# Workplace Safety and Health Guidelines

## Process Safety Performance Indicators

# Contents

## Preface

This guideline is the initiative of the Workplace Safety and Health Council (Chemical Industries) Committee to help companies (especially SMEs) improves process safety performance in Singapore. It is consistent with the aim of the WSH 2018 national strategy to reduce the incident rate in the workplace. Process safety incidents are often catastrophic or serious in nature. However, due to their low likelihood of occurrence, more emphasis has traditionally been placed on personnel safety. Recent industry experience clearly demonstrates the need for process industries to change this mindset and provide equal importance to process safety within the company's management system.

The Workplace Safety and Health Council (Chemical Industries) Committee encourages process industries to adopt this guideline as part of their strategy towards safety excellence.

# 1. Introduction

This set of guidelines aims to introduce the concept of process safety performance indicators, with a greater focus on leading indicators in performance monitoring for process safety management. It provides guidance on the development of process safety performance indicators, and how these indicators can contribute to better safety and health outcomes in the process industry.

This set of guidelines is intended to assist the middle-to-senior management and WSH personnel of companies in the process industry, including the SMEs and plants of smaller operation scale. It will help these stakeholders to identify any possible risks arising from their work processes, and take steps to rectify them before the risks manifest into undesired consequences. With more knowledgeable and responsible management and employers, the process industry can achieve improved safety and health standards.

## 1.1 The Process Industry

The process industry, in general, encompasses any industrial activity where raw materials are treated and converted into finished product by a series of manufacturing stages through batch or continuous operation via physical and/or chemical processing. The process industry broadly includes the chemical, petroleum, petrochemical and wafer fabrication industries, industries involved in the production of paper, polymer, synthetic fibre, food and pharmaceuticals as well as industrial activities involving water purification and waste treatment.

## 1.2 Process Safety versus Personnel Safety

### Process Safety

Process safety focuses on the prevention of incidents involving leaks, spills, fires or explosions by making sure that facilities are well designed, safely operated and properly maintained. In particular, it involves ensuring that facilities are designed and engineered properly with systems in place to monitor and control hazards. Process safety may also be considered the result of a wide range of technical, management and operational systems working together to achieve the desired outcome. When the desired outcome is not achieved, a process safety incident occurs. The safety pyramid in the figure below illustrates the progression to a process safety incident.

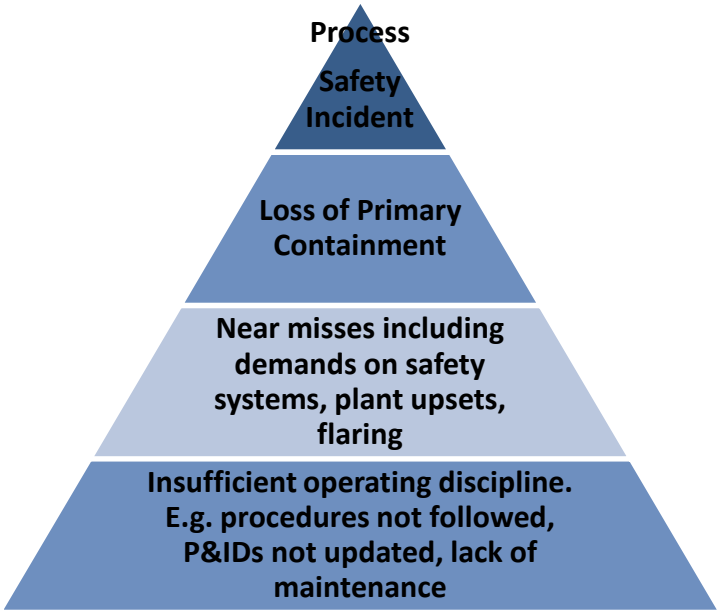


Figure 1: Process safety pyramid (Adapted from CCPS[1])

Process safety risks typically give rise to low frequency high consequence events such as loss of containment, fire and explosions.

**Personnel Safety**

On the other hand, personnel safety focuses on things that may cause injury or harm to an individual. Personnel safety risks result in high frequency low consequence events such as slips, trips and falls.

Over reliance on occupational illness and injury rates can lead to a *false sense of security* about process safety.

[1] The Center for Chemical Process Safety (CCPS), New York, USA, assists the industry in avoiding or mitigating catastrophic accidents.

The following boxes highlight and explain the key differences between process safety and personnel safety issues.

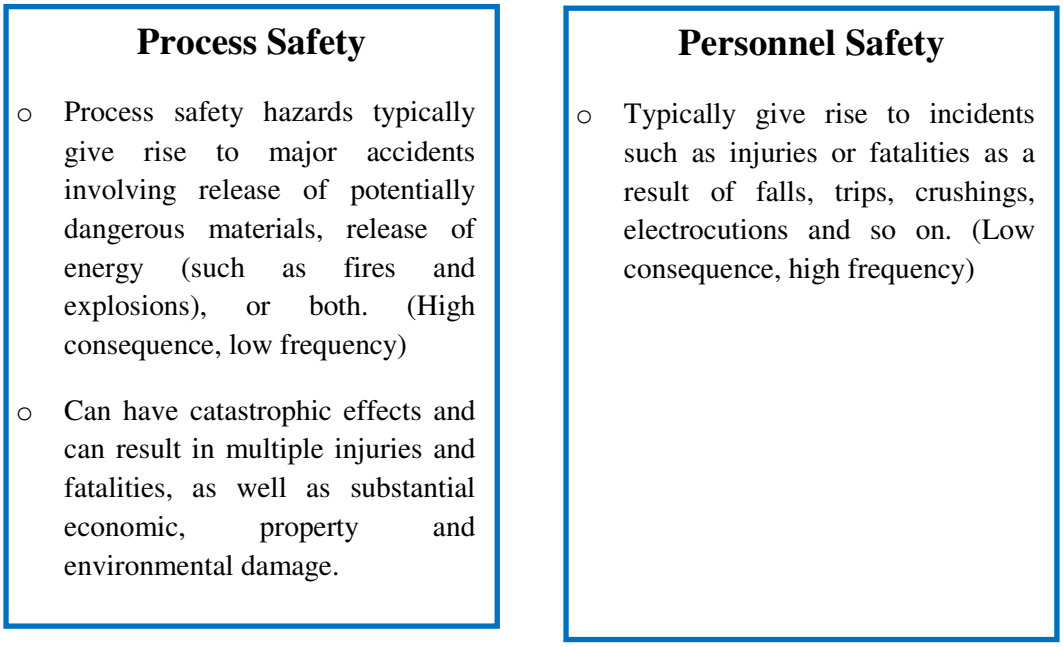


Figure 2: Comparison between process safety and personnel safety

### 1.3 Business Case for Process Safety Performance Indicators

Good process safety management ensures that process risks are effectively controlled and major incidents avoided. Business interruption is minimised, workers are kept safe and there is minimal downtime. The improved business performance leads to higher workforce morale and hence more productive workers. Coupled with good WSH performance, there is also more efficient use of resources. The company saves on lower corporate insurance for good WSH track record, protects the bottom line, and results in greater business profitability. In the long run, with strong WSH fundamentals, the company is able to generate new and repeat business from customers who share the same philosophy towards safety. Safety can therefore be viewed as a competitive advantage, and enables new business opportunities and creates access to wider market. Process safety performance indicators help us stay on course.

# 2. Performance Monitoring

Performance monitoring for process safety can improve safety and reduce the risk of a process safety incident. These monitoring indicators provide assurance that process safety risks are adequately controlled. In turn, there is greater business efficiency, and systems and procedures continue to operate as intended. There are two types of process safety performance indicators, namely, leading and lagging indicators.

## 2.1 Leading and Lagging Indicators

Leading indicators monitor proactively the effectiveness of risk control systems and provide feedback on safety performance before an incident or accident happens. On the other hand, lagging indicators monitor reactively the effectiveness of risk control systems, identify gaps and weaknesses in these systems, and report on incidents or accidents to check that the controls in place are adequate.

Leading indicators evaluate the present state of workplace through routine and systematic inspections actively. This can include areas such as maintenance of pressure vessels, relief systems, staff training and operational discipline. The data collected from such inspections may give early indication of deterioration in the effectiveness of key risk control systems. Lagging indicators, however, step in when the desired safety outcome has failed. They are the suite of control measures generated from reactive monitoring or after an incident or accident had occurred.

We need to proactively identify the hazards and associated risks arising from processes and activities in order to achieve better safety and health outcomes in the process industry. This is in tandem with the principle under the WSH framework in Singapore to adopt a proactive risk-based approach, where occupiers and employers are required to manage the risks arising from their work processes and/or activities. Leading indicators fit in to identify possible risks from these processes.

To effectively manage process safety hazards, a proactive approach to risk management is undoubtedly essential. Leading indicators thus play a rigorous role in process safety performance monitoring. More importantly, a robust performance monitoring system should be established to manage process safety that combines the use of both leading and lagging indicators. In figure 1, the safety pyramid illustrated the progression to a process safety incident. Figure 3 below gives a clear overview of how this progression relate to the concept of leading and lagging indicators.

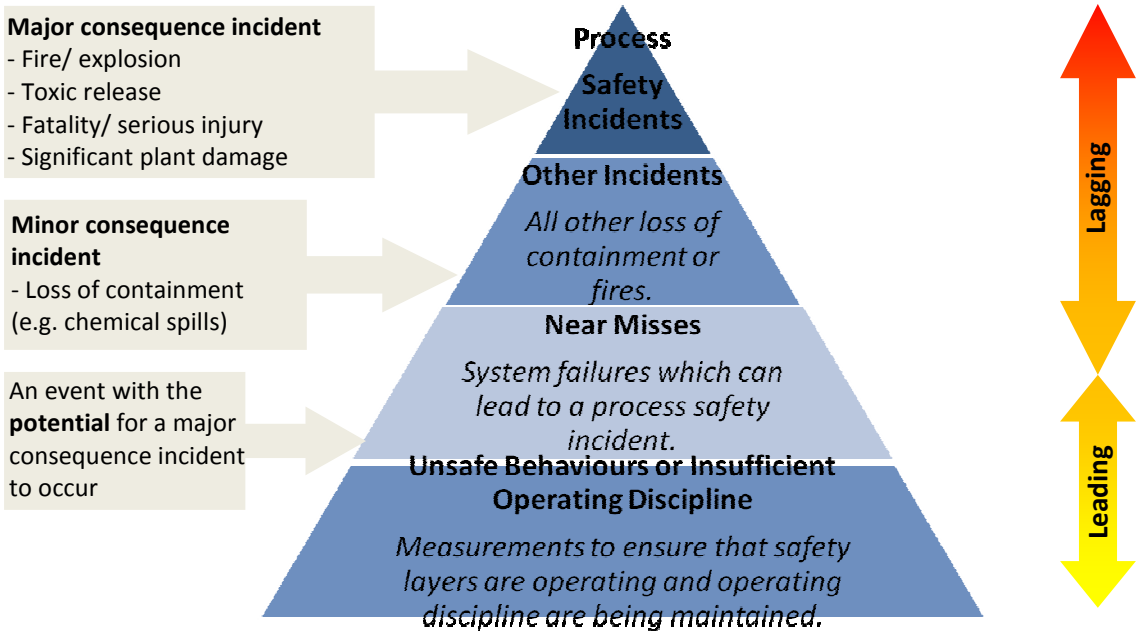


Figure 3: Process safety pyramid and performance indicators (Adapted from CCPS)

Typically, lagging indicators measure the downstream incidents and/or near misses which would lead to process safety incidents having major consequences. Therefore, to prevent such incidents, steps would have to be taken upstream, which include leading indicators that monitor and identify lapses within the process safety management system.

# 3. Process Safety Management Framework

Process safety focuses on process safety hazards. Appendix A shows the elements of process safety management (PSM).

PSM is a pre-requisite for process safety performance monitoring. It describes those aspects of an organisation's management system that focuses on preventing major incidents. This management system requires procedures or systems that will assure a desired safety outcome. Process safety performance indicators evaluate the effectiveness of these procedures or systems via both leading and lagging indicators. The outcome of the evaluation enables an organisation to enhance the robustness of its operational system.

## 3.1 Step-by-Step Methodology

The methodology outlined below describes a four-step process that can be adopted by organisations to implement a programme of performance monitoring for process safety risks (herein referred as Programme). See Figure 4 below.

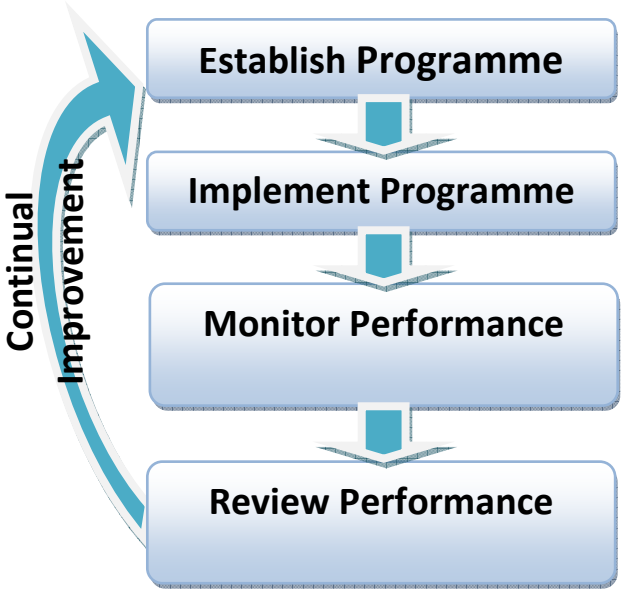


Figure 4: Methodology for process safety performance monitoring

A balanced approach is employed using a combination of leading and lagging indicators for the process safety performance monitoring programme. The table below details the steps in the methodology for process safety performance monitoring.

| Step | Methodology | Tasks | Information Source | Deliverable(s) |
|---|---|---|---|---|
| 1 | Establish Programme | - Decide on scope of programme<br>- Form implementation team | - Consult top management on team member selection<br>- Guidelines on Process Safety Performance Indicators | - List of implementation team members<br>- Subset of PSM elements in focus |
| 2 | Implement Programme | - Identify safety critical activities<br>- Identify risk control measures for the critical aspects<br>- Establish priorities/ Set desired safety outcome | - Risk Assessment (RA) forms<br>- Process Hazard Analysis (PHA) reports | - Set of lagging indicators<br>- Set of leading indicators for each critical aspect |
| 3 | Monitor Performance | - establish process data collection system<br>- design reporting format | - Data from Step 2 | - Monitoring report |
| 4 | Review Performance | - Review performance of each PSM element in focus<br>- review monitoring scope and performance tolerance | - Performance benchmarking vs. desired safety outcome in Step 2 | - List of programme enhancements |

Table 1: Steps in methodology for process safety performance monitoring

## 4. Process Safety Monitoring Indicators

The following table shows some examples of leading and lagging process safety performance indicators, as referenced in Appendix A.

| No. | PSM Element | Basic Criteria | Leading/ Lagging | Monitoring Indicator* | Definition of Monitoring Indicator |
|---|---|---|---|---|---|
| 1 | Process safety information (PSI) | Safety data sheet (SDS) management system | Lagging | Percentage of SDSs available and current | "Current" indicates:<br>- SDS updated with a change in supplier or manufacturer, or<br>- Less than 3 years from last update, or<br>- There is a change in the manufacturer's specifications or processes (for chemical manufacturers) |
| 2 | Process safety information (PSI) | PSI procedure identifying PSI documents | Lagging | Percentage of process safety documentation available, as-built and current | "Process safety documents" are process flow diagrams, process and instrumentation diagrams (P&IDs), equipment specifications, reaction calorimetry data, safeguarding system documentation, SDS, etc. |
| 3 | Process safety information (PSI) | PSI management procedure | Leading | Percentage of process safety documents with identified owners | All process safety documents should have an identified owner. The |

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| | | | | | owner is responsible to ensure that the document is kept as-built and current based on the changes made in the process. |
| 4 | Process hazard analysis (PHA) | Hazard identification and review plan | Leading | Percentage of PHA or review completed as per plan | Review plan should be in place to review high risk hazards in time. |
| 5 | Process hazard analysis (PHA) | Hazard identification and follow up action plan | Leading | No. of open & overdue PHA action items | All action items from risk studies should effectively addressed and closed out in a reasonable timeframe. |
| 6 | Process hazard analysis (PHA) | PHA procedure | Leading | Percentage of processes analysed by PHA and documented | All process units identified should be analysed before start-up and re-evaluated every 5 years. |
| 7 | Operating procedures | Critical activities effectively managed through well documented procedures | Leading | Percentage of procedures reviewed as per schedule (e.g. all critical procedures reviewed every 5 years) | Critical procedures must be kept up-to-date to ensure relevance as a safety barrier. Critical procedures are those that govern high risk activities onsite. |
| 8 | Operating procedures | An operational log of product transfer failures | Lagging | Number of times product transfer does not occur as planned due to incorrect/unclear operational procedures | An indicator that would help companies to improve their operating procedures. |
| 9 | Operating procedures | Inventory of safety critical activities | Leading | Percentage of safety critical activities with documented | Safety critical activities are those that are identified |

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| | | | | Standard Operating Procedures (SOPs) | through the on-site safety risk assessment. |
| 10 | Operating procedures | Critical activities effectively managed through well documented procedures | Leading | Percentage field adherence to SOPs | Actual compliance by operations staff in day-to-day activities<br>- Structured sampling covering all SOPs at least once over a period of 5 years |
| 11 | Employee participation | Incident and near miss reporting system | Leading | Percentage employees involved in reporting unsafe process safety conditions and/or near-miss reporting | Employee participation in identifying hazards / potential unsafe situations before the occurrence of an incident |
| 12 | Employee participation | Process safety activity plan | Leading | Percentage of direct/operational/technical employees involved in routine process safety activities (e.g. pre startup safety review (PSSR), Audit, process hazard analysis (PHA), inspections, etc.) | Direct employees are those that are involved with manufacturing activities directly. Excludes procurement, administrative and human resource (HR) personnel. A wider involvement indicates a broader awareness of process safety aspects. |
| 13 | Employee participation | Employee suggestion system | Leading | Percentage of employees involved in process safety improvement suggestions or project implementation | A measure of employee participation in making and closing process safety improvements. |
| 14 | Training | Process safety training | Leading | Percentage identified | Ensuring that employee |

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| | | and competency plan | | training completed as per plan | knowledge & skills are refreshed / kept up to date. |
| 15 | Training | Process safety training and competency evaluation procedure | Lagging | Percentage of training evaluated for its effectiveness | Effectiveness means that the training provides the employee with the necessary skills to carry out their assigned tasks in a safe and competent manner. |
| 16 | Training | Process safety training needs analysis | Lagging | Percentage of jobs with identified training needs and plan | Training plan includes:<br>- Both initial and refresher training for employees, suppliers, contractors and others who interact with the processes<br>- Competency requirements of the job task |
| 17 | Contractors | Contractor employee assessment | Leading | Percentage of contractors employees assessed as conforming to skill standards | Number of contractors employees whose skills were assessed for high risk jobs either during the task or prior to it. Example hot work, forklift driving etc. |
| 18 | Contractors | Contractors safety & health management system performance evaluation | Leading | Percentage of contractors safety and health performance reviewed | A measure of the number of contractors meeting the safety and health performance requirements. This measure enables company to advise contractor on the improvement required and |

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| | | | | | keeps contractors focused on safety & health performance as per schedule. |
| 19 | Contractors | Incident analysis | Leading and Lagging | Percentage of near-miss and accidents involving contractors per year | An indicator of the contributors to incidents - Contractor employees or company employees. This measure allows the company to allocate resources to effectively manage the contractor. |
| 20 | Contractors | Relevant contractor training plan | Leading | Percentage of contractors who have attended required safety training prior to commencement of work | The number of contractors trained on the companies' operations, hazards and controls expected inclusive of mandatory training. |
| 21 | Pre-Startup Safety Review (PSSR) | PSSR checklist | Leading | Number of PSSR identified action items opened, and their criticality level (hi, mid, low) | Action items are those items identified during PSSR as not meeting the original or design intent of the management of change (MOC). Criticality is determined by the risk matrix. |
| 22 | Pre-Startup Safety Review (PSSR) | PSSR procedure | Leading | Percentage of equipment commissioned with PSSR | PSSR should be conducted before any new equipment is commissioned as a last check to ensure that it is |

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| | | | | | safe to start up. |
| 23 | Mechanical integrity | Preventive maintenance (PM) of safety critical equipment/ instruments | Leading | Percentage of safety critical equipment/ instrument overdue for PM, inspections, calibrations, etc. in the period | Mechanical integrity program for safety critical equipment/ instruments not conducted on time. (Examples of safety critical equipment/instrument are, pressure relief devices, interlocks, emergency shutdown system etc.) |
| 24 | Mechanical integrity | Availability of Standard Maintenance Procedures (SMP) | Lagging | Percentage of tasks where SMP was not followed when inspected | A measure of SMP compliance level. |
| 25 | Mechanical integrity | PM, calibrations and inspections schedule | Leading | Percentage adherence to PM, calibrations and inspections | A measure of PM, calibrations and inspections carried out on time. |
| 26 | Mechanical integrity | Breakdown work order system | Lagging | Percentage of equipment requiring breakdown maintenance | A measure of the equipment breakdown during operation / while in use. |
| 27 | Mechanical integrity | System to record failure of safety devices | Lagging | Number of times safety devices were triggered but failed to operate during normal operation | A measure of the number of times an identified relief device did not perform as designed or intended. Examples given below: Pressure Relief Device (PRD): opening of rupture disc, pressure safety valve, or control valve to atmosphere or flare. Failure to open as designed. |

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| | | | | | - Safety Instrumented System (SIS): activation by "out of acceptable range" process variable. Failure to activate as designed.<br>- Process deviation or excursion: process operation outside defined safe operating limits |
| 28 | Hot work permit | Hot work permit system and controls | Leading | Percentage of hot work permits issued where the hazards, risks and control measures were adequately specified | Number of Hot work permits clearly specified control measures to be taken such as gas tests, fire watchman and fire fighting equipment readily for use. It indicates the level of awareness of the control required for hot work |
| 29 | Hot work permit | Hot work compliance | Leading | Percentage of work conducted in accordance with permit conditions | Measure of compliance to the hot work permit conditions. Examples of Hot work permit conditions : gas tests, fire watchman and fire fighting and emergency equipment etc. |
| 30 | Hot work permit | Hot work and incompatible works ( Fire risk control) | Leading | Percentage of permits rejected due to incompatible work | A measure of the permit issuers' appreciation of work that is incompatible with hot work, such as spray painting. |

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| 31 | Management of change (MOC) | Temporary MOCs system defined under MOC | Leading | Number (and Percentage) of overdue temporary MOCs | A measure of timely closure of temporary MOCs. |
| 32 | Management of change (MOC) | MOC compliance Level | Leading | Number (and Percentage) of changes without MOC | Percentage of changes made without evaluation. Changes without MOC should be investigated (Absence of MOC = Near-miss) |
| 33 | Management of change (MOC) | MOC implementation | Lagging | Number of incidents where deficiency in MOC is found to be a contributing factor | MOC deficiencies found in investigation. This indicator provides the level of understanding of the change. |
| 34 | Incident investigation | Incident reporting system including reporting of process safety incidents | Lagging | Process safety incidents rate | A process safety incident must meet three criteria:<br>1. Chemical Involvement: chemical or chemical process directly involved<br>2. Quantity Threshold: $25,000 in fire/explosion damage or release exceeding quantity threshold or fire/explosion/release resulting in serious injury<br>3. Location: occur in production, storage, distribution, utility, pilot plant, or lab area. Transportation incidents are |

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| | | | | | not included. |
| 35 | Incident investigation | Prompt investigation of process incidents | Leading | Percentage of incidents / accidents are investigated within target time frame | Incident investigation should be initiated within 48 hours. This is a measure of the company's promptness in investigating process safety. |
| 36 | Incident investigation | Corrective actions items follow up | Leading | Percentage of corrective actions completed / closed within target time | Percentage of action plans completed vs. planned. |
| 37 | Incident investigation | Incident reporting system inclusive of definition of repeat process safety incidents | Lagging | Number (and Percentage) of repeated incidents | Repeat of similar incident. This is a measure of effectiveness of the previous root cause analysis and corrective actions. |
| 38 | Emergency planning and response | Critical emergency response equipment preventive and predictive maintenance list | Leading | Percentage adherence to preventive or predictive maintenance schedule for emergency response equipment | Preventive and predictive maintenance of critical emergency response equipment as per schedule. Indicates action taken to ensure equipment identified for emergency use will function as expected |
| 39 | Emergency planning and response | Emergency exercise/ desktop review planned or scheduled | Leading | Percentage emergency exercises completed on schedule | Number of emergency exercises completed vs. planned. A measure of the companies emergency preparedness through practice. |

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| 40 | Emergency planning and response | Initial and refresher training plan for emergency response team | Leading | Percentage of Emergency Responders (ERs) who have completed scheduled training | Number of emergency responders who have completed the scheduled emergency response training as per plan. Includes refresher training and new equipment training. |
| 41 | Emergency planning and response | List of corrective actions from emergency response exercises | Leading | Percentage of corrective actions arising from emergency exercises completed on time | Timely closure of corrective actions from previous emergency exercises. Signifies better preparedness to deal with an emergency vs. previous status. |
| 42 | Compliance audit | Audit schedule and audit checklists covering impact to process safety management | Leading | Percentage of internal audits conducted on time | Number of audits completed vs. planned. Demonstration of the companies' commitment towards process safety management. |
| 43 | Compliance audit | Audit schedule and audit checklists covering impact to process safety management (PSM) | Leading | Percentage of corrective actions completed in the expected time frame | Closure of actions identified from PSM audits. Demonstration of the companies' commitment towards PSM. |

Table 2: Process safety management indicators

**Please note that the list of monitoring indicators presented in Table 2 is not exhaustive. Users should develop those indicators suitable and relevant to their nature of business and operations to achieve the desired process safety outcome.*

## 5. Terms and Definitions

The following terms and definitions are used in the context of this guideline.

| Term | Definition |
|---|---|
| **Process safety** | The prevention of major incidents involving leaks, spills, fires or explosions by making sure that facilities are well designed, safely operated and properly maintained. |
| **Personnel safety** | The prevention of injury or harm to an individual. |
| **Leading indicators** | Indicators that proactively measure the effectiveness of risk controls. |
| **Lagging indicators** | Indicators that monitor reactively the effectiveness of risk controls. |
| **Process safety incident (PSI)** | A process safety incident is defined as the loss of containment of hazardous material or energy, resulting in undesired consequences such as fatalities, injuries, environmental and/or property damage. |
| **Risk controls** | Control measures established to prevent or mitigate PSI. |
| **Risk management (RM)** | The identification, assessment and prioritisation of Workplace Safety and Health (WSH) risks followed by the application of control measures to minimise the probability and/or impact of undesirable WSH consequences. |
| **Risk assessment (RA)** | The process of evaluating the probability and consequences of injury or illness arising from exposure to an identified hazard, and determining the appropriate measures for risk control. |
| **Risk** | The likelihood that a hazard will cause a specific bodily injury to any person. |
| **Hazard** | Anything, any source or any situation with the potential to cause bodily injury or ill-health. |

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| **Process safety management (PSM)** | Application of management systems and controls (programs, procedures, audits, evaluations) to a manufacturing or chemical process in a way that process hazards are identified, understood, and controlled so that process-related injuries and process incidents are prevented. |
| **Process hazard analysis (PHA)** | A systematic approach to assess potential hazards associated with a process operation. |
| **Safety data sheet (SDS)** | Information on the physical, chemical and hazardous properties together with the necessary precautions to take of hazardous or potentially hazardous substances. |
| **Safety critical activities** | Safety critical activities are those that are identified through the on-site safety risk assessment |
| **Standard operating procedure (SOP)** | A documented method to perform a specific operation or task. |
| **Standard maintenance procedure (SMP)** | A documented method to perform specific maintenance of an equipment or process. |
| **Preventive maintenance (PM)** | A proactive maintenance strategy based on servicing, replacing or overhauling an item at a periodic interval. |

# Appendix A – Elements of Process Safety Management

The PSM framework depicted in this guideline are based on Singapore Standards SS506 Part 3 and US OSHA PSM, §1910.119. The elements are briefly described below.

1. Process Safety Information
   Process safety information includes information on the (i) hazards of the highly hazardous chemicals used or produced by a process, (ii) technology of the process, and (iii) equipment used in the process. This compilation of written information will serve as precursor to Process Hazard Analysis (PHA) as it provides the basis for identifying and understanding the hazards of a process. The information may also be necessary for complying with the other elements of Process Safety Management (PSM) such as Management of Change (MOC) and incident investigations.

2. Process Hazard Analysis
   Process hazard analysis (PHA) is a thorough, organised and systematic approach used to identify, evaluate and control the hazards of processes involving highly hazardous chemicals. PHA methodologies include the what-if technique, the checklist technique, the what-if/checklist methodology, the hazard and operability (HAZOP) study, failure mode and effects analysis (FMEA), fault tree analysis, or an equivalent methodology (e.g. event tree analysis).

3. Operating Procedures
   PSM requires written operating procedures to be developed and implemented, consistent with the process safety information, providing clear instructions for the safe conduct of process activities. The procedures should cover the (i) steps for each operating phase (including startup, normal operations, emergency operations and shutdown), (ii) operating limits, and (iii) safety & health considerations.

4. Employee Participation
   Employers are encouraged to involve their employees in the development and implementation of each PSM element. Under PSM, a written plan of action for implementing employee participation is required.

5. Training
   Each employee needs to be trained in an overview of the process and its operating procedures. Training includes initial training as well as refresher training and should include safety and health hazards, safe work practices and emergency operations. A training record should be kept containing the identity of the employee, the date of training, and the means used to verify that the employee has understood the training.

6. Contractors

PSM also applies to contractors performing maintenance or repair, turnaround, major renovation, or specialty work on or adjacent to a process. It does not apply, however, to contractors providing incidental services that do not influence process safety, such as janitorial, food and drink, laundry, delivery, or other supply services.

When selecting a contractor, employers should obtain and evaluate information regarding the contract employer's safety performance and programs. The employer must also inform the contract employer of the known potential fire, explosion, or toxic release hazards related to the contractor's work and the process; explain to the contract employer the applicable provisions of the emergency action plan; develop and implement safe work practices to control the presence, entrance, and exit of contract employers and contract employees in process areas; evaluate periodically the performance of contract employers in fulfilling their obligations; and maintain a contract employee injury and illness log related to the contractor's work in the process areas.

7. Pre-Startup Safety Review

PSM requires that a pre-startup safety review (PSSR) be performed for new facilities and modified facilities (so long as the modification is significant enough to require a change in the process safety information). Prior to the introduction of a highly hazardous chemical to a process, the PSSR should confirm that (i) construction and equipment are in accordance with design specifications, (ii) safety, operating, maintenance, and emergency procedures are in place and adequate, (iii) a PHA has been carried out for new facilities and recommendations have been resolved or implemented before startup, and modified facilities meet the requirements under MOC, and (iv) training of each employee involved in operating the process has been completed.

8. Mechanical Integrity

Prior to startup, it is important that process equipment be checked to ensure that they are designed and installed correctly. Once installed, employers should establish and implement written procedures to maintain the ongoing integrity of process equipment including pressure vessels and storage tanks, piping systems, relief and vent systems and devices, emergency shutdown systems, pumps as well as instrumentation and control systems. Employees involved in maintaining the ongoing integrity of process equipment have to be aware of the process hazards and trained in the safe work procedures applicable to the job.

9. Hot Work Permit

It is important for a permit to be issued for all hot work operations conducted on or near a process. The permit must document that fire prevention and protection measures have been

put in place prior to hot work commencement; it must indicate the date(s) authorised for the hot work; and identify the object on which hot work is to be performed.

10. Management of Change
    Any contemplated changes (whether permanent or temporary) to a process must be thoroughly evaluated to fully assess their impact on employee safety and health. Written procedures to manage changes (except for "replacements in kind") to process chemicals, technology, equipment, and procedures, as well as any change to facilities that affect a process, should be established and implemented. Considerations to be addressed prior to any change include the technical basis for the proposed change, the impact of the change on employee safety and health, the modifications to the process safety information and operating procedures required as a result of the change, the necessary time period for the change to be effected, and the authorisation requirements for the change.

11. Incident Investigation
    PSM requires the investigation of each incident that resulted in, or could reasonably have resulted in, a catastrophic release of a highly hazardous chemical in the workplace. The incident investigation should be initiated as promptly as possible. The investigation must be by a team consisting of at least one person knowledgeable of the process, including a contract employee if the incident involved the work of a contractor, and other persons with the appropriate knowledge and experience to investigate and analyse the incident thoroughly.

    An investigation report is to be prepared at the conclusion of the investigation providing at least the date and time of incident, the date investigation began, a description of the incident, the factors that contributed to the incident, and the recommendations resulting from the investigation.

    A system should be established to promptly address and resolve the incident report findings and recommendations. Resolutions and corrective actions should be documented and the report reviewed by all affected personnel whose job tasks are relevant to the incident findings (including contract employees when applicable).

12. Emergency Planning & Response
    If, despite the best planning, an incident occurs, it is essential that emergency pre-planning and training make employees aware of, and able to execute, proper actions. For this reason, an emergency action plan for the entire facility must be developed and implemented. In addition, the emergency action plan should include procedures for handling small releases of hazardous chemicals.

13. Compliance Audit

To be certain PSM is effective, employers should certify that they have evaluated compliance with the provisions of PSM every 3-5 years. This is to verify that the procedures and practices developed under PSM are adequate and being followed. The compliance audit must be conducted by at least one person knowledgeable in the process and a report of the findings developed and documented noting deficiencies that have been corrected. The two most recent compliance audit reports should be kept on file.

**Key Guidance for each PSM Element**

| | PSM Element | Key Guidance |
|---|---|---|
| 1 | Process Safety Information | • Information concerning process chemistry, process technology and process equipment must be complete and kept up-to-date<br>• Safety Data Sheets must be current and easily available |
| 2 | Process Hazard Analysis | • Important to carry out process hazard identification, evaluation and implementation of control measures<br>• To be updated and revalidated at least once every 5 years |
| 3 | Operating Procedures | • Operating procedures must be properly documented, kept up-to-date and readily available<br>• Specific instructions must be developed for startup, normal operation, shutdown and emergency situations as well as non-routine tasks<br>• To be reviewed every 3-5 years to ensure currency & accurateness |
| 4 | Employee Participation | • Involve employees in process safety activities (e.g. process hazard analysis, pre-startup safety review, participation in safety and health committee, etc)<br>• Set up employee participation plan and record |
| 5 | Training | • Provide employees with initial training to acquire the knowledge, skills and abilities to safely carry out the work<br>• Provide refresher training at least once every 3 years to ensure that the employee understands and adheres to the |

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| | | current operating procedures<br>• Keep proper training record including how employee understanding was verified |
| 6 | Contractors | • Employers must subject all contractors to a rigorous selection and evaluation process before hire<br>• Appointed contractor(s) to adhere to all company safe work procedures and undergo the relevant training prior to work commencement |
| 7 | Pre-Startup Safety Review | • Critical for a safety review to be conducted prior to plant start-up for new / modified facilities and for processes requiring the introduction of a highly hazardous chemical<br>• Safety review to ensure that construction and equipment are as per design specifications, process hazard analysis has been performed, operating procedures are in place, management of change requirements have been met, process safety information is up-to-date, training for operations personnel completed |
| 8 | Mechanical Integrity | • Important to establish a mechanical integrity program for critical process equipment<br>• Inspection and testing to follow recognised standards and results properly documented<br>• Equipment deficiencies to be corrected before further use unless provisions are in place to ensure continued safe operation |
| 9 | Hot Work Permit | • Admin procedure must be instituted for control of hot work operations especially for non-routine tasks conducted in or near a process area; only authorised work that has obtained the necessary clearance may be allowed to proceed |
| 10 | Management of Change | • Written procedures for management of change (both permanent and temporary, except for “replacements in kind”) must be established and properly implemented<br>• Any change to a process must be technically reviewed, thoroughly evaluated to assess the impact of the change and authorised before the change is effected |

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| | | • All personnel whose job tasks will be affected by the change must be made aware of the change and receive the necessary training to handle the change<br>• The changes must be properly documented e.g. the process safety information and operating procedures will need to be updated as a result of the change |
| 11 | Incident Investigation | • Process safety incidents to be promptly investigated by a team as soon as reasonably practicable following the incident<br>• The investigation should determine the facts and the factors contributing to the incident, so that corrective measures can be developed and implemented<br>• Employer to address, resolve the investigation findings and share the lessons learnt |
| 12 | Emergency Planning & Response | • Develop an action plan for proper handling and control of emergency situations<br>• Train employees via regular drills and exercises<br>• Review the action plan and update as necessary |
| 13 | Compliance Audit | • Each PSM element to be audited for compliance in a recommended timeframe of once every 3-5 years<br>• Audit findings to be documented noting deficiencies that need to be addressed; identified corrective action(s) to be tracked to completion<br>• The two most recent compliance audits to be kept on file |

## References

ANSI/API Recommended Practice 754 on Process Safety Performance Indicators for the Refining and Petrochemical Industries

Center for Chemical Process Safety (CCPS), New York, USA. Process Safety Leading and Lagging Metrics

http://www.aiche.org/uploadedFiles/CCPS/Metrics/CCPS_ProcessSafety_Metrics_2011_FINAL.pdf

Process Safety Management (OSHA 3132) published by US Department of Labor, Occupational Safety and Health Administration

http://www.osha.gov/Publications/osha3132.pdf

Appendix C to §1910.119 -- Compliance Guidelines and Recommendations for Process Safety Management

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9763

Singapore Standard SS506 Occupational Safety and Health (OSH) Management System Part 3: 2006 – Requirements for the Chemical Industry

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