the point of explosion.

A first approach to this is stated in the TRGS 721/TRBS 2152-1: The affected measures in “areas with explosion impacts exceeding the usual degree” in scope and type must be taken into account and in NFPA 654, which says that the use of specific protective systems requires a detailed Process Hazard Analysis or, in some cases, an *additional* Process Hazard Analysis.

For instance, in a plant’s high-traffic areas (for example, meeting places, corridors with dense traffic, residential buildings and larger office premises) that are located in a hazardous zone, only protective systems that cannot be manipulated, deactivated or otherwise prevented from functioning should be allowed to be used.

Furthermore, with passive explosion protective systems, which normally are not installed and checked by the manufacturer, operators should undertake a visual inspection periodically to avoid misapplication or malfunction.

In this context, it becomes clear that a risk-oriented categorization of protective explosion measures also must occur with regard to the probability of the occurrence of effective ignition sources.



LEVEL OF RISK

Probability	IV	III	II	I
A	🟥	🟥	🟥	🟥
B	🟩 Risk after use of protective measures	🟥	🟥	🟥 Risk before use of protective measures
C	🟩	🟩	🟥	🟥
D	🟩	🟩	🟥	🟥
E	🟩	🟩	🟩	🟥
F	🟩	🟩	🟩	🟩

Figure 2: This risk matrix demonstrates that if an explosion’s effects are limited to a nonsevere level using explosion protective measures, an acceptable residual risk arises almost independently of the probability of occurrence.

In comparison with preventive explosion safety measures in which an explosion is not permitted in principle, an impact-related categorization also must take place that considers the expected measure of damage.

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SUMMARY

The contexts of preventive and protective explosion safety measures are addressed in American and European standards and legislation. An appropriate explosion safety concept based predominantly on the use of protective measures (most frequently explosion venting in connection with explosion isolation) permits the forgoing of additional, more cost-intensive preventive measures.

If ignition sources in explosion-prone systems cannot be avoided in operational practice with sufficient safety, then a technically safe and economically reasonable combination of preventive and protective measures can be used according to professional discretion. It is the operator's responsibility to adjust the scope of these preventive safety measures, which reduce the probability of occurrence, to the operator's own requirements, resulting in a reasonable safety system that fits that particular explosion risk situation. This approach ensures the most efficient and effective explosion protection and prevention system is implemented. ●

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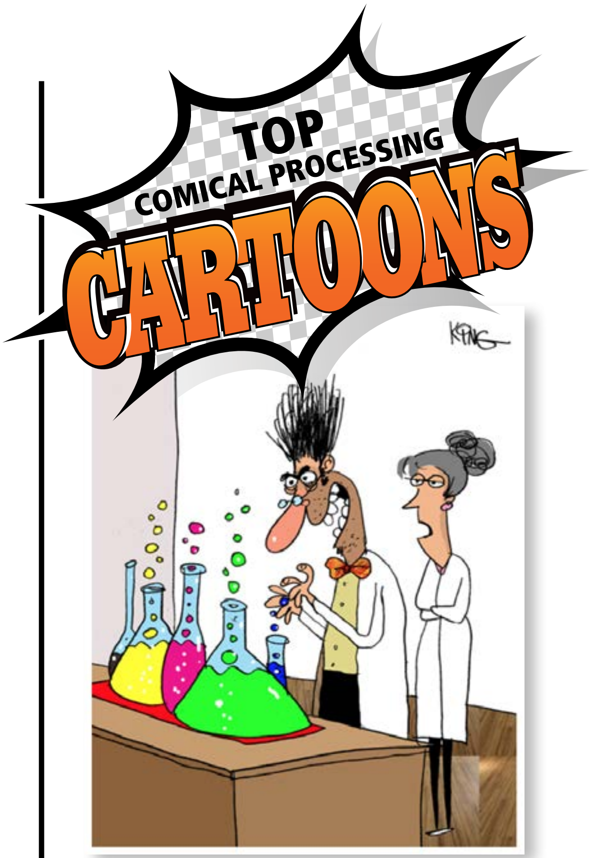

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