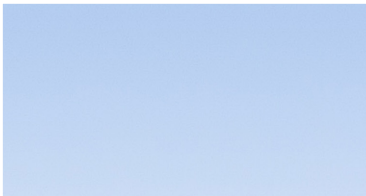
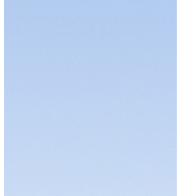
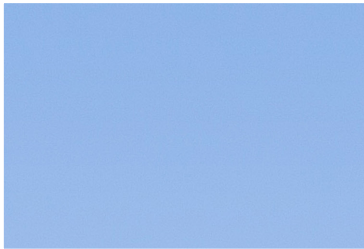
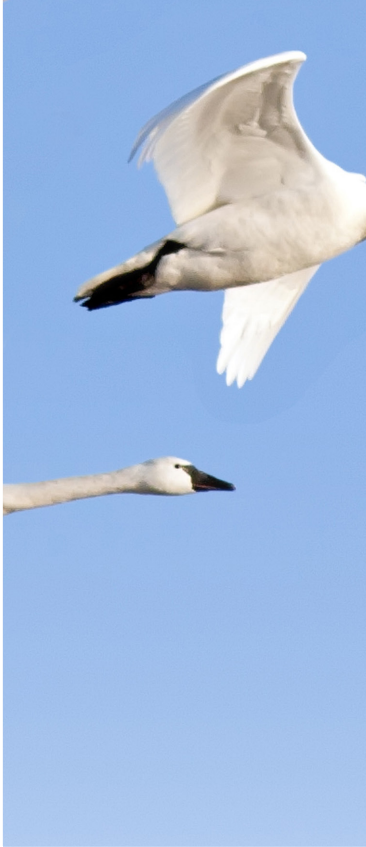
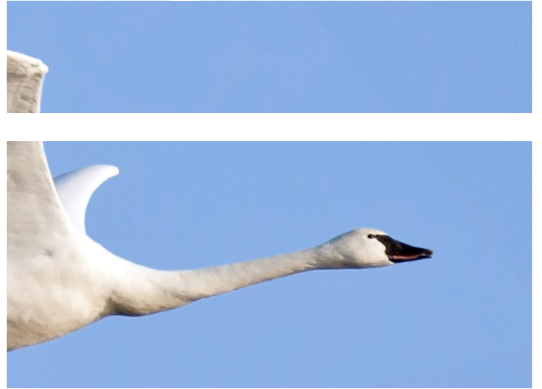
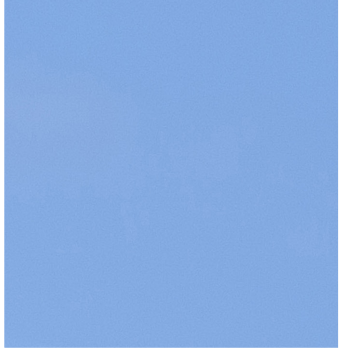
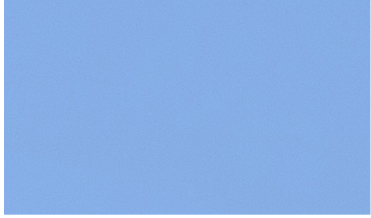


IChemE

IChemE Safety Centre Guidance

Lead Process Safety Metrics –
selecting, tracking and learning
2015





Contents

| | |
|--------------------------------------|-----------|
| Preface | 4 |
| Acknowledgements | 6 |
| Disclaimer | 6 |
| Terminology and acronyms | 7 |
| How to use this guidance | 8 |
| The metrics | 9 |
| Knowledge & competence | 10 |
| Engineering & design | 12 |
| Systems & procedures | 18 |
| Assurance | 28 |
| Human factors | 32 |
| Culture | 36 |
| Appendix 1 | 39 |
| Process safety audit | 39 |
| Process safety barriers | 39 |
| Process safety audit characteristics | 40 |
| References | 42 |

Preface

The IChemE Safety Centre (ISC) is an industry-funded and led organisation, focussed on improving process safety through sharing information and learnings. ISC members can nominate specific areas of focus, and ISC leads the development work in these areas, working with personnel from member companies. Once a specific need is defined by the ISC Advisory Board, a project sponsor is appointed and a team is nominated. The team then sets about progressing the project.

Lead process safety metrics were identified as an initial area of work for ISC. This consisted of reviewing the lead metrics reported by each member company, first looking for commonality. Once this was established, the metrics were selected, or not, for further development, based on their apparent value, ie what decision or action they would drive, and their ease of collection. A priority was put on the high value, easy-to-collect metrics. The team then set about further reviewing and establishing definitions, calculations, and suggested directions of metrics for improvement etc.

The need for lead process safety metrics is well established, via a number of prominent process safety incidents. A prominent example of this is the BP Texas City Refinery explosion¹, resulting in the development of the American Petroleum Institute Recommended Practice 754, known as API RP 754² (API, 2010), to focus on process safety metrics. Process safety metrics must be tracked and understood in addition to occupational safety metrics. We cannot infer from the lost-time injury rate, for example, whether we have a process safety problem developing. Tracking process safety metrics is vital, to help us understand the state of our facilities and systems, as well as providing us with an indication of impending issues. Importantly, while lagging process safety metrics will inform you of history, which can be used to monitor improvement, they will not necessarily predict future loss-of-control events. While leading metrics are proactive and provide the opportunity to manage developments, they are also not predictive of the future.

There are well-established guidelines to focus more so on lagging indicators, such as API RP 754 (API, 2010), the Centre for Chemical Process Safety (CCPS) guidance³ (CCPS, 2007), International Oil and Gas Producers (IOGP) reporting requirements⁴ (IOGP, 2011), and the UK HSE⁵ (HSE, 2006). These publications also provide guidance on how to establish leading metrics. This guidance document is focussed purely on leading process safety metrics, with specific metrics that work and that can be adopted into your organisation. This means that there are some obvious process safety metrics which are missing, such as incident rates, losses of containment etc. These are not inadvertent omissions – rather deliberate, as we are shifting the focus from lagging to leading indicators. Efforts have been made to include some metrics which measure the quality of activities rather than just their occurrence.

This document is aimed at industries that manage processing hazards. These include areas such as oil and gas, chemical, mining, food and pharmaceutical, to name a few. While not all the metrics may always be applicable to all sectors, it is worth understanding their background, to see if they would indeed provide value, perhaps in a different configuration. The final decision regarding selecting and implementing metrics will depend on the maturity level of the site and specific focus at the time. Adopting this guidance is a start to developing some consistency in lead process safety metrics, and will allow effective benchmarking. This will help demonstrate improvements to stakeholders. You may not be able to adopt all of the metrics contained in this guidance, but you should try to understand how you are monitoring systems and processes if you do not have these metrics in place.

The layout of this guidance has been developed along the lines of the ISC functional elements of process safety⁶ (ISC, 2014). This premise is that effective management of process safety requires leadership across six functional elements in an organisation. These are:

- knowledge and competence;
- engineering and design;
- systems and procedures;
- assurance;
- human factors; and
- culture.



These elements can be thought of as a chain of safety, rather than application of Reason's Swiss Cheese model⁷ (Reason, 1997). This is because we do not need failures in all elements to have an incident, but rather multiple failures in one element could result in an incident. The integrity of the chain is in the multiple layers behind it; hence at least one metric is monitoring the health of each element.

The metrics selected here have been chosen on a basis of providing valuable information, to inform decisions and actions in an organisation. After all, if you are recording a metric, but it is not informing you of any decision or action, one must ask what the purpose of recording it is. It is acknowledged that some of these metrics may be more difficult for some companies to record than others. It is up to each company to understand their capability, and their needs and work toward the implementation, if it is of value.

The metrics have been mapped back to the six elements above. Each element is covered by at least one metric. This reinforces the premise that leadership in these areas is fundamental. The metrics in this guidance provide you with a way to monitor these elements of your business. In addition to this, we have provided some guidance on how to focus on the auditing of the specific process safety aspects of various systems. It is important to ensure any metrics selected monitor the whole organisation with respect to process safety. There is a risk of missing some vital information if only some aspects of the organisation are monitored.

Some of the metrics defined may be more informative at an individual site level, and some may need to be rolled up to corporate level to prove useful. Where this is the case, it is noted in the appropriate sections.

When analysing lead metrics, it is important to view the data as individual metrics, but also as a collective set of data. This allows insight into whether the metrics are providing the same story about the health of the systems. If leading metrics are not complementing each other as expected, there may be some underlying issues to be resolved. Additionally, if after a period of time, depending on the metric, leading metrics are showing great improvement, but lagging metrics are not, the metrics and analysis should be revisited to determine whether the leading metrics are assisting the organisation or not. There may be different leading metrics required to drive different behaviours.

This guidance focusses on the operational phase of an organisation. For this reason, metrics which would be used in a design or construction phase have not been included in this edition. These metrics might cover aspects such as inherently safety design.

Lastly, this is a living document and we expect the metrics and their tracking systems to evolve over time. If you are recording other metrics that are proving useful, keep recording them, but please give us with feedback so we can review for possible future inclusion.

This project reviewed a substantial number of metrics, many of which were not selected for inclusion. If you would like to know what these were, please contact ISC.

Acknowledgements

The ISC would like to acknowledge the efforts of the following companies, who participated in the development of this guidance:

- Quadrant Energy – Steve Fogarty, Philip Weerakody
- Orica – Allan McGregor
- Todd Corporation – Grant Slater
- Woodside – Simon Bugg
- MMI Engineering – Paul Heierman-Rix, Garry Law
- EnVizTec – John Cormican, Andrew Marcer
- Simon Casey Risk and Safety Consultant – Simon Casey



Contact
the ISC

email: safetycentre@icheme.org



Disclaimer

The information provided in this document is provided in good faith but without liability on the part of IChemE or the IChemE Safety Centre.

Terminology and acronyms

Assurance task

This could be a system audit performed on specific process safety elements or a simple checklist or inspection or a hardware test for full functionality of a barrier. The assurance task needs to be designed to test the health of the barrier, taking into account the multiple failure modes possible.

Barrier

Different organisations have different terminology for similar elements, such as control, barriers, layers of protection etc. This guidance uses the term 'barriers' to avoid duplication. It is also important to recognise that some barriers are passive (eg the design of a pressure vessel), while some are active (eg an automated pressure shutdown), and the management of these varies.

Deviation

A deviation is where a failure mechanism occurs, making a system no longer operate as designed, or where it has been taken out of service or is bypassed.

Failure on demand

A barrier may be deemed to have failed on demand when it has been called upon to perform its designed function and has not met the requirements. An example may be a pressure relief valve relieving at a pressure other than its set pressure (outside of its acceptable tolerance) or a shutdown system that did not shut down when initiating triggers were reached.

Failure on test

A barrier may be deemed to have failed on test when it has been called upon to perform its designed function and has not met the requirements, or it no longer meets the defined standards. An example may be a pressure relief valve during a bench test relieving at a pressure other than its set pressure (outside of its acceptable tolerance) or corrosion causing the equipment to be deemed not fit for service during inspection..

Fit for service

Fitness for service is defined in the joint American Petroleum Institute, American Society of Mechanical Engineers publication API 579-1/ASME FFS-1, *Fitness-For-Service*⁸ (API/AMSE, 2007).

Leading metric

At this point in the document it is important to define the meaning of leading. There are two interpretations of leading metrics. In the first, leading points to doing things right (positive re-enforcement), ie doing all that is required for equipment integrity monitoring, following critical procedures every time and getting them right, having all the required information available and accessible etc. So for this type of metric a 100% compliance is an ideal target. In the second interpretation a leading metric is akin to holes starting to appear in a layer of Swiss cheese⁷ (Reason, 1997). So it is failure of one barrier but other barriers still exist and continue to prevent an incident. So in a sense it is actually a lagging indicator of a single barrier failure or barrier weakness. For this metric you want to drive the target down. Put simply, the first one looks for the barrier being always present and strong and the second one tracks weaknesses in a barrier after they have happened. The other publications mentioned have several indicators of the second type. ISC has strived to achieve a balance between these two types of leading metrics.

Management of Change (MOC)

This is about conducting structured risk-based reviews on changes to hardware, systems or organisation structures prior to effecting the change, to ensure all hazards and risks have been identified and addressed. Depending on time frames, facility requirements and the type of changes, there can be several different types of management of change. These include emergency, temporary and permanent. An emergency change is one done during an emergency or time-critical situation to effect a change to ensure the facility continues to function safely. A temporary change is one that is put in place for a fixed period of time and then reversed. An example of this may be a temporary barrier while a more permanent barrier is implemented. A permanent change is one that is implemented with the intent for it to be in place for the foreseeable future. An example of this would be installing a new barrier on a system.

Primary containment

Primary containment is the first level of containment of a fluid, such as a pipe, tank or vessel.

Safety critical elements (SCE)

This is a barrier that has been deemed to be critical by the facility or organisation. This is usually done on the basis of understanding what consequence the barrier is preventing or mitigating, the likelihood of that consequence happening and the reliability of the barrier. SCEs can be hardware, control system related, or administrative, such as procedures. This document has not sought to define different categories of SCE, as this is an additional task outside the development of this guidance.

How to use this guidance

This guidance defines a set of leading metrics across all functional elements of an organisation. These metrics have been tested and used in different industries and have been found to provide value and input into decision making.

Recommended steps on how to implement this guidance:

1. Determine the scope for implementation
 - a. are the metrics to be applied across an entire organisation or an individual facility?
2. Map your current leading metrics to the list in Table 1
 - a. you may find you are already recording some of these metrics, or very similar ones
3. Determine any gaps between your current metrics and the metrics outlined in Table 1
4. Where gaps are identified, determine if you have other metrics to cover them
 - a. where you have metrics covering the gaps, and they are useful, continue to record them
 - b. if the metrics covering the gaps are not useful, consider adopting the metrics in this guidance
 - c. ensure that you have a comprehensive picture of the health of your barriers with the metrics that you are recording
5. Develop an action plan to address the gaps identified
 - a. review the implementation section of each metric to see how challenges can be overcome

It is also important to start to educate the management, executives and directors where the metrics reported will change. It is vital they understand the rationale behind the information they receive so they can make appropriate decisions based on it.

API RP754² (API, 2010) is often used as a reference of base document for organisations to develop their leading metrics. The ISC guidance differs from API RP754 in that it is intended to be applicable to a wide range of industries. This guidance also does not look at lagging metrics, and takes a deep dive into the leading metrics, to offer information on how to implement these metrics. It allows you to choose predefined metrics, rather than focussing on developing your own unique version of other metrics.

Table 1: List of metrics and their corresponding element

| Elements | Metrics |
|--------------------------|--|
| Knowledge and competence | Conformance with Process Safety related role competency requirement |
| Engineering and design | Deviations to safety critical elements (SCE) Short term deviation to SCE Open management of change on SCEs Demand on SCE Barriers failing on demand |
| Systems and procedures | SCE Inspections Performed Versus Planned Barriers fail on test Damage to primary containment detected on test/inspection SCE maintenance deferrals (approved corrective maintenance deferrals following risk assessment) Temporary operating procedures (TOPs) open Permit to work checks performed to plan Permit to work non-conformance Number of process safety related emergency response drills to plan |
| Assurance | Number of process safety related audits to plan Number of non conformances found in process safety audits |
| Human factors | Compliance with critical procedures by observation Critical alarms per operator hour (EEMUA, 1999) Standing alarms (EEMUA, 1999) |
| Culture | Open process safety items Number of process safety interactions that occur |

Note: It could be argued that some of the metrics could be allocated to other elements as they cross over, however Table 1 shows ISC's consensus on the allocation.

The metrics

The metrics listed below are grouped within their elements. Each element lists the relevant metrics, and then each metric is defined covering the following information:

Title

a generic term for the metric.

Purpose

this section focuses on what behaviours and decisions the metric should inform across all levels in an organisation. It provides the context for why the metric is important and worth tracking.

Description

this section covers the detail of the metric, with how to measure the data, how to normalise the data, what the suggested metric result or trend should be to show improvement, the frequency of the data capture and analysis (this may vary).

Metric consolidation

this section describes how metrics can be consolidated for higher level reporting, or broken down for more specific information (from site to corporate reporting).

Implementation

this section speaks about challenges to implementing the metrics and suggestions on how these may be overcome.

Linkages

this section ties the metrics back together and highlights where there may be linkages with other elements or the auditing process discussed in this guidance.

Note: where leading metrics are showing a very positive outcome and all trending in the right direction, extra attention should be taken to ensure this is the actual result. There is always a temptation for people to want the metrics to look better, which may drive manipulation of results. The presence of a negative result for a leading metric is actually a positive outcome for the organisation, as it provides the opportunity to address the issue prior to an incident occurring. In this manner, negative results should be embraced and encouraged. It is also important to examine the culture of the organisation and that the metric results are reflecting the activities occurring in the organisation. This leads to the auditing component being a vital periodic check on the systems. Given this, caution should always be taken when including process safety related metrics into performance bonus structures, as they can often drive unintended consequences. An interesting book on this topic is *Risky Rewards – How Company Bonuses Affect Safety*¹⁰ (Hopkins, Maslen, 2015).

Knowledge & competence

Knowledge and competence is about ensuring the workforce has the relevant awareness and familiarity to understand the impact of their actions, as well as the ability to perform tasks consistently on a sustainable basis. This is a combination of practical experience and thinking skills. A metric that measures the effectiveness of the knowledge and competency system is:

Title

Conformance with Process Safety related role competency requirements

Purpose

A measure of the overall capability of personnel to consistently manage and implement work activities in accordance with company requirements and expectations (including behaviours).

Description

The percentage conformance metric is based on the following equation:

$$\frac{\text{Number of process safety related roles assessed as competent}}{\text{Total number of process safety related roles}} \times 100 = \% \text{ conformance}$$

This metrics should trend toward 100% conformance. The number of process safety roles assessed as competent refers to a formal assessment process against predefined competency requirements. A process safety related role is one that has an impact on the process safety outcomes at a facility. As roles differ across different organisations, there is no specific definition referenced here. However, ISC has published a guidance document called *Process safety competency – a model*¹¹ (ISC, 2015). This document defines a generic process safety competency model which could be used as a benchmark for this metric. The determination of roles and competency will vary between organisations, but the model provides advice on this.

The suggested frequency of capture is based on the concept of weekly roster planning and review. This is especially required where the workforce work in a fly-in fly-out roster. It is important have the right people on site at any point in time where site-based roles are concerned. Where roles are non site based, this frequency could be extended to monthly capture and annual analysis.

| | |
|------------------------|---------|
| Frequency of capture: | Weekly |
| Frequency of analysis: | Monthly |

Metric consolidation

This metric may be tracked and analysed on a site-by-site basis, though it is also recommended that it be consolidated and reported at a regional and/or divisional level for review by senior executives and the board.

Implementation

There are several variables that may adversely impact upon recording and reporting this metric. Clear definition of the roles considered process safety related within a company's management system and processes (in addition to those defined within the applicable regulations) is key and will thereby determine the minimum number of positions.


This measurement is heavily dependent on the competence and independence of the assessor. Assessors should be trained in PSM competency and should come from an outside organisation or a corporate governance (or similar) department.

A clear rating system should accompany the competency evaluation, to ensure standardisation in scoring.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, include '% of roles where refresher training is completed to plan', '% conformance to process safety training plan' and '% turnover of roles from facility (or company)' (as a 12-month rolling average).

Linkages

This metric links to the majority of other ISC functional elements of process safety, as the effective management of process safety requires competent people across all the other five functional elements of an organisation.



An example

This metric monitors whether requirements such as achieving the minimum emergency response team manning on shift as per the emergency response plan are being met.



Engineering & design

Engineering and design is about applying the hierarchy of controls in the design and engineering of equipment and safety systems. This includes the concept of inherently safer design as a starting point. This area focuses on monitoring the health of the hardware barriers across the facility. Metrics that measure the effectiveness of the engineering and design processes include the following:

- deviations to safety critical elements;
- short term deviation to safety critical elements;
- open management of change on safety critical elements;
- demand on safety critical elements; and
- barriers failing on demand.

Title

Deviations to safety critical elements

Purpose

To provide a measure of the confirmed weaknesses (or deviations) to safety critical elements that do not meet their minimum performance requirements. It is an indication of the additional risk exposure as a result of known and approved non-compliances with SCE performance standards. An example of a temporary deviation to a safety critical element might be the removal from service of a SCE for a duration exceeding a day. This would typically require some form of formal risk assessment to approve operations during this period.

NOTE: This excludes permanent deviations and number of defects to primary containment systems.

Description

The metric is the

- absolute number (as opposed to a normalised rate) of temporary deviations in place on a weekly basis.

There is no specific target, this metric requires trending with a focus to minimise the number and duration of deviations to minimise exposure. For example the risk of an element having a deviation for a day verses a month presents a different risk exposure.

| | |
|------------------------|---------|
| Frequency of capture: | Weekly |
| Frequency of analysis: | Monthly |

Metric consolidation

This metric may be tracked and analysed on a site-by-site basis, though it is also recommended that it be consolidated and reported at a regional and/or divisional level for review by senior executives.

Implementation

Using an automated, computerised system for recording and reporting deviations is a key enabler. A classification process to ensure that the deviations reported are specific to safety critical equipment is required. This metric requires an established risk management system which has been used to determine the acceptability of deviating from the design case.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, include 'average number of days a temporary deviation is open (as a 12-month rolling average)' or '% of temporary deviations overdue or extended (per month)' to provide a perspective as to the duration that a temporary deviation is in place.

Linkages

This metric also links to the systems and processes element, an effective management system and supporting processes would be expected to minimise the requirements for temporary deviations or the duration that they are in effect.

Combining this metric with short-term deviations to safety critical elements gives a combined measure of the deviations to SCE.

This metric is aided by auditing of the following areas:

- assurance tasks on safety critical elements; and
- deviation and temporary operating procedures.

An example

This metric monitors instances such as a pressure transmitter being out of service due to it failing, and other measures are put in place until it is repaired and returned to service.



Title

Short term deviations to safety critical elements

Purpose

To provide a measure of the weaknesses to a safety critical element introduced through critical device function testing and equipment bypassing for non-function testing purposes. This can be for safety systems (ie overrides) as well as hardware, such as relief valves. An example of a safety critical element bypassed might be the removal from service of a SCE for a duration of less than a day.

Description

The metric is

- the absolute number (as opposed to a normalised rate) of short term deviations to safety critical elements.

There is no specific target, this metric requires trending with a focus to minimise the number and duration of deviations to minimise exposure.

| | |
|------------------------|---------|
| Frequency of capture: | Daily |
| Frequency of analysis: | Monthly |

This metric requires an established risk management system which has been used to determine the acceptability of bypassing from the design case.

These events need to be reviewed to determine if they are repetitious, as this may indicate a deeper issue to be resolved.

Metric consolidation

This metric can be broken into specific equipment types, to highlight if a specific barrier of protection is being bypassed on a very frequent basis. This metric may be tracked and analysed on a site-by-site basis, though it is also recommended that it be consolidated and reported at a regional and/or divisional level for review by senior executives and the board. It is also possible to report the deviations for function testing and non-function testing separately.

Implementation

The use of an automated, computerised system for the recording and monitoring of bypasses is a key enabler based on the governing management system or process that these are managed under.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, include 'average number of days a bypass is in place (as a 12-month rolling average)' or '% of bypasses overdue or extended (per month)' to provide a perspective as to the duration that a bypass is in place.

Linkages

This metric links to the management and systems element, given that the implementation of bypasses would be expected to be managed through a formal permit to work (or equivalent system). Preference would be to minimise the need for bypass safety critical equipment functionality through the provision by design of testing functionality without the need for a bypass or provision of redundancy.

Combining this metric deviation to safety critical elements gives a combined measure of the deviations to SCE.

This metric is aided by auditing of the following areas:

- permit to work;
- assurance tasks on safety critical elements; and
- deviation and temporary operating procedures.

An example

This metric monitors instances such as when the blow down of a vessel is required and gas detectors in the vicinity may be bypassed to prevent spurious alarms, resulting in the detectors not functioning as designed in an actual release.



Title

Open Management of Change on safety critical elements

Purpose

To ensure safety critical MoCs are identified and prioritised for timely closure. The MoC may impact on the SCE directly, or it may have the potential to impact on the SCE or management of it.

Description

The metric is

- the absolute number (as opposed to a normalised rate) of the number of open MoCs.

There is no specific target, this metric requires trending with a focus to minimise the number and duration of open MoCs to minimise exposure. Trending up may indicate additional items being identified, or a lack of control in managing close out.

| | |
|------------------------|----------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Annually |

Metric consolidation

This metric may be tracked and analysed on a site-by-site basis, though it is also recommended that it be consolidated and reported at a regional or divisional level for review by senior executives and the board.


Implementation

This metric requires an established MoC process that has the ability to identify when safety critical elements are being modified. It is possible that some temporary deviations may result in the need for a permanent change, requiring MoC. In this instance, the item would cease to be tracked by the 'temporary deviation to safety critical element' metric and commence being tracked by the MoC metric. The age of open MoCs could also be considered, with an ageing list, such as 30, 60, 90, 120 days open. A measure for the time taken from hardware completion to close out completion highlights some risk exposure until all documentation is updated.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation include differentiation between emergency, temporary and permanent MOCs.

Linkages

The quality of MoCs conducted is monitored via the audit process, focussing on process safety elements. Temporary deviations may result in MoC where a permanent fix is required.



An example

This metric monitors situations such as when a new hazard is identified as part of an incident and requires an instrumented system to be installed. This would require a management of change to be completed and closed out. Until this is done, there is a risk of the incident reoccurring.

Title

Demand on safety critical elements

Purpose

Provides an indication of the frequency when safety systems are called to function. A demand on a safety system design to prevent or mitigate a LoPC or loss of control event.

Description

This metric is not intended to focus on static SCE, such as pressure vessels, storage tanks or pressure piping, as by their design they are constantly under demand. The metric is

- the absolute number (as opposed to a normalised rate) of demands on safety critical elements.

This identifies whether the actual demand is in line with the rate of demand expected. It can highlight continuous demand issues, which then need to be considered for modification, such as a review or redesign of the system to reduce the demand requirements. There is no specific target, this metric requires trending with a focus to minimise the number and duration of deviations to minimise exposure.

Metric consolidation

This metric can be broken into equipment types, to highlight if specific barriers of protection are seeing demand above design specification. This metric may be tracked and analysed on a site-by-site basis, though it is also recommended that it be consolidated and reported at a regional and/or divisional level for review by senior executives and the board.

Implementation

Clarity is required to define what constitutes a demand on safety critical equipment. There are typically a variety of safety systems that may need to be relied upon², for example, activation of a:

- Safety Instrumented System (SIS);
- Mechanical shutdown system; or a
- Pressure Relief Device (PRD) not classified as a Tier 1 or Tier 2 PS Event².

The availability of data and ability to report is likely to be significantly different for each safety system and may limit reporting.

Intentional and controlled activation of a safety system during periodic device testing, or manual activation is excluded from this metric.

A normalisation that may be considered in support of this metric, pending confirmation as to the ease of their implementation, could include a denominator of the number of installed like items, or the number of hours of operation of like items.

Linkages

This metric also links to the systems and procedures element, and may also be an indicator or measure of operational control and discipline to maintain production within pre-defined technical integrity limits.

This metric is aided by auditing of the following areas:

- safety critical procedures; and
- near miss and incident reporting and investigation.

An example

This metric monitors situations such as during the startup of a vessel where the level drops, resulting in a low-level shutdown being triggered.

Title

Barriers failing on demand

Purpose

To provide a measure of the weaknesses of a safety critical element (or barrier) that's relied upon to function as intended to prevent or mitigate an LoPC or loss of control event. While this may appear to be a lagging metric, it is included to recognise that some barriers will fail on demand without the consequence happening, like a near miss. A high number of failures upon demand would indicate either an engineering design issue or the need for improvement in the effectiveness of the inspection and maintenance of the barrier or determine if the demand frequency matches the design of the protection loop.

Description

The metric is

- the absolute number (as opposed to a normalised rate) of instances a barrier fails on demand.

There is no specific target, this metric requires trending with a focus to minimise the number and duration of deviations to minimise exposure. The number of instances a barrier fails on demand should reduce over time, though an instance of zero is likely to represent a failure in detection of the failure, rather than lack of failures. Failure results should match the assumptions in a layer of protection analysis (LOPA) and should link back to verify the risk study.

| | |
|------------------------|----------|
| Frequency of capture: | Weekly |
| Frequency of analysis: | Annually |

Failure rates experienced from this metric should be consistent with barriers failing on test. Where this is not the case there may be an instance of testing methods being inadequate. Methods and frequency should be reviewed for effectiveness.

Metric consolidation

This metric can be broken down into equipment categories, to highlight if specific barriers of protection are failing if required. This metric may be tracked and analysed on a site-by-site basis, though it is also recommended that it be consolidated and reported at a regional and/or divisional level for review by senior executives and the board.

Implementation

Clarity is required to define what constitutes a failure upon demand so that a system of reporting and monitoring may be implemented. This may need to be categorised given there are typically a variety of safety systems that may need to be relied upon, for example, activation of:

- Safety Instrumented System (SIS);
- Mechanical shutdown system; or a
- Pressure Relief Device (PRD) not classified as a Tier 1 or Tier 2 PS Event².

The availability of data and ability to report is likely to be significantly different for each safety system and may limit reporting.

Failure upon demand is recognised as a separate metric to a failure during a routine (or planned) performance test (accepting that a rate of failure is likely to be assumed within the design and assessment of that barrier).

A classification process to ensure that a failure upon demand is reported and appropriately acted upon to determine both the root cause of the demand and also failure of the barrier to perform as intended.

Linkages

This metric links to the systems and procedures element as effective inspection, testing and maintenance systems and procedures are required to ensure that if a demand is made that the system is likely to perform as intended.

This metric is aided by auditing of the following areas:

- assurance tasks on safety critical elements, and
- incident and near miss reporting and investigation to ensure barrier failures have been identified.

An example

This metric monitors when a process excursion might occur, resulting in high pressure in a vessel, however the high pressure trip fails to activate. Subsequently the pressure safety valve lifts, relieving pressure. The failure of the pressure trip is a failure on demand.

Systems & procedures

Systems and procedures is about having high-level management systems in place, be that safety, maintenance or other management systems, setting a standard to be adhered to. Metrics that measure the effectiveness of the systems and procedures include the following:

- safety critical element (SCE) inspections performed versus planned;
- barriers fail on test;
- damage to primary containment detected on test/inspection;
- SCE maintenance deferrals (approved corrective maintenance deferrals following risk assessment);
- temporary operating procedures (TOPs) open;
- permit to work checks performed to plan;
- permit to work non-conformance; and
- number of process safety related emergency response drills to plan.

Title

Safety Critical Element (SCE) Inspections Performed Versus Planned

Purpose

A measure of the timeliness of preventive maintenance on SCEs to ensure SCE integrity is maintained. The metric identifies the level to which SCEs are not being inspected or tested within the required inspection period. The metric will indicate problems related to planning, resourcing requirements or culture relating to the acceptability to allow SCEs to remain in service after required inspection periods have lapsed.

Review of the metric should consider if achievable inspection schedules exist given the current availability of resources. Additionally, the priority given to the inspection of SCEs will need to be reviewed if this metric identifies a low level of inspections performed to planned inspections. This may also highlight a general attitude of acceptance of uninspected equipment continuing to operate with no further safeguards. This metric should also be linked to review of temporary operating procedures/deviations which should have been raised where inspection periods have been exceeded.

Decision making will occur initially at the supervisor level which is escalated to the operations manager level if additional resourcing or a cultural change is required.

Description

This metric requires knowledge of the number of inspections planned, versus the number of inspections conducted. It is important not to manage the metric by using a process to alter the plan. The metric is about ensuring inspections are conducted, not deferred. The normalised metric is based on the following equation:

$$\frac{\text{Number of performed inspections or tests on or prior to scheduled date on SCEs in period}}{\text{Number of planned SCE inspections or test in period}} \times 100 = \%$$

This metric should trend towards 100%, to demonstrate that safety critical equipment inspection and testing is being conducted as required.

| | |
|------------------------|---------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Monthly |

This metric can be tracked and analysed at a site-by-site basis. For board-level reporting, it would still be required at a site-by-site basis. This is to ensure they can meet their due diligence requirement in ensuring that appropriate resources are applied to eliminate or minimise risks to health and safety.

Implementation

Two key challenges to implement this metric are a lack of a maintenance management system in place for effective planning and tracking of activities and if they have not effectively defined their safety critical elements (SCE).

To overcome these challenges it is necessary to ensure there is a structured process to schedule and track completion of inspection and testing works. It is preferred to have a computerised system for this, however a manual system could be used. It is also critical to have defined and differentiated the SCEs, so that they can be tracked effectively. A vital component is that the system must not be allowed to have the scheduled inspection date modified such that tracking of overdue inspections is not possible. The system must also distinguish planned activities from reactive activities, ie repair.


Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation include the number of instances where planned work is deferred following an appropriate risk assessment process, or the number of instances where planned work is deferred without following an appropriate risk assessment process. In addition, a quality check of the inspection is performed, with a random sample of work reports reviewed for completeness. This could indicate how well the inspections are being completed.

Linkages

This metric also links to the engineering and design pillar, as the correct design and installation is required to identify and test SCEs.

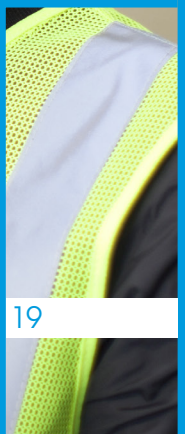
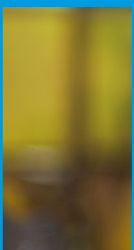
This metric is aided by auditing of the following areas:

- completion of assurance tasks on safety critical elements; and
- deviation and temporary operating procedures, if inspections have not been performed, the assumption must be made that the SCE may not be performing as designed.



An example

This metric monitors whether the necessary inspections, such as bench testing of a pressure relief valve at a defined frequency, have been completed.



Title

Barriers Fail on Test

Purpose

A measure of the operating condition of process safety barriers, other than primary containment systems (piping, vessels, machinery). The metric shall collate the total number of failures of safety critical elements failures identified during testing.

Identification of high numbers of failures would indicate either a product design issue, a common mode environment issue or a need for further maintenance, which would need to be investigated. Very low failures could also indicate a lack of testing or incorrect test procedures which are not identifying failures.

Decision making will occur initially at the technician and supervisor levels, and is escalated to the ops manager level if additional resourcing or further support is required for investigation.

Description

This metric requires knowledge of the number of failures of safety critical barriers on inspection or test. All failures should be reported, investigated and understood. It is assumed that there may be an expected failure rate, but this metric aims to track what is beyond that defined failure rate. Failures may necessitate changes to the testing frequency or level of testing of the element. Different equipment in different services will have an established failure rate, either company specific or externally recognised. The failure rates mentioned here should be aligned with these established rates. The metric is a direct count of the following:

- number of barriers that fail on inspection or test, excluding expected failure rate.

This metric could be normalised, by looking at the number of barriers that fail relative to the number of barriers installed. However, given there is no definitive categorisation on types of SCEs, it is difficult to achieve consistency across organisations. This would mean some organisations would define the number of barriers included differently, and comparison would be misleading. This metric should trend towards zero, showing that the barriers have integrity. However it should be noted that a consistent result of zero may be misleading and in this instance, the testing regime and methods should be reviewed.

| | |
|------------------------|----------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Annually |

Metric consolidation

Can be broken down into lower layers based on the barriers of protection (ie piping integrity, process control system, active mitigation layers) if required by the company. Once broken down to equipment type level, it is recommended to track this as a percentage with the number of failed tests over the planned number of tests. It is recommended that a rolled-up value is provided to management/board levels. This is to ensure they can meet their due diligence requirement and ensure that appropriate resources are applied to eliminate or minimise risks to health and safety.

Implementation

Barrier failure data will come from test reports or temporary deviations raised on equipment that has failed testing. Collating this information from multiple systems will require a manual process. One challenge will be in identifying barrier failures within the incident and deviation recording systems. For clarity, it is important that failures are recorded as well as fixed, and not just fixed.

Ensuring that incident reporting systems and deviations tracking systems can categorise records to identify barrier failures on test and on demand will assist in collating this data.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation include the time taken to rectify the plant after the barrier has failed.

Linkages

This metric also links to the engineering and design pillar, as the correct design and installation is required to identify and test SCEs.

This metric is aided by auditing the following areas:

- assurance tasks on safety critical elements; and
- deviation and temporary operating procedures.



An example

This metric monitors whether the testing of a barrier has passed or failed, such as a pressure safety valve being bench tested prior to overhaul, and failing to lift at the required pressure.

Title

Damage to primary containment detected on test/ inspection

Purpose

This metric may be considered a subset of barriers failing on test. However it is included separately because it focuses on primary containment.

It is a measure of a damage condition (including corrosion) to primary containment systems (piping, vessels, machinery) rated outside acceptable limits, resulting in the equipment being deemed not fit for service.

Identifying a high number of failures would indicate either a product design issue, a common mode environment issue, or a need for further maintenance, which would need to be investigated. Very low failures could also indicate a lack of testing or incorrect test procedures which are not identifying failures.

Decision making will occur initially at the supervisor level, which is escalated to the ops manager level if additional resourcing or a cultural change is required.

Description

This metric requires knowledge of the number of failures, defects or damage to a primary containment system on inspection or test. This would be based on the number of inspections, not the number of faults found in a single inspection (eg multiple corrosion points). The metric is a direct count of the following:

- number of instances a primary containment system fails on inspection or test.

This metric should trend towards zero, showing that the barriers have integrity. However it should be noted that a consistent result of zero may be misleading and in this instance, the testing regime and methods should be reviewed. It is also acknowledged that as facilities age, they will suffer some deterioration that requires additional maintenance and inspection.

| | |
|------------------------|---------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Monthly |

Metric consolidation

This metric cannot effectively be consolidated or broken down.

Implementation

Primary containment damage records will generally come from the deviations reporting system or a near-miss and incident-investigation system. Collating this information from multiple systems will require a manual process.

Ensure that incident reporting systems and deviations tracking systems can categorise records to identify primary containment damage identified, which can be separated based on identification of the damage on test and on demand.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation include the time taken to rectify the plant after the barrier has failed.

Linkages

This metric also links to the engineering and design pillar, as the correct design and installation is required to identify and test primary containment systems.

This metric may be considered a subset of the 'barriers failing on test' metric.

This metric is aided by auditing of the following areas:

- completion of assurance tasks on safety critical elements; and
- deviation and temporary operating procedures.

An example

This metrics monitors whether primary containment systems continue to be fit for service.

Title

SCE maintenance deferrals (approved corrective maintenance deferrals following risk assessment)

Purpose

To identify the level to which SCE corrective maintenance work is being deferred and therefore potentially extending the period of non-compliance to performance standards. The metric identifies problems related to planning, resourcing requirements or culture, relating to the acceptability to allow SCEs remain out of service for extended periods of time. The metric does not consider inspection and testing preventive maintenance deferrals.

Review of the metric should consider if achievable corrective maintenance schedules exist given the current availability of resources. Additionally, priority assigned to the maintenance work needs to be reviewed if this metric identifies a low level of work performed to planned work. This may also highlight a general attitude of acceptance of continuing to operate the plant with SCEs out of service. This metric should also be linked to review of temporary operating procedures/deviations which should have been raised where an SCE was out of service and the required corrective maintenance was deferred beyond the allowed temporary operating procedure/deviation period.

Decision making will occur initially at the supervisor level which is escalated to the ops manager level if additional resourcing or a cultural change is required.

Description

This metric requires knowledge of the number of performed corrective maintenance tasks, versus the number of corrective maintenance tasks planned. It is vital to track the items corrected, as the initial failure may be a weak signal that there is a bigger issue developing. The normalised metric is based on the following equation:

$$\frac{\text{Number of performed corrective maintenance tasks on or prior to scheduled date on SCEs in period}}{\text{Number of planned corrective maintenance tasks on SCEs in period}} \times 100 = \%$$

This metric should trend towards 100%, to demonstrate that safety critical corrective maintenance is being conducted as required. Preventative maintenance is addressed under the metric SCE inspections performed verses planned.

| | |
|------------------------|---------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Monthly |

Metric consolidation

This can be broken down into lower layers based on the barriers of protection (ie piping integrity, BPCS, active mitigation layers) if required by the company. It is recommended that a rolled up value is provided to management/board levels.

Implementation

A key challenge to implement this metric is if facilities have not effectively defined their safety critical elements (SCE).

The maintenance management system (MMS) is required to identify safety critical elements and their associated maintenance work from maintenance on other parts of plant. The MMS must distinguish planned maintenance (ie inspections) from corrective maintenance (ie repair). The MMS must not be allowed to have the scheduled work date modified such that tracking of overdue work is not possible.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, include the number of instances planned work is deferred without following an appropriate risk assessment process. In addition, a quality check of the inspection performed, with a random sample of work reports reviewed for completeness. This could indicate how well the inspections are being completed.

Linkages

This metric also links to the engineering and design pillar, as the correct design and installation is required to identify and test SCEs.

This metric is aided by auditing the following areas:

- assurance tasks on safety critical elements; and
- deviation and temporary operating procedures.

An example

This metric monitors whether corrective maintenance, such as repairing a leaking seal on a fire water pump, is being completed as planned.

Title

Temporary operating procedures (TOPs) open

Purpose

A measure of the implied reliance on (or transfer of risk to) personnel to manage and maintain safe operation outside of normally-approved operating and design modes.

A high level of TOPs open during a period would indicate a requirement to review plant design or maintenance if the TOP is a consequence of equipment being out of service. It should be ensured that TOPs are being closed within a reasonable timeframe, either through corrective maintenance or change management. This metric may highlight a culture of over reliance on procedural barriers to keep the plant in operation.

Decision making will occur initially at the supervisor level which is escalated to the ops manager level if additional resourcing or a cultural change is required.

Description

The metric is the

- absolute number (as opposed to a normalised rate) of temporary operating procedures in place on a weekly basis.

Where the TOP is part of an MoC, it need not be counted here. There is no specific target, this metric requires trending with a focus to minimise the number and duration of temporary procedures to minimise exposure.

This metric should decrease based on the previous months results and should trend towards zero, to demonstrate that process safety related temporary processes are minimised, in favour of routine processes.

| | |
|------------------------|---------|
| Frequency of capture: | Weekly |
| Frequency of analysis: | Monthly |

Metric consolidation

It is recommended that a rolled up value is provided to management/board levels.

This ensures they can meet their due diligence requirement in ensuring that appropriate processes are applied to eliminate or minimise risks to health and safety.

Implementation

Additional metrics that may be considered in support of this metric include 'average number of days a temporary operating procedures in open (as a 12-month rolling average)' or number of TOPs open greater than 90 days' or '% TOPs overdue or extended (per month)' to provide a perspective of how long temporary operations are in place.

Clear start and conclusion dates on TOP tracking systems or within the TOP will help in extracting this metric.

Linkages

This metric is aided by auditing of the following areas:

- deviation and temporary operating procedures; and
- management of change.

An example

This metric monitors how many temporary operating procedures are in place, such as a procedure defining a requirement to limit hot work in a particular area of the plant due to an underperforming fire system.

Title

Permit to work checks performed to plan

Purpose

A measure that work activities on the facilities are planned and executed in a controlled and efficient manner in accordance with mandatory company requirements and expectations.

The permit to work check is a method to check that the system is functioning. As such, there should be a target set for the number of permit to work checks completed. As a rule of thumb, sample sizes can be the square root plus one of the total number of permits issued.

Reviewing this metric will indicate whether permit to work checks are occurring at an adequate frequency and therefore whether there is sufficient priority given to assurance of the performance of the permit to work system.

Description

This metric requires knowledge of the planned number of permit to work checks, versus the number of permit to work checks conducted. The normalised metric is based on the following equation:

$$\frac{\text{Number of permit to work system checks executed in period}}{\text{Number of permit to work system checks planned in period}} \times 100 = \%$$

This metric should trend towards 100%, to demonstrate that the permit to work system is being undertaken as required.

Alternatively, the metric could use the number of permit to work system checks executed in period versus the number of permits raised in the same period. In this case the target for the metric should be a proportion of permits raised. Checks should cover high hazard tasks such as hot work or confined space entry as well as routine tasks.

| | |
|------------------------|-----------------------|
| Frequency of capture: | Weekly or fortnightly |
| Frequency of analysis: | Monthly |

Metric consolidation

This metric can be consolidated into a running 12-month trend for the site. Consolidating upwards across sites is possible but may be biased if the number of permits raised at each site varies significantly.

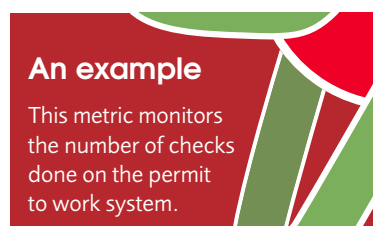
Implementation

This metric only indicates that permit to work checks have been undertaken, it does not measure the effectiveness or appropriateness of the checks.

Linkages

This metric is aided by auditing the following area:

- permit to work.



Title

Permit to work non-conformance

Purpose

A measure that work activities on the facilities are planned and executed in a controlled and efficient manner in accordance with mandatory company requirements and expectations.

High levels of non-conformance might indicate problems with competency and training and possibly a culture of acceptance of not following procedures. Consistently very low values of this metric could also indicate inadequate checks of completed permits.

Decision making will occur initially at the technician and supervisor level, which is escalated to the ops manager level if additional training programmes or a cultural change is required.

Description

This metric requires knowledge of the number of permit to work non-conformances found during the checking process, as well as the number of checks conducted. The normalised metric is based on the following equation:

$$\frac{\text{Number of PTW non conformances}}{\text{Number of PTW audits or checks completed}} \times 100 = \%$$

A non-conformance would occur when a step in the procedure has not been executed correctly. This metric should trend downwards towards 0%. However, it assumes that the number of audits conducted is not zero. This shows the percentage time when the permit system was not functioning as designed or expected.

| | |
|------------------------|-----------------------|
| Frequency of capture: | Weekly or fortnightly |
| Frequency of analysis: | Monthly |

Metric consolidation

This may be broken down into minor and severe non-conformances so that minor non-conformances are distinguished.

Implementation

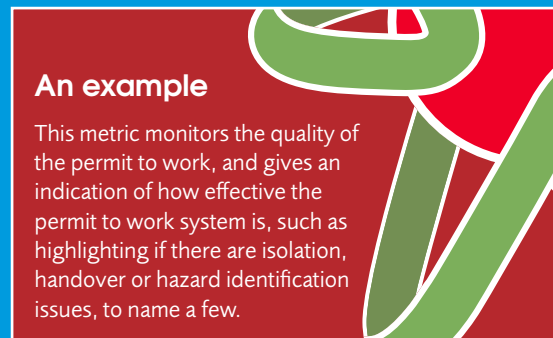
PTW non conformances numbers may not be tracked electronically and may require manual calculation and categorising of the severity of non-conformance.

Following PTW audits, the number of minor and major non-conformances should be logged in an electronic system by the auditor.

Linkages

This metric is aided by auditing of the following area:

- permit to work.



An example

This metric monitors the quality of the permit to work, and gives an indication of how effective the permit to work system is, such as highlighting if there are isolation, handover or hazard identification issues, to name a few.

Title

Number of process safety related emergency response drills to plan

Purpose

A measure of the preparedness of a facility and company for a process safety emergency event.

Reviewing this metric will indicate whether process safety emergency response drills are occurring at an adequate frequency and therefore whether there is sufficient priority given to preparedness for process safety hazard events. This excludes exercising non process safety related emergencies, such as personal injury or bomb threat etc.

Decision making will occur initially at the manager level.

Description

This metric requires knowledge of the number of defined process safety emergency response drills planned, versus the number of defined process safety emergency response drills conducted. The normalised metric is based on the following equation:

$$\frac{\text{Number of process safety emergency response drills executed in period}}{\text{Number of process safety emergency response drills planned in period}} \times 100 = \%$$

This metric should trend towards 100%, to demonstrate that process safety emergency preparedness is being maintained as required.

| | |
|------------------------|------------------|
| Frequency of capture: | Every six months |
| Frequency of analysis: | Annually |

Metric consolidation

This metric cannot effectively be consolidated or broken down.

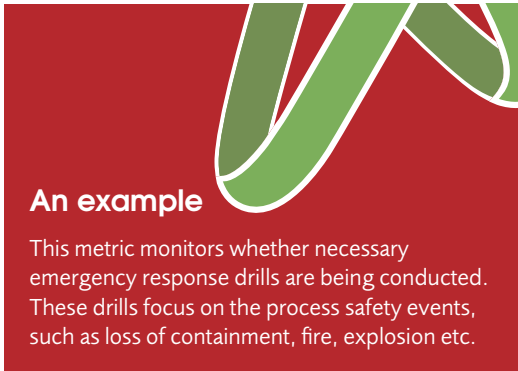
Implementation

This metric requires process safety specific emergency exercises to be planned and undertaken. There are no significant challenges seen in implementing this metric.

Linkages

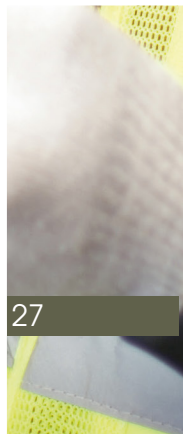
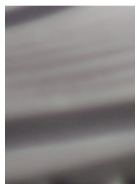
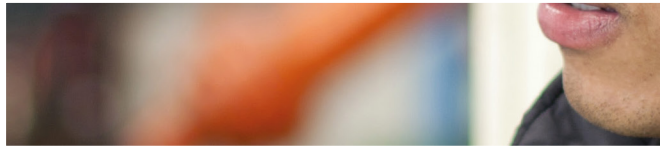
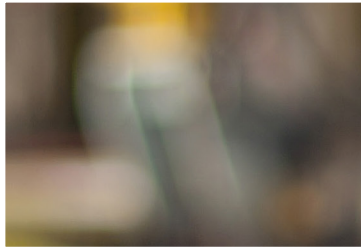
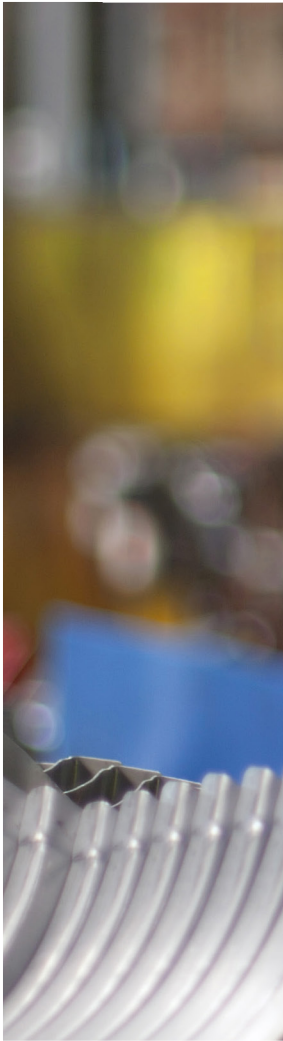
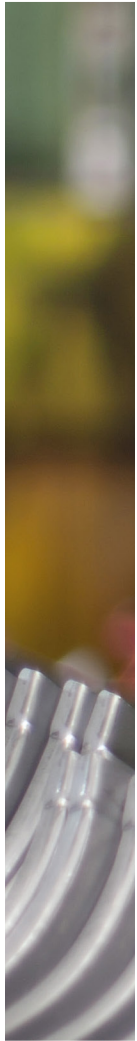
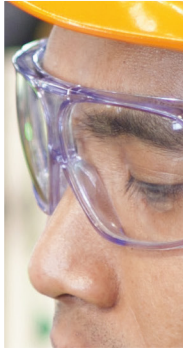
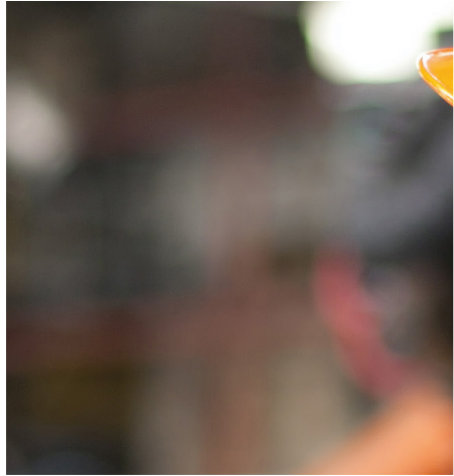
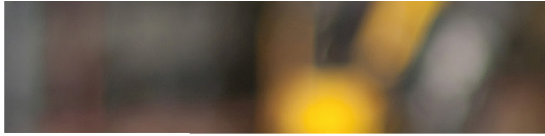
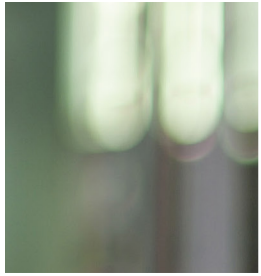
This metric is aided by auditing the following area:

- emergency preparedness for process safety related incidents.



An example

This metric monitors whether necessary emergency response drills are being conducted. These drills focus on the process safety events, such as loss of containment, fire, explosion etc.



Assurance

Assurance is a defined programme for systematic monitoring and evaluation of all aspects of a business. This includes tools such as inspection, testing, monitoring, verification and audit. This also applies to defining performance standards and metrics for an organisation and reporting performance against them, in addition to the feedback loop, resulting in actions based on data.

Assurance should be undertaken at both an internal level in an organisation, such as audit, inspection and testing, and also at a governance level by the board. It is important that boards seek assurance of the processes and operations, rather than reassurance that everything is ok. Metrics that measure the effectiveness of the systems and procedures include the following:

- number of process safety related audits to plan; and
- number of non conformances found in process safety audits.

Title

Number of process safety audits to plan

Purpose

To provide assurance to the senior management and ultimately to the board that process safety systems are implemented and effective.

Due to ease of data capture, a number of process safety lead metrics are based on a measure of activity completion to plan, but do not readily measure the quality of the activity tasks. The purpose of having process safety auditing as a safety metric is to provide assurance of the quality of activities associated with other process safety lead metrics..

Description

This metric measures the planned number of process safety audits, versus the number of process safety audits conducted. The normalised metric is based on the following equation:

$$\frac{\text{Number of process safety audits executed in period}}{\text{Number of process safety audits planned in period}} \times 100 = \%$$

This metric should trend towards 100%, to demonstrate that assurance of the process safety system is being undertaken as required.

| | |
|------------------------|--|
| Frequency of capture: | Monthly or quarterly, depending on the number of process safety audits planned |
| Frequency of analysis: | Annually |

Metric consolidation

Consolidating upwards across sites is possible particularly if a process safety audit programme exists at a business or corporate level.

Where sufficient audits are undertaken, the metric can be divided into the specific process safety areas (procedure, permits, etc).

Implementation

This metric indicates that process safety audits have been undertaken to plan. It does not measure the scope, effectiveness or appropriateness of the process safety audits, nor whether the process safety audit plan is appropriate. Refer to the section *Auditing Guidance for Process Safety Metrics*, which describes how an audit programme can be used to ensure that other process safety lead metrics reflect the quality of an activity, and not just a quantity.

A process safety audit programme should be implemented for the following process safety management system elements:

- assurance tasks on safety critical elements;
- deviation and temporary operating procedures;
- emergency preparedness for process safety related incidents;
- incident reporting and investigation;
- maintenance of safety critical elements;
- management of change;
- permit to work; and
- safety critical procedures.

Linkages

This metric is aided by auditing the following area:

- assurance tasks on safety critical elements.

See Appendix 1 for guidance on audits.

An example

This metric monitors whether process safety audits are being conducted – eg an audit of the lock-open, lock-closed manual valves to ensure that the registers are maintained appropriately and labels are installed and valves locked as required.



Title

Number of non conformances found in process safety audits

Purpose

To provide assurance to the senior management and ultimately to the board that process safety systems are implemented and effective.

Description

The metric is

- the absolute number of major/significant non-conformances identified during process safety audits.

The target for major/significant non-conformances should be zero and in addition to tracking the number raised, the outstanding non-conformances can be tracked and trended to manage close-out of non-conformances. Attention should be given to consistent zero results, to ensure this is the actual result, and not a case for major/significant non conformances being downgraded. Where major/significant non conformances are found, an implementation plan is needed to ensure tracking and testing upon completion. In an effort to ensure these non conformances remain top of mind, an absolute number has been chosen for this metric, rather than detail becoming lost in a percentage.

| | |
|------------------------|-----------|
| Frequency of capture: | Quarterly |
| Frequency of analysis: | Annually |

Metric consolidation

Consolidating upwards across sites is possible, particularly if a process safety audit programme exists at a business or corporate level.

Implementation

Process safety audit non-conformances may be tracked electronically through an action tracking system. It may be necessary to manually categorise the severity of non-conformances and to identify those specifically from process safety audits.

Linkages

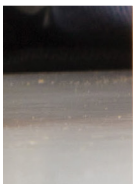
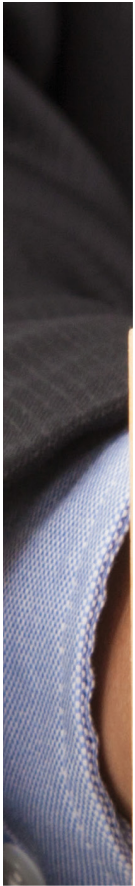
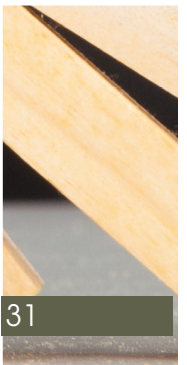
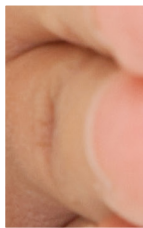
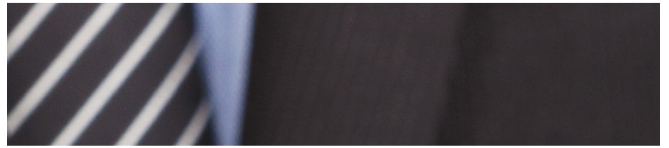
This metric is aided by auditing of the following area:

- assurance tasks on safety critical elements.

See Appendix 1 for guidance on audits.

An example

This metric monitors the number of major/significant non conformances found during audits, such as safety systems being bypassed without correct authorisation and risk assessment being conducted.



Human factors

Human factors is about understanding the interaction between the three main factors affecting human performance at work – the job, the individual and the organisation. Metrics that measure the effectiveness of the systems and procedures include the following:

- compliance with critical procedures by observation;
- critical alarms per operator hour⁹; and
- standing alarms⁹.

Title

Compliance with safety critical (SC) procedures by observation

Purpose

To track compliance with safety critical procedures at all levels of the organisation, in particular those related to the processing facility safety critical elements and tasks where failure to follow the procedure correctly could lead to a process safety incident. A low metric score indicates unsatisfactory implementation of safety critical tasks/procedures and immediate attention required to address weaknesses

Description

This metric requires knowledge of the number of procedural observations performed, as well as a judgement of whether the task was performed adequately. This metric assumes that a sufficient number of safety critical procedures have in fact been observed. A suggested target would be 10%; however, each safety critical task should be observed at least annually or as it occurs. Examples of safety critical procedures include startup/shutdown, process isolation, lock open/lock closed and emergency/incident response procedures. The normalised metric is based on the following equation:

$$\frac{\text{Number of procedural observations deemed adequately performed in period}}{\text{Number of procedural observations performed in period}} \times 100 = \%$$

This metric should trend towards 100%, to demonstrate that procedures are being followed as required.

The task observation should be sufficiently detailed to confirm the correct procedure was used for the safety critical task and that all safety critical steps within the procedure were performed correctly and in the right sequence.

The company technical or procedural audit guidelines should be consulted to specify the criteria for non-compliance. For example, this metric counts only compliant ratings, which are Good or Satisfactory, meaning assurance or compliance targets are met. Where the observation was deemed Less than Satisfactory (meaning non-compliance and immediate attention required to address weaknesses) it would not be deemed adequately performed.

| | |
|------------------------|---------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Monthly |

Metric consolidation

This can be viewed at an individual site level. It is recommended that a rolled up value is also provided to management/board levels.

Implementation

It is suggested that each company develops and enforces an annual SC task observation schedule to ensure audits are completed across all facility SC procedures on a rolling basis and that the compliance metric has a sufficient sample of data each month (eg minimum 10). The observation schedule is normally developed, implemented and tracked by the HSEQ or QA/QC teams to ensure sufficient focus by supervisors and management teams.

The criteria for compliance and non-compliance needs to be agreed prior to the annual observational audit programme and associated metric implementation to avoid debate once the observation findings and monthly results are published.

Procedural observations used to create this metric should focus on safety critical steps that could lead to a process safety incident if they are incorrectly applied, omitted or completed out of sequence. It should be noted that this applies to the process safety aspects of the procedure.

Linkages

This metric also links to the systems and procedures, assurance and culture elements.

This metric is aided by auditing the following area:

- safety critical procedures.

An example

This metric monitors whether critical procedures, such as start up procedures, are correctly followed. For example, procedure requires a valve line-up check being completed prior to restarting a piece of equipment.



Process safety audit characteristics

In order for the audit to be used as a process safety metric, it needs to have certain characteristics, related to general audits characteristics that reflect good audit practice and specific process safety characteristics of the barrier.

| General audit characteristics | Comment |
|--|--|
| Audit schedule defined in advance | Where number of audits undertaken to schedule is a metric. |
| Formal close-out of each audit | To allow tracking of metric. |
| Tracking non-compliances from audits | Non-compliances from the audit should be identified and tracked. |
| Independence of auditor | The person auditing the system should be independent from the personnel undertaking the activity. |
| Competence of auditor | The person undertaking the audit should have sufficient process safety competence to ensure process safety considerations are considered during the audit. |
| Representative sample audited | Where there is doubt, a size of square root plus one is a reasonable guide*. |
| Audits undertaken at regular intervals | To be effective as a lead indicator, audits should be undertaken at regular intervals throughout the year, rather than in large blocks. This allows the performance of the system to be tracked. |
| Documented audit protocol that considers process safety measures | For the audit to be used as a process safety metric, there should be specific audit questions to cover the process safety aspects of the barrier. |

*A sampling scheme for agricultural inspections from the 1920s, it was semi formalised in 1927 in an unpublished paper by the Association of Official Agricultural Chemists.

| Audit characteristics for specific audits | Typical requirements for process safety metrics |
|---|---|
| Assurance tasks of safety critical elements | <p>Safety critical elements are defined, performance standards are developed that include the assurance tasks required to demonstrate effective operation of the safety critical element.</p> <p>Assurance tasks are undertaken to the required quality level.</p> <p>Outcomes of assurance tasks are recorded and actioned appropriately.</p> <p>The schedule for undertaking assurance tasks is appropriate and justifiable.</p> <p>Assurance tasks are not deferred without valid justification.</p> |
| Deviations and temporary operating procedures | <p>Deviations and temporary operating procedures documented appropriately.</p> <p>Appropriate risk assessments are undertaken prior to implementing deviations and temporary operating procedures.</p> <p>The duration of deviations and temporary operating procedures are not extended without valid justification.</p> <p>Deviations and temporary operating procedures are authorised appropriately.</p> |
| Emergency preparedness for process safety related incidents | <p>Emergency preparedness includes processes for responding to process safety incidents.</p> <p>The schedule for undertaking emergency response drills relating to process safety incidents is appropriate and justifiable.</p> |
| Incident reporting and investigation | <p>Process safety incidents are reported.</p> <p>Process safety incidents are investigated based on the potential process safety consequence.</p> <p>Incident Investigations relating to process safety incidents are completed in a timely manner and actions are tracked to completion.</p> |
| Management of change | <p>Management of change is undertaken for process safety related changes.</p> <p>Appropriate levels of risk assessment is undertaken as part of the management of change process.</p> <p>Management of change is approved and closed out at the appropriate level, in a timely manner and documented appropriately.</p> |
| Permit to work | <p>Permits include appropriate consideration of process safety risks and affected safety critical elements.</p> <p>Safety critical procedures required by the permit are understood and complied with.</p> <p>Permits are approved by personnel with appropriate process safety competency.</p> |
| Safety critical procedures | <p>Safety critical procedures are identified for process safety risks and include the appropriate hazards and controls.</p> <p>Safety critical procedures are developed and reviewed appropriately including involvement of the appropriate personnel.</p> <p>Safety critical procedures are available to personnel when required to undertake a task and are clear.</p> |

Title

Critical alarms per operator hour

Purpose

To track compliance with the number of plant control system critical alarms per hour using EEMUA 191 [1]: *Alarm systems – a guide to design, management and procurement*⁹ guidance metrics as a benchmark. Metric data can be used by control room technicians, operations supervisors/managers, control and process engineers to ensure the control room operators are not overwhelmed by too many critical alarms and have sufficient time to respond to plant upsets. Positive changes to plant operation and design can be justified using this metric.

Description

Uses plant control systems (eg DCS) alarm data for average and maximum critical alarms per operator hour. Critical alarms are defined as those that require manual interventions and corrective actions from the facility operators to prevent the situation escalating towards a process safety incident. The number of alarms should trend downwards towards zero.

It is suggested that alarm data is split for different operating units, plant processes or equipment items.

System engineers should collect and analyse data daily or on a weekly basis. Metric data can be reported to operations, engineering and management once a week or monthly.

Compare data versus EEMUA 191 [1] *Alarm systems – a guide to design, management and procurement*⁹

| | |
|------------------------|-------------------|
| Frequency of capture: | Daily |
| Frequency of analysis: | Weekly or Monthly |

Metric consolidation

For definition of 'critical alarms' see EMMUA ref.1, section 2.5.1 *Alarm Prioritisation*⁹. Critical or the highest priority alarms in a control and safeguarding system normally carry a safety risk reduction factor of at least SIL1 equivalent.

The EEMUA alarm guidance⁹ includes metrics for the average alarm rate in steady operation, the number of alarms in 10 minutes after a plant upset, the average number of standing alarms and the average number of shelved alarms. It is also a useful reference for defining and setting metric target values. See reference 9 Section 4.1 Performance Metrics and associated appendices for more details.

This can be viewed at an individual unit or site level. It is recommended that it is also rolled up value to be provided to management/board levels.

Implementation

Data can be collected automatically in spreadsheets or databases using plant information (PI) tags linked to control/safety system critical alarms. Knowledge of instrument alarm tag and critical alarm set point is required to set up the database.

Malfunctioning instrumentation, alarm overrides and periods of plant shutdown should be factored into the alarm analysis.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, may be found in EEMUA 191[1]: *Alarm systems – a guide to design, management and procurement*⁹.

Linkages

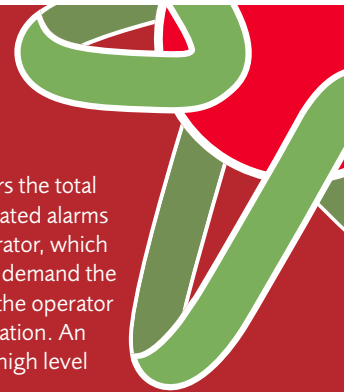
This metric also links to the engineering and design pillar.

This metric is aided by auditing the following areas:

- none identified.

An example

This metric monitors the total number of annunciated alarms presented per operator, which is a measure of the demand the plant is placing on the operator during steady operation. An example may be a high level alarm in a vessel.



Title

Standing alarms

Purpose

To benchmark standing alarm rate against industry guidance. Metric data can be used by control room technicians, operations supervisors/managers, and control and process engineers to ensure the control room operators are not overwhelmed by too many alarms and have sufficient time to respond to critical alarms and plant upset conditions. Positive changes to plant operation and design can be justified using this metric.

Description

Use plant control systems (eg DCS) alarm data for average standing alarms per hour and individual standing alarms that last longer than a predefined period (eg longer than a shift). Critical alarms are defined as those that require manual interventions and corrective actions from the facility operators to prevent the situation escalating towards a process safety incident. The number of alarms should trend downwards towards zero.

It is suggested that alarm data is split for different operating units, plant processes or equipment items.

System engineers should collect and analyse data daily or on a weekly basis. Metric data can be reported to operations, engineering and management once a week or monthly.

Compare data versus EEMUA 191[1]: *Alarm systems – a guide to design, management and procurement*⁹ guidance metric for standing alarms.

| | |
|------------------------|-------------------|
| Frequency of capture: | Daily |
| Frequency of analysis: | Weekly or Monthly |

Metric consolidation

This can be viewed at an individual unit or site level. It is recommended that a rolled up value is provided to management/board levels.

Implementation

Data can be collected automatically in spreadsheets or databases using plant information (PI) tags linked to DCS critical alarms. Knowledge of instrument alarm tag and critical alarm set point may be required to set up the database.

Malfunctioning instrumentation, alarm overrides and periods of plant shutdown should be factored into the alarm analysis.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, may be found in EEMUA 191[1]: *Alarm systems – a guide to design, management and procurement*⁹.

Linkages

This metric also links to the engineering and design pillar.

This metric is aided by auditing of the following area:

- none identified.

An example

This metric monitors the number of standing alarms present in an operating system. Standing alarms indicate the system is in an abnormal condition, such as low pressure on a standby pump.



Culture

In 1985, Edgar Schein¹² defined culture as:

"The pattern of basic assumptions that a group has invented, discovered or developed, to cope with its problems of external adaptation or internal integration that have worked well and are taught to new members as the way to perceive, think, feel and behave."

Establishing and maintaining a positive culture is complex. The UK HSE⁵ has issued some guidance on how to establish and measure a safety culture. Metrics that measure the effectiveness of a culture, especially its willingness to report and learn in a just manner include the following:

- open process safety items; and
- number of process safety interactions that occur.

Title

Open process safety items

Purpose

A measure of the operational discipline in identifying and closing process safety related action items identified from:

- internal audits;
- internal or external incident investigations;
- regulatory compliance actions;
- risk assessments; and
- hazard identification (cards).

A healthy process safety culture will include critical review of incident investigations, risk assessments and audits to identify PS safety related issues/opportunities, which are followed up with an action plan.

Failure to raise PS actions from internal sources may indicate a reluctance to raise issues or a culture of complacency. This could be linked back to a lack of PS knowledge if hazards are not being identified.

It should be ensured that process safety audit items are being closed within a reasonable timeframe, either through corrective maintenance or change management. A high level or increasing numbers of open items may indicate a lack of monitoring the status of action items, unrealistic closure dates or a lack of resources to design and implement the required actions.

Review of the metric occurs at the supervisor level. Decision making will occur at the ops manager level if cultural change, increased resources or knowledge improvements are required.

Description

The metric is

- a measure of the total number of open process safety items at the review date, as well as the total number of new items raised in the current review period.

This metric should show a steady or decreasing trend for items open, and an increase in the number of items opened in each period. This shows both resolution of open items as well as raising of new items.

| | |
|------------------------|----------|
| Frequency of capture: | Monthly |
| Frequency of analysis: | Annually |

Metric consolidation

It is recommended that site based values are recorded and rolled up values provided to management/board levels.

Implementation

This metric will require collation of data from multiple sources/systems such as incident reporting systems and audit reviews. Additionally, the data will need to be filtered to only include process safety related items which are deemed medium to high risk.

It should use a single electronic action tracking system that allows for process safety items to be identified and filters based on risk level.

Additional metrics that may be considered in support of this metric pending confirmation as to the ease of their implementation, include '% of overdue process safety related audit actions', '% of overdue process safety related investigation actions' or '% of overdue process safety related regulatory compliance notices'. There could also be a measure of the number of process safety hazards identified as a ratio to the number of process safety incidents reported.

Linkages

Applicable pillar(s):

Knowledge and competence

This metric is aided by auditing the following areas:

- assurance tasks on safety critical equipment; and
- incident reporting and investigation.

Conducting periodic cultural surveys to determine how individual and corporate cultures align may be a useful activity, though it is difficult to use to generate metrics. There are a number of surveys and papers available, which may be useful. These include the survey conducted as part of *The report of the BP US Refineries Independent Safety Review Panel*¹³, a *Framework for best in class safety culture*¹⁴, and *Safety Culture Maturity® Model*¹⁵.

An example

This metric monitors the exposure to identified items that are yet to be closed, for example to modify the permit to work procedure to include the requirement for an independent checker to verify isolation certificate prior to issuing following an audit.



Title

Number of process safety interactions that occur

Purpose

This metric ensures there is an open culture where individuals will review execution of process safety related tasks to ensure accuracy, compliance and continuous improvement.

A regular and consistent level of process safety interactions should be occurring across all levels of the organisation, which could be structured under behaviour-based safety programmes. A lack of interactions would indicate a requirement to upgrade safety programmes for further emphasis on PS interactions or promote a culture of regular interactions by the workforce.

Response to low levels of interaction would require intervention initially at the supervisor level, which can then be escalated to the operations manager level if additional resourcing or a cultural change is required.

Description

This metric should include process safety related interactions (observation and feedback) including peer-to-peer interactions and a management walk-around during execution of PS tasks. The normalised metric is based on the following equation:

$$\frac{\text{Number of process safety related interactions}}{\text{Number of people (engaged in process safety)}} = \text{ratio}$$

A threshold for each facility or organisation should be set. It may be something like one interaction per person per week. This metric should reflect the threshold being achieved or exceeded. The number of people engaged in process safety needs to be defined for each facility, and this should include the leadership as well as worker level, to ensure that peer-to-peer interactions occur.

| | |
|------------------------|---------|
| Frequency of capture: | Weekly |
| Frequency of analysis: | Monthly |

Metric consolidation

This metric is typically for a site and not usually rolled up. However executive reporting could be done on the senior levels of an organisation, demonstrating their involvement.

Implementation

Measuring interactions can sometimes drive quota-seeking behaviour. Efforts need to be made to ensure that the interactions are of a suitable quality, and not just for the purposes of counting the number. The roll out of such a system is important to ensure the message is understood and it is not just another 'thing to do'. Emphasis should be placed on the quality of the process safety interactions. On occasion, actions may be required to be raised following interactions and should be addressed as part of the normal business process.

Linkages

This metric is linked to systems and procedures and culture.

An example

This metric monitors the level of understanding and open communication concerning process safety and in particular barriers and the health of barriers. Examples of process safety interactions would include peer-to-peer discussion about changes to a barrier; toolbox talks that focus on the process safety hazards; walk-arounds where process safety, rather than personal safety is discussed; workers conducting inspections on barriers discussing the suitability of their equipment (test dates, calibration etc) prior to undertaking testing; and control room operators discussing with maintainers how to respond while equipment is out of service for testing. Many of these items may seem like day-to-day activities, and they are. The important distinction here is that the focus is on process safety awareness and understanding.

Appendix 1

Process safety audit

Auditing for process safety metrics

There are two situations where auditing can be used in process safety metrics:

- audits undertaken on the process safety management system itself, either system audits or compliance audits; and
- audits undertaken on process safety barriers (or controls) where the audit is used as a method for measuring the effectiveness of that barrier. This is usually undertaken on system/procedural barriers where there is no direct or real-time method of measuring whether the barrier is functioning.

This document is focussed on the second situation, ie the situation where an audit is the measurement method for barrier performance. In this situation, the metric for the barrier would normally be:

- number/percentage of audits on the particular barrier that are undertaken to schedule; and/or
- number of non-compliances identified during the audit – this could be qualified by just being significant non-conformances (ie not administrative non-conformances).

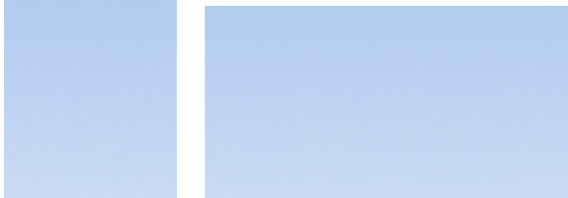
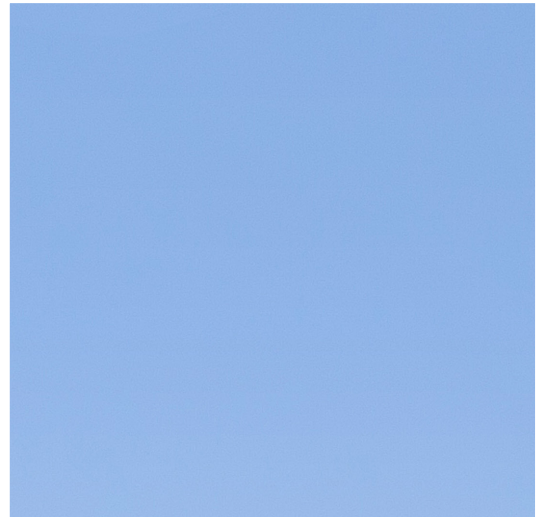
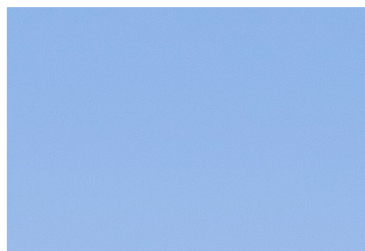
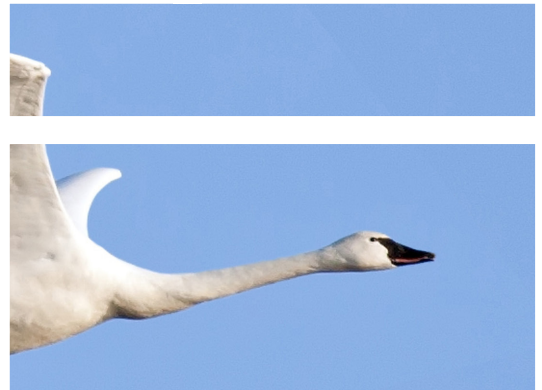
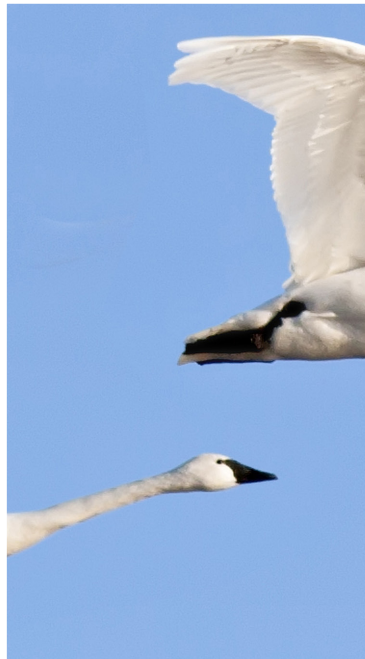
Process safety barriers

Auditing should only be used as a process safety metric where an active monitoring measure is not readily available or effective. Auditing is often not undertaken regularly enough to be classified as a lead indicator. Barriers where an audit metric could be appropriate for measuring process safety are:

- assurance tasks on safety critical elements;
- deviation and temporary operating procedures;
- emergency preparedness for process safety related incidents;
- incident reporting and investigation;
- management of change;
- permit to work; and
- safety critical procedures.

References

1. *Investigation report – Refinery Explosion and Fire*, CSB, Washington DC, 2007.
2. *Recommended Practice 754 – Process Safety Performance Indicators for the Refining and Petrochemical Industries*, API, Washington DC, 2010.
3. *Process Safety Leading and Lagging Metrics... You Don't Improve What You Don't Measure*, CCPS, New York, 2007.
4. *Process Safety – Recommended Practice on Key Performance Indicators*, IOGP, London, 2011.
5. *Developing process safety indicators*, HSE, Surrey, 2006.
6. *Process safety and the ISC*, ISC, Melbourne, 2014.
7. Reason, J, *Managing the Risks of Organizational Accidents*. Ashgate Publishing, Hampshire, 1997.
8. *Fitness for service*, API/AMSE, 2007.
9. *191[1]: Alarm systems – a guide to design, management and procurement*. EEMUA, UK, 1999.
10. Hopkins, AM, Maslen, S, *Risky Rewards – How Company Bonuses Affect Safety*, Ashgate Publishing, Surrey, 2015.
11. *Process safety competency – a model*. ISC, Melbourne, 2015.
12. Schein, E, *Organization Culture and Leadership*, Jossey-Bass, San Francisco, 1985.
13. *The report of the BP US Refineries Independent Safety Review Panel*. Washington, 2007.
14. Mannan, M M, *Framework for creating best-in-class safety culture*, *Journal of Loss Prevention in the Process Industries*, 1423–1432, 2013.
15. *Safety Culture Maturity® Model*, The Keil Centre, Norwich, Health & Safety Executive, 2000.



Contact us for further information

UK

☎ +44 (0)1788 578214

✉ membersupport@icheme.org

Australia

☎ +61 (0)3 9642 4494

✉ austmembers@icheme.org

Malaysia

✉ malaysianmembers@icheme.org

New Zealand

☎ +64 (0)4 473 4398

✉ nzmembers@icheme.org



www.icheme.org

Incorporated by Royal Charter 1957. The Institution of Chemical Engineers (trading as IChemE) is a registered charity in England and Wales (214379) and Scotland (SC039661). The Institution also has associated entities in Australia, Malaysia and New Zealand.