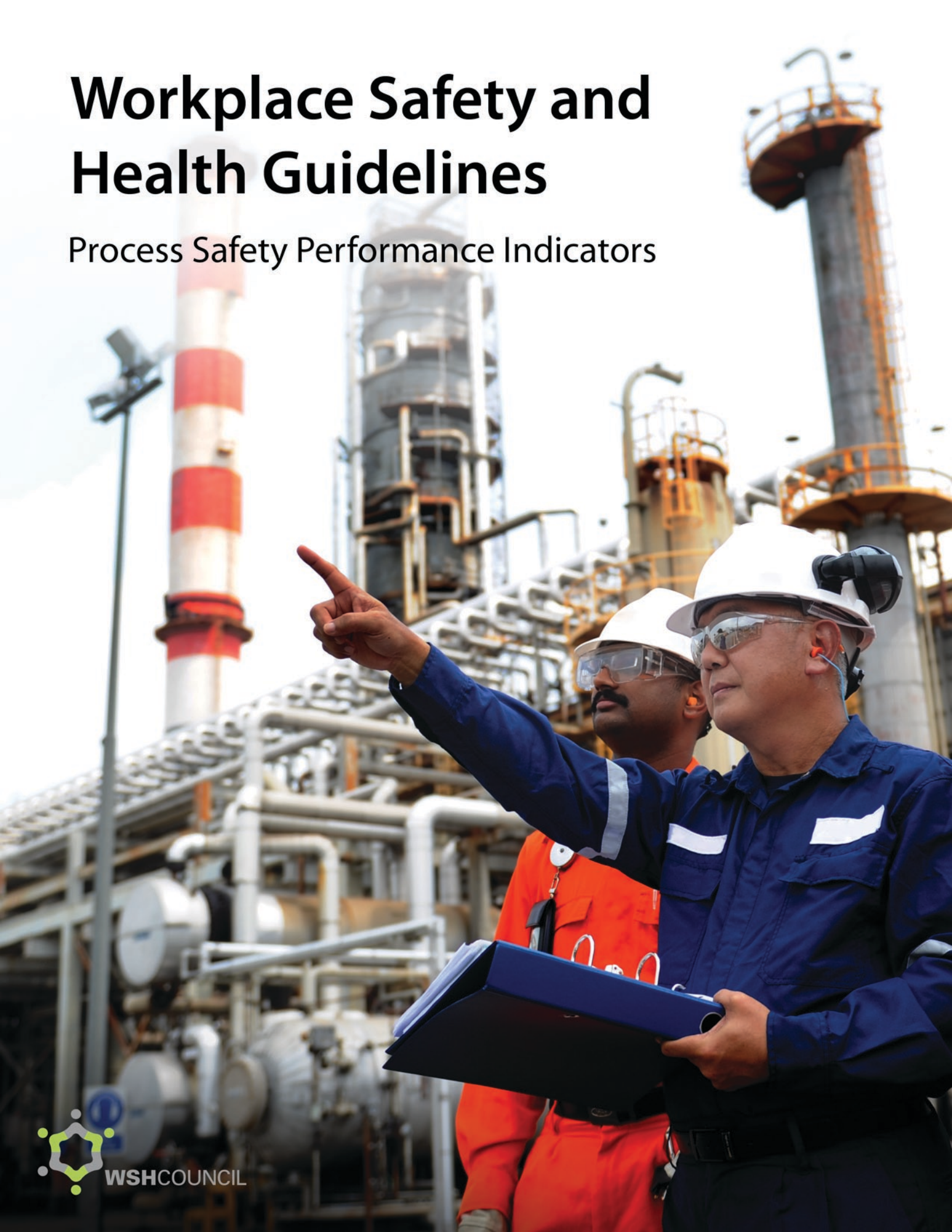


Workplace Safety and Health Guidelines

Process Safety Performance Indicators



Contents

Preface	2
1. Introduction	3
1.1 The Process Industry	3
1.2 Process Safety versus Personnel Safety	4
1.3 Business Case for Process Safety Performance Indicators	6
2. Performance Monitoring	7
2.1 Leading and Lagging Indicators	7
3. Process Safety Performance Monitoring Framework	9
3.1 Step-by-Step Methodology	9
4. Process Safety Monitoring Indicators	11
5. Terms and Definitions	24
Appendix A – Elements of Process Safety Management	26
References	32
Acknowledgements	33

Preface

This guideline is the initiative of the Workplace Safety and Health Council (Chemical Industries) Committee to help companies (especially SMEs) improve 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.



Figure 1: A typical oil refinery

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 figure 2 illustrates the progression to a process safety incident.

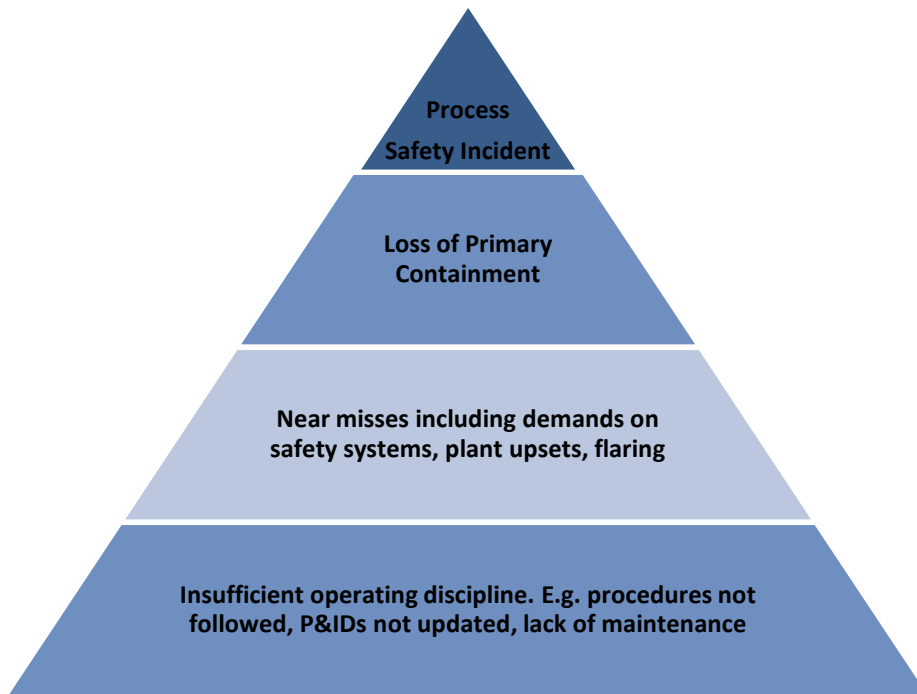


Figure 2: Process safety pyramid (Adapted from CCPS¹)

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

¹ The Center for Chemical Process Safety (CCPS), New York, USA. Process Safety Leading and Lagging Metrics.

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.

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

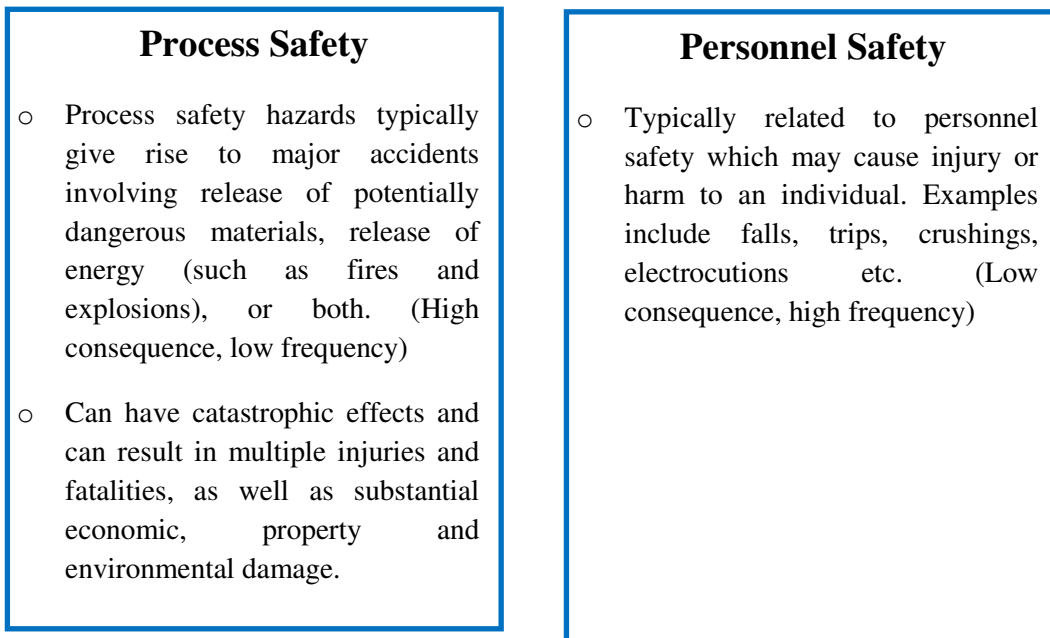


Figure 3: Comparison between process safety and personnel safety

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.



Figure 4: A typical column in a chemical plant

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 2, the safety pyramid illustrated the progression to a process safety incident. Figure 5 below gives a clear overview of how this progression relate to the concept of leading and lagging indicators.

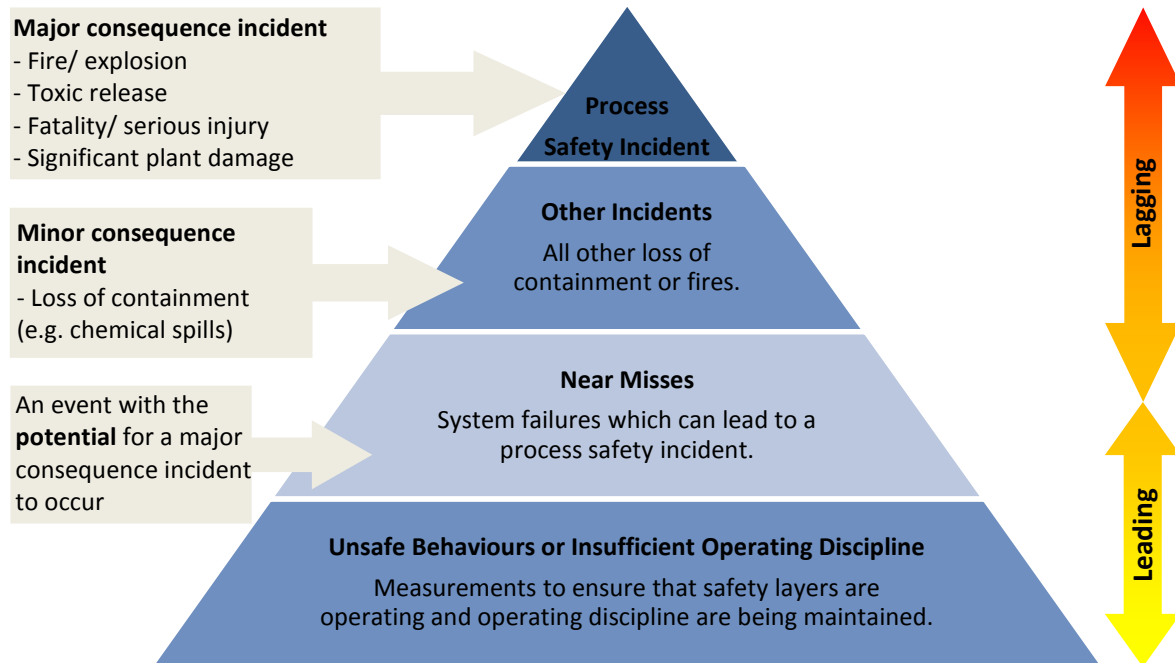


Figure 5: Process safety pyramid and performance indicators (Adapted from CCPS¹)

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 Performance Monitoring 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 6 below.

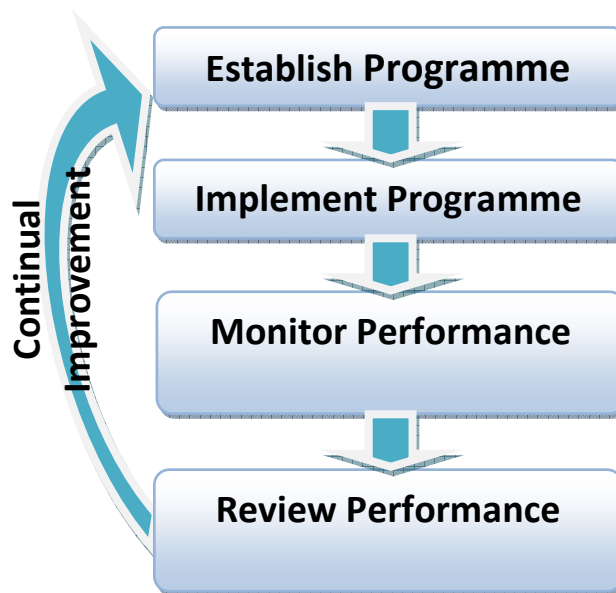


Figure 6: Methodology for process safety performance monitoring

A balanced approach is employed using a combination of leading and lagging indicators for the process safety performance monitoring programme. Table 1 details the steps in the methodology for process safety performance monitoring.

Step	Methodology	Tasks	Information Source	Deliverable(s)
1	Establish Programme	<ul style="list-style-type: none"> - Decide on scope of programme - Form implementation team 	<ul style="list-style-type: none"> - Consult top management on team member selection - Guidelines on Process Safety Performance Indicators 	<ul style="list-style-type: none"> - List of implementation team members - Subset of PSM elements in focus
2	Implement Programme	<ul style="list-style-type: none"> - Identify safety critical activities - Identify risk control measures for the critical aspects - Establish priorities/ Set desired safety outcome 	<ul style="list-style-type: none"> - Risk Assessment (RA) forms - Process Hazard Analysis (PHA) reports 	<ul style="list-style-type: none"> - Set of lagging indicators - Set of leading indicators for each critical aspect
3	Monitor Performance	<ul style="list-style-type: none"> - establish process data collection system - design reporting format 	<ul style="list-style-type: none"> - Data from Step 2 	<ul style="list-style-type: none"> - Monitoring report
4	Review Performance	<ul style="list-style-type: none"> - Review performance of each PSM element in focus - review monitoring scope and performance tolerance 	<ul style="list-style-type: none"> - Performance benchmarking vs. desired safety outcome in Step 2 	<ul style="list-style-type: none"> - List of programme enhancements

Table 1: Steps in methodology for process safety performance monitoring

4. Process Safety Monitoring Indicators

The following table shows typical examples of leading and lagging process safety performance indicators for the PSM elements found in Appendix A. Companies should develop their own set of indicators that are suitable and relevant to their nature of business and operations.

No.	PSM Element	Basic Criteria	Leading/ Lagging	Monitoring Indicator*	Definition of Monitoring Indicator
1	Process safety information (PSI)	Safety data sheet (SDS) management system	Leading	Percentage of SDSs available and current	"Current" indicates: <ul style="list-style-type: none"> - SDS updated with a change in supplier or manufacturer, or - Less than 3 years from last update, or - There is a change in the manufacturer's specifications or processes (for chemical manufacturers)
2	Process safety information (PSI)	PSI procedure identifying PSI documents	Leading	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 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 material flow or transfer failures	Lagging	Number of times material flow or transfer in the process system does not occur as planned due to incorrect/unclear operational procedures	An indicator that would help companies to improve their operating procedures by recognising the activities that do not go according to plan.
9	Operating procedures	Inventory of safety critical activities	Leading	Percentage of safety critical activities with documented Standard Operating Procedures (SOPs)	Safety critical activities are those that are identified 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 - 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 with the relevant knowledge and experience. 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 and competency plan	Leading	Percentage identified training completed as per plan	Ensuring that employee knowledge & skills are refreshed / kept up to date.
15	Training	Process safety training and competency evaluation procedure	Leading	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	Leading	Percentage of jobs with identified training needs and plan	Training plan includes: - Both initial and refresher training for employees, suppliers, contractors and others who interact with the processes - 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 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 open, and their criticality level (e.g. 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 and implementation are 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 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)	Leading	Percentage of tasks where SMP was not followed when inspected	A measure of SMP compliance level during an audit.
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 unexpected 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	<p>A measure of the number of times an identified relief device did not perform as designed or intended.</p> <p>Examples given below:</p> <ul style="list-style-type: none"> - Pressure Relief Device (PRD): opening of rupture disc, pressure safety valve, or control valve to atmosphere or flare. Failure to open as designed. - Safety Instrumented System (SIS): activation by “out of acceptable range” process variable. Failure to activate as designed. - 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 including conflicting work activities. Examples of Hot work permit conditions : gas tests, fire watchman and fire fighting and emergency equipment etc.
30	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.
31	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)
32	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.

33	Incident investigation	Incident reporting system including reporting of process safety incidents	Lagging	Process safety incidents rate	<p>Companies may use their own definition of what constitutes a process safety incident, however if one is not available, the following definition could be considered - A process safety incident must meet three criteria:</p> <ol style="list-style-type: none"> 1. Chemical Involvement: chemical or chemical process directly involved 2. Quantity Threshold: Release exceeding quantity threshold (e.g. API 754) or fire/explosion/release resulting in serious injury 3. Location: occur in production, storage, distribution, utility, pilot plant, or lab area. <p>Transportation incidents are not included.</p>
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34	Incident investigation	Prompt investigation of process incidents	Leading	Percentage of incident / accident investigations initiated and completed within an agreed time frame	Incident investigation should be initiated as soon as it is reasonably practical (typically the next working day or not more than 48 hours) and completed based on the severity of the incident and the company's incident reporting standards. This is a measure of the company's promptness in investigating process safety incidents.
35	Incident investigation	Corrective actions items follow up	Leading	Percentage of corrective actions completed / closed within target time	Percentage of action plans completed vs. planned.
36	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.

37	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.
38	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.
39	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.
40	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.

41	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.
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Table 2: Process safety monitoring indicators

**Please note that the list of monitoring indicators presented in Table 2 is not exhaustive. Companies 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.

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.

Table 3: Terms and definitions

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) authorized 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	<ul style="list-style-type: none">• Information concerning process chemistry, process technology and process equipment must be complete and kept up-to-date• Safety Data Sheets must be current and easily available
2	Process Hazard Analysis	<ul style="list-style-type: none">• Important to carry out process hazard identification, evaluation and implementation of control measures• To be updated and revalidated at least once every 5 years
3	Operating Procedures	<ul style="list-style-type: none">• Operating procedures must be properly documented, kept up-to-date and readily available• Specific instructions must be developed for startup, normal operation, shutdown and emergency situations as well as non-routine tasks• To be reviewed every 3-5 years to ensure currency & accurateness
4	Employee Participation	<ul style="list-style-type: none">• Involve employees in process safety activities (e.g. process hazard analysis, pre-startup safety review, participation in safety and health committee, etc)• Set up employee participation plan and record• Employees participating in such activities should have the relevant training and knowledge of the process safety activity.

5	Training	<ul style="list-style-type: none"> • Provide employees with initial training to acquire the knowledge, skills and abilities to safely carry out the work • Provide refresher training at least once every 3 years to ensure that the employee understands and adheres to the current operating procedures • Keep proper training record including how employee understanding was verified
6	Contractors	<ul style="list-style-type: none"> • Employers must subject all contractors to a rigorous selection and evaluation process before hire • 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	<ul style="list-style-type: none"> • 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 • 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	<ul style="list-style-type: none"> • Important to establish a mechanical integrity program for critical process equipment • Inspection and testing to follow recognised standards and results properly documented • Equipment deficiencies to be corrected before further use unless provisions are in place to ensure continued safe operation
9	Hot Work Permit	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Written procedures for management of change (both permanent and temporary, except for “replacements in kind”) must be established and properly implemented • 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 • 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 • 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	<ul style="list-style-type: none"> • Process safety incidents to be promptly investigated by a team as soon as reasonably practicable following the incident • The investigation should determine the facts and the factors contributing to the incident, so that corrective measures can be developed and implemented • Employer to address, resolve the investigation findings and share the lessons learnt
12	Emergency Planning & Response	<ul style="list-style-type: none"> • Develop an action plan for proper handling and control of emergency situations • Train employees via regular drills and exercises • Review the action plan and update as necessary
13	Compliance Audit	<ul style="list-style-type: none"> • Each PSM element to be audited for compliance in a recommended timeframe of once every 3-5 years • Audit findings to be documented noting deficiencies that need to be addressed; identified corrective action(s) to be tracked to completion • The two most recent compliance audits to be kept on file

Table 4: Key guidance for PSM elements

References

- i. ANSI/API Recommended Practice 754 on Process Safety Performance Indicators for the Refining and Petrochemical Industries
- ii. Center for Chemical Process Safety (CCPS), New York, USA. Process Safety Leading and Lagging Metrics
- iii. Process Safety Management (OSHA 3132) published by US Department of Labor, Occupational Safety and Health Administration
- iv. Appendix C to §1910.119 -- Compliance Guidelines and Recommendations for Process Safety Management, Occupational Safety and Health Administration
- v. Singapore Standard SS506 Occupational Safety and Health (OSH) Management System Part 3: 2006 – Requirements for the Chemical Industry

Acknowledgements

Singapore Institution of Safety Officers	Mr Niranjan Masurekar
Society of Loss Prevention in the Process Industries	Mr Tay Cheng Pheng
Singapore Chemical Industry Council	Mr Mashhad Dohadwala
Association of Process Industry	Mr Steven Nah
Clariant (Singapore) Pte Ltd	Mr Desmond Lim
Ministry of Manpower	Mr Go Heng Huat
	Mr Ronnie Lim
Workplace Safety and Health Council	Mr Edd Hong Shuqi
	Mr Edison Joseph Loh
	Ms Lin Peifen

Workplace Safety and Health Council and Ministry of Manpower would like to thank Shell for their valuable assistance with the images used in this guideline.

Published in September 2012 by the Workplace Safety and Health Council in collaboration with the Ministry of Manpower.

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Email: contact@wshc.sg

