 

# THE USE OF PROCESS SAFETY PERFORMANCE INDICATORS TO ENSURE THE EFFECTIVE MANAGEMENT OF MAJOR ACCIDENT HAZARD RISKS – THE HEALTH AND SAFETY EXECUTIVE'S EXPERIENCE

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## INTRODUCTION

In 2006 HSE, in collaboration with the Chemical Industries Association published a guidance document on the development of process safety performance indicators, "Developing Process Safety Indicators: A step by step guide for chemical and major hazard industries", HSE publication HSG 254[1]. In this paper we will discuss the approaches that HSE has undertaken to continue to promote the application of metrics in the chemical and major hazards industries, and the developing experience in the practical application of metrics at major accident hazard establishments.

## PROMOTING THE USE OF PROCESS SAFETY PERFORMANCE INDICATORS

There has been considerable support for the step-by-step approach to the development of process safety performance metrics outlined in HSG 254. Most notably, the report of the BP US Refineries independent review panel, established on the request of the US Chemical Safety and Hazard Investigation Board following the BP Texas City disaster[2] (and commonly known as the Baker panel), recommends that BP develop, implement, maintain and periodically modify an integrated set of leading and lagging performance indicators to measure how the BP US refineries are performing with regard to process safety. In this recommendation BP are advised to refer to the guidance developed by bodies such as the Health and Safety Executive, and consider the example of leading and lagging indicators provided in this guidance.

[1]"Developing process safety indicators: a step-by-step guide for chemical and major hazard industries" HSE Books 2006 HSG 254 ISBN 0717661806
[2]"The Report of the BP US Refineries Independent Safety Review Panel" James A Baker III et al. January 2007. http://www.chemsafety.gov/index.cfm?folder=completed_investigations&page=info&INV_ID=52

The recommendation from the Baker panel has been very influential in increasing the interest and understanding of the importance of process safety metrics. Following the publication of HSG 254, HSE had a plan of work to publicise the approach and encourage its adoption among operators of chemical and major accident hazard sites, with the expectation that all operators of top tier COMAH establishments should in time develop appropriate metrics to monitor the effectiveness of the process safety management system on their site. The approach has been a combination of direct contact with duty holders on their sites, and the engagement with intermediaries such as industry trade associations to encourage the development, where appropriate, of sector indicators, to enable duty holders to benchmark their process safety performance against their peers.

The Baker panel findings, following on from the finding of the investigation into the major incidents at BP Grangemouth in 2000[3] and subsequent findings by the Buncefield Major Incident Investigation Board (MIIB)[4] have confirmed that performance metrics on key risk control measures are a vital component of the safety management system for any operation managing major accident hazard risks. The conclusions of these studies into the occurrence of major accidents demonstrate that the probability of the major accidents occurring could have been significantly reduced had the appropriate management systems been in place to ensure that senior decision makers within the relevant organisations received regular targeted information on the health of key components to prevent and mitigate major accidents. For this reason HSE HID CI is expecting operators of Top Tier COMAH establishments to have systems in place to measure the performance of key process safety risk control systems, or to be carrying out a programme of work to develop such a set of metrics.

One very effective mechanism that we have adopted in the development and application of the guidance on process safety performance metrics has been carrying out site specific workshops with operators of major accident hazard plant, using part of their major accident hazard plant as an example to work through the process outlined in the guidance document, to build up a suite of leading and lagging indicators for the key aspects of the major accident hazard safety management system in place for that particular piece of process. This approach, developing site specific leading and lagging metrics in collaboration with major accident plant operators, to enable them to work with the developed metrics, and to judge their practicability and efficacy, has been most effective in promoting the application and training those responsible for their development in how to undertake the process.

[3]"Major Incident Investigation Report – BP Grangemouth Scotland: A Public Report Prepared by the HSE on behalf of the Competent Authority" Health and Safety Executive. August 2003.

[4]"Recommendations on the design and operation of fuel storage sites" Buncefield Major Incident Investigation Board. March 2007. http://www.buncefieldinvestigation.gov.uk/reports/index.htm

In addition, we have worked directly with trade bodies to encourage the development of suites of sector indicators. For example, we have worked closely with the Chemical Industries Association Chlorine Users Group in the development of an extensive suite of process safety performance indicators of particular relevance to operators of sites where the principal major accident hazard is associated with their use of large quantities of chlorine. Representatives from the sector worked with HSE, identified the principal sources of hazard on chlorine handling sites, the key risk control systems (RCSs) relied upon to prevent and mitigate major accident hazards, and some example metrics for which site operators could collect data to monitor the effectiveness of these key risk control systems. The result is an extensive list of potential metrics. From this list site operators can choose a smaller set of particular relevance to their operations and for which they can collect data to monitor their major accident hazard safety management system.

The most important step in the implementation of an effective process safety performance indicators programme at major hazard establishments is the senior management commitment to, and support of the process. Another major recommendation from the Baker panel report, and also a recommendation from the Buncefield MIIB report into the design and operation of fuel storage sites is that senior managers should demonstrate leadership in the area of process safety. The Buncefield MIIB report states "Implementing our recommendations will require the sector to show clear leadership in setting high standards of process safety and environmental protection and in pursuing excellence in operations." Senior management involvement in the establishment and implementation of a PSPI programme is a clear demonstration of their commitment to leadership in the area of process safety, and the continued use of performance indicators to inform decision making continues the demonstration of that commitment.

## TYPES OF INDICATORS

In our work with duty holder in the development of site specific process safety performance indicators we have found a number of common themes. In general, the metrics developed can be identified into one of three categories: process specific **operational control process safety indicators**; site **generic risk control system process safety indicators**; and **programme work process safety indicators**. These cover in turn the specific measures, engineering and human that are relied upon at the Unit level to prevent and mitigate major accidents; site wide common safety management system processes in place to ensure the prevention of major accidents; and site-wide or corporate programmes of work undertaken to underpin the delivery of effective process safety management.

There are a number of key aspects that any major accident hazard safety management system would expect to include. An effective process safety performance indicators system would be expected to have in place some metrics to enable the effectiveness of the delivery of all these elements of the SMS to be monitored and their effectiveness judged. Depending on the nature of the operations undertaken, it should be possible on most establishments to collect data from indicators in the three identified categories (operational

control indicators, generic risk control system indicators and programme indicators) to give information on the effectiveness of the delivery of all the key components of the safety management system.

## OPERATIONAL CONTROL INDICATORS

Operational control process safety indicators are those collected at the Unit or process level that relate directly to the measures in place to prevent loss of containment. These may typically relate to key pieces of process plant being inspected and maintained to the appropriate schedule, process controls and operating envelopes being set correctly, and operators undertaking key steps in safety critical activities at the correct time and in the correct manner.

Lagging indicators for operational control indicators should be set to identify challenges to the integrity of the process, and if possible set at the earliest point of deviation.

Leading indicators may, for example, be determined from data collected on:

- Operator actions to set process controls;
- Operator actions to maintain routine operations;
- Operator effectiveness to take remedial action if the process deviates from the identified safe operating envelope; and/or
- Inspection and maintenance of process control instruments and alarms.

## GENERIC RISK CONTROL SYSTEM INDICATORS

Generic risk control system process safety indicators are those relating to site wide risk control systems that are applied similarly across all units on an establishment. These may be, for example the permit-to-work system, management of change system or emergency response arrangements.

Lagging indicators relating to the generic risk control systems will be incidents that are identified on investigation to be as a result of failures of the generic RCS. These may be loss of containment incidents, process upsets or any particular demands on critical safety systems.

Leading indicators in this category will be identified by checking that the critical tasks required by the RSC are undertaken correctly, for example by audit of isolations under the Permit-to-Work system, or of risk assessments undertaken as part of the management of change system.

## PROGRAMME WORK INDICATORS

Programme work process safety indicators are those relating to statutory or other programme demands that are undertaken across the establishments. These are generally scheduled programmes of work that are expected to be delivered to ensure that the relevant safety management process can be relied upon. This covers key aspects of the safety management system, such as statutory inspections, audits, training of staff in safety critical tasks and development and maintenance of procedures.

The indicators for programme work will predominantly be leading rather than lagging, as it is difficult to identify failure of programme delivery as a single cause of failure of a component of the management system. The leading indicators could be for example:

- Percentage of statutory inspections completed on time;
- Percentage of staff trained to a specific competence; or
- Percentage of the procedures that are up-to-date.

## LEADING AND LAGGING PROCESS SAFETY PERFORMANCE INDICATORS

When discussing the issue of process safety performance indicators, they are regularly referred to as being either leading or lagging metrics, and in the guidance document HSG 254 this terminology is used extensively. In particular, the guidance document promotes the use of leading and lagging indicators in conjunction to give "dual assurance" for each risk control system under examination.

### LAGGING INDICATORS

The lagging indicators are derived to show whether or not the desired outcome for the relevant RCS is being delivered. In many examples of the use of process safety performance indicators, lagging indicators are metrics of loss of containment, fires or other releases that could be precursors to major accidents. However, it is possible to define lagging indicators as being any early indication that the relevant risk control system is failing to deliver its desired outcome, and depending upon the data collection and potential metrics available around the RCS, lagging indicators can be set to give early warnings of the deterioration of the RCS before loss of containment occurs. Lagging indicators should help identify challenges to the integrity of the RCS, and wherever possible should be selected to identify the lowest reasonably detectable event that demonstrates a compromise of the identified safe operating envelope. Depending on the system under consideration, this may be identified by determining that there is overfilling of a vessel, overpressure in a reactor, over-temperature in a furnace, low-flow in a pipeline or excessive corrosion of the pressure containment envelope. The indication point for the relevant metric should be set at the earliest point of deviation, so that reasonable quantities of data can be collected on the number of occasions that the RCS has failed to deliver its desired outcome, resulting in the detectable event occurring. Lagging indicators give no intelligence on why the deviation has occurred; why the RCS has on this occasion failed to deliver its desired outcome. The continuous collection of data of this nature about the key risk control systems that are relied upon to deliver process safety enables data trending to be undertaken and presented, to give evidence of whether the RCS is continuing to deliver the level of protection that is expected of it, whether that level of protection is improving as modifications and enhancements are made to the RCS, or whether the effectiveness of the RCS is deteriorating, indicated by an increasing rate of the relevant lagging metric. The guidance document recommends the establishment of tolerances around the metrics; setting values for

acceptable ranges of the metric with a threshold value such that if the metric reaches a certain level such that it has deviated beyond the acceptable level then there is upwards reporting of this information to enable decisions to be made at an appropriate level as to whether intervention is necessary to address the reduction in the effectiveness of the delivery of the relevant RCS.

### LEADING INDICATORS

The leading indicators derived using the methodology described in HSG 254 relate to the most important parts of the relevant risk control system under consideration; the activities that must be undertaken correctly every time, the aspects of the system that are liable to deterioration or the key activities that are undertaken most frequently. This must obviously be related to some aspect of the RCS that can be measured in some way to enable the collection of appropriate metric data. The leading metrics should be selected to show that for each relevant key RCS the critical controls to reduce and prevent major accidents are working as intended. If selected appropriately, leading indicators should highlight whether the risk control systems in place to deliver process safety are operating as designed. Similarly to the lagging indicators, tolerances should be set such that when deviation of the delivery of the key activity is beyond some acceptable level, there is upwards reporting to enable appropriate remedial action to be initiated.

However, it is recommended that duty holders don't get too concerned about determining whether the indicators that they are developing are leading or lagging. In some cases it is not immediately obvious, and a lot of time can be spent determining into which category a particular indicators sits. If duty holders are able to collect useful, informative data about the performance of the key risk control systems that they are relying on, such that they will get early indication that the RCS is deteriorating, and some indication what needs to be done to improve its performance, then that is valuable information that should be collected, analysed, reported and used.

## LINKING METRICS TO THE PROCESS SAFETY MANAGEMENT SYSTEM

A typical major accident hazard safety management system would be expected to contain the following components:

- Inspection/Maintenance
- Process instrumentation, controls and alarms
- Permit-to-Work system
- Management of Change process
- Safe Plant Design
- Risk Assessments
- Emergency Arrangements
- Competence Framework
- Control of Contractors
- Operational Procedures

- Effective Communications
- Audit and Review

Ideally, each of these components of the SMS should be subject to monitoring of their effectiveness by the use of performance metrics derived from one or more levels within the organisation. In this way, managers at the unit, plant or corporate level, can determine the level of reliance that can be placed on these components to deliver process safety, and can receive early indication of any developing deterioration of the effectiveness of these key components, in advance of any serious loss of containment events occurring.

The information supplied to site managers, and upwards to corporate managers should be a representative sample of the current status of all of the relevant components of the safety management system. These metrics may come from any of the three levels, depending upon the nature of the risk control system, and should include a balance of leading and lagging metrics. Operators should regularly review and revise the metrics chosen for upwards reporting to ensure that the snapshot that is being examined is representative of operations across the establishment, and to ensure that some areas are not being dealt with in a different way because of the collection of particular metrics data.

## REVIEW AND REVISION OF METRICS

It is recommended in the guidance document HSG 254 that all performance indicators are subject to periodic review. A review of the safety management system should be undertaken, based on the metrics information collected to confirm that it is delivering the critical outcomes that it is expected to. The metrics should be updated in the event of any modifications to the plant or process, or to the associated safety management system and risk control systems. In addition, as metrics are developed and used, they can be tailored and improved. Initially metric data may be collected to confirm that a particular aspect of a risk control system is in place, but as experience of the collection and use of metrics develops, and managers require more specific confirmation, data can be collected to determine the degree that a risk control system meets its functional demand. For example, an initial metric to determine the level of staff competence to undertake a safety critical activity may be based on the percentage of staff that have undertaken training in the safety critical activity. This will give some information on the receipt of training, but it will not confirm understanding of the training and translation of the training into working in a safe way. Therefore, a second level, quality metric relating to staff competence may be based on intermittent testing or auditing of those undertaking the safety critical task, and be percentage of staff who, on questioning, understand how to carry out the task in a safe way, or percentage of staff who when observed undertake the task in a safe way.

## EXPERIENCE

The informal feedback so far received from organisations that have developed and adopted process safety performance metrics is very positive. Potential weaknesses have been

 

**Types of Process Safety Indicators**

| Operational Control Indicators | | | Generic RCS e.g. PTW, Plant change, Emergency Arrangements | | Programme Indicators |
|---|---|---|---|---|---|
| Lagging Indicators | Leading Indicators | | Lagging Indicators | Leading Indicators | Leading Indicators |
| Identify challenges to integrity<br><br>Select the lowest detectable event (breach of process control envelope<br><br>Set indicator at earliest point of deviation | Critical operator actions to:<br><br>Set process controls / operating envelope correctly<br><br>Take remedial action if process deviates from operating envelope<br><br>Routine operation control – monitoring actions | Inspection and maintenance of process control instruments and alarms | Loss of containment incidents<br><br>Process upsets<br><br>Demands on safety systems | Critical tasks undertaken correctly e.g. PTW isolations, plant change, risk assessment | % statutory inspections completed to time<br><br>% audits completed to time<br><br>% audit actions closed out on time<br><br>% staff trained to specified competence<br><br>% procedures up to date |

**Figure 1.**

identified and important issues prioritised. A major part of this benefit has been delivered during the process of developing the metrics, where potential weaknesses in the layers of protection being relied upon can be identified. HSE needs to continue to work with organisations that have developed and adopted metrics to determine the benefits that can be gained from going through this process, so that this can be judged against the level of work required to implement such a programme to confirm scale of the benefit and the practicability of applying this process.

 

## CONCLUSIONS

HSG 254 has been very influential in the development and adoption of process safety performance indicators on major accident hazard sites. Even so, there is still the need for continued promotion of the adoption of metrics, as they are very effective in the identification of potential failure in major accident hazard safety management systems.

HSE HID CI is expecting operators of Top Tier COMAH establishments to have systems in place to measure the performance of key process safety risk control systems, or to be carrying out a programme of work to develop such a set of metrics.

HSE will undertake further work with organisations that have adopted metrics to confirm the scale of the benefits to be gained.

It important that senior managers are committed to the application and use of performance metrics to ensure that they continue to be collected, and that the information that they reveal is understood and acted upon.

Data should be collected at the unit and site wide levels, and metrics from the delivery of key safety programmes should also be collected. These metrics should be selected and analysed to allow senior managers to receive brief summary data on the effectiveness of the key aspects of the safety management system on a regular basis. In this way senior managers can demonstrate understanding of the measures being relied upon to prevent and mitigate serious accidents, and be able to take informed decisions on the need for improvements in the management system as a result of the metrics information.

Both leading and lagging indicators should be developed to test the effectiveness of the safety management system, but in some cases it will not be possible to develop both, or it will be difficult to determine if an indicator is leading and lagging. If the metric is one that can be collected and that will give valuable information on the performance of the safety management system, then it is not necessary to determine whether it is leading or lagging, just that the information that it supplies is used effectively.