MARSH

Energy Practice

RISK ENGINEERING POSITION PAPER – 04

PROCESS SAFETY PERFORMANCE INDICATORS – PSPIs

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1. BACKGROUND

The process industry has a long history of major incidents that are well-publicised with many valuable lessons to be learned. It has been recognised that the focus on personal safety is one side of preventing accidents. However, a major incident can cause as much harm to people in an instant as all the injuries that have been avoided in a decade of personal safety programmes. The underlying causes of major incidents are often related to failures in what is commonly known as 'process safety management'.

The primary aim of process safety management is to reduce the risk of a major accident by controlling major accident hazards. A major accident is typically defined as a fire, explosion, or a significant release of environmentally harmful or toxic material with costly or damaging consequences in terms of fatalities and injuries, pollution, loss of revenue, damage to the assets, and/or company reputation.

Such consequences are generally defined in the organisation's risk assessment matrix by class (human, environment, financial, reputation) and by degree.

The range of process safety activities is enormous – everything from standardising routine operator rounds to modelling the capacity of the flare system. Such activities can prevent incidents if they are done well, or cause incidents if they are not done well, or not done at all. These activities are the barriers that could stop an incident before it starts or control it if it does. Process safety management is concerned with putting these barriers in place and maintaining them so that they work effectively. These barriers can be physical systems, instrumented systems, or management/people systems. They rely heavily on competence and diligence across all disciplines and at all levels in the organisation.

All of the above barriers are interdependent. For example, closed systems are designed to physically cope with the operating pressure; instrumented systems are designed to control the pressure within the design limit; additional physical systems are installed to relieve the pressure if the logical system fails to control it; inspection and maintenance systems are designed to ensure integrity of the physical systems; instrument testing and calibration systems are designed to ensure the integrity of the logical systems; management systems such as procedures, competency and performance management, and audits are designed to ensure that all of the other systems work effectively.

As with any aspect of management systems, it is important to have metrics in place to understand how effectively a system is working to deliver its objective. The metrics for process safety management systems are commonly called 'process safety performance indicators' (PSPIs).

PSPIs can be separated into leading and lagging indicators; leading indicators being those that precede a failure of the process safety management system and lagging indicators being those that follow a failure of the process safety management system. For example, a measurement of the completion of pressure safety valve (PSV) testing would be a leading indicator and the number of times PSVs fail to lift at the set pressure (in use or during testing) would be a corresponding lagging indicator.

PSPIs should be tailored to show how well the relevant barriers are being maintained (a leading indication) and how well they are working (a lagging indication).

The development of an effective PSPI system can provide a clear view on how well process safety is being managed at a site and across the wider organisation. Common PSPI systems can allow comparisons to be made and lead to more focused knowledge sharing – from proactive information as well as reactive.

2. OBJECTIVE

The objective of this position paper is to define the standards rated by Marsh as very good for a set of process safety performance indicators in the oil, gas, and petrochemical industry. These standards are incorporated in the Marsh energy risk ranking criteria. They can be used to support and define risk improvement recommendations and also to provide detailed advice to clients seeking to better understand and improve their process safety performance.

3. SCOPE

The scope of this position paper includes the identification and application of PSPIs in the oil, gas, and petrochemical industry.

4. SPECIFIC REQUIREMENTS

4.1 POLICY AND PROCEDURE

PSPIs should be part of the corporate strategy to reduce exposure to major accident hazards. As such, the site measures should, where possible, relate to and roll up into the corporate performance measures. In well-developed corporate systems there are common standards and definitions used to set and monitor site and business sector PSPIs. Where this is the case, they should be defined in a corporate policy and procedure (P&P) and reflected in a site P&P as part of the health, safety, and environment management system (HSE-MS).

The P&P should define the PSPIs so that all monitoring and reporting is carried out on a consistent, comparable basis.

Many sites are now basing their PSPIs – certainly their lagging PSPIs – on API RP 754, PSPIs for refining and petrochemical industries. It is essential that organisations should adopt the measures that reflect their major accident exposures and the control features they have put in place to prevent them.

Corporate and site annual objectives and five-year plans should include PSPI targets (current and next year) and aspirations (five-year horizon).

4.2 OWNERSHIP AND DEVELOPMENT

PSPIs for the site should be owned by the site leadership team and accountability for the input should be delegated to the various departments and plant area teams. It is recommended that a senior management team member acts as a 'champion for PSPIs' during their development.

PSPIs should ideally be derived from a rigorous process that identifies the key major accident hazards and uses the accident trajectory analysis to work out the likely causes and associated control measures. PSPIs can then be based on causes identified in this analysis as the most likely to occur and linked to the most serious consequences. Some organisations use a bow-tie analysis and layers of protection analysis (LOPA) to gain insight into their risk exposures.

Alternatively PSPIs could be derived from a combination of:

- Facilitated consultation with a cross section of workforce.
- Review of the site safety case.
- Analysis of the incident and accident database.
- Learning from external incidents.

Opportunities for selecting PSPIs should consider the risk control system and identify leading (those that are evident before the incident occurs) and lagging indicators (those that are evident after the incident occurs).

It is recommended that the selected PSPIs are linked to the barriers that are identified as being of particular significance to the prevention and mitigation of process safety accidents on the site.

For example, critical barriers that should be considered relevant for process safety include:

- Plant design.
- Staff competence.
- Operational procedures.
- Permit to work.
- Communication.
- Instrumentation and alarms.
- Plant change control.
- Inspection and maintenance.
- Emergency arrangements.

For barriers identified as being of particular relevance, consideration should be given to the development of both leading and lagging indicators.

This should be a continuous process to sharpen the focus and maintain the set of PSPIs up-to-date with changes in the plant and the standards. A model set of PSPIs would include no more than eight measures, reported on a monthly basis to site management and with an annual review of the measures to ensure the effectiveness of the PSPIs.

The range of PSPIs should include high level site measures, not necessarily limited to those reported to the corporation, plus a subset of area or departmental measures.

4.3 IDENTIFICATION OF PSPIs

There is a wide range of potential PSPIs. The classification of PSPIs can be divided into leading and lagging indicators (see Appendix A).

The following is considered to be a typical practical selection for a site to use.

PSPI CATEGORY	PSPIs
INCIDENTS	• Specific types of incident such as: – Loss of containment incidents – major and minor categories; both including and excluding flaring and relief valve activation. – Process unit trips – complete unit or section trips. – Fires and explosions. – Operating window excursions – operating outside limits for more than a given amount of time in a defined period.
PERMITS	• Field audits (% of permits) – compared to a set target (not necessarily 100%). • Document audits (% of permits) – compared to a set target (not necessarily 100%). • Permit non-compliances (open/closed) – note the trend is more important than the absolute number and any comparison across plants/companies would be difficult due to variable standards.
AUDITS	• Site leadership team plant visits (man-hours/year). • Plant safety audits (number/month). • Audit action items overdue (annual number and %).
SIS TESTING/COMPLIANCE (ESD/EDP/TRIPS/ROIV)	• Overdue tests (annual number and %). • Testing failure to danger (annual number and %) – note the need to define tolerance. • Failure on demand (events/year) – link to process unit trip measurements. • Trip bypasses registered with durations >1 day; >1 month and >3 months.
INSPECTION	• Overdue inspections without waiver. • Inspection waivers (annual number and % of inspections). • Overdue inspection recommendations (number and %). • PSV pre-pop test fail to danger (number and % of tests). • Number of leak clamps installed.
FIRE PROTECTION	• Completion of all scheduled tests (%) (firewater pumps run/capacity tests, deluge systems activation and application, F&G alarms, fire and gas detectors – it may be useful to break this down by category).
EMERGENCY RESPONSE	• Call-in and pager testing (% success rate). • Crisis management muster drills (number versus target). • Crisis management exercises (number versus target). • Plant drills (number versus target – by shift team).
OPERATIONS ROUTINES	• Daily/shift safety checks completion (%). • Periodic safety checks completion (%). • (CSO/CSC, PSV status, drains/blanks, safety equipment, critical valves, and actuators position). • Housekeeping audits by operators (%). • Start-up/shutdown pro-forma log completion (%).
ALARM MANAGEMENT	• Standing alarms (number per console). • Alarm rate – normal operations (no/operator/hour). • Alarm faults – priority 1 and 2 (number/%).
PROCESS SAFETY MANAGEMENT SYSTEMS	• MoC – number of open MoCs by year and number of overdue temporary MoCs. • Scheduled hazard reviews (HazOps) completed and associated action items completed. • Procedure updates (annual % of scheduled updates). • Staff safety critical competencies compliance (%). • Contractor competency compliance (%). • PHA programme compliance – annual % of scheduled updates completed.

NOTES:
For the purpose of this position paper, the following abbreviations apply:

SIS	Safety instrumented system
ESD	Emergency shutdown
EDP	Emergency depressurisation
ROIV	Remotely operated isolation valve
F&G	Fire and gas
CSO	Carseal open
CSC	Carseal closed
MOC	Management of change
HAZOP	Hazard and operability review
PHA	Process hazard analysis

The P&P should define the PSPIs so that all monitoring and reporting is carried out on a consistent comparable basis.

The reporting of PSPIs can be split into four categories:

MAJOR INCIDENTS

Major process safety incidents should be investigated to determine corrective actions. For major incidents there will be specific reporting and investigation protocols to be followed and these may involve the authorities and may require investigation by a special team.

MINOR INCIDENTS

Minor process incidents should be investigated to determine corrective actions. Minor process safety incidents should be incorporated in the site PSPIs.

NEAR MISSES

Reporting of near-miss process safety incidents should be encouraged across the site; repeated near-miss incidents will eventually lead to actual consequences. The whole workforce should be educated to recognise near-miss incidents and report them. This requires a 'no blame' culture to encourage open reporting.

Near-miss process safety incidents should be investigated to determine corrective actions.

Near-miss process safety incidents should be incorporated in the site PSPIs.

HEIGHTENED RISK EXPOSURE

Heightened risk exposure cases should be reported and investigated as though they were actual incidents:

- Identify heightened risk exposure cases through monitoring, auditing and reporting.
- Encourage reporting of heightened risk exposure cases – educate personnel to recognise process safety hazards as well as personal safety hazards.
- Investigate serious heightened risk exposure cases to the required degree and determine corrective actions.
- Incorporate in PSPIs and analyse trends.

SUMMARY

The foregoing discussion of the process safety incident classification can be summarised as follows:

- Structure process safety performance indicators in relation to the classification of process safety incidents.
- Educate personnel to recognise lower order incidents and situations.
- Encourage reporting of heightened risk exposures and near-miss incidents.
- Investigate significant heightened risk exposures, near-miss incidents, and major/minor incidents to determine corrective actions.
- Establish regular external assessments of process safety standards.
- Learn from external incidents.
- Use reported process safety incident data to identify key areas and aspects of exposure.

4.4 USE OF PSPIs IN IMPROVING SAFETY MANAGEMENT

PSPIs should be part of the site safety management system and used specifically to monitor performance and identify opportunities for improvement.

For example, the number of fires could be a typical lagging PSPI. If the number was to increase or to be significantly higher than the number for peer comparison organisations then the range of causes of fires could be further analysed to identify a significant common factor or factors. These factors could then be the subject of further PSPIs at the site. Ideally, these would be a mix of leading and lagging PSPIs.

PSPIs should be reported along with the other key performance indicators (KPIs) for the site and in particular alongside the more traditional safety performance measures such as lost time injury (LTI) frequency rates etc. As such, they should be reviewed by the site safety steering committee to determine follow-up actions and to provide the basis for communication to the site personnel.

Corporations should use PSPIs to identify best practices and to manage risk exposures.

5. REFERENCE TO INDUSTRY LOSSES

The report of the BP US Refineries Independent Safety Review Panel (The Baker Panel Report) January 2007, based on the BP Texas City refinery incident 23 March 2005:

- Recommendation #7 refers to establishing leading and lagging performance indicators for process safety.

The major accident investigation report, prepared by the UK HSE on three incidents that occurred at the BP Grangemouth complex, between 29 May 2000 and 10 June 2000:

- Recommendation #4 on Group Safety Assurance – "BP should review its Group safety assurance process as a key part of corporate assurance process. In particular BP should develop performance measures for major accident hazards."

6. REFERENCE TO INDUSTRY STANDARDS

HSG254 Step-By-Step Guide to Developing Process Safety Performance Indicators, UK Health and Safety Executive (HSE), 2006.

Process Safety Leading and Lagging Metrics, Center for Chemical Process Safety (CCPS), American Institute of Chemical Engineers (AIChE), 2011.

API Recommended Practice 754, Process Safety Performance Indicators for the Refining and Petrochemical Industries, American Petroleum Institute (API), 2010.

7. APPENDICES

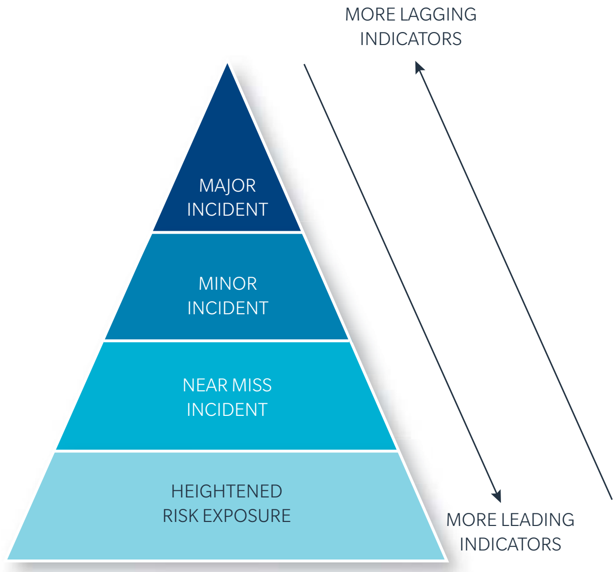
APPENDIX A – CLASSIFICATION OF PROCESS SAFETY INCIDENTS

Personal safety incidents are well recognised from definitions such as fatality, lost time injury, medical treatment, first aid, near miss, and hazard. These are often shown as hierarchy or pyramid where the frequency of occurrence of the lower order incidents is said to influence the likely occurrence of the higher order incidents as they reflect the overall safety culture in the organisation.

Personal safety incidents have historically received more attention and are more readily reported and investigated. Process safety incidents and heightened risk exposures with low or no actual consequences are not so readily recognised or reported. In general, personal safety incidents tend to be higher frequency and low consequence, affecting individuals in most cases; in comparison, process safety incidents may appear to be less frequent, but typically have major consequences – actually or potentially affecting larger numbers of people as well as the environment, the community, the assets, profitability, and reputation. Obviously, the process safety incidents with significant actual consequences are notified and thoroughly investigated; however, the equivalent near-miss incident may not even be recognised. Consequently, there may be an underlying problem with process safety management that does not become evident until the major incident occurs. In order to bring the underlying process safety issues to the attention of the management team, it is necessary to ensure that all incidents and near-miss situations are recognised, reported, and investigated. The following hierarchy is intended to provide the framework for this.

A parallel process safety incident hierarchy can be illustrated as follows by a similar pyramid of consequences as that which is often used for personal safety; each of the incident types is described in more detail below.

The following definitions for 'major' and 'minor' incidents have been developed using reporting criteria from the CCPS and API 754 Process Safety Performance Indicators guidance documents. The reporting criteria for loss of primary containment (LOPC) are based on the United Nations recommendations on transportation of dangerous goods, section 2. The objective is to provide a recognised system for defining threshold quantities of uncontrolled releases of material.



SAFETY INCIDENT PYRAMID APPLIED TO PROCESS SAFETY

MAJOR INCIDENT

This is an incident with major/catastrophic consequences (equivalent to API 754 tier 1 process safety event) defined as follows:

- Fatality or hospital admission.
- LOPC (see appendix B for threshold quantities).
- Fire or explosion resulting in direct company loss >US$25,000.

Examples of Major Incidents:

- Vapour cloud explosion (VCE) from hydrocarbon leak causing fatalities and major damage.
- Floating roof full surface fire taking several days to extinguish.
- Spill fire beneath vacuum tower causing collapse.
- Ship colliding with jetty and causing major damage.
- Uncontrolled internal tube leak resulting in complete destruction of furnace.
- Total power failure causing crash shutdown extended by consequential damage.

MINOR INCIDENT

This is an incident with minor moderate consequences (equivalent to API 754 tier 2 process safety event) defined as follows:

- Recordable injury.
- LOPC (see appendix B for threshold quantities).
- Fire or explosion resulting in direct company loss >US$2,500.

Examples of minor incidents:

- Pump seal leak – hydrocarbon released but not ignited.
- Emergency shutdown of process unit due to heater tube failure – repaired within 3 days.
- Leak on hydrocarbon piping – weld failure due to construction defect.
- Flexible hose bursts on truck loading rack – manual ESD activated by operator.
- Plug blows out of sight glass on fluid catalytic cracker (FCC) fractionator – isolated and replaced by operator.
- Floating roof rim seal fire due to lightning strike – extinguished by foam pourers.
- Explosion within furnace on light off due to ineffective purging by operator; minor damage to refractory.

NEAR-MISS INCIDENT

This is an incident with no actual consequences; however, if the circumstances were slightly different there could be serious consequences. In many cases the first barrier fails but subsequent barriers or fortuitous intervention prevents the full development of the incident. A near-miss incident is equivalent to API 754 tier 3 process safety events.

Examples of process safety near-miss incidents:

- ESD valve fails to close automatically but operator responds to alarm and closes the valve manually from the local station.
- Minor leak from hydrocarbon line due to incorrect gasket on pump discharge flange – able to switch to spare pump, isolate and fix the fault without a plant shutdown.
- High liquid level in flare knockout drum; level indicator faulty – but problem identified by operator visual checks before liquid carried over to flare stack.
- Defective construction weld on hydrocarbon line discovered by inspection at turnaround.
- Interlock bypass used for start-up but kept on until noticed by relieving panel operator two days later.
- Tank filled above safe filling height without activating the alarm but no spill occurs; picked up by operator on rounds and level reduced below safe filling height.

HEIGHTENED RISK EXPOSURE

A heightened risk exposure is an action or a lack of action that increases the likelihood or consequences of a potential incident. A heightened risk exposure is also a significant gap in process safety management standards compared to world class.

There is no actual incident or event in these cases. Heightened risk exposures are equivalent to unsafe acts or unsafe conditions that are recognised as personal safety hazards. Failure to perform risk control activities as required by site/company and actions that could lead to or increase the potential consequences of an incident would be regarded as heightened risk exposures. There would also be a heightened risk exposure if there are significant gaps in risk control standards compared to world-class process safety management standards. A heightened risk exposure is equivalent to API 754 tier 4 process safety events.

Examples of heightened risk exposures:

- Work permit non-compliance: error on equipment number.
- Diesel firewater pump extended outage – total reliance on electrically driven machines and therefore exposed to power failure during fire emergency.
- Inspection waiver not risk assessed and not sanctioned according to site policy.
- MoC process failed to specify operator training required before new system started up.
- New plant started up with construction blinds used for isolation.
- Furnace ESD function tested but ESD valves not tested to verify tight-shutoff (TSO) capability.
- A number of large hydrocarbon inventories are not protected by remote operated isolation valves – this would be an example of a gap in risk control standards compared to world-class practices.

Gaps versus world-class process safety management standards present a continuous exposure. These gaps are typically identified by:

- Site incident investigation.
- Process hazard analysis.
- External audits.
- Process safety reviews (internal and external).
- Learning from incidents (external).

Once identified, the decision on whether to close these gaps should reflect company/site policy on risk management.

APPENDIX B – CLASSIFICATION OF LOSS OF PROCESS CONTAINMENT (LOPC) FOR MAJOR AND MINOR INCIDENTS

MAJOR INCIDENT (EQUIVALENT TO API 754 TIER 1 PROCESS SAFETY EVENT)

MATERIAL HAZARD CLASSIFICATION	THRESHOLD QUANTITY (OUTDOOR RELEASE) 1	THRESHOLD QUANTITY (INDOOR RELEASE) 1
Toxic inhalation hazard zone A materials	5 kg	2.5 kg
Toxic inhalation hazard zone B materials	25 kg	12.5 kg
Toxic inhalation hazard zone C materials	100 kg	50 kg
Toxic inhalation hazard zone D materials	200 kg	100 kg
Flammable gases or liquids with initial boiling point <35˚C and flash point <23˚C or other packing group I materials (excluding strong bases and acids)	500 kg	250 kg
Liquids with initial boiling point >35˚C and flash point <23˚C or other packing group II materials (excluding moderate bases and acids)	1000 kg or 7 barrels	500 kg Or 3.5 barrels
Liquids with initial boiling point >35˚C and flash point <60˚C or liquids with flash point >60˚C released at a temperature at or above flash point or strong bases or acids or other packing group I materials	2000 kg or 14 barrels	1000 kg Or 7 barrels

Notes:

1. United Nations recommendations on transportation of dangerous goods, section 2.

MINOR INCIDENT (EQUIVALENT TO API 54 TIER 2 PROCESS SAFETY EVENT)

MATERIAL HAZARD CLASSIFICATION	THRESHOLD QUANTITY (OUTDOOR RELEASE) 1	THRESHOLD QUANTITY (INDOOR RELEASE) 1
Toxic inhalation hazard zone A materials	0.5 kg	0.25 kg
Toxic inhalation hazard zone B materials	2.5 kg	1.2 kg
Toxic inhalation hazard zone C materials	10 kg	5 kg
Toxic inhalation hazard zone D materials	20 kg	10 kg
Flammable gases or liquids with initial boiling point <35°C and flash point <23°C or other packing group I materials (excluding strong bases and acids)	50 kg	25 kg
Liquids with initial boiling point >35°C and flash point <60°C or liquids with flash point >60°C released at a temperature at or above flash point or other packing group II materials (excluding moderate bases and acids) or strong bases and acids	100 kg or 1 barrel	50 kg or 0.5 barrel
Liquids with flash point >60°C released at a temperature below flash point or moderate bases and acid	1000 kg or 10 barrels	500 kg or 5 barrels

Notes:

1. United Nations recommendations on transportation of dangerous goods, section 2.

THE ENGINEERING SERVICES TEAM

Marsh's Risk Engineering Services team has been established for over 25 years and is uniquely qualified to provide risk managers and underwriters with the essential information they need to determine the right limit and scope of cover and the right price.

Each member of the team is a qualified engineer, with practical experience in design, construction, operation, and maintenance across a broad range of oil, gas, and petrochemical risks.

They have all been trained in advanced insurance skills, in the ability to assess and analyse risk, and to communicate effectively and frequently in more than one language.

The goal is to build bridges between risk engineering, insurance and risk management, and between the client and the underwriter. At the same time, the comparative skills of the team permit a benchmarking system which gives a global opinion of the risk, assessed against peer plants world-wide.

From the earliest planning stage to the last operational phase, the engineering services team is able to contribute practical and cost-effective advice, and assistance.

In addition to tailored programmes, the team has a series of core packages, covering everything from managing a major emergency to risk reduction design features, and safe working practices.

The Engineering Services team uses its breadth of expertise, experience, and its practical knowledge and skills to communicate a real understanding of physical risks, your insurance implications and the commercial operating environment.

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