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Lead Process Safety Metrics

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Abstract: Metrics have existed for many years across the occupational realm. In more recent times, there has been a focus on the use of metrics to monitor process safety. This has traditionally focused on lag metrics, as these are easier to monitor and analyse than their leading relatives. Excellent publications, such as the American Petroleum Institute Recommended Practice754, *Process Safety Performance Indicators for the Refining and Petrochemical Industries,* have emerged to provide guidance on how to develop and monitor metrics. Rightly, as defined in the recommended practice, each facility needs to understand what is important for themselves and implement their own leading metrics. This however, has lead to a divergence in what is measure and how it is done. In an effort to enable effective benchmarking, the members of the IChemE Safety Centre initiated a project to develop a suite of common lead metrics. This work, which occurred over a 12 month period, culminated in the release of a guidance document that details lead metrics that can be commonly applied across varied industries. This paper defines the process used to establish the common metrics and shows some examples of the metrics chosen.

1 Introduction

The IChemE Safety Centre (ISC) is an industry funded and led organisation, focused on improving process safety through the sharing of information and learnings. The ISC members can nominate specific areas of focus, and the ISC leads the development work in these areas, with personnel from the 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 the ISC. This consisted of reviewing the lead metrics reported by each member company, looking for commonality. Once this was established, the metrics were selected, or not, for further development, based on their apparent value, i.e. 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 trending indicating improvement.

The metrics selected were chosen on the 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 a 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.

2 Why leading metrics?

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 Texas City Refinery explosion in 2005, which resulted in the development of the American Petroleum Institute Recommended Practice 754 (API RP 754) [1], 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. The tracking of process safety metrics are vital, to help us understand the state of our facilities and systems, as well as provide indication to us of impending issues. Importantly, while lagging process safety metrics will inform you of history, which can be compared to monitor improvement, they will not necessarily predict future loss of control events. While leading metrics are proactive and afford the opportunity to manage potential safety issues. It should be noted that lead metrics are also not an absolute predictor of process safety.

There is guidance material available from other sources, such as the Center for Chemical Process Safety [2], International Association of Oil and Gas Producers [3] and the United Kingdom Health and Safety Executive [4] . These guidance documents focus more on either lagging metrics or guidance on how to develop your own metrics. The guidance developed by the ISC focuses purely on leading process safety metrics and defines specific metrics that work and can be adopted across different organisations. 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 the occurrence of activities. While harder to measure they typically offer more value.

The guidance is aimed at industries that face 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 the background of them, to see if they would indeed provide value, perhaps in a different configuration. The final decision regarding selecting and implementation of metrics will depend on the maturity level of the site and specific focus at the time. Adopting this guidance will start to develop some consistency in lead process safety metrics, and allow effective benchmarking. This will help demonstrate improvements to stakeholders. An organisation may not be able to adopt all the metrics contained in this guidance, however they should endeavour to understand how they are monitoring systems and processes if they do not have these metrics in place.

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 complimenting each other as expected, there may be some underlying issues to be resolved. Additionally, if after a period of time, dependant 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 outcomes.

3 Managing process safety

The ISC believes that effective management of process safety requires leadership across six functional elements in an organisation [5]. These are;

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

Figure 1: ISC process safety framework [5]

These elements can be thought of as a chain of safety, rather than application of Reason's [6] Swiss Cheese model. This is because we do not need failures in all elements to have an incident, but rather single or 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 in the guidance document is monitoring the health of each element.

4 The metrics

There are two types of lead metrics. The first identifies positive situations, such as work being completed to schedule. This is based on positive reinforcement. This is akin to the concept of Safety-II [7] where the focus is on understanding how things go right in a quest to replicate it, as opposed to understanding how things go wrong in a quest to prevent reoccurrence. The premise is that there are far more instances of things going right, so there is a greater source of information to learn form. The focus for this metric is to trend toward 100% compliance, however achieving 100% is not cause to relax, it is cause to explore to ensure the metric is accurate and not misleading about the health of the system. The second type of lead metric is akin to holes forming in the swiss cheese barriers [6]. Therefore this metric measure failure of a barrier, so for it to be considered a lead metric, there must be other barriers that have prevented the consequence occurring. This can be thought of as a measure of the barrier weakness. The focus on this metric is to drive it towards zero, but again a result of zero, or very low should be challenged to ensure it is accurate. So the first type looks for barriers being present and strong, while the second type looks for weaknesses in barriers. A balance between these two types of metrics is important.

It is important to understand the similarities and differences between barriers, primary containment and safety critical elements. In writing the guidance document, a number of assumptions regarding how a facility or organisation has defined these items were made. It is up to each organisation to define these for themselves, on the basis of the major incidents that are preventing. For example, when a metric is referring to the integrity of barriers or primary containment, the items covered should be a final defence prior to a major incident.

Organisations will vary in how they define barriers, so this makes it more difficult to define standard guidelines on barriers. The term safety critical element (SCE) has been chosen to simplify the discussion. A SCE can either be a hardware or administrative barrier that has been determined as being critical in preventing or mitigating a major incident. Some SCE's will be passive, such as fire proofing, and some will be active, such as an emergency shutdown system. Different types of barriers require different management. For this reason, it is important to understand what types of barriers you have in place.

4.1 How the metrics are defined

When considering the metrics, it was important to define multiple aspects of them, such as their purpose, how they could be implemented, what types of decisions the data should support and how they can be consolidated for high level reporting. The following sections were used to define each metric in the guidance document [8].

I. Title
   - a generic term for the metric
II. 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.
III. 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)
IV. 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).
V. Implementation
   - this section speaks about challenges to implementing the metrics and suggestions on how these may be overcome.
VI. Linkages
   - this section ties the metrics back together and highlights where there may be linkages with other pillars or the auditing process discussed in this guidance.

4.2 How the metrics are grouped

It is important to note that the list of metrics defined in the guidance document were first selected on their merit. Once the list was established, they were allocated into their element. At this stage it was found that there were metrics in each element. The metrics are listed in Table 1 with their corresponding element. The metrics are grouped across the six elements by a consensus decision of the ISC and are shown in Table 1.

Table 1: List of metrics with 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 for EEMUA, 1999 see reference [9]

5 Worked example

Figure 2 is an example of a systems and procedures metric is lifted directly from the draft guidance document.

Figure 2: SCE maintenance deferrals extract [8]

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
- 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

6 Conclusion

Defining leading process safety metrics is a challenging task for any organisation. While the majority of available guidance states that each facility must develop their own metrics based on their individual needs, a comprehensive review of the ISC member companies showed commonality in leading metrics. This paper outlined the process followed and rationale behind the metrics chosen to be published in a consolidated guidance document. It is hoped that the implementation of this guidance document will lead to industry benchmarking, to drive improvement in process safety outcomes.

This paper is essentially a summary of the guidance document due to be published in July 2015. At the time of writing this paper the final guidance document was still being finalised. It will be available at the conference, but it was not possible to reference the document in this paper.

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