

# Sustain Effective Process Safety Programs to Achieve Excellent Performance<sup>1</sup>

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Efforts to achieve excellent process safety performance are nothing new [1], and for most companies require continuous focus and dedication. Sometimes just one mistake or equipment failure can lead to catastrophic results. Experience shows that sustained excellent process safety performance is difficult, but not impossible with appropriate effort and resources. People make mistakes and equipment can fail at any time. But some mistakes can be prevented or their impact can be anticipated and safeguarded. Similarly, equipment can be designed appropriately and effectively maintained, and the impact of failures can be anticipated and safeguarded.

Excellent performance requires a continuous effort to implement, sustain, and improve effective process safety programs [2]. Guidance on the design and implementation of process safety programs has been available for many years [3], and in practice, most companies now have the technical knowledge and capabilities to safely identify and manage process hazards and risks. After all, process safety regulations have been in effect for over 25 years, and industry guidance and resources are widely available. In the early 1990s, Kletz [4] expressed that “new” accidents rarely occur; rather, the same types of accidents are repeated and should be known and therefore are preventable. More recently, Hendershot [5] similarly stated that “We know how to improve process safety performance... We need to actually do what we already know how to do, we need to do it well, and we need to do it everywhere and all of the time.”

Yet, process safety performance concerns in industry unfortunately remain too common: serious and near-miss process incidents still occur too frequently due to ineffective process safety programs or the lack of recognition that a process safety program is needed. Serious process safety incidents can lead to (1) fatalities and serious injuries, (2) catastrophic property damage, (3) significant environmental harm, (4) critical business disruption, (5) business reputational damage, and, in some cases, (6) negative community impacts. For example, a refinery explosion [6] resulted in 15 fatalities, 180 injuries, and major facility

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damage, as shown in Figure 1. Serious incidents and frequent near misses highlight significant performance problems and the ongoing need to achieve better process safety performance, despite industry emphasis on incident prevention and continuous improvement efforts. This paper discusses the requirements for sustaining effective process safety programs to help achieve excellent process safety performance.

**Figure 1. Refinery Explosion and Fire [6]**



## Process Safety Performance

The primary objectives of effective process safety programs are identifying, evaluating, and managing process hazards to help achieve excellent performance and ensure safe processes and facilities. How is performance defined? A basic definition is ‘excellent performance prevents serious injuries and incidents.’ However, there are two potential problems with this definition. First, injury and incident statistics may be mixed with personal safety statistics, such as lost workday cases, that may not provide a clear view of process safety performance. For example, subsequent investigation [7] following the refinery explosion in Figure 1 found that “reliance on injury rates significantly hindered... perception of process risk.” Second, injury and incident statistics are *lagging* metrics, representing events that have already occurred rather than helping identify problems before they can lead to more serious injuries and incidents (i.e., *leading* metrics). Since serious injuries and incidents are hopefully infrequent, these indicators do not provide true measurement of how a process safety program may be performing. Are process safety systems working the way they should be day-to-day, or are there problems that may be leading to higher risks? How would facility personnel know?

A better definition of performance relates to executing process safety program requirements and systems with the intent of achieving program goals and objectives. Program goals should include (1) how to prevent serious injuries and incidents related to process activities and (2) other leading and lagging indicators to measure the functioning and effectiveness of process safety program activities to provide early warning of possible problems. Like medical professionals who measure vital signs such as blood pressure and cholesterol levels for early warning of potential health problems, appropriate goals and metrics should be established, monitored, and responded to by accountable facility personnel to monitor process safety performance. For example, failing to (1) document and assess changes to process equipment or (2) conduct equipment tests and inspections on the required schedules can greatly increase the risk of process-related injuries and incidents. Meaningful process safety program goals with appropriate leading and lagging metrics and management review of system performance must be established to obtain a clearer view of process safety performance, as will be discussed later. While excellent performance can be demonstrated using lagging metrics, ultimately excellent future performance can typically only be pursued using appropriate process safety goals and leading metrics. Some of the driving forces for achieving excellent process safety performance are listed in Table 1, and some potential causes of poor process safety performance are listed in Table 2.

**Table 1. Some Driving Forces for Improving Process Safety Performance** (adapted from [2])

- Near miss and incident learning, including significant incidents internally or externally as well as incident trends
- Poor or degrading leading and lagging process safety metrics, including audits
- Costs associated with poor performance (e.g., lost production, repair costs, poor quality)
- New regulations and industry consensus standards and guidance
- New technology, including new hazards as well as new applications
- Benchmarking with other companies
- Corporate restructuring, acquisitions, and mergers
- Stakeholder relations (e.g., communities, stockholders, employees, and regulators)

**Table 2. Some Potential Causes of Poor Process Safety Performance** (adapted from [2])

- Weak safety culture and/or leadership
- Lack of senior leadership operational or safety experience, focus, and commitment
- Compliance-based mentality rather than risk-based mentality
- Poor awareness, interpretation, and/or implementation of regulations and industry standards and guidance
- Poor hazard recognition/identification
- Poor process safety system design with inadequate risk assessment/management
- Poor operational discipline
- Cost/staffing/resource pressures

- Poor management of mergers and acquisitions
- Lack of experienced, knowledgeable management, technical, and safety personnel
- Poorly designed feedback/measurement systems
- Complacency/no sense of vulnerability resulting from past performance

## **Current Performance and Direction**

Key questions of process safety performance include:

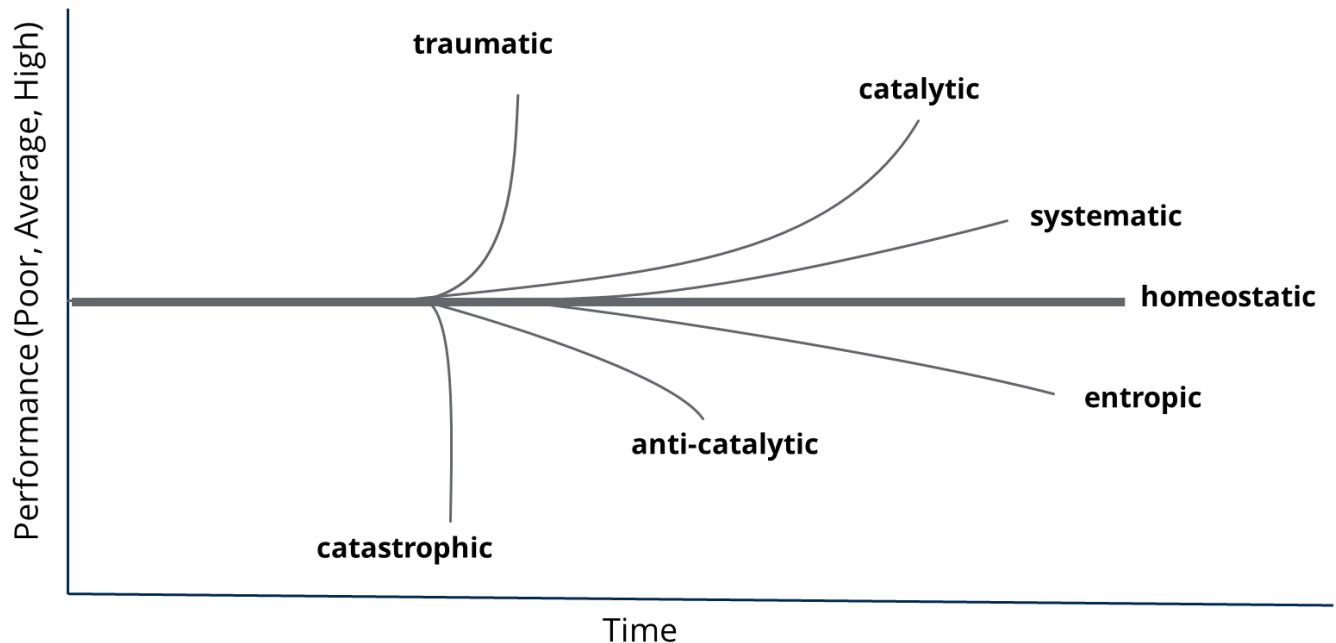
- What is the current level of performance, such as high (excellent), average, or poor?
- Is performance likely to get better, stay about the same, or get worse?

The answers to these questions are obviously very specific to company or facility process safety goals based on (1) the process hazards and risks that may be present and (2) management priorities.

While assessing current performance seems straightforward, serious process safety incidents are (hopefully) rare, and therefore performance is typically assessed in terms of conformance to process safety system requirements. But systems and expectations differ and what may be considered excellent performance at one company may not be at another, based on the goals and leading and lagging metrics that have been established. Companies may also believe they have excellent performance, but relative to industry standards and regulatory expectations, performance may not be as good as believed. Both internal and external measurements should be considered when evaluating process safety performance. Facilities must, at a minimum, be aware of industry standards and best practices for comparison and should benchmark operating results with other facilities and companies whenever possible.

The second question is more difficult. Several possible pathways or scenarios are shown in Figure 2. The Y axis measures performance where the current status can be generally categorized as high, average, or poor. The current status is important because if a company already has excellent performance, it should mainly desire to maintain that high level. If a company has poor performance, it should set goals and provide resources for improvement. From the current status, several performance scenarios are possible:

**Figure 2. Process Safety Performance Scenarios**



- **Entropic** – In the Entropic scenario, there is a slow degradation of performance. This is most common where continued attention to process safety performance is not maintained, which often results from either (1) complacency (e.g., lack of any recent significant incidents leads to confidence that the process safety performance must be adequate), (2) lack of awareness of degradation (e.g., no leading metrics or inadequate audits), or (3) competing priorities (e.g., financial pressures) that prevent appropriate focus on process safety performance. Without continued attention, any system, including a process safety system, will degrade over time as training and human performance expectations lag, equipment continues to age, and other distractions can lead to incidents. Performance may continue along this path until an event (e.g., incident, audit) triggers a change of focus.
- **Homeostatic and Systematic** – These scenarios reflect continued goal setting to maintain and/or improve performance. Generally, performance is likely to already be good so the intent is to continue to provide resources to appropriately manage process risks. If performance is not already strong, then these scenarios may indicate insufficient management attention or resources to substantially improve performance until an event again triggers a change of priority for process safety. These scenarios are the most likely performance targets for many companies.
- **Catalytic and Anti-catalytic** – These scenarios represent triggering events that either lead to rapid improvement or degradation of performance. Typical trigger events may include (1) a near-miss event to raise awareness of possible issues, (2) a change of leadership, such as a new plant manager with a different priority level for safety, (3) an acquisition or merger, especially where there are significant differences in

corporate safety culture, (4) financial considerations due to a change in the economy or company cost control, (5) a regulatory change or inspection, (6) internal audits, inspections, or management visits that either question or confirm performance, and (7) lawsuits or other legal considerations.

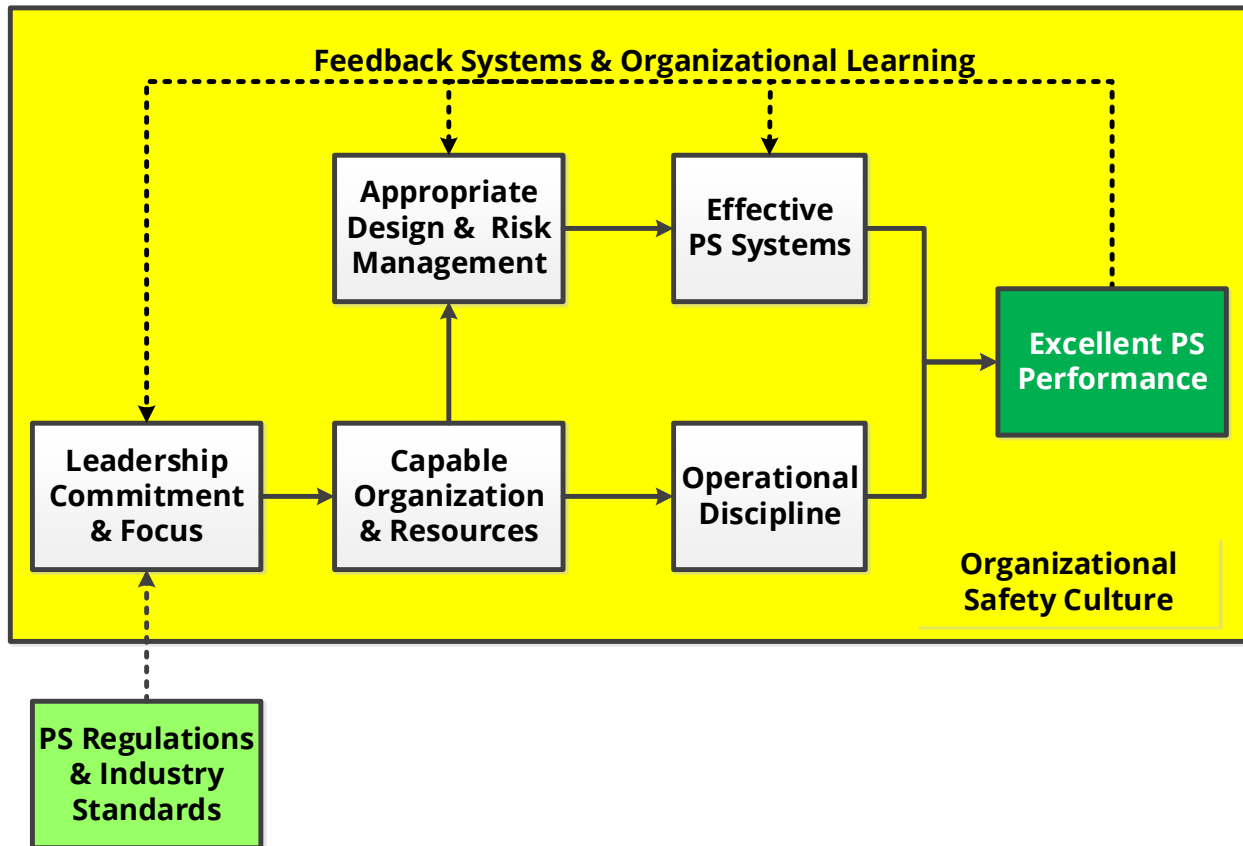
- ***Traumatic and Catastrophic*** – These scenarios represent significant, rapid performance changes typically resulting from serious process incidents at a facility, in the same company, or in a related industry. If a serious incident occurs at the facility, obviously performance will drop immediately, and the disruption and distractions caused by the incident may lead to continued performance issues or even perhaps closure of the facility. If the serious incident occurs at another facility in the company or industry, it may serve as a wake-up call to motivate management to focus immediately on providing resources to improve process safety programs.

Consideration of these two questions – What is our current performance? and What will it be in the future? – is essential for achieving desired performance levels on both absolute (internal) and relative (external) criteria. Achieving excellent performance, of course, does not simply happen. It must be the result of management support of effective process safety programs, setting annual program goals, and constant measurement and review of performance through appropriate feedback systems. A model of important factors that impact performance is discussed in the next section.

## **Achieving Excellent Process Safety Performance**

While all aspects of effective process safety programs are ultimately important, the performance model [2, 8] shown in Figure 3 provides principal program activities that impact performance and indicates how they interact [2]. The key elements of this model are discussed below, with one or more possible actions that companies/facilities can take to help improve performance for each aspect.

**Figure 3. Process Safety Performance Model** (adapted from [2, 8])



- Process Safety Regulations and Industry Standards** – Companies must be aware of regulatory requirements and industry best practices. In addition, effective implementation of programs to comply with industry codes and standards (often referred to as recognized and generally accepted good engineering practices [RAGAGEPs]), such as standards issued by the American Petroleum Institute, helps ensure equipment is properly designed and less likely to fail. Lack of knowledge of regulations, best practices, and RAGAGEPs will seriously reduce the effectiveness of process safety programs. Knowledge of external information and activities is essential for (1) leveraging organizational capabilities in process safety and (2) ensuring, among other things, proper equipment design and maintenance. The Center for Chemical Process Safety (CCPS), for example, has provided comprehensive guidance on risk-based process safety programs [3] and continues to develop new guidance based on industry best practices. Exposure to process safety literature through selected conferences and journals can also help keep process safety professionals current on new industry developments and practices. Part of organizational learning, discussed below, is to maintain an active external focus to enhance internal activities.

*Possible Action:* (1) Develop systems to ensure proper awareness, access, and use of external process safety regulations and guidance.

- **Organizational Safety Culture** – The effectiveness of process safety programs and the ability to achieve excellent performance are strongly influenced by the safety culture. Differences in safety culture, often due to conflicting priorities such as financial or production considerations, can have dramatic effects on safety performance. A poor safety culture, for example, may be able to achieve excellent performance in the short term, but is unlikely to sustain excellent performance over the long term. A good definition of safety culture [2] is “The normal way things are done at a facility, company, or organization, reflected expected organizational values, beliefs, and behaviors, that set the priority, commitment, and resource levels for safety programs and performance.” Characteristics that describe the essential features of safety cultures have been defined [3, 9] and can be used to evaluate strengths and opportunities for improvement. As part of the safety culture, a sense of vulnerability should be maintained to help prevent complacency issues, especially when performance has been strong for a long time. Failing to maintain a sense of vulnerability can directly lead to a mistaken belief that success is routine rather than something requiring continued focus and diligence [10]. This is the “entropic” performance scenario shown in Figure 2.

*Possible Actions:* (1) Periodically conduct safety culture assessments. (2) Develop strategies to maintain a sense of vulnerability in personnel at all levels to help prevent complacency.

- **Leadership Commitment and Focus** – Leadership at a company or facility is (1) influenced by the safety culture (e.g., in setting daily priorities for safety versus production) and (2) able to influence the culture (e.g., strengthen or weaken the culture over time). As discussed earlier, a change in leadership such as a new plant manager can lead to catalytic or anti-catalytic changes in process safety performance. Leadership necessarily encompasses all levels of management from the Board of Directors to first-line supervision [7]. If a shift supervisor is making decisions contrary to higher level guidance, such as to complete certain work tasks in an unsafe manner, leadership credibility is challenged and the safety culture can degrade. Leadership commitment and focus on process safety are critical for ensuring resources are provided to help build a capable organization in terms of financial, personnel, and time considerations. Process safety program policies, goals, metrics, and accountabilities must be established with appropriate resources provided to support excellent performance. Direct leadership involvement in process safety activities is also essential for building trust and securing employee engagement through visibility and consistent action.

*Possible Actions:* (1) Set appropriate, actionable, and measurable process safety improvement goals annually. (2) Ensure that appropriate process safety training is

provided to all leadership as part of specific job roles and career advancement criteria.

- **Capable Organization and Resources** – Leadership must provide purposeful and sufficient resources for implementing and sustaining effective process safety programs to support safe, high quality, and reliable operations. This includes developing internally trained and capable process safety professionals and others with expertise and knowledge of process operations and process safety regulations and RAGAGEPs to help ensure process goals can be met. Since it is increasingly difficult for everyone to know everything about all technical areas, appropriate policies and guidance should be documented, training conducted, and networking and mentoring opportunities provided, especially for new or less-experienced personnel. In some cases, it is often more effective to involve specialty resources, such as consulting services, for (1) designing effective process safety systems, (2) conducting process safety audits, and (3) assisting with risk management. The decision to develop in-house capabilities versus using specialist consultants and contractors is often based on the risk of processes operated by the company/facility and other factors such as company size. Ultimately, process safety must become part of everyone’s job in terms of ensuring process safety program goals and requirements are met. A well-defined training strategy should therefore be developed and implemented with refresher training at appropriate intervals to help (1) ensure awareness and understanding of process hazards that may be present and (2) process safety program requirements for managing these hazards.

*Possible Actions:* (1) Review training strategies to support effective process safety program implementation and performance. (2) Implement an organizational change process to evaluate organizational capabilities and manage personnel changes.

- **Appropriate Design and Risk Management** – Well-designed processes are the starting point for safe and reliable operations and for achieving excellent process safety performance. Process design must provide the desired product, of course, but must also be based on identifying, evaluating, and managing process hazards and risks. Where possible, process hazards should be eliminated using inherently safer technology approaches [11]. Remaining process hazards must be evaluated using appropriate hazard evaluation methodologies to help ensure process hazards are identified and the consequences of administrative and engineering controls have been evaluated to ensure safeguards are provided, typically using multiple layers of protection [2, 3]. These evaluations are also used to ensure process safety systems are designed and implemented as part of effective process safety programs to continually manage process safety activities and performance.

*Possible Actions:* (1) Ensure process safety information that serves as the basis for process design (e.g., hazard information, process design basis, equipment design basis) has been properly compiled and is being maintained. (2) Review current risk

management practices to evaluate if hazard evaluations are being properly conducted during all stages of the process life cycle (e.g., initial design to decommissioning).

- **Effective Process Safety Systems** – Process safety systems provide the detailed requirements of the process safety program to help ensure (1) process hazards have been identified and evaluated before being first introduced into the workplace and (2) process risks are successfully controlled at all times as facility personnel complete their daily work activities. Process safety systems must be designed appropriately based on process hazards and risks that are present, applicable regulatory requirements, and best practice industry guidance. Various approaches have been proposed, ranging from 8 management systems [2] to 20 risk-based elements [3]. OSHA process safety management in the United States has 14 elements. Core process safety requirements are typically present in these elements, such as operating procedures, training, mechanical integrity, incident investigation, management of change, etc. Proper functioning of these process safety systems is essential for achieving excellent process safety performance, such that qualified and trained resources should be assigned to lead and monitor individual systems/elements, and specific metrics should be provided to monitor if system requirements are being met. Many leading metrics are associated with proper functioning of these systems, which provide early warning of both current and future performance problems.

*Possible Action:* (1) Ensure appropriate leading and lagging metrics are being monitored to review process safety system performance.

- **Operational Discipline** – Process safety systems only work as intended if personnel are actually following them; even highly trained people occasionally make mistakes. The reality is that human error should be anticipated, and appropriate systems and safeguards should be provided to make sure errors do not lead to serious injuries and other consequences, especially if work tasks include higher-risk activities involving significant process hazards. Operational discipline (OD) is used to describe human behavior in following required systems and procedures correctly, every time, to consistently achieve safer and more reliable operations. Developing an OD program [2, 12] intended to support day-to-day awareness and commitment by all company personnel can help (1) minimize the potential for human error, (2) ensure process safety program requirements are rigorously followed, and (3) support excellent process safety performance. An OD program focuses on both organizational and personal OD to (1) help company or facility management develop the programs and work environment to support strong operational discipline and (2) provide resources for supporting OD improvement efforts. Personal OD programs are based on ensuring personnel at all levels have the knowledge, commitment, and awareness to complete their individual work activities correctly and safely every time.

*Possible Action:* (1) Identify OD improvement opportunities based on implementing an OD program or conducting additional OD evaluations as part of an existing OD program.

- **Feedback Systems and Organizational Learning** – Methods to monitor process safety program effectiveness using both leading and lagging metrics are essential for achieving high performance [2, 3]. Without appropriate program feedback, warning signs of problems may be missed and learning opportunities for improving performance can be lost. Ensuring the right things are measured and evaluated, based on process safety program goals, provides information on the current performance level (e.g., poor, average, high) and trend (e.g., getting better or worse). Metrics by themselves are of little use unless they are acted on, identifying strengths and weaknesses, and initiating specific improvement opportunities. Learning from experience is a common process safety theme, and the use of organizational learning approaches to collect, analyze, share, and retain critical process safety information helps promote sensitivity to operations, a sense of vulnerability, and knowledge of past problems and successes [2]. Developing a process safety learning plan, based on learning goals, competency needs, information collection, and retention of knowledge can strengthen process safety programs and performance over time.

*Possible Action:* (1) Develop a process safety learning plan.

A summary of the possible actions discussed for improving process safety performance is provided in Table 3. Many more actions are possible, of course, based on specific facility goals, current performance, and identified improvement opportunities.

## Summary

Are you happy with your process safety performance? What is the level of current performance relative to company expectations and industry standards? Will performance be better in the future? What specific approaches are being taken to make sure performance remains excellent or improves? Experience shows that sustained excellent process safety performance is possible, but requires continued commitment and resources to implement, sustain, and improve effective process safety programs. Past success will not ensure future success, as competing priorities and other challenges will always be present. The technical knowledge and capabilities to implement and maintain robust process safety programs and achieve high levels of performance are readily available, based on process safety regulations, industry guidance, and resources such as RAGAGEPs. Several possible actions for helping improve process safety performance have been discussed in this paper, but ultimately deciding to (1) set appropriate performance goals and (2) evaluate specific facility or company opportunities for improving performance will lead to increased likelihood of process safety success.

### **Table 3. Possible Actions for Improving Process Safety Performance**

1. Develop systems to ensure proper awareness, access, and use of external process safety regulations and guidance.
2. Periodically conduct safety culture assessments.
3. Develop strategies to maintain a sense of vulnerability in personnel at all levels to help prevent complacency.
4. Set appropriate, actionable, and measurable process safety improvement goals annually.
5. Ensure that appropriate process safety training is provided to all leadership as part of specific job roles and career advancement criteria.
6. Review training strategies to support effective process safety program implementation and performance.
7. Implement an organizational change process to evaluate organizational capabilities and manage personnel changes.
8. Ensure process safety information that serves as the basis for process design (e.g., hazard information, process design basis, equipment design basis) has been properly compiled and is being maintained.
9. Review current risk management practices to evaluate if hazard evaluations are being properly conducted during all stages of the process life cycle (e.g., initial design to decommissioning).
10. Ensure appropriate leading and lagging metrics are being monitored to review process safety system performance.
11. Identify OD improvement opportunities based on implementing an OD program or conducting additional OD evaluations as part of an existing OD program.
12. Develop a process safety learning plan.

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