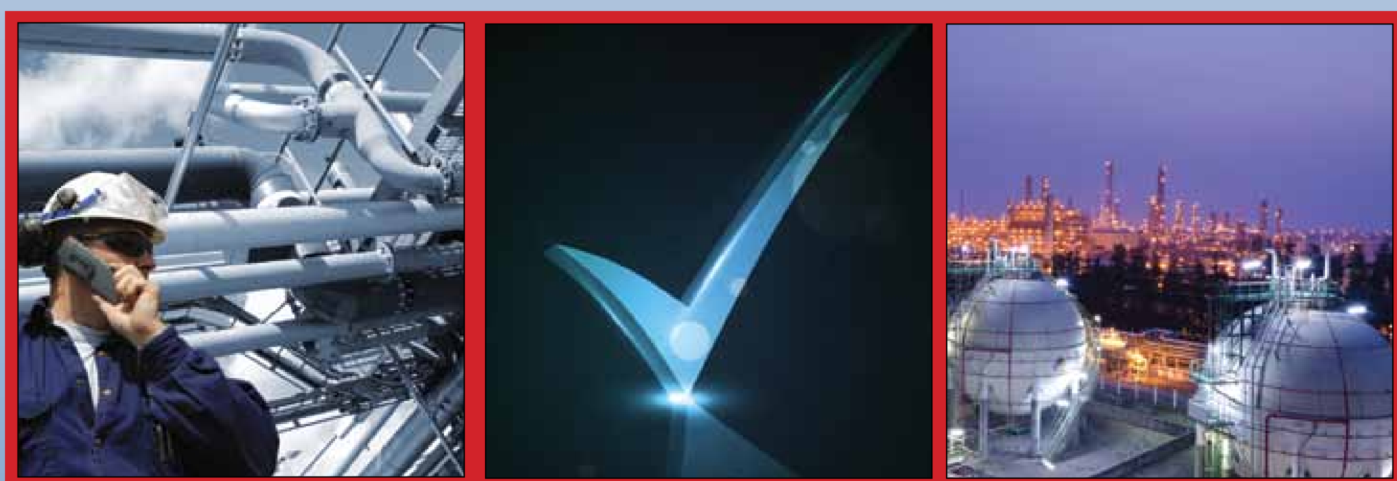
An AIChE Technology Alliance

CCPS

Center for Chemical Process Safety

Process Safety Leading Indicators Industry Survey



The survey includes a complete version of Process Safety Leading and Lagging Metrics … You Don't Improve What You Don't Measure

CCPS Process Safety Leading Indicators Industry Survey

Preface

The Center for Chemical Process Safety (CCPS) was established in 1985 by the American Institute of Chemical Engineers (AIChE) for the express purpose of assisting industry in avoiding or mitigating catastrophic chemical accidents. In 2012, CCPS updated our mission to eliminate process safety incidents, in all industries. To accomplish this, more than 150 corporate members around the world have created and sustain a community committed to process safety. Together, we drive the activities of CCPS.

In 2006, the CCPS Technical Steering Committee authorized a project committee to develop a Guideline book for the development and use of Leading and Lagging Process Safety Metrics. That committee identified that a key breakthrough opportunity for industry was the establishment of an industry lagging metric that would become the benchmark across the chemical and petroleum industry for measuring process safety performance. To achieve this objective, representatives and members from each of the major chemical and petroleum trade associations as well as other key stakeholders were engaged.

The outcome of that effort was published in December 2007. Many companies and organizations have used those metric definitions since publication. Those definitions established in 2007 were a key input to the creation of a new ANSI/API standard (ANSI/API RP 754), which was finalized and released in April 2010. CCPS and several members of the original CCPS Metric committee were involved in the API standard committee.

In 2011, CCPS updated of the December 2007 publication with the intent to align CCPS and API documents. A copy of this stand-alone document, "Process Safety Leading and Lagging Metrics… You Don't Know What You Don't Measure"[2] is available at the CCPS Website at http://www.aiche.org/sites/default/files/docs/embedded-pdf/CCPS_ProcessSafety2011_2-24-web.pdf.

For ease of use, this document has been included in Appendix D of this report. These documents, when used together create a solid foundation for the establishment and use of both Leading and Lagging indicators.

In 2013, CCPS continues its efforts for the development and use of Leading and Lagging Process Safety Metrics with this update publication focused on the use of leading process safety metrics.

This publication provides an update on the chemical, petroleum and other process industries use, direction and effectiveness of leading indicators and to provide recommended leading indicators to help drive performance improvement and lead to the reduction in the number and severity of process safety incidents. As the use of leading indicators is in its early stages, it is anticipated that this topic will continue to evolve. Additional surveys will be conducted and updates published periodically.

Executive Summary

The purpose of this document is to provide an update on the use, direction, and effectiveness of Process Safety leading indicators in the chemical, petroleum and other process industries. Leading Indicators are intended to help drive performance improvement and lead to reduction in the number and severity of process safety incidents. The information presented in this document was collected through a survey of CCPS member companies.

A high percentage of companies recognize the value in utilizing leading indicators to support management in focusing engagement and efforts of the engineering and operations personnel. Although the survey would indicate that the industry is still 'experimenting and discovering' as to which indicators provide the greatest value, three different focus areas or approaches were identified as most effective in improving performance. These are as follows:

Ensuring Follow-up on Actions across the Spectrum of Process Safety Management Systems.

- Audit Corrective Actions
- PHA Actions
- Completion of Safety Critical Equipment Inspections or Calibrations
- MOC Actions
- Unplanned Event Corrective or Preventive Actions

Leveraging Learning Experiences and Management of Deviations

- Process Safety Near Miss Reporting including Fires
- Challenges to Safety Systems in general and specifically calling out: Safety Instrumented Systems and Relief Device Activations

Ensuring Management Engagement

Picking the most pertinent measures to your operation and getting them in front of leadership; including them in agendas of various operational reviews and ensuring action.

The survey indicates there is still work needed to assist companies to reach a better understanding of the definitions intended for certain leading indicators to harmonize the understanding and usage. Most of the companies responding indicated they roll their measures up into meaningful scorecards, prompting management action, and review with senior leadership, in some cases all the way up to board members. Most companies also publish the data on internal review reports, websites and in newsletters for communication and action throughout their company.

Needless to say, it is essential to have management involvement, mentoring (conversation with employees) and support in implementation. Leading indicators, by their nature, may tend to convey a negative connotation as a weakness in Management Systems, but if considered as opportunities for improvement, they will start to drive improvements. As is the case with any company program, senior management support and commitment are essential for the implementation and sustainability of a successful metrics program.

Long-term success in making process safety robust and reliable will involve management commitment to widen the scope of leading indicators and to actively share and learn with others in the industry.

1. Introduction: Project Purpose and Scope

As outlined in the *CCPS Process Safety Leading and Lagging Metric…You Don't Improve What You Don't Measure 2012*[2] publication, an essential element of any improvement program is the measure of existing and future performance. Therefore, to continuously improve upon process safety performance, it is essential that companies in the chemical and petroleum industries implement effective leading and lagging process safety metrics.

This document summarizes the respondents' survey input regarding:

- Which leading indicators companies are currently utilizing and are finding most effective in driving performance objectives.
- The identification of barriers during implementation.
- The strategies used to overcome barriers in the implementation.

This document began with a project to perform a broad survey of chemical companies' use of leading metrics in order to determine:

- Commonalities of approach
- Areas of potential difference
- Good practices worthy of consideration
- Areas needing improvement

The anticipated result of this project is the continuous updating of member companies' and their journey on the effective use of leading indicators. Process improvement is realized overtime through subsequent reporting which will drive process safety performance progress.

1.1 Background

Chemical Process Safety Indicators are generally broken down into the following categories:

"Lagging" Metrics – a retrospective set of metrics that are based on incidents that meet the threshold of severity that should be reported as part of the industry-wide process safety metric.

"Challenges to Safety Systems, Near Miss" and other internal Lagging Metrics – the description of less severe incidents (i.e., below the threshold for inclusion in the industry lagging metric), or unsafe conditions which activated one or more layers of protection. Although these events are actual events (i.e., a "lagging" metric), they are generally considered to be a good indicator of conditions which could ultimately lead to a more severe incident.

"Leading" Metrics – a forward looking set of metrics which indicate the performance of the key work processes, operating discipline, or layers of protection that prevent incidents.

These three types of metrics can be considered as measurements at different levels of the "safety pyramid[2]" illustrated in Figure 1. Although Figure 1 is divided into four separate layers (process safety incidents, other incidents, near miss, and unsafe behaviors/Insufficient operating discipline), it is easier to describe metrics in terms of the three categories defined in Figure 1. It is strongly recommended that all companies incorporate each of these three types of metrics into their internal process safety management system.

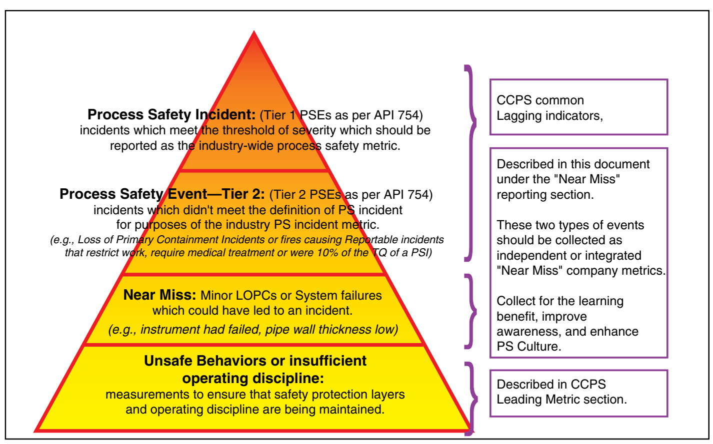


Figure 1. CCPS, "Process Safety Leading and Lagging Metrics… You Don't Know What You Don't Measure" AICHE, New York, 2011

Lagging indicators for the industry are fairly well defined and efforts are underway for formally gaining a standardized global definition. CCPS has received input from the industry that publications on Process Safety Metrics are incomplete regarding leading indicator recommendations in its Tier 3 (challenges to safety systems) and Tier 4 (Operating Discipline), which will present a challenge to implementation. Also, in some regions where formal Process Safety Metrics do not apply, there is a growing desire for recommended leading indicators to help drive performance in a common direction.

Tier 3 indicators are an actual event or discovery of a potentially unsafe situation; therefore these metrics fall within the continuum of "leading" and "lagging" metrics. A large number or increasing trend in such events could be viewed as an indicator of a higher potential for a more significant event; therefore, many companies use Near Miss metrics as a surrogate for a "Leading" metric. Tier 3 incidents by definition are a failure of our process safety management systems and give an excellent road map to where management systems need to be strengthened.

Tier 4 Leading indicators monitor the health of important aspects of the process safety management system. If measured and monitored, data collected for leading metrics can give early indication of deterioration in the effectiveness of key safety systems, and enable remedial action to be undertaken to restore the effectiveness of these key barriers, before any loss of containment event takes place.

2. Data Summary

The received survey results were tabulated and analyzed to determine the number of leading indicators used by companies. Of the 43 responding companies (95% of the responding companies), 41 used leading indicators, thus indicating broad use of leading indicators.

The use of leading indicators varies by company, from a low of three leading indicators to as many as 28 leading indicators for a company.

The chart shown in Figure 2 plots the number of leading indicators used by companies; with tier 3 leading indicators shown in red and tier 4 leading indicators shown in blue.

Each of the 25 leading indicators was used by one or more of the responding 43 companies. However 12 or more leading indicators were used by 20 or more of the 41 companies, or over 45% of the companies that responded to the survey.

The red box on the chart (Figure 2) highlights the 12 leading indicators used by the 20 or more companies.

2.1 Metrics found most effective / how do you make them visible?

We received input from 31 of the 43 companies in this area. Although the survey would indicate that the industry is still 'experimenting and discovering' as to which indicators make the most sense, three different focus areas or approaches were identified as most effective in improving performance. These are as follows:

2.1.1 Follow-up on actions across the spectrum of Process Safety Management Systems

- Audit Corrective Actions
- PHA Actions
- Completion of Safety Critical Equipment Inspections or Calibrations
- MOC Actions
- Unplanned Event Corrective or Preventive Actions

2.1.2 Learning Experiences and Management of Deviations

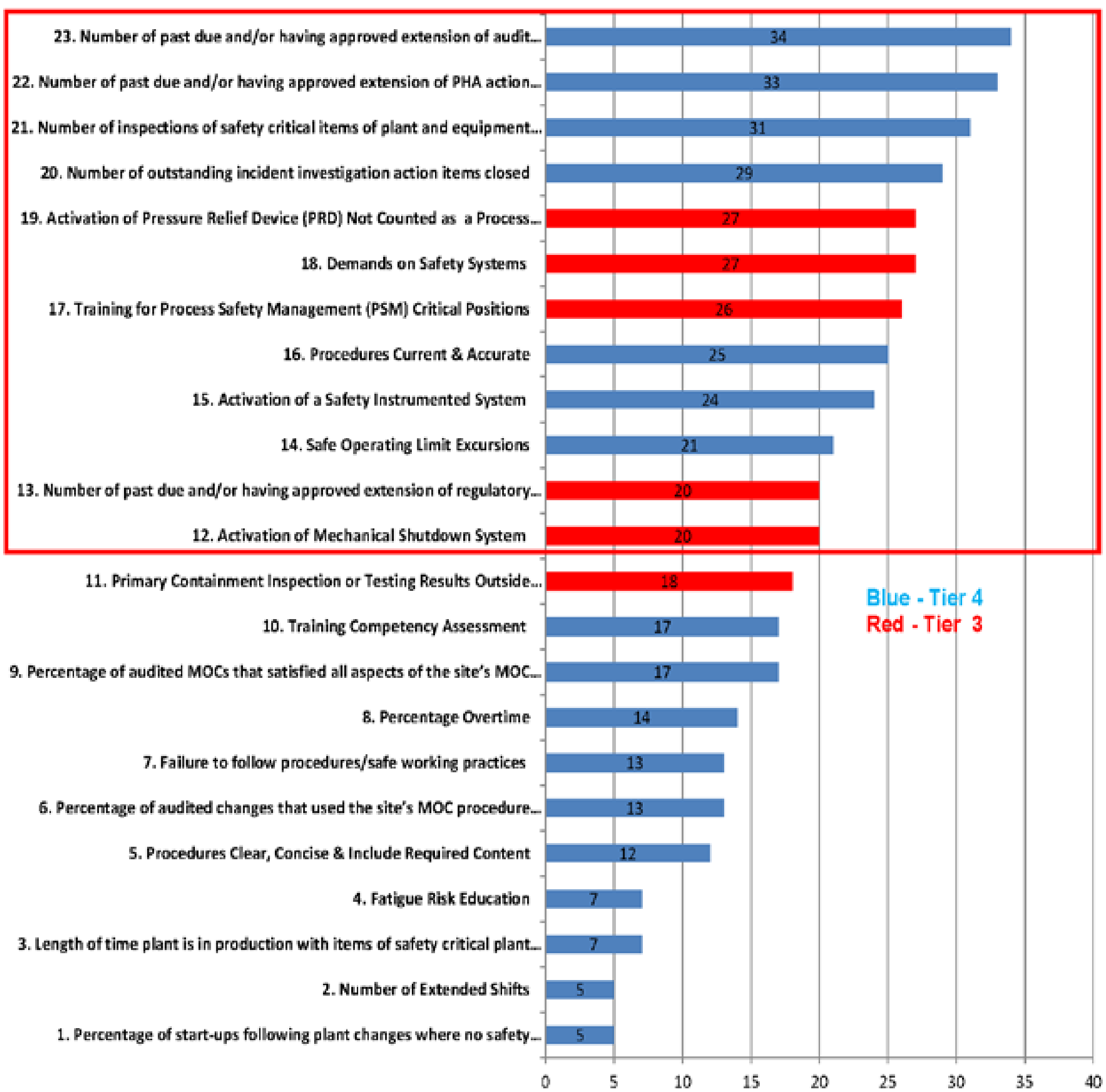
- Process Safety Near Miss Reporting including fires
- Challenges to Safety Systems in general and specifically calling out Safety Instrumented System and Relief Device Activations

2.1.3 Management Engagement

- Picking the most pertinent measures to your operation and getting them in front of leadership
- Including the pertinent measures in agendas of various operational reviews and ensuring action

Figure 2 -Number of Companies using a Specific Indicator*

*see Appendix B for numeric data and a list of leading indicator names



3. Metric Selection

Two companies indicated that they had not started on Tier 3 and Tier 4 measures. However they had just implemented Tier 1 & 2 metrics and were seeing an immediate impact; i.e., improved performance. One company indicated they have seen strong improvements from monitoring "work permit auditing statistics". These points demonstrate the adage: "You Don't Improve What You Don't Measure."

Most of the companies responding indicated they roll their measures up into meaningful scorecards which prompts management action, and review with senior leadership. In some cases the review is elevated all the way up to the board member level. Most also publish the data on internal review reports, websites and in newsletters for communication and action throughout their company.

4. Where More Guidance is Needed

The specific survey question asked if further definition and guidance is needed on the definition for "challenges to safety systems."

As companies start to collect data on metrics, specific situations arise which demonstrate that the original definitions are not sufficient. Through dialogue between Member Companies, agreement can be reached on common definitions and conventions. Consistency is needed between companies and within companies to ensure that there is a common understanding of the meaning of "challenge to a safety system" so that tracking of progress on this metric will be on a consistent basis.

Twenty-five companies responded to this question and the responses were mixed on this topic.

- Fifteen of the responding companies felt that the existing guidance was sufficient. Eight of the companies indicated they had been using these metrics and were comfortable in their understanding. Three companies indicated that they were not yet using these metrics.
- Seven companies felt additional guidance would be useful to ensure that "challenges to safety systems" is used consistently within and between companies. The need for internal understanding and consistency between operators and engineers was also raised by one of the companies that indicated no additional industry guidance is required.
- Two companies included examples of what they would consider as challenges to safety systems in their responses.

The issue of definitions is also addressed more broadly in the section on Barriers to Implementation.

5. Barriers to Implementation

5.1 Introduction

Of the 43 responders to the CCPS PS KPI Survey, 35 either provided feedback on what types of issues/ barriers they encountered in their PS KPI implementation activities or shared learning on what approaches worked best for them. As one would expect, there were a number of common elements.

5. 2 Commitment/Support

As is the case with any company program, senior management support and commitment is essential for the implementation and sustainability of a successful metrics program. Furthermore, it also makes sense to undertake an effort to align the metrics with the company business plan and culture. Too many metrics can result in information overload making it more difficult for executives to understand the information and how to apply it in selecting improvement opportunities.

5. 3 Definitions

Another key barrier was the differences in understanding the metrics definitions. Comments would indicate there is just enough vague wording in metrics definitions to cause some company inconsistencies in their application. Companies with a large number of facilities scattered around North America had the added issue of reconciling the apparent differences in which individual facilities viewed the definitions. Global companies add yet another layer of complexity to definition application. The challenge of integrating acquisition facilities should not be underestimated.

5. 4 Data Collection

Data collection systems often did not readily produce the information companies wanted to track; i.e., designed for injury tracking but not for Process Safety incidents. Developing good metrics often involves changing and standardizing systems so that the scope of what is and isn't included is consistent. Significant time and money are needed in the development of data collection systems to enable easier collection of information relating to leading indicators. Automated data output is also essential if company management is to utilize the information in a timely manner. It is essential to be clear as to why the data is being collected and how it will be used. If the need for measuring performance is not seen, it will not be done.

Communication to the workforce about the criteria for inclusion can take a great deal of time and effort. Training, open communication channels and recognizing that data consistency will not be perfect from the start but will improve over time are important messages that employees at all levels need to hear.

The result from the collected information needs to be presented in a format that those who are expected to act on it can readily understand the messages. Simplified charts and graphic representations as opposed to heavily detailed charts worked best. Likewise, accompanying interpretation statements which are concise and not overly detailed are recommended.

5. 5 Resources

In general, the view was that the collection of data to track a metric takes a large amount of resources in order to report them in a timely manner. Those companies that already had some computerized data collection systems in place mentioned resource challenges but did so to a much lesser degree. Maintaining trained resources who understood the definitions and how to extract the data from the computer tracking system presented another challenge due to transfers, turnovers and retirements.

5. 6 Reluctance to Implement

Starting a new program or modifying an existing safety program almost always has some resistance to change. Because of the potential performance aspects of tracking KPIs, a few companies indicated the presence of a lingering cultural heritage at some sites that may have discouraged reporting because of the connection to discipline. Progress has been made and will continue in this regard as management demonstrates a clear focus on system weaknesses rather than simply blaming human error. It takes a while to change culture. Take it slow, implement simple metrics and try not to implement too many metrics at once.

6. Metrics Discarded and New Metrics being Considered

The choice of which leading metrics are the most effective for an organization is expected to change over time for any number of good reasons, including diminishing value for a particular metric due to implementation of effective change.

6.1 Revising metrics which become "Habit Strength"

Thirty-three of the companies responded to the question "Do you switch metrics after performance improves or the Management System reaches 'habit strength'"?

Twelve of these companies responded yes and cited the following reasons for doing so:

- Due to substantial improvements, the earlier leading metrics no longer represent areas where focus or improvement efforts were needed. This was decided after periodic reviews of performance and prioritization efforts to identify the areas of higher need.
- Some companies have evolved their leading metrics to better focus on the issues. While staying close to the original issue, the emphasis may be changed to better align with an improved understanding of the underlying issue that was intended to be addressed.
- As performance improved on key metrics, these metrics are often moved to the background and others brought forward for additional emphasis. Even as this is done, the old metrics often are continued to ensure that progress is maintained.
- Some leading metrics are used to help drive the management system improvements – for instance early on there is often an emphasis on data collection in a given topic area. Over time data collection improves and the metric can be redirected at a related issue which is more indicative of the PSM performance.

Those companies who have not yet changed their leading metrics (as those 21 companies) typically felt they were too early in the process to make changes. As opposed to continuing to gain experience and assessing what the leading metrics were indicating.

6.2 Discarding Metrics

Twenty-eight companies responded to the question regarding discarded metrics. Twenty-two stated that they had not discarded any metrics at this time, but some metrics had been de-emphasized since tracking had started.

Six of the responding companies stated that they had changed their leading metrics and cited the following reasons for doing so:

- The initial metric was intended to be only useful over the short-term to drive certain initiatives and when sufficient momentum was attained, the metric was intended to be changed.
- The metric was modified to make it more useful, but the underlying intent remained much the same.
- Some metrics were found to have limited usefulness and were of much less value than the effort to collect the data.
- As metric performance shows full implementation or compliance, these offer the opportunity to sunset these metrics and implement others.
- A few companies stated they dropped a few leading metrics because they did not see value in continuing to monitor that particular issue/metric.

The following are metrics which the responding companies have chosen to discard as they were not felt to lead to improved performance:

- Fatigue Risk Management
- Number of MOCs completed
- Maintenance Costs
- Number of contractor audits performed
- Number of audit findings
- Ratio of safety critical emergency work orders to total work orders
- Average time to complete incident investigations
- Presence in PSM related committees

6.3 New Leading Indicators

Thirty-three companies responded to the question regarding which leading indicators are being considered for the future. Twenty-nine stated that they were considering new metrics.

Of the companies who are considering new leading indicators, some had very specific areas that they wanted to focus on and others were vague.

Specific examples included:

- Preventive Maintenance activities which reveal a deficiency

- Alarm management, including nuisance alarms and disabled alarms
- Senior leadership time in the field
- Measure the performance of Independent Protection Layers
- Reporting of Process Safety near misses
- PHA recommendation progress (number open, number closed, time to closure)
- Fatigue risk management

Examples of less specific leading indicators which are being considered include:

- Process Safety Culture
- Tier 3 and Tier 4 metrics
- Improve the quality of the measures currently used
- Monitor procedures [quality]
- Incident investigation quality

In summary, key metrics tend to be more dynamic for companies who have been collecting data longer, as they have a better understanding of what metrics are important to drive the changes they want to effect. Many of these companies continue to collect data on their earlier metrics, but often will move these to the background as new metrics are added to their portfolio.

Companies with less experience are still learning how to capture the data and assess if the data is providing meaningful information and, as such, they tend to keep their initial set of leading metrics.

7. Conclusions

A high percentage of companies recognize the value in utilizing Leading Indicators to assist management in focusing engagement and efforts of the engineering and operations personnel. Although the survey would indicate that industry is still 'experimenting and discovering' as to which indicators make the most sense, three different focus areas or approaches were identified as most effective in improving performance. These are as follows:

7.1 Follow-up on Actions across the Spectrum of Process Safety Management Systems.

- Audit Corrective Actions
- PHA Actions
- Completion of Safety Critical Equipment Inspections or Calibrations
- MOC Actions
- Unplanned Event Corrective or Preventive Actions

7.2 Learning Experiences and Management of Deviations

- Process Safety Near Miss Reporting including fires
- Challenges to Safety Systems in general and specifically calling out Safety Instrumented Systems and Relief Device Activations

7.3 Management Engagement

- Picking the most pertinent measures to your operation and getting them in front of leadership.
- Leadership inclusion on all agendas and various operational reviews insure action.

The survey indicates there is still work needed to assist companies to reach a better understanding of the definitions intended for certain leading indicators that harmonize their understanding and usage. Most of the companies responding indicated they roll their measures up into meaningful scorecards, prompting management action, and review with their senior leadership. In some cases the review process goes all way the way up to the board member level. Most also publish the data on internal review reports, websites and newsletters for communication and action throughout their company.

Needless to say, it is essential to have management involvement, mentoring and conversation with employees and support in implementation. Leading indicators by their nature will tend to convey a negative connotation as weakness in Management Systems but if considered as opportunities for improvement they start to drive improvements. As is the case with any company program, senior management support and commitment are essential for the implementation and sustainability of a successful metrics program.

Long term success in making process safety robust and reliable will involve management commitment to widen the scope of leading indicators and to actively share and learn with others in the industry.

8. Future Steps

The following activities are scheduled to continue the focus on the development of leading indicators in the chemical industry:

- Paper Presentation at the 9th Global Congress on Process Safety in April 2013.
- Publication of the Document in CCPS website for comments.
- Communication to CCPS Member companies to adopt leading indicators and inform CCPS of the list of indicators adopted along with the definitions and examples.
- The members of this Project Team to share their own company experiences in use of leading indicators.
- The review to be included in the 2014 Global Congress on Process Safety.
- Biannual Survey from the CCPS members.

9. References

[1] American Petroleum Institute, ANSI/API Recommended Practice 754, Process Safety Performance Indicators for the Refining and Petrochemical Industries, First Edition, Washington D.C., 2010.

[2] CCPS, Process Safety Leading and Lagging Metrics …You Don't Improve What You Don't Measure, hhttps://www.aiche.org/ccps/resources/overview/process-safety-metrics/recommended-process-safety-metrics.

10. Appendices

Appendix A

Process Safety Metrics Leading Indicator Survey Data

Process Safety Metrics Leading Indicator Survey Data can be provided by contacting ccps@aiche.org.

Appendix B

Numeric Data/Leading indicators used in Fig.2

Leading indicators*	Number of Companies using Leading Indicators
1. Percentage of start-ups following plant changes where no safety problems related to the changes were encountered during re-commissioning or start-up	5
2. Number of Extended Shifts	5
3. Length of time plant is in production with items of safety critical plant or equipment in a failed state, as identified by inspection or as a result of breakdown	7
4. Fatigue Risk Education	7
5. Procedures Clear, Concise & Include Required Content	12
6. Percentage of audited changes that used the site's MOC procedure prior to making the change	13
7. Failure to follow procedures/safe working practices	13
8. Percentage Overtime	14
9. Percentage of audited MOCs that satisfied all aspects of the site's MOC procedure	17
10. Training Competency Assessment	17
11. Primary Containment Inspection or Testing Results Outside Acceptable Limits	**18**
11. Activation of Mechanical Shutdown System	**20**
13. Number of past due and/or having approved extension of regulatory issue	20
14. Safe Operating Limit Excursions	**21**
15. Activation of a Safety Instrumented System	**24**
16. Procedures Current & Accurate	25
17. Training for Process Safety Management (PSM) Critical Positions	26
18. Demands on Safety Systems	**27**
19. Activation of Pressure Relief Device (PRD) Not Counted as a Process Safety Incident (PSI) or Loss of Primary Containment (LOPC)	**27**
20. Number of outstanding incident investigation action items closed	29
21. Number of inspections of safety critical items of plant and equipment due during the measurement period and completed on time	31
22. Number of past due and/or having approved extension of PHA action items	33
23. Number of past due and/or having approved extension of audit action items	34

** NOTE: Tier 3 indicators shown in red; Tier 4 indicators shown in black*

Appendix C

Process Safety Metrics Survey Form

Process Metrics Survey

A survey of Leading indicator Process Metrics

Company Name

Name

Title First Last Suffix

Phone Number

- ### -

Phone Number - If International

Company Email Address

Company Type - Select a Choice

Commodity and Special chemicals

Tier 3 Metrics - Challenges to Safety Systems / Process Safety Near Miss (PSNM)
Do you follow CCPS or API RP 754 definitions for Tier 3?

if so, check the "yes" box for the leading indicator and the check the boxes for the region or regions

Safe Operating Limit Excursions

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Primary Containment Inspection or Testing Results Outside Acceptable Limits

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Demands on Safety Systems

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Activation of a Safety Instrumented System

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Activation of Mechanical Shutdown System

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Activation of Pressure Relief Device (PRD) Not Counted as a Process Safety Incident (PSI) or Loss of Primary Containment (LOPC)

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Process Safety Metrics Survey Form (continued)

Other Loss of Primary Containment (LOPC) Events and other comments

Tier 4 Metrics - Management System Health
Do you follow CCPS or API RP 754 definitions for Tier 4?
If so, check the "yes" box for the leading indicator and the check the boxes for the region or regions

• Maintenance of mechanical integrity:

Number of inspections of safety critical items of plant and equipment due during the measurement period and completed on time

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Length of time plant is in production with items of safety critical plant or equipment in a failed state, as identified by inspection or as a result of breakdown

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Other Maintenance of Mechanical integrity Leading indicators and other comments

• Action items follow-up:

Number of past due and/or having approved extension of audit action items

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Number of past due and/or having approved extension of PHA action items

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Number of outstanding incident investigation action items closed

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Number of past due and/or having approved extension of regulatory issue

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Other Action items follow up Leading indicators and other comments

• Management of change (MOC):

Percentage of audited MOCs that satisfied all aspects of the site's MOC procedure

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Percentage of audited changes that used the site's MOC procedure prior to making the change

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Process Safety Metrics Survey Form (continued)

Percentage of start-ups following plant changes where no safety problems related to the changes were encountered during re-commissioning or start-up

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Other Management of Change Leading Indicators and other comments

---

• Process safety training:

Training for Process Safety Management (PSM) Critical Positions

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Training Competency Assessment

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Failure to follow procedures/safe working practices

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Other Process Safety Training Leading Indicators and other comments

---

• Fatigue Risk Management

Fatigue Risk Education

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Percentage Overtime

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Number of Extended Shifts

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Other Fatigue Risk Management Leading Indicators and other comments

Process Safety Metrics Survey Form (continued)

Section Break

- Operating & Maintenance Procedures

Procedures Current & Accurate

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Procedures Clear, Concise & Include Required Content

☐ yes ☐ Company-wide ☐ Business-level ☐ Facility -level ☐ Regional

Other Operating & Maintenance Procedures
Leading Indicators and other comments

Do you switch metrics after performance improves or the Management System reaches "habit strength"
If so, please describe

How do you make these visible and how do you communicate?
Please describe

Process Safety Metrics Survey Form (continued)

How do you characterize the level of risk at the site and how the level of maturity might affect the metrics?
Please describe

•Which metrics have not correlated to improved performance and have been discarded?
Please list and discuss

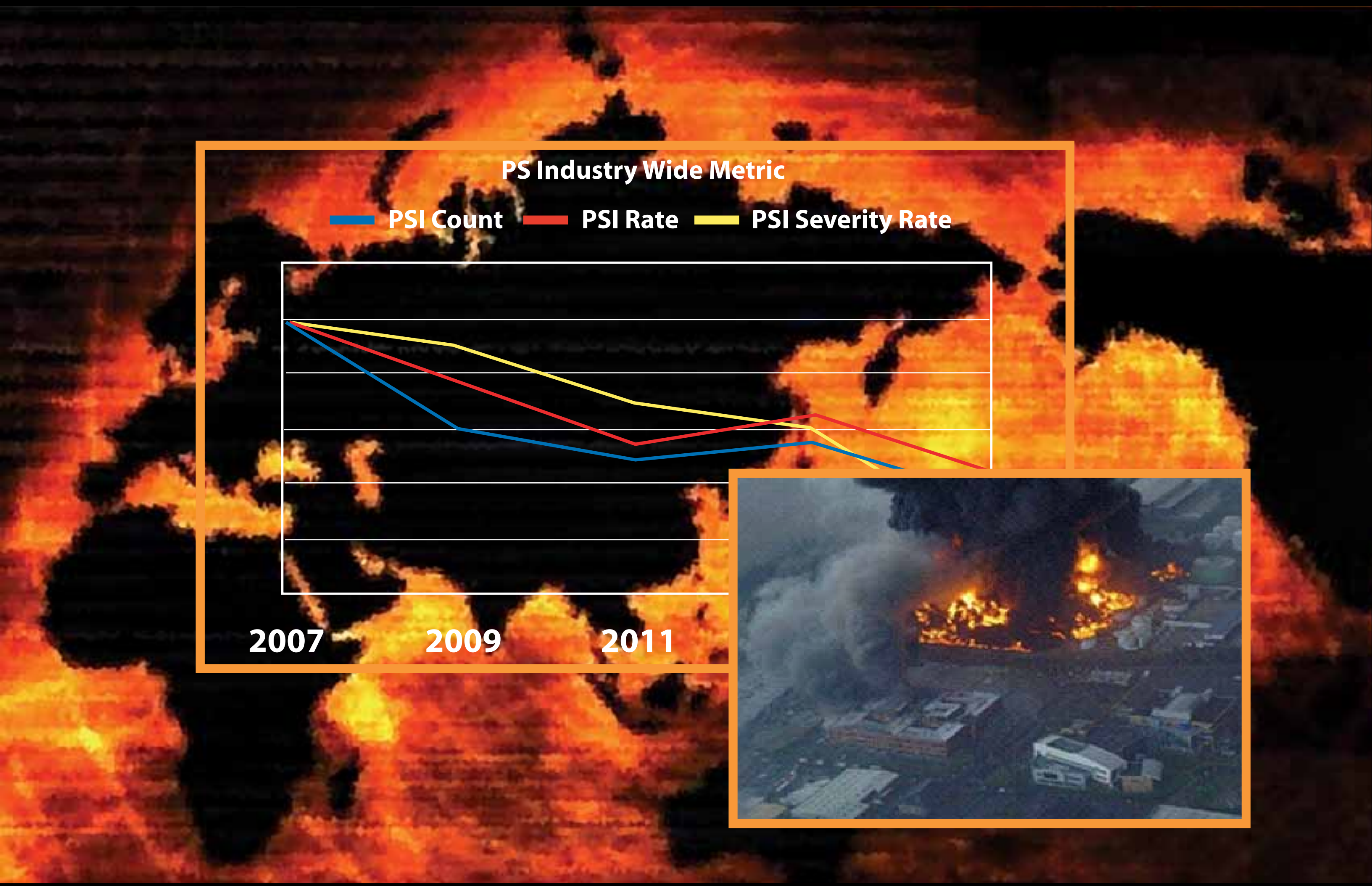
•Did you specifically consider other Leading Indicators from the recommended list of metrics for the 20 elements of Risk Based Process Safety (RBPS), if so please list

Appendix D

"Process Safety Leading and Lagging Metrics … You Don't Know What You Don't Measure" © 2011

Process Safety Leading and Lagging Metrics

...You Don’t Improve What You Don’t Measure



An AIChE Technology Alliance

CCPS

An AIChE Industry Technology Alliance

Revised: January 2011

Preface

The Center for Chemical Process Safety (CCPS®) was established in 1985 by the American Institute of Chemical Engineers (AIChE) for the express purpose of assisting industry in avoiding or mitigating catastrophic chemical accidents. More than 130 corporate members around the world drive the activities of CCPS.

In 2006, the CCPS Technical Steering Committee authorized the creation of a project committee to develop a Guideline book for the development and use of Leading and Lagging Process Safety Metrics. That committee identified that a key breakthrough opportunity for industry was the development of an industry lagging metric that would become the benchmark across the chemical and petroleum industry for measuring process safety performance. To achieve this objective, representatives and members from each of the major chemical and petroleum trade associations as well as other key global stakeholders were engaged.

The outcome of that effort was published in December 2007. Many companies and organizations have used those metric definitions since 2008. Those definitions established in 2007 were a key input to the creation of a new ANSI/API standard (ANSI/API RP 754), which has been finalized and released in April 2010. CCPS and several members of the original CCPS Metric committee were involved in the API standard committee.

CCPS has elected to update the original (December 2007) document describing the CCPS metric recommendations with minor revisions with the intent to align the CCPS and API documents. The intent is that if a company or organization utilizes either the CCPS or API definitions for the top tier process safety incident definitions that they will count the same incidents. However, there are a few principles described in the CCPS metric document which are not incorporated in the API document (e.g., the description and use of a severity-weighted metric). Since the API document references the CCPS definition it is important to retain both documents, yet maintain good alignment between the two.

There are also a few additions incorporated into the ANSI/API RP 754 document which may not be deemed necessary by all companies or trade associations internationally that have already began utilizing the 2007 CCPS document (e.g., the definitions of a "Tier 2" process safety event). This updated CCPS metric document will note those differences, yet describe those as "optional" metrics or definitions.

The ultimate goal of the 2006 CCPS project was to develop and then promote the use of common metrics across the industry and around the world. CCPS continues to support that objective, whether via adoption of the ANSI/API RP 754 definitions or via use of this document.

[1] American Petroleum Institute, ANSI/API Recommended Practice 754, *Process Safety Performance Indicators for the Refining and Petrochemical Industries*, First Edition, Washington D.C., 2010.

For more information on CCPS or these metrics
please visit www.ccpsonline.org

CCPS Process Safety Metrics

"*You don't improve what you don't measure*"

Introduction

An essential element of any improvement program is the measure of existing and future performance. Therefore, to continuously improve upon process safety performance, it is essential that companies in the chemical and petroleum industries implement effective leading and lagging process safety metrics. This document describes the recommendations assembled by the Center for Chemical Process Safety (CCPS) Process Safety Metric committee for a common set of company and industry leading and lagging metrics.

Within this document is a description of three types of metrics:

"Lagging" Metrics – a retrospective set of metrics that are based on incidents that meet the threshold of severity that should be reported as part of the industry-wide process safety metric.

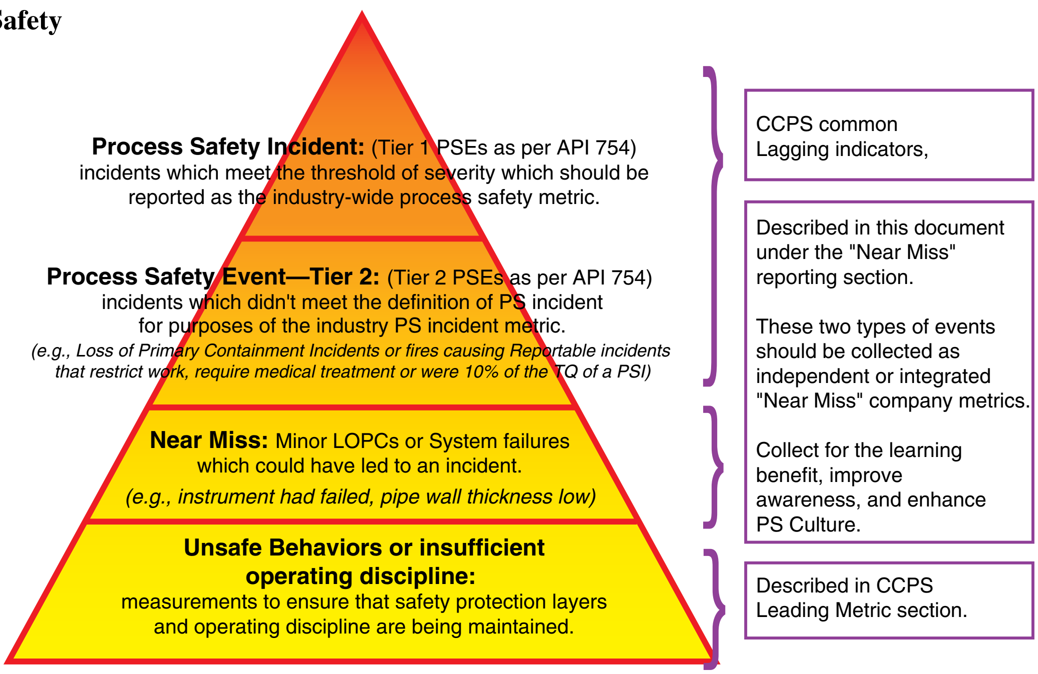
"Leading" Metrics – a forward looking set of metrics which indicate the performance of the key work processes, operating discipline, or layers of protection that prevent incidents

"Near Miss" and other internal Lagging Metrics – the description of less severe incidents (i.e., below the threshold for inclusion in the industry lagging metric), or unsafe conditions which activated one or more layers of protection. Although these events are actual events (i.e., a "lagging" metric), they are generally considered to be a good indicator of conditions which could ultimately lead to a more severe incident.

These three types of metrics can be considered as measurements at different levels of the "safety pyramid" illustrated in Figure 1. Although Figure 1 is divided into four separate layers (Process safety incidents, Other incidents, Near miss, and Unsafe behaviors/Insufficient operating discipline), it is easier to describe metrics in terms of the categories shown above. Figure 1 illustrates how each of these four areas is captured under the three sections of this document.

It is strongly recommended that all companies incorporate each of these three types of metrics into their internal process safety management system. Recommended metrics for each of these categories are included in the three primary sections of this document.

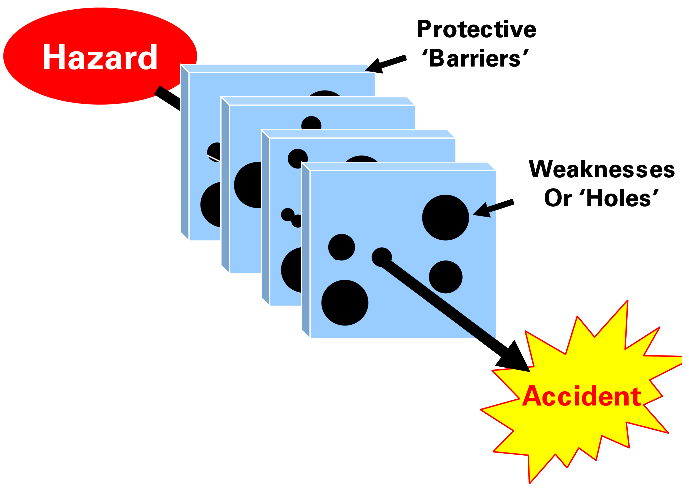
Figure 1: Process Safety Metric Pyramid



Another way to consider metrics is that the incidents at the top of the pyramid reflect situations where failures to the multiple layers of protection which are intended to prevent an incident (both physical layers and work process/operating procedure layers) have failed, while the bottom of the pyramid reflects failures or challenges to one or two of these layers of protection – yet other layers continue to function. The multiple layer of protection concept is represented in Figure 2.

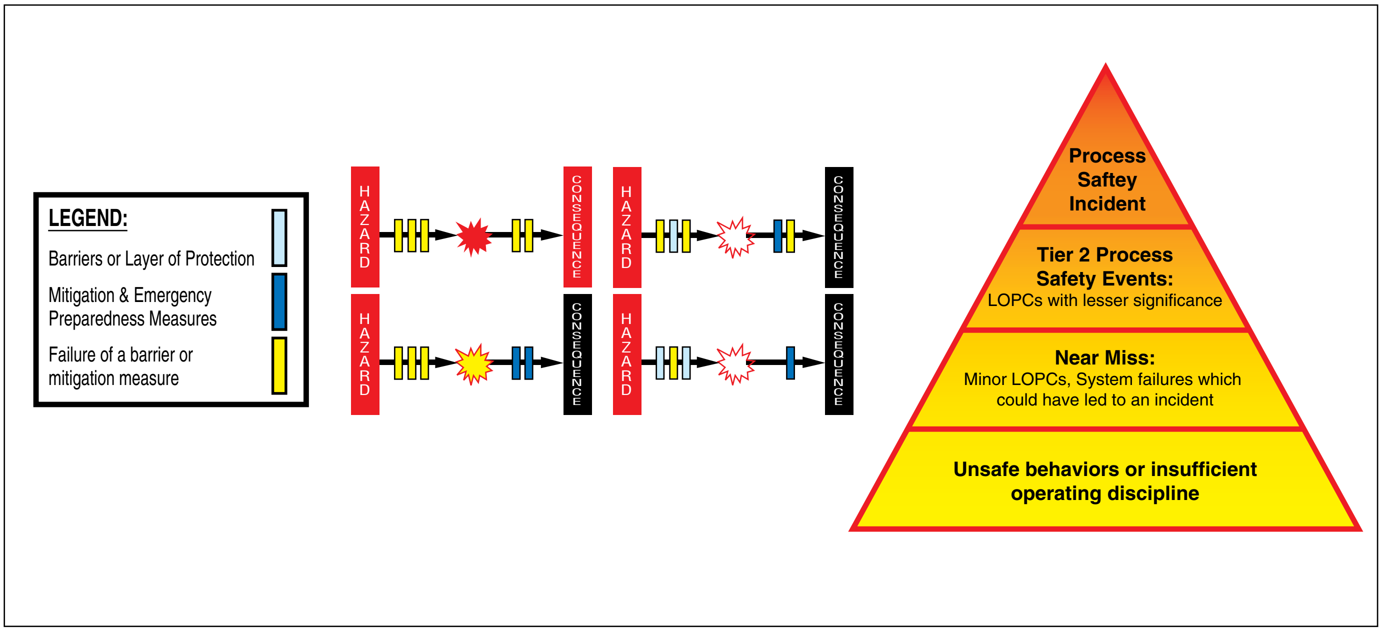
Figure 2: Swiss Cheese Model

- Hazards are contained by multiple protective barriers
- Barriers may have weaknesses or holes'
- When holes align, the hazard passes through the barriers resulting in the potential for adverse consequences.
- Barriers may be physical engineered containment or behavioral controls dependent on people
- Holes can be latent/incipient, or actively opened by people



Incorporating the layer of protection concept, Figure 1 can then be redrawn as shown in Figure 3, to reflect that additional layers of protection or mitigation have failed as you progress from the bottom of the pyramid to the top.

Figure 3: Process Safety Pyramid / Failed Protection Layers



I. Lagging Metrics

The BP US Refineries Independent Safety Review Panel ("Baker Panel")[2] and US Chemical Safety Board[3] each recommended improved industry-wide process safety metrics in their final reports dealing with the 2005 explosion at the BP Texas City refinery. CCPS member companies also share the vision of a new industry-wide process safety metric, including a common set of definitions and threshold levels that will serve individual companies and industry as a whole by providing a mechanism to:

- indicate changes in company or industry performance, to be used to drive continuous improvement in performance;
- perform company-to-company or industry segment-to-segment benchmarking and
- serve as a leading indicator of potential process safety issues which could result in a catastrophic event.

This section of the document describes a set of definitions and metrics recommended as industry-wide lagging metrics.

1.0 Process Safety Incident (PSI) (Tier 1 PSE per API RP - 754):

For the purposes of the common industry-wide process safety lagging metrics, an incident is reported as a process safety incident if it meets all four of the following criteria:

(1) Process involvement
(2) Above minimum reporting threshold
(3) Location;
(4) Acute release

Process Involvement

An incident satisfies the chemical or chemical process involvement criteria if the following is true:

> *A process must have been directly involved in the damage caused. For this purpose, the term "process" is used broadly to include the equipment and technology needed for chemical, petrochemical and refining production, including reactors, tanks, piping, boilers, cooling towers, refrigeration systems, etc. An incident with no direct chemical or process involvement, e.g., an office building fire, even if the office building is on a plant site, is not reportable.*

An employee injury that occurs at a process location, but in which the process plays no direct part, is not reportable as a PSI (though it could be an OSHA or other agency reportable injury). The intent of this criterion is to identify those incidents that are related to process safety, as distinguished from personnel safety incidents that are not process-related. For example, a fall from a ladder resulting in a lost workday injury is not reportable simply because it occurred at a process unit. However, if the fall resulted from a chemical release, then the incident is reportable.

Reporting Thresholds

An unplanned or uncontrolled release of any material, including non-toxic and non-flammable materials (e.g., steam, hot condensate, nitrogen, compressed CO_2 or compressed air), from a process that results in one or more of the consequences listed below:

Note: Steam, hot condensate, and compressed or liquefied air are only included in this definition if their release results in one of the consequences other than a threshold quantity release. However, other nontoxic, nonflammable gases with defined UNDG Division 2.2 thresholds (such as nitrogen, argon, compressed CO_2) are included in all consequences including, threshold releases

1. An employee or contractor day(s) away from work injury and/or fatality, or hospital admission and/or fatality of a third party (non-employees/contractor)
2. An officially declared community evacuation or community shelter-in-place;
3. Fires or explosions resulting in greater than or equal to $25,000 of direct cost to the company, or;
4. An acute release of flammable, combustible, or toxic chemicals greater than the chemical release threshold quantities described on Table 1. Note that table 1 has an additional threshold quantity level column which is recommended for indoor releases
    - Releases include pressure relief device (PRD) discharges, whether directly or via a downstream destructive device that results in liquid carryover, discharge to a potentially unsafe location, on-site shelter-in-place, or public protective measures (e.g., road closure)

[2] Baker, J.A. et al., "The Report of the BP U.S. Refineries Independent Safety Review Panel," January 2007 http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/SP/STAGING/local_assets/assets/pdfs/Baker_panel_report.pdf

[3] U.S. Chemical Safety and Hazard Investigation Board, Investigation Report No. 2005-04-I-TX, "Refinery Explosion and Fire," BP, Texas City, March 2005.

Table 1 – Process Safety Incident Threshold Values

Threshold Release Category	Material Hazard Classification [a,c,d]	Threshold Quantity	Recommended Threshold Quantity for indoor[b] releases (Optional)
1	TIH Zone A Materials	5 kg (11 lb)	2.5 kg (5.5 lb)
2	TIH Zone B Materials	25 kg (55 lb)	12.5 kg (27.5 lb)
3	TIH Zone C Materials	100 kg (220 lb)	50 kg (110 lb)
4	TIH Zone D Materials	200 kg (440 lb)	100 kg (220 lb)
5	Flammable Gases or Liquids with Initial Boiling Point ≤ 35 °C (95 °F) and Flash Point < 23 °C (73 °F) or Other Packing Group I Materials excluding strong acids/bases	500 kg (1100 lb)	250 kg (550 lb)
6	Liquids with Initial Boiling Point > 35 °C (95 °F) and Flash Point < 23 °C (73°F) or Other Packing Group II Materials excluding moderate acids/bases	1000 kg (2200 lb or 7 bbl	500 kg (1100 lb) or 3.5 bbl
7	Liquids with Flash Point ≥ 23 °C (73 °F) and ≤ 60 °C (140 °F) or Liquids with Flash Point > 60 °C (140 °F) released at a temperature at or above Flash Point or strong acids/ bases or Other Packing Group III Materials or Division 2.2 Nonflammable, Nontoxic Gases (excluding Steam, hot condensate, and compressed or liquefied air)	2000 kg (4400 lb) or 14 bbl	1000 kg (2200 lb) or 7 bbl

It is recognized that threshold quantities given in kg and lb or in lb and bbl are not exactly equivalent. Companies should select one of the pair and use it consistently for all recordkeeping activities.

a Many materials exhibit more than one hazard. Correct placement in Hazard Zone or Packing Group shall follow the rules of DOT 49 CFR 173.2a [14] or UN Recommendations on the Transportation of Dangerous Goods, Section 2 [10]. See Annex B.

b A structure composed of four complete (floor to ceiling) walls, floor, and roof.

c For solutions not listed on the UNDG, the anhydrous component shall determine the TIH zone or Packing Group classification. The threshold quantity of the solution shall be back calculated based on the threshold quantity of the dry component weight.

d For mixtures where the UNDG classification is unknown, the fraction of threshold quantity release for each component may be calculated. If the sum of the fractions is equal to or greater than 100%, the mixture exceeds the threshold quantity. Where there are clear and independent toxic and flammable conse quences associated with the mixture, the toxic and flammable hazards are calculated independently. See Annex A, Examples 29, 30 and 31.

For a full list of materials cross-referenced to the UN Dangerous Goods definitions, see chemical list or spreadsheet tools posted on the web site www.ccpsonline.org

Location

An incident satisfies the location criteria if:

> The incident occurs in production, distribution, storage, utilities or pilot plants of a facility reporting metrics under these definitions. This includes tank farms, ancillary support areas (e.g., boiler houses and waste water treatment plants), and distribution piping under control of the site.

All reportable incidents occurring at a location will be reported by the company that is responsible for operating that location. This applies to incidents that may occur in contractor work areas as well as other incidents.

At tolling operations and multi-party sites, the company that operates the unit where the incident initiated should record the incident and count it in their PSI metric.

For further clarification, look at the exclusions described in Section 6 (Applicability).

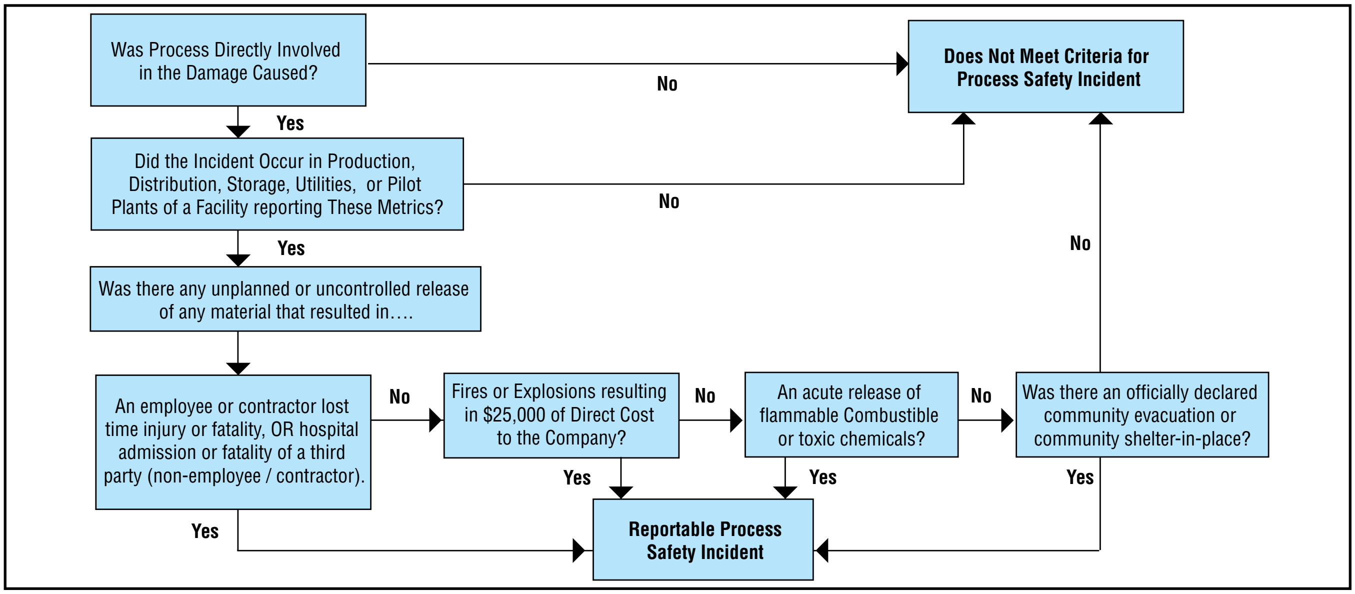
Acute Release

A "1-hour" rule applies for the purpose of the reporting under this metric, i.e. the release of material reaches or exceeds the reporting threshold in any 1-hour period. If a release does not exceed the TQ level during any 1-hour period, it would not be treated as a PSI. Typically, acute releases occur in 1-hour or less; however, there may be some releases that would be difficult to prove if the threshold amount release occurred in 1-hour. (Example: A large inventory of flammable liquid is spilled from a tank or into a dike overnight due to a drain valve being left upon prior to a transfer operation. It may not be discovered for several hours, so it is difficult to know the exact time when the threshold quantity was exceeded.) If the duration of the release cannot be determined, the duration should be assumed to be 1 hour.

Flowchart

The criteria for reporting incidents as a PSI described above are illustrated in the attached flowchart (Figure 4).

Figure 4: Determining if an incident meets definition of a reportable Process Safety Incident (PSI) under the definitions of the CCPS Industry Lagging Metric



Process Safety Incident Severity

A severity level will be assigned for each consequence category for each process safety incident utilizing the criteria shown in Table 2.

Table 2: Process Safety Incidents & Severity Categories

Severity Level (Note 4)	Safety/Human Health (Note 5)	Fire or Explosion (including overpressure)	Potential Chemical Impact (Note 3)	Community/Environment Impact (Note 5)
NA	**Does not meet or exceed Level 4 threshold**	**Does not meet or exceed Level 4 threshold**	**Does not meet or exceed Level 4 threshold**	**Does not meet or exceed Level 4 threshold**
4 (1 point used in severity rate calculations for each of the attributes which apply to the incident)	Injury requiring treatment beyond first aid to employee or contractors (or equivalent, Note 1) associated with a process safety incident (In USA, incidents meeting the definitions of an OSHA recordable injury)	Resulting in $25,000 to $100,000 of **direct cost**	Chemical released within secondary containment or contained within the unit - see Note 2A	Short-term remediation to address acute environmental impact. No long term cost or company oversight. Examples would include spill cleanup, soil and vegetation removal.
3 (3 points used in severity rate calculations for each of the attributes which apply to the incident)	Lost time injury to employee or contractors associated with a process safety event	Resulting in $100,000 to 1MM of **direct cost**.	Chemical release outside of containment but retained on company property **OR** flammable release without potential for vapor cloud explosives - see Note 2B	Minor off-site impact with precautionary shelter-in-place **OR** Environmental remediation required with cost less than $1MM. No other regulatory oversight required. **OR** Local media coverage
2 (9 points used in severity rate calculations for each of the attributes which apply to the incident)	On-site fatality - employee or contractors associated with a process safety event; multiple lost time injuries or one or more serious offsite injuries associated with a process safety event.	Resulting in $1MM to $10MM of **direct cost**.	Chemical release with potential for injury off site or flammable release resulting in a vapor cloud entering a building or potential explosion site (congested/confined area) with potential for damage or casualties if ignited - see Note 2C	Shelter-in-place or community evacuation **OR** Environmental remediation required and cost in between $1MM - $2.5 MM. State government investigation and oversight of process. **OR** Regional media coverage or brief national media coverage.
1 (27 points used in severity rate calculations for each of the attributes which apply to the incident)	Off-site fatality or multiple on-site fatalities associated with a process safety event.	Resulting in **direct cost** >$10MM	Chemical release with potential for significant on-site or off-site injuries or fatalities - see Note 2D	National media coverage over multiple days **OR** Environmental remediation required and cost in excess of $2.5 MM. Federal government investigation and oversight of process. **OR** other significant community impact

NOTE 1: For personnel located or working in process manufacturing facilities.

NOTE 2: It is the intent that the "Potential Chemical Impact" definitions shown in Table 2 to provide sufficient definition such that plant owners or users of this metric can select from the appropriate qualitative severity descriptors without a need for dispersion modeling or calculations. The user should use the same type of observation and judgment typically used to determine the appropriate emergency response actions to take when a chemical release occurs. However, CCPS does not want to preclude the use of a "sharper pencil" (e.g. dispersion modeling) if a company so chooses. In those cases, the following notes are being provided, as examples, to clarify the type of hazard intended with the four qualitative categories:

A: AEGL-2/ERPG-2 concentrations (as available) or 50% of Lower Flammability Limits (LFL) does not extend beyond process boundary (operating unit) at grade or platform levels, or small flammable release not entering a potential explosion site (congested/confined area) due to the limited amount of material released or location of release (e.g., flare stack discharge where pilot failed to ignite discharged vapors).
B: AEGL-2/ERPG-2 concentrations (as available) extend beyond unit boundary but do not extend beyond property boundary. Flammable vapors greater than 50% of LFL at grade may extend beyond unit boundaries but did not entering a potential explosion site (congested/confined area); therefore, very little chance of resulting in a VCE.
C: AEGL-2/ERPG-2 concentrations (as available) exceeded off-site OR flammable release resulting in a vapor cloud entering a building or potential explosion site (congested/confined area) with potential for VCE resulting in fewer than 5 casualties (i.e., people or occupied buildings within the immediate vicinity) if ignited.
D: AEGL-3/ERPG-3 concentrations (as available) exceeded off-site over the defined 10/30/60 minute time frame OR flammable release resulting in a vapor cloud entering a building or potential explosion site (congested/confined area) with potential for VCE resulting in greater than 5 casualties (i.e., people or occupied buildings within the immediate vicinity) if ignited.

NOTE 3: The Potential Chemical Impact table reflects the recommended criteria. However, some companies may object to making a relative ranking estimate on the potential impact using the terms described. In those situations, it would be acceptable for those companies to substitute the following criteria corporate wide: Severity Level 4: 1X to 3X the TQ for that chemical, Level 3: 3X to 9X, Level 2: 9X to 20X, and Level 1: 20X or greater the TQ for that chemical. However, if a company elects to use this alternative approach they should be consistent and use this approach for all releases. They should not select between the two methods on a case-by-case basis simply to get the lowest severity score.

NOTE 4: The category labels can be modified by individual companies or industry associations to align with the severity order of other metrics. It is important is to use the same severity point assignments shown.

NOTE 5: The severity index calculations include a category for "Community/Environmental" impact and a first aid (i.e., OSHA "recordable injury") level of Safety/Human Health impact which are not included in the PSI threshold criteria. However, the purpose of including both of these values is to achieve greater differentiation of severity points for incidents that result in any form or injury, community, or environmental impacts.

2.0 Tier 2 Process Safety Events (Tier 2 - PSE as per API 754)

Tier 2 Indicator Purpose

The count of Tier 2 Process Safety Events represent those LOPC incidents with a lesser consequence than a PSI. Tier 2 PSEs, even those that have been contained by secondary systems, indicate barrier system weaknesses that may be potential precursors of future, more significant incidents. In that sense, Tier 2 PSEs can provide a company with opportunities for learning and improvement of its process safety performance.

Process Involvement

The same Process Involvement criteria apply to Tier 2 – PSEs as apply to PSI (Tier 1 – PSEs)

Tier 2 Indicator Definition and Consequences

A Tier 2 PSE is an event with lesser consequence then a PSI event. A Tier 2 LOPC is an unplanned or uncontrolled

release of any material, including non-toxic and non-flammable materials (e.g. steam, hot condensate, nitrogen, compressed CO_2 or compressed air), from a process that results in one or more of the consequences listed below and is not reported in Tier 1:

NOTE Steam, hot condensate, and compressed or liquefied air are only included in this definition if their release results in one of the consequences other than a threshold quantity release. However, other nontoxic, nonflammable gases with defined UNDG Division 2.2 thresholds (such as nitrogen, argon, compressed CO_2) are included in all consequences including, threshold releases

1. an employee, contractor or subcontractor recordable injury;
2. a fire or explosion resulting in greater than or equal to $2,500 of direct cost to the Company;
3. An acute release of flammable, combustible, or toxic chemicals from the primary containment (i.e., vessel or pipe) greater than the release threshold quantities described on Table 2, Note that table 2 has an threshold quantity level column which are recommended for indoor releases.
    - o including pressure relief device (PRD) discharges, whether directly or via a downstream destructive device that results in liquid carryover, discharge to a potentially unsafe location, on-site shelter-in-place, or public protective measures (e.g., road closure)

Table 3 – Process Safety Incident Threshold Values

Threshold Release Category	Material Hazard Classification [a,c,d]	Threshold Quantity	Recommended Threshold Quantity for indoor[b] releases (Optional)
1	TIH Zone A Materials	0.5 kg (1.1 lb)	0.25 kg (0.55 lb)
2	TIH Zone B Materials	2.5 kg (5.5 lb)	1.2 kg (2.8 lb)
3	TIH Zone C Materials	10 kg (22 lb)	5 kg (11 lb)
4	TIH Zone D Materials	20 kg (44 lb)	10 kg (22 lb)
5	Flammable Gases or Liquids with Initial Boiling Point ≤ 35 °C (95 °F) and Flash Point < 23 °C (73 °F) or Other Packing Group I Materials excluding strong acids/bases	50 kg (110 lb)	25 kg (55 lb)
6	Liquids with a Initial Boiling Point > 35 °C (95 °F) and Flash Point <€60 °C (140 °F) or Liquids with Flash Point > 60 °C (140 °F) released at or above Flash Point; Or Other Packing Group II and III Materials excluding moderate acids/bases or Strong acids and bases	100 kg (220 lb) or 1 bbl	50 kg (110 lb) or 0.5 bbl
7	Liquids with Flash Point > 60 °C (140 °F) released at a temperature below Flash Point or Moderate acids/bases or Division 2.2 Nonflammable, Nontoxic Gases (excluding Steam, hot condensate, and compressed or liquefied air)	1000 kg (2200 lb) or 10 bbl	500 kg (1100 lb) or 5 bbl

In order to simplify determination of reporting thresholds for Tier 2, Categories 6 and 7 in Tier 1 have been combined into one category in Tier 2 (Category 6). A new category 7 has been added.

a Many materials exhibit more than one hazard. Correct placement in Hazard Zone or Packing Group shall follow the rules of DOT 49 CFR 173.2a [14] or UN Recommendations on the Transportation of Dangerous Goods, Section 2 [10]. See Annex B.

b A structure composed of four complete (floor to ceiling) walls, floor and roof.

c For solutions not listed on the UNDG, the anhydrous component shall determine the TIH zone or Packing Group classification. The threshold quantity of the solution shall be back calculated based on the threshold quantity of the dry component weight.

d For mixtures where the UNDG classification is unknown, the fraction of threshold quantity release for each component may be calculated. If the sum of the fractions is equal to or greater than 100%, the mixture exceeds the threshold quantity. Where there are clear and independent toxic and flammable consequences associated with the mixture, the toxic and flammable hazards are calculated independently. See Annex A, Examples 29, 30 and 31.

Location and Acute Release Criteria

The same location and acute release criteria apply to Teir 2 – PSEs as apply to PSIa (Tier 1 – PSEs)

3.0 Definitions

Acids/Bases, Moderate
Substances with pH ≥ 1 and < 2, or pH > 11.5 and ≤ 12.5, or more precisely, substances that cause full thickness destruction of intact skin tissue within an observation period up to 14 days starting after the exposure time of 60 minutes or less, but greater than three minutes, consistent with Globally Harmonized System of Classification and Labeling of Chemicals (GHS) Skin Corrosion Category 1B.

Acids/Bases, Strong
Substances with pH < 1 or > 12.5, or more precisely, substances that cause full thickness destruction of intact skin tissue within an observation period up to 60 minutes starting after the exposure time of three minutes or less, consistent with GHS Skin Corrosion Category 1A.

Acute Release: A sudden release of material that reaches or exceeds the reporting threshold in any one (1) hour period.

BBL: Barrels; 42 U.S. gallons (35 Imperial gallons)

Company: "Company" (when designated with a capital C) or "the Company", refers to the operating company in the refining and petrochemical industries and/or any of its divisions, and/or any of its consolidated affiliates.

Contractor: Any individual not on the Company payroll, including subcontractors, whose exposure hours, injuries and illnesses are routinely tracked by the host Company.

Days Away From Work Injury
Work-related injuries that result in the employee being away from work for at least one calendar day after the day of the injury as determined by a physician or other licensed health professional. This is an abridged version of the definition used to report days away from work injuries for OSHA.

Deflagration Vent
An opening in a vessel or duct that prevents failure of the vessel or duct due to overpressure. The opening is covered by a pressure-relieving cover (e.g. rupture disk, explosion disk, or hatch).

Destructive Device
A flare, scrubber, incinerator, quench drum, or other similar device used to mitigate the potential consequences of a PRD release.

Direct Cost: Cost of repairs or replacement, cleanup, material disposal, environmental remediation and emergency response. Direct cost does not include indirect costs, such as business opportunity, business interruption and feedstock/product losses, loss of profits due to equipment outages, costs of obtaining or operating temporary facilities, or costs of obtaining replacement products to meet customer demand. Direct cost does not include the cost of the failed component leading to LOPC, if the component is not further damaged by the fire or explosion.

Employee: Any individual on the Company payroll and whose exposure hours, injuries and illnesses are routinely tracked by the Company. Individuals not on the Company payroll, but providing services under direct company supervision are also included (e.g. government sponsored interns, secondees, etc.).

Explosion: A release of energy that causes a pressure discontinuity or blast wave (e.g. detonations, deflagrations, and rapid releases of high pressure caused by rupture of equipment or piping).

Definitions con't.

Facility
The buildings, containers or equipment that contain a process.

Fire
Any combustion resulting from a LOPC, regardless of the presence of flame. This includes smoldering, charring, smoking, singeing, scorching, carbonizing, or the evidence that any of these have occurred.

Flammable Gas
Any material that is a gas at 35 °C (95 °F) or less and 101.3 kPa (14.7 psi) of pressure and is ignitable when in a mixture of 13 % or less by volume with air, or has a flammable range of at least 12% as measured at 101.3 kPa (14.7 psi).

Hospital Admission
Formal acceptance by a hospital or other inpatient health care facility of a patient who is to be provided with room, board, and medical service in an area of the hospital or facility where patients generally reside at least overnight. Treatment in the hospital emergency room or an overnight stay in the emergency room would not by itself qualify as a "hospital admission."

Loss Of Primary Containment (LOPC): An unplanned or uncontrolled release of material from primary containment. including non-toxic and non-flammable materials (e.g. steam, hot condensate, nitrogen, compressed CO^2 or compressed air).

Major Construction
Large scale investments with specific, one-time project organizations created for design, engineering, and construction of new or significant expansion to existing process facilities.

Material
Substance with the potential to cause harm due to its chemical (e.g. flammable, toxic, corrosive, reactive, asphyxiate) or physical (e.g. thermal, pressure) properties.

Office Building
Buildings intended to house office workers (e.g. administrative or engineering building, affiliate office complex, etc.).

Officially Declared
A declaration by a recognized community official (e.g. fire, police, civil defense, emergency management) or delegate (e.g. Company official) authorized to order the community action (e.g. shelter-in-place, evacuation).

Pressure Relief Device (PRD)
A device designed to open and relieve excess pressure (e.g. safety valve, thermal relief, rupture disk, rupture pin, deflagration vent, pressure/vacuum vents, etc.).

Primary Containment: A tank, vessel, pipe, rail car or equipment intended to serve as the primary container or used for the transfer of the material. Primary containers may be designed with secondary containment systems to contain and control the release. Secondary containment systems include, but are not limited to, tank dikes, curbing around process equipment, drainage collection systems into segregated oily drain systems, the outer wall of double walled tanks, etc.

Definitions con't.

Process
Production, distribution, storage, utilities, or pilot plant facilities used in the manufacture of chemical, petrochemical and petroleum refining products. This includes process equipment (e.g. reactors, vessels, piping, furnaces, boilers, pumps, compressors, exchangers, cooling towers, refrigeration systems, etc.), storage tanks, ancillary support areas (e.g. boiler houses and waste water treatment plants), on-site remediation facilities, and distribution piping under control of the Company.

Process Safety
A disciplined framework for managing the integrity of hazardous operating systems and processes by applying good design principles, engineering, and operating and maintenance practices.

Process Safety Event (PSE)
An unplanned or uncontrolled LOPC of any material including non-toxic and non-flammable materials (e.g. steam, hot condensate, nitrogen, compressed CO2 or compressed air) from a process, or an undesired event or condition that, under slightly different circumstances, could have resulted in a LOPC of a material.

PSI: Process Safety Incident.

Secondary Containment
System designed to contain or control a release from primary containment. Secondary containment systems include, but are not limited to tank dikes, curbing around process equipment, drainage collection systems, the outer wall of double walled tanks, etc.

Public Receptors
Offsite residences, institutions (e.g. schools, hospitals), industrial, commercial, and office buildings, parks or recreational areas where members of the public could potentially be exposed to toxic concentrations, radiant heat, or overpressure, as a result of a LOPC.

Recordable Injury
A work-related injury that results in any of the following: death, days away from work, restricted work or transfer to another job, medical treatment beyond first aid, loss of consciousness, or a significant injury diagnosed by a physician or other licensed health professional. This is an abridged version of the definition used to report days away from work injuries for OSHA.

Third Party: Any individual other than an employee, contractor or subcontractor of the Company. [e.g., visitors, non-contracted delivery drivers (e.g. UPS, U.S. Mail, Federal Express), residents, etc.].

Tolling Operation
A company with specialized equipment that processes raw materials or semi-finished goods for another company.

Total employee, contractor & subcontractor work hours: Total hours worked for refining, petrochemical, or chemical manufacturing facilities. Using the same definitions that would be applicable for the OSHA injury/illness formula. Man-hours associated with major construction projects or corporate administration would not be included.

United Nations Dangerous Goods (UNDG) hazard categories: A classification system used to evaluate the potential hazards of various chemicals, if released, used by most international countries as part of the product labeling or shipping information. In the United States, these hazard categories are defined in US Department of Transportation regulations (49 CFR 172.101). and listed in 49 CFR 172, Subpart B For more information on this ratings, see the UN web site (http://www.unece.org/trans/danger/publi/adr/adr2007/07ContentsE.html)

4.0 Rate Adjusted Metrics

Utilizing the definitions described above, there are a variety of rate-based metrics which can be generated. These include:

Process Safety Total Incident Rate (PSTIR):

$$\frac{\text{Total PS incidents x 200,000}}{\text{Total employee \& contractor work hours}}$$

Process Safety Incident Severity Rate (PSISR) (i.e., severity-weighted Process Safety incident rate formula):

$$\textbf{PSISR} = \frac{\text{Total severity score for all PS incidents x 200,000}}{\text{Total employee, contractor \& subcontractor work hours}}$$

In determining this rate, 1 point is assigned for each Level 4 incident attribute, 3 points for each Level 3 attribute, 9 points for each Level 2 attributes, and 27 points for each Level 1 attributes. Theoretically, a PSI could be assigned a minimum of 1 point (i.e., the incident meets the attributes of a Level 4 incident in only one category) or a maximum of 108 points (i.e., the incident meets the attributes of a Level 1 incident in each of the four categories..

PS Level "X*" incident rate:

$$\frac{\text{Total Severity Level “X*” PS incidents x 200,000}}{\text{Total employee, contractor \& subcontractor work hours}}$$

Where X* can be the total count of Severity Level 4, 3, 2, or 1 incidents. The severity level of an incident is the maximum severity rating of the four consequence categories.

Tier 2 PSE Rate (Tier 2 IR):

$$\frac{\text{Total Tier 2 PSE Count x 200,000}}{\text{Total employee \& contractor work hours}}$$

5.0 Industry Process Safety Metrics

It is recommended that companies implement and publicly report the following three process safety metrics.

Total Count of Process Safety Incidents (PSIC): The count of all incidents which meet the definitions of a PSI described within this document.

Process Safety Total Incident Rate (PSTIR): The cumulative (annual) count of incidents normalized by man-hours, per the formula described in section 2.0.

Process Safety Incident Severity Rate (PSISR): The cumulative (annual) severity-weighted rate of process safety incidents per the formula described in section 2.0.

To assist in benchmarking, it would be beneficial if trade associations or consortiums collect and publish this information for member companies.

Optionally, companies should also consider implementing and publicly reporting the count and rate of **Tier 2 Process Safety Events**.

6.0 Applicability

It is recommended that companies record and report PSIs occurring at Company-owned or operated facilities, **except** as noted below:

1. PSIs that originated off Company property;
2. Marine transport vessel incidents, except when the vessel is connected to the facility for the purposes of feedstock or product transfer;
3. Truck and/or rail incidents, except when the truck or rail car is connected to the facility for the purposes of feedstock or product transfer;
4. Vacuum truck operations, except on-site truck loading or discharging operations, or use of the vacuum truck transfer pump;
5. Routine emissions that are allowable under permit or regulation;
6. Office, shop, and warehouse building incidents (e.g., office heating equipment explosions, fires, spills, releases, personnel injury or illness, etc.);
7. Personnel safety "slip/trip/fall" incidents that are not directly associated with evacuating from, or responding to a loss of containment incident;
8. Loss of Primary Containment (LOPC) incidents from ancillary equipment not connected to the process (e.g., small sample containers);
9. Planned and controlled drainage of material to collection or drain system designed for such service (Note: Exclusion does not apply to an unintended and uncontrolled release of material from primary containment that flows to a collection or drain system);
10. Mechanical work being conducted outside of process units or in maintenance shops; and,
11. Quality Assurance (QA), Quality Control (QC) and Research and Development (R&D) laboratories are excluded. (Pilot plants are included.)
12. On-site fueling operations of mobile and stationary equipment (e.g. pick-up trucks, diesel generators, and heavy equipment).

7.0 Interpretations and Examples

The following interpretations and examples have been prepared to help clarify areas of potential uncertainty in the evaluation of reportable Process Safety Incidents (PSI).

They are for illustrative purposes only. The following areas are addressed:

- Company Premises
- PSIs With Multiple Outcomes
- Loss Of Containment
- Acute Releases
- Flares & Emission Control Devices
- Safety Relief Device/System
- Toxic Gas, Vapor or Aerosol
- Lost Time Incidents
- Pipelines
- Fires Not Associated with Chemical Release
- Marine Vessels
- Truck and Rail
- Office Building
- Man-Machine Interface Incidents
- Examples of Use of Assignment of Severity Scores
- Mixtures
- Vacuum Truck Operations
- Direct Costs
- Officially Declared Evacuation or Shelter-in -Place

COMPANY PREMISES

1. A third-party truck loading a flammable product on Company Premises, experiences a leak and subsequent fire and property loss damages of $75,000 (direct costs). Although the truck is "Operated-by-Others", it is connected to the process. The incident would be a reportable PSI if property losses in direct costs were equal to or greater than $25K or some other PSI threshold was met or exceeded (e.g., a fatality).

2. Similar example as #1. The truck loaded with flammable product overturns in route out of the plant, resulting in a fire and loss of the truck. This would not be reported as a PSI since the truck is no longer connected to the plant.

3. A pipeline leaks and releases 2000 lb of flammable vapor above ground within 1 hour. A public road bisects the main facility and its marine docks. This pipeline originates in the facility and goes to the docks. The leak site happens to be off the site's property in the short segment of piping that runs over the public road. Although the leak technically occurs off-site, this is a reportable PSI since the facility owns and operates the entire segment of pipeline.

PSIs WITH MULTIPLE OUTCOMES

4. There is a 200 bbl spill of flammable liquid that results in significant flammable vapor being released, ignited and causing a fire. The fire damages other equipment resulting in a toxic gas release above the reporting threshold, along with multiple lost time injuries, including a fatality. This event should be reported as a single PSI, but with multiple outcomes. When applying the severity metric, the appropriate severity point assignment (1, 3, 9, or 27 points each) would be selected from Table 2 for the fire damage, the chemical release potential impact, the human health impact, and the community/environmental impact. The sum of these individual severity points will be used in calculating the overall severity rate metric.

LOSS OF CONTAINMENT

5. Ten barrels of gasoline (1400 kg, 3100 lbs.) leak from piping onto concrete and the gasoline doesn't reach soil or water. Site personnel estimate that the leak was "acute" (e.g., occurred within a 1-hour timeframe). This is a reportable PSI because there was an "acute" loss of primary containment (e.g., within "1 hour") of 1000 kg (2200 lbs) or more of "Flammable Liquid".

6. A faulty tank gauge results in the overfilling of a product tank containing "flammable liquids". Approximately 7000 kg (15500 lbs) of liquid overflows into the tank's diked area. This incident is a reportable PSI since it is an "acute" spill greater than 2200 lbs, regardless of secondary containment.

7. A maintenance contractor opens a process valve and gets sprayed with sulfuric acid resulting in a severe burn and lost time injury. This would be a reportable PSI. It is an unintended event involving a material and a loss of containment. For fatalities and days away from work injuries and illnesses, there is no release threshold amount.

8. An operator opens a quality control sample point to collect a routine sample of product and receives a bad hand laceration requiring stitches due to a broken glass bottle and misses the next day of work. This is not a reportable PSI because it is not related to a loss of containment.

9. A bleeder valve is left open after a plant turnaround. On startup, an estimated 10 bbls of fuel oil (1700 kg, 3750 lbs.) is released, at 100°F, onto the ground and into the plant's drainage system before the bleeder is found and closed. This would not be a PSI because it is less then the release criteria of 2000 kg or 4400 lbs of a "Combustible Liquid".

10. Operations is draining water off of a crude oil tank (operated at 120°F) into a drainage system designed for that purpose. The operator leaves the site and forgets to close the valve. 20 bbls of crude oil is released into the drainage system. This would be a PSI because the release of crude oil, a "Combustible Liquid", is unintended and it is greater then the release criteria of 2000 kg or 4400 lbs.

11. A pipe corrodes and leaks 10 Bbls (1700 kg, 3750 lbs.) of Heavy Cycle Oil (HCO) at the operations temperature of 550°F to the ground. The HCO has a flash point of 300°F.. This would not be a PSI. Although the HCO is a high flash material released above its flash point, the release did not exceed the threshold quantity of 2000 kg (4400 lbs) or 14 bbls.

12. An operator purposely drains 20 bbls of combustible material into an oily water collection system within one hour as part of a vessel cleaning operation. The drainage is planned and controlled and the collection system is designed for such service. This is not a reportable PSI since it is consistent with a specific exclusion. If the

material had been unintentionally released or it had become uncontrolled and flowed to an open drain, sewer or other collection system, it would be a reportable PSI.

13. Hydrocarbon fumes migrate into the QA/QC laboratory located within the facility and results in a fire with $5000 damage. The source of the hydrocarbon fumes is the oily water sewer system. Although the fire was the result of an unplanned or uncontrolled loss of primary containment, this incident is not a PSI since the damage threshold of $25,000 was not exceeded.

14. A forklift truck delivering materials inside a process unit knocks off a bleeder valve leading to the release of iso-pentane and a subsequent vapor cloud explosion with asset damage greater than $25,000. This is a PSI since an unplanned or uncontrolled LOPC resulted in a fire or explosion causing greater than $25,000 damage.

15. There is a loss of burner flame in a fired heater resulting in a fuel rich environment and subsequent explosion in the fire box with greater than $25,000 in damages to the internals of the heater. There was no release outside of the fire box. This would be a reportable PSI since after the flameout the continuing flow of fuel gas is now an uncontrolled release. The intent is for combustion of the fuel gas at the burner and not for fuel gas to be contained in the fire box.

16. There is a tube rupture in a fired heater causing a fire (contained in the heater) resulting in greater than $25,000 in damages to the heater internals (beyond that of replacing the failed tube). The tube failure is a loss of primary containment of the process fluid and combined with the additional damages greater than $25,000 makes this a reportable PSI.

ACUTE RELEASES

17. There is a 10 bbl spill of gasoline (1400 kg, 3100 lbs.) that steadily leaked from piping onto soil over a two-week time period. Simple calculations show the spill rate was approximately 0.03 bbls per hour (9 lbs./hr). This is not a reportable PSI since the spill event was not an "acute" release (e.g., the 1000 kg (2200 lbs.) threshold exceeded in any 1 hour period).

18. Same example as above, except that the 10 bbl leak was estimated to have spilled at a steady rate over a period of 1 hour and 30 minutes. Simple calculations show that the spill rate was 6.7 bbls (933 kg or 2060 lbs.) per hour. The spill rate was slightly less that the reporting threshold of 1000 kg (2200 lbs.) within any "1 hour" period, and therefore is still not a reportable PSI.

19. While troubleshooting a higher-than-expected natural gas flow rate, operating personnel find a safety valve on the natural gas line that did not reseat properly and was relieving to the atmospheric vent stack through a knock-out drum. Upon further investigation, it is determined that a total of 1 Million lbs of natural gas was relieved at a steady rate over a 6 month period. This is not a reportable PSI as the release rate (~100 kg per hour) is not “acute”, (i.e. does not exceed the 500 kg TQ for flammable vapors in any 1 hour time period).

Note: This size release may be reportable under environmental regulations.

20. An operator discovers an approximate 10 bbl liquid spill of aromatic solvent (e.g. benzene, toluene) near a process exchanger that was not there during his last inspection round two hours earlier. Since the actual release duration is unknown, a best estimate should be used to determine if the TQ rate has been exceeded (it is preferred to err on the side of inclusion rather than exclusion). This incident is a PSI because the solvents involved are

Packing Group II materials and the threshold quantity of 7 bbl is exceeded if the time period is estimated to be less than one hour.

DOWNSTREAM DESTRUCTIVE DEVICES (e.g., flares, scrubbers, incinerators, quench drums)

21. The flare system is not functioning properly due to inactive pilots on the flare tip. During this time, a vapor load is sent to the flare due to an overpressure in a process unit. The volume of the vapor through the pressure relief device is greater than the threshold and it results in the formation of a flammable mixture at grade. This would be classified as a PSI since the relief valve discharge is greater than the threshold quantity and resulted in an unsafe release.

22. 100 bbl of naphtha liquid are inadvertently routed to the flare system through a pressure relief device. The flare knockout drum contains most of the release; however, there is minimal naphtha rainout from the flare. This is a PSI since the volume released from the pressure relief device to a downstream destructive device does exceed the threshold quantity and resulted in one of the four listed consequences (i.e. liquid carryover).

23. A pressure relief device release less than threshold quantity is routed to a scrubber which is overwhelmed by a flow rate greater than design and exposes personnel to toxic vapors resulting in a days away from work injury. This is a PSI since an loss of primary containment resulted in a days away from work injury. The rules for pressure relief device discharges are superseded by the actual harm caused.

24. A propane tank over-pressures through a pressure relief device to the flare system. The pilots on the flare system are not working properly, and the flare does not combust the vapors. The event transpires over a period of 45 minutes. The volume of propane release was estimated to be 1300 pounds and the release dissipated into the atmosphere above grade and above any working platforms. Even though the release exceeded the threshold quantity, this is not a PSI since the discharge was routed to a downstream destructive device with none of the listed consequences.

25. An upset causes a pressure relief device to open and release fuel gas to the facility flare system. The flare system works properly and combusts the vapor release which came from the pressure relief device. This is not a PSI since the pressure relief device release was routed to a downstream destructive device that functioned as intended (i.e. did not cause one of the four listed consequences).

SAFETY RELIEF DEVICE / SYSTEM

26. There is a unit upset and the relief valve opens to an atmospheric vent which has been designed per API Standard 521 for that scenario, resulting in a gas release to the atmosphere with no adverse consequences. This would not be a reportable PSI since vapors and gases released to atmosphere from safety valves, high-pressure rupture disks, and similar safety devices that are properly designed for that event per API Standard 521 or equivalent are excluded, as long as the release did not result in liquid carryover, discharge to a potentially unsafe location, an on-site shelter-in-place, or public protective measures (e.g. road closure) and and a PRD discharge quantity greater than the threshold quantity.

27. A chlorine vessel has a Pressure Relief Device (PRD) that was identified in a recent PHA to be undersized. In the process of making a transfer, the vessel overpressures. A release of 60 pounds of chlorine gas (TIH Zone B material) occurs through this PRD to a safe location over a period of 25 minutes. This would not be a Tier 1 or Tier 2 PSE, regardless of the HAZOP finding, so long as it did not result in a liquid carryover, on-site shelter-in-place, public protective measure or other indication of discharge to an unsafe location.

28. There is a unit upset and the relief valve fails to open, resulting in overpressure of the equipment and an "acute" release of flammable gas from a leaking flange. The amount released is above the 500 kg (within 1 hour) threshold. This is a reportable PSI. Releases from flanges are not excluded from PSI reporting.

TOXIC GAS, VAPOR OR AEROSOL

29. A leak on a high pressure hydrochloric acid line results in a spill of 1900 lbs of hydrochloric acid. Flash calculations indicate that greater than 220 lbs. of hydrogen chloride would be released as a vapor. The 1900 lbs release of hydrochloric acid is not a reportable PSI since this liquid is categorized as a “Packing Group II” corrosive liquid, with a 2200 lbs reporting threshold. However, since the liquid flashed or was sprayed out as an aerosol, producing more than 220 lbs of hydrogen chloride as vapor the event would be reportable due to exceeding the 100 kg (~220 lbs) or more of Toxic Inhalation Hazard Zone C material within 1 hour.

30. A pipe containing CO_2 and 10,000 vppm (1% by volume) H_2S leaks and 7,000 kg (15,400 lbs) of the gas is released within a short time period (e.g., less than one hour). Calculations show that the release involved about 55 kg (120 lbs) of H_2S. The release is a reportable PSI since the reporting threshold for Toxic Inhalation Hazard Zone B chemicals is any amount greater than 25 kg (55 lbs) of the toxic chemical (e.g., H_2S).

31. Same as above, except that the H_2S concentration in the pipe is 50 vppm, rather than 10,000 vppm. The incident would still be reportable as a PSI since the release of CO_2 is greater than the 2000 kg (4400 lb) threshold.

DAYS AWAY FROM WORK INCIDENTS

A ”days away from work” incident (or fatality) inclusion as a reportable Process Safety Incident depends upon it being caused by the loss of containment of a material or is directly related to evacuating from or responding to the loss of containment..

32. .An operator is walking, then slips and falls to the floor and suffers a lost time injury. The slip/fall is due to weather conditions, "chronic" oily floors and slippery shoes. This is not a reportable PSI. Personnel safety "slip/trip/fall" incidents that are not directly associated with evacuating from or responding to a loss of containment incident are specifically excluded from PSI reporting.

33. Same as above, except that the operator slipped and fell while responding to a small flammable liquid spill (e.g., less than 1000 kg in 1 hour). This would be PSI reportable since the operator was responding to a loss of containment incident. A PSI is reportable if the loss of primary containment occurs on Company Premises and results in a lost time incident or fatality. For fatalities and lost time incidents, there is no release threshold quantity requirement.

34. Same as above, except that the operator slipped and fell several hours after the incident had concluded. This would not be PSI reportable. The terms "evacuating from" and "responding to" in the reporting exclusion mean that the loss of containment and associated emergency response activities are on-going. Slips/trip/falls after the event have concluded (such as "after-the-fact" clean-up and remediation) are excluded from PSI reporting.

35. A scaffold builder suffers a lost time injury after falling from a scaffold ladder while evacuating from a loss of containment incident on nearby equipment. This is a reportable PSI.

36. An operator walks past an improperly designed steam trap. The steam trap releases and the operator's ankle is burned by the steam, resulting in a lost time injury. This is a reportable PSI because even though the loss of containment was

steam (vs. hydrocarbon or chemical), the physical state of the material was such that it caused a lost time injury. Non-toxic and non-flammable materials are excluded from the threshold quantity criteria, but are subject to the other consequence criteria.

37. An enclosure has been intentionally purged with nitrogen. A contractor bypasses safety controls, enters the enclosure and dies. This is a reportable fatality, but not a reportable PSI since there was no unplanned or uncontrolled loss of primary containment.

    Note: This fatality may be reportable under safety regulations and may need to be recorded on a company's injury and illness log.

38. Same as above, except that nitrogen inadvertently leaked into the enclosure. This would be a reportable PSI (and fatality) since there was a fatality associated with an unplanned loss of primary containment.

39. An operator responding to an H_2S alarm collapses and has a "days away from work" injury. If the alarm was triggered by an actual unplanned or uncontrolled H_2S LOPC, the event would be a reportable PSI. If the alarm was a false alarm, the event would not be a reportable PSI because there was no actual release.

PIPELINES

40. An underground pipeline leaks and releases 1,000 bbls of diesel (combustible material) over 3 days (13.9 bbl/hr).. The spill results in contaminated soil that is subsequently remediated. This is not a reportable PSI since there were no safety consequences and the quantity did not exceed the . "acute" threshhold of 14 bbls or greater. .

41. A pipeline leaks and releases 2000 lbs. of flammable vapor above ground within 1 hour. However, the release occurred in a remote location within the site. The release is PSI reportable, since "remoteness" is not a consideration and it release exceeds the threshold quantity.

42. A DOT covered pipeline that is owned, operated, and maintained by Company A crosses through Company B's property. The DOT covered line has a 1500 lb release within an hour from primary containment of flammable gas and causes a fire resulting in greater than $25,000 damage to Company A's equipment. This is not a reportable PSI for Company B since the pipeline is not owned, operated or maintained by Company B. This would be a transportation incident for Company A.

FIRES or ENERGY RELEASES NOT ASSOCIATED WITH LOSS OF PRIMARY CONTAINMENT

As a general rule, a fire or energy release is reported as a PSI only if caused by a loss of primary containment or results in a chemical release in excess of the reporting quantities. Examples include:

43. An electrical fire impacts the operation of the process resulting in the release of 4000 lbs. of toluene. This event would be reported as a PSI since if the loss of primary containment exceeds the 2200 lb. reporting threshold for toluene.

44. An electrical fire, loss of electricity, or any other loss of utility which causes a plant shutdown and possibly incidental equipment damage greater than $25,000 (e.g., damage to reactors or equipment due to inadequate shutdown) but does not cause a loss of primary containment that results in one of the identified consequences would not be reported as a PSI. To be a reportable PSI, there must be a loss of primary containment.

45. A bearing fire, lube oil system fire, electric motor failure, or similar fire occurs which damages the equipment (> $25,000) but does not cause a loss of primary containment that results in one of the identified consequences would not be reported as a PSI since no chemical release greater than the threshold quantity or injuries occurred.

46. .If in the examples #44 or #45, if either an injury or chemical release exceeding the threshold quantity had occurred these would have been reportable PSI events.

47. An internal deflagration in a vessel causes equipment damage > $25,000, but there was no loss of containment. While this is a serious process event and should be investigated as such, it does not meet the definition of a reportable PSI since there was no loss of primary containment.

48. The vent on a storage tank containing chemicals becomes plugged and vacuum caused by routine pump out collapses the tank resulting in equipment damages >$25,000. This event would not be reported as a PSI since there was no loss of primary containment.

49. If in the example #48, if a tank seam failed resulting in a spill of contents in excess of the TQ quantity for that material, it would have been reported as a PSI (even if the contents were captured in secondary containment dikes).

50. A scaffold board is placed near a high pressure steam pipe and subsequently begins to burn, but is quickly extinguished with no further damage. The investigation finds that the board had been contaminated by some oil, but there is no indication of an oil leak in the area. This is not a reportable PSI since there was no unplanned or uncontrolled LOPC.

MARINE TRANSPORT VESSELS

51. A company operated Marine Transport Vessel has an onboard "acute" spill of combustible material greater than 14 bbls. The event is not PSI reportable since Marine Transport Vessel incidents are specifically excluded, except when the vessel is connected to the process for the purposes of feedstock or product transfer.

52. A third-party barge is being pushed by a tug and hits the company dock. A barge compartment is breached and releases 50 bbl of diesel to the water. The event is not a reportable PSI since the marine vessel was not connected to the process for the purposes of feedstock or product transfer..

TRUCK AND RAIL

53. A company railcar derails and spills more than 7 bbls of gasoline while in transit outside the facility. The incident is not PSI reportable since railcar was connected to the process for the purposes of feedstock or product transfer or being used for onsite storage.

54. A third-party truck/trailer overturns while in the Company Premises, resulting in an "acute" spill of gasoline greater than 7 bbls. The incident is not reported as a PSI reportable if the truck is no longer connected to the loading/unloading facilities. However, companies may choose to have transportation incident metrics, which would capture this event.

55. A contract truck hauler is unloading caustic and the hose separates and generates an airborne aerosol and/or liquid caustic spill of 2500 kg. The event is a reportable PSI since the caustic TQ of 1000 kg was exceeded and

the truck was still connected to the loading/unloading facility immediately prior to the incident.

56. Two chlorine railcars have been delivered to the facility. One is connected to the process and the other is staged at the unloading rack but is not connected to the process. While at the unloading rack but not connected to the loading rack, the second railcar develops a leak and 6 lb is released in less than an hour. This is not a reportable PSI since truck and railcars are expressly excluded unless connected to the process or being used for on site storage. Staging while waiting to unload is not considered storage.

OFFICE BUILDING

57. There is a boiler fire at the Main Office complex, and direct cost damages totaled $75,000. The incident is not PSI reportable since Office Building incidents are specifically excluded.

MAN-MACHINE INTERFACE INCIDENTS

58. An operations technician is injured while working around the finishing equipment in a polymers plant. The injury is caused by the mechanical, man-machine interface with the equipment. This would not be a reportable Process Safety Incident because there was no unplanned or uncontrolled loss of containment.

ASSIGNMENT OF SEVERITY SCORES

59. A leak on a high pressure hydrochloric acid line results in a spill of 4000 lbs of hydrochloric acid. Flash calculations indicate that greater than 500 lbs. of hydrogen chloride would be released as a vapor. Three employees in the plant received inhalation injuries, resulting in hospitalization for multiple days. The toxic cloud was witnessed by emergency response crews to extend into adjacent plants within the site, but there was no evidence that a harmful toxic concentration extended beyond the plant fenceline. However, a precautionary shelter-in-place and closure of adjacent interstate highway occurred for 2 hours. Resulting in extensive local media coverage and brief national media coverage. This incident clearly is a reportable PSI incident since the Hydrochloric acid and HCI vapors released each exceeded the chemical release TQ. Furthermore, the injuries to employees exceeded the health effects threshold for reporting. The Safety/Human Health severity level is a "2" (9 severity points) due to multiple lost-time injuries; the Fire/Explosion severity level is "N/A" (0 severity points) due to no equipment damages or clean-up costs greater than $25,000; the Potential Chemical Impact severity level is a "3" (3 severity points) since the chemical release extended outside of containment but retained on company property; and the Community/Environmental Impact severity level is a "2" (9 severity points) due to the shelter-in-place and media attention. The maximum of the four categories was a Severity level "2"; therefore, the overall incident could be classified as a Severity Level "2" PSI. The Severity points which would be used in the **Process Safety Incident Severity Rate (PSISR)** calculation would be 21 points (9+0+3+9=21).

60. The release of 10,000 lbs of ethylene (flammable vapor) occurs when a flange on a compressor fails. The flammable vapor cloud collects within the compressor building and adjacent pipe rack (i.e., a Potential Explosion Site), but fortunately does not ignite. As a precautionary measure, the occupants of the plant and surrounding plants are evacuated. But no injuries or substantial damages occur. There is no off-site impact. This incident is a reportable PSI incident since the ethylene vapors released exceeded the 1100 lb chemical release TQ for a flammable vapor. The Safety/Human Health, Fire/Explosion, and Community/Environmental severity levels are each "N/A" (0 severity points) due to none of these impacts of this event exceeding the thresholds for classification as a Severity Level "4" for that category. The Potential Chemical Impact severity level is a "2" (9 severity points) since the flammable vapor release resulted in a vapor cloud entering a building or potential

explosion site (congested/confined area) with potential for damage or casualties if ignited. The maximum of the four categories was a Severity level "2"; therefore, the overall incident could be classified as a Severity Level "2" PSI. The Severity points which would be used in the **Process Safety Incident Severity Rate (PSISR)** calculation would be 9 points (0+0+9+0=9).

61. The release of 10,000 lbs of ethylene (flammable vapor) occurs when a flange on a compressor fails. The flammable vapor cloud collects within the compressor building and adjacent pipe rack and ignites. The resulting vapor cloud explosion causes $30MM in damages or other direct costs, severely injures 3 employees (i.e., the injuries each meet the definition of "lost time injury"), and gains regional media attention for several days. The Safety/Human Health severity level of this event meets the threshold for classification as a Severity Level "2" (9 severity points) due to the multiple lost time injuries, the Fire/Explosion severity level would be classified at the Severity Level "1" (27 severity points), the Potential Chemical Impact severity level is a "2" (9 severity points) since the flammable release resulting in a vapor cloud entering a potential explosion site (congested/ confined area) as demonstrated by the results, and the Community/ Environmental severity level meets the threshold for classification as Severity Level "2" (9 severity points) due to the media coverage. The maximum of the four categories was a Severity level "1"; therefore, the overall incident could be classified as a Severity Level "1" PSI. The Severity points which would be used in the **Process Safety Incident Severity Rate (PSISR)** calculation would be 54 points (9+27+9+9=54). A company could argue that the potential chemical impact severity level for this even should be "N/A" (0 points) since much of the fuel is consumed in the explosion. However, since there is a potential that all fuel was not consumed and/or the event could have been even more significant under slightly different circumstances – the Potential Chemical Impact severity level of "2" (9 severity points) is appropriate.

MIXTURES

62. A chemical manufacturer spills 10,000 lbs of a formulated product containing multiple chemicals downstream of a mixing operation. This material is marketed as specific product (e.g., a heating fluid, brake fluid, etc.). Since this material is shipped in this formulation, the company has previously evaluated the mixture per all of the UN Dangerous Goods definitions (or DOT regulations in the USA) and classified the mixture as a "Packing Group III" material. Since the spill exceeded the 2000 kg (4400 lb.) threshold quantity of a Packing Group III material, this spill would be reported as a PSI.

63. A pipe fitting in a specialty chemicals plant fails, releasing 4000lb of a mixture of 30% formaldehyde, 45% methanol, and 25% water in less than one hour. This mixture is not classified by the UN Dangerous Goods/U.S. DOT protocols; therefore, the threshold quantity mixture calculation is applied. The pure component reporting threshold of formaldehyde is 4400 lb and methanol is 2200lb.

Component	wt.% (lb)	Release Qty (lb)	PSE TQ	% of TQ
Formaldehyde	30%	1200	4400	27.3%
Methanol	45%	1800	2200	81.8%
Water	25%	1000	n/a	0%
				109.1%

This release is a Tier 1 PSE since the cumulative percentage exceeds 100% even though the individual components do not exceed their individual threshold quantities.

Note: This is an alternative shortcut approach and can give more or less conservative results. A more precise approach is to use the rules of DOT 49 CFR 173.2a [14] or UN Recommendations on the Transportation of Dangerous Goods, Section 2.

VACUUM TRUCK OPERATIONS

64. After collecting a load from an adjacent unit, a vacuum truck is parked at the wastewater treatment facility awaiting operator approval to discharge. While waiting the vacuum truck malfunctions and vents process material to the atmosphere. This is not a PSi since vacuum truck operations are excluded unless loading, discharging, or using the truck's transfer pump.

65. A vacuum truck outfitted with a carbon canister on the vent is loading a spill of hydrocarbons. The carbon canister catches fire which escalates to the point of creating more than $45,000 in damage to the vacuum truck. This is a PSI since the original spill of hydrocarbons constitutes the LOPC and the response to the LOPC results in fire damage greater than $25,000.

DIRECT COSTS

66. A pump seal fails and the resultant loss of containment catches on fire. The fire is put out quickly with no personnel injuries. However, the fire resulted in the need to repair some damaged instrumentation and replace some insulation. The cost of the repairs, replacement, cleanup, and emergency response totaled $20,000. This is not a PSI. It should be noted the cost of replacing the seal is not included in the direct cost calculation—only the costs for repair and replacement of the equipment damaged by the fire, not the cost to repair the equipment failure that led to the fire.

OFFICIALLY DECLARED EVACUATION OR SHELTER-IN-PLACE

67. A small quantity of very odorous material enters a cooling water system via tube leak. The material is dispersed into the atmosphere at the cooling tower. An elementary school teacher decides not to conduct recess outside due to a noticeable odor even though officials deemed no shelter-in-place was necessary; therefore, this is not a PSI.

68. Less than 1 pound of Hydrogen Fluoride gas is released while unloading a truck at a refinery. The release is detected by a local analyzer and triggers a unit response alarm. An off-duty police officer living in a nearby home advises his neighbors to evacuate because "an alarm like that means there's a problem at the refinery." This is not an officially declared evacuation or shelter-in-place because in this situation the officer is acting as a private citizen suggesting a precautionary measure; therefore this is not a PSI.

II. Leading Metrics

This section contains a number of potential leading metrics. These indicate the health of important aspects of the safety management system. If measured and monitored, data collected for leading metrics can give early indication of deterioration in the effectiveness of these key safety systems, and enable remedial action to be undertaken to restore the effectiveness of these key barriers, before any loss of containment event takes place.

The safety systems that leading metrics have been developed for are:

- Maintenance of mechanical integrity;
- Action items follow-up;
- Management of change; and
- Process safety training and competency (and training competency assessment).

It is recommended that all companies adopt and implement leading process safety metrics, including a measurement of process safety culture. However, given the number of metrics described below it may be impracticable to collect and report data for each of these categories. Companies should identify which of these components are most important for ensuring the safety of their facilities, and should select the most meaningful leading metrics from the examples below for the identified components, and where significant performance improvement potentially exists. Other leading metrics may be defined as well if applicable.

These leading process safety metrics were selected based upon the experience of the organizations represented by the work group, including

- Barriers related to the hazards inherent in their operations,
- Barriers related to the critical causal factors or immediate causes of major incidents and high potential near-misses experienced by their operations, and
- Review of the metrics detailed in the CCPS Risk Based Process Safety book.

These leading metrics will continue to be refined as the CCPS Metric Committee finalizes the Metric Guideline book in 2008. Enhancements or suggestions to these metrics are welcome.

1.0 Mechanical Intergrity

A. (Number of inspections of safety critical items of plant and equipment due during the measurement period and completed on time/Total number of inspections of safety critical items of plant and equipment due during the measurement period) x 100%.

- This metric is one measure of the effectiveness of the process safety management system to ensure that safety critical plant and equipment is functional.
- This involves collecting data on the delivery of planned inspection work on safety critical plant and equipment.
- The calculation of the metric involves
  - Define the measurement period for inspection activity.
  - Determine the number of inspections of safety critical plant and equipment planned for the measurement period.
  - Determine the number of inspections of safety critical plant and equipment completed during the measurement period.
- Inspections not undertaken during the previous measurement period are assumed to be carried forward into the next measurement period

Definitions:

Safety critical plant and equipment: Plant and equipment relied upon to ensure safe containment of hazardous chemicals and stored energy, and continued safe operation. This will typically include those items in a plant's preventative maintenance program, such as:

- Pressure vessels
- Storage Tanks
- Piping systems
- Relief and vent devices
- Pumps
- Instruments
- Control systems
- Interlocks and emergency shutdown systems
- Emergency response equipment

B. (Length of time plant is in production with items of safety critical plant or equipment in a failed state, as identified by inspection or as a result of breakdown/Length of time plant is in production) x 100%

This is a metric to determine how effectively the safety management system ensures that identified deficiencies of process safety equipment are fixed in a timely manner.

2.0 Action Items Follow-up

(Number of past due of process safety action items / Total number of action items currently due) x 100%..

This metric may be configured as one aggregate metric or several individual metrics of specific past due items, such as:

- (Number of past due audit action items / total number of audit action items currently due) x 100%
- (Number of past due PHA action items / total number of PHA action items currently due) x 100%
- (Number of past due incident investigation action items / total number of incident investigation action items currently due) x 100%
- (Number of past due PHA action items / total number of PHA action items active or open) x 100%

Definitions:

Currently Due: Actions with a due date less than or equal to the current date.

Past Due: Actions that are active or open and past their assigned completion date.

3.0 Management of Change

A. Percentage of sampled MOCs that satisfied all aspects of the site's MOC procedure.

- This metric measures how closely the site's MOC procedure is being followed.
- Involves a periodic audit of completed MOC documentation. Steps in conducting the audit:
  - Define the scope of the audit: time frame, frequency, and operating department(s).
  - Determine the desired and statistically-significant sample size. This can be done using widely-available tables, based on the total number of MOC documents in the population.

- Review the completed MOC documentation, including backup documentation such as the hazard review and updated Process Safety Information such as operating instructions and P&IDs.
- Calculate the metric:

$$\textbf{\% of MOCs properly executed} = \frac{\textbf{100 x (\# of properly executed MOCs)}}{\textbf{(total \# of MOCs)}}$$

B. Percentage of identified changes that used the site's MOC procedure prior to making the change.

- This metric measures how well a department/site (i) recognizes changes that require use of the site's MOC procedure and (ii) actually makes use of the procedure prior to implementing changes.
- Involves a periodic audit of the changes made in a department/site and a determination of which changes required use of MOC. Steps in conducting the audit:

  -Define the scope of the audit: time frame and operating department(s).
  -Identify the types of changes that may have bypassed the site's MOC procedure, based on how the site's MOC procedure defines changes (see definition below).
  -Identify changes that bypassed the MOC procedure. This can be done by:

    - Reviewing maintenance work orders,
    - Reviewing documentation from capital and maintenance projects,
    - Reviewing Distributed Control System programming changes, and/or
    - Interviewing department personnel.
    - Calculate the metric:

$$\textbf{\% of changes using MOC} = \frac{\textbf{100 x (\# of MOCs)}}{\textbf{(\# of MOCs + \# of changes that bypassed MOC)}}$$

Other Ideas: The two MOC metrics above provide a means by which companies can readily measure how well they are identifying changes that need to be evaluated by MOC and how well they are executing the MOCs they do identify. Following are ideas companies may want to consider if they want to develop more sophisticated internal MOC metrics:

- A refinement to the metric for how well a company is executing their MOC procedure is to include a grading system for how well a given MOC followed the procedure, rather than the yes/no ranking provided above. For example, if the company identified 25 key aspects to a properly completed MOC and a given MOC satisfied 20 of these aspects, then the MOC would receive a grade of 0.8. An audit of multiple MOCs could generate an overall average grade for the audit sample. An even more sophisticated approach could include a relative weighting of the criticality of the, say, 25 aspects to a properly completed MOC.

- A company may desire to have a metric for the number of temporary MOCs not closed out in the prescribed time period. Temporary MOCs are typically executed for emergency, start-up or trial situations. The prescribed time period may be specified in the particular MOC or as a maximum allowable duration under the site's temporary MOC procedure. The temporary MOC must be closed out by restoring the system to original design condition or by making the change permanent via the site's regular MOC procedure. Failure to close out in a timely fashion could present risks.

- A company may desire to have a metric that measures how effective the site's MOC procedure is at identifying and resolving hazards related to changes. If so, the following may be considered:

Percentage of start-ups following plant changes where no safety problems related to the changes were encountered during re-commissioning or start-up.

- Involves real-time logging of start-ups, including safety problems encountered during recommissioning and start-up, followed by a determination of which problems had a root cause related to a change that was made.

- Involves a periodic audit of completed MOCs that involved a shut-down and restart of a unit or portion of a unit. Steps in conducting the audit:

  - Define the scope of the audit: time frame and operating department(s).

  - Determine the number of start-ups of the unit(s) or portions of the unit(s) following the implementation of changes.

  - Determine the number of these start-ups where a change-related safety problem was encountered after checkout, during the recommissioning or start-up phases.

  - Calculate the metric:

% of safe start-ups following changes = 100 x (# of start-ups following changes without change - related safety problems during recommissioning and start-up) / (total # of start-ups following changes)

A complicating factor that must be considered is the fact that problems from the change may not show up until a long time after start-up.

Definitions:

Changes requiring MOC review: The types of changes requiring use of the site's MOC procedure should be defined by the procedure. Normally this will include:

- Changes to equipment, facilities and operating parameters outside the limits defined in the unit's Process Safety Information.
- Process control modifications.
- Introduction of new chemicals.
- Changes to chemical specifications or suppliers
- Building locations and occupancy patterns.
- Organizational issues such as staffing levels and job assignments.

Checkout: The phase after a change is made and before the introduction of chemicals and other hazardous materials when system integrity is confirmed. Potentially hazardous conditions can be identified and corrected during checkout without resulting in an incident.

Recommissioning: The phase after checkout and before start-up when chemicals are introduced to the system and pressures/temperatures may be increased. Potentially hazardous conditions identified during recommissioning may result in a safety and/or environmental incident.

Start-up: The phase after recommissioning when production operations are initiated. Potentially hazardous conditions identified during start-up may result in a safety and/or environmental incident.

4.0 Process Safety Training and Competency

A. Training for PSM Critical Positions

(Number of Individuals Who Completed a Planned PSM Training SessionOn-time)/(Total Number of Individual PSM Training Sessions Planned)

__**Definitions:**__

PSM Critical Position: Any facility position that includes key activities, tasks, supervision, and/or responsibility for component procedures critical to the prevention of and recovery from major accident events.

Planned PSM Training Session: A specific exercise designed to enhance an individual's knowledge, skill, and/or competency in a PSM critical position for areas that directly influence the prevention of and recovery from major accident events. A single individual may have multiple training sessions during a reporting period. A single exercise may involve multiple individual training sessions (e.g., a training class with multiple individuals).

B. Training Competency Assessment

(Number of Individuals Who Successfully Complete a Planned PSM Training Session on the First Try)/(Total Number of Individual PSM Training Sessions with Completion Assessment Planned for that time period)

__**Definitions:**__

Successful Completion: A passing grade on an exam or competency assessment for which there is no requirement to repeat/redo the training, exam, competency assessment or any part thereof.

Training Session with Completion Assessment: A planned PSM training session for which there is a required demonstration of knowledge or skill through an examination or competency assessment.

C. Failure to follow procedures/safe working practices

(Number of safety critical tasks observed where all steps of the relevant safe working procedure were not followed/Total number of safety critical tasks observed) x 100%

To determine by work place observation of tasks identified as being safety critical that have a relevant safe operating procedure, whether all of the relevant steps are followed.

5.0 Safety Culture

A mechanism for measuring the effectiveness of process safety culture within chemical process organizations would be to adopt the use of a cultural survey of the type included as Appendix G of the Baker panel report and discussed throughout the report used to determine the adequacy of the safety culture at BP's US refineries.

The chemical and downstream oil processing sectors should consider use of this or similar survey. If used, the safety culture survey should be undertaken in such a way that the results are made anonymous, so that respondent cannot be identified and that there will be no negative judgment on respondents that may affect their willingness to participate or their level of openness.

Undertaking a culture survey of this nature will not enable comparison of results between organizations because of the many other factors that can affect the results, but it will be of benefit in determining changes within an organization over time.

6.0 Operating & Maintenance Procedures

A. **Procedures Current & Accurate**

(Number of operating or maintenance procedures reviewed/updated per year / Total number of operating or maintenance procedures required to be reviewed/updated during the measurement period) x 100%.

This metric measures the progress of the review/update cycle. A downward trend may indicate that more attention or resources are needed to maintain procedures.

B. **Procedures Clear, Concise & Include Required Content**

(Number of operating or maintenance procedures reviewed for content / Total number of operating or maintenance procedures) x 100%.

This metric measures the progress of creating clear, concise, and effective operating and maintenance procedures. A checklist of procedure criteria will need to be developed that addresses:

- Document control
- Action steps that are clear and properly ordered
- Cautions, Warnings, and Notes
- Safe operating limits, consequences of deviations from limits, and steps to take to maintain the process within the safe operating limits
- Limiting conditions for operation
- Checklists (where appropriate)

C. Confidence in Procedures

(Number of operators or maintenance technicians who believe that procedures are current, accurate, and effective / Total number of operators or maintenance technicians affected by the procedures) x 100%.

Results of opinion surveys of operators or maintenance technicians my provide early indication of changes in the accuracy or effectiveness of procedures. The survey should identify concerns about time required to update procedures, accuracy, and user friendliness.

7.0 Fatigue Risk Management

A. Fatigue Risk Education

(Number of affected employees educated on the causes, risk and potential consequences of fatigue / Total number of affected employees) x 100%.

The education should acquaint all affected employees with the basic scientific principles of sleep, sleep disorders, alertness, circadian, and fatigue physiology so that they can make informed decision which will help them reduce the fatigue risk for themselves, their colleagues, and the people they may supervise or manage. This education should also provide information designed to increase family member awareness of how they can help the affected employee keep alert, safe and healthy.

B. **Percentage Overtime (median, mean, top 10 %)**

(Number of overtime hours / Total number of standard work hours during the measurement period) x 100% per person.

C. Number of Extended Shifts

Number of extended shifts per person during the measurement period

Extended shifts are time an employee is assigned to work that extends outside their regularly scheduled shift hours and into other shifts. Extended shifts include holdovers to participate in training, safety meetings, and the like. It does not include time needed for normal shift handoff.

III. Near Miss Reporting and other Lagging Metrics

The CCPS committee recommends that all companies implement a Near Miss reporting metric(s). Since a near miss is an actual event or discovery of a potentially unsafe situation, this metric could be defined as a “lagging” metric. A large number or increasing trend in such events could be viewed as an indicator of a higher potential for a more significant event; therefore, many companies use Near Miss metrics as a surrogate for a “Leading” metric. Many companies have discovered that an increasing trend in near misses reported, at least for the first several months after implementation, is a positive sign of improved culture and process safety awareness by the organization. Therefore, it is quite possible that the number and count of more significant incidents decrease as the number of near misses reported increase.

It is important that all companies have some type of near miss reporting system implemented. The metric and definitions described below (created by harmonization of definitions used by contributing companies) should be considered if implementing a new system. If a company already has an effective near miss reporting system, which includes or aligns well with the following definitions, there should be no reason to replace that existing system.

It is recommended that all companies have an internal metric to report all Losses of Primary Containment (LOPC) and unplanned fires/flames. This will include all pressure relief device discharges excluded from the industry lagging metric. For the purposes of the industry-wide process safety incident lagging metric, a threshold value has been established for events that should be reported as part of that metric. Companies should have additional metrics, or include within their overall "Near Miss" metric, any additional LOPC or unplanned fires/flames which fell below the PSI or PSE – Tier 2 threshold and were not recorded in the industry-wide lagging metrics. There are important learning values from recording and investigating these events.

A "**near miss**" has three essential elements. While various wordings for a near miss definition are used within industry, the overwhelming majority has these elements:

- an event occurs, or the discovery of a potentially unsafe situation;
- the event or unsafe situation had reasonable potential to escalate, and
- the potential escalation would have led to adverse impacts.

For purposes of this discussion, the following near miss definition is used.

> **Near Miss**: An undesired event that under slightly different circumstances could have resulted in harm to people, damage to property, equipment or environment or loss of process.

This near miss definition may be applied to any aspect of an EHS management program, used for reporting environmental, personnel safety or process safety near misses for example.

Definition of a Process Safety Near Miss

In order to specifically focus on process safety in a near miss reporting program, many companies have also developed a definition for a process safety near miss. Again, for purposes of this discussion, the following process safety near miss definition is used.

Process Safety Near Miss:

- any significant release of a hazardous substance that does not meet the threshold for a "Process Safety Incident" lagging metric, or
- a challenge to a safety system, where:

Challenges to a safety system can be divided into the following categories:

- Demands on safety systems (pressure relief devices, safety instrumented systems, mechanical shutdown systems),
- Primary containment inspection or testing results outside acceptable limits
- Process deviation or excursion.

Examples of Process Safety Near Miss

Near misses for Demands on Safety Systems may fall into a category of either creation of a demand with successful safety system operation or creation of a demand with failure of the safety system given a legitimate demand. Examples include:

- Opening of a rupture disc, a pressure control valve to flare or atmospheric release, or a pressure safety valve when pre-determined trigger point is reached.
- Failure to open of a rupture disk, a pressure control valve to flare or atmospheric release, or a pressure safety valve when the system conditions reac h or exceed the prescribed trigger point.
- Activation of a safety instrumented system when "out of acceptable range" process variable is detected.
  - activation of high pressure interlock on polyethylene reactor to kill reaction/shut off feed
  - compressor shutdown from a high level interlock on the suction knockout drum
- Any time a safety instrumented system fails to operate as designed when a demand is placed on the system (i.e. unavailability on demand).

- The number of times a mechanical shutdown system is called upon to function by a valid signal whether or not the device actually responds.

  Mechanical shutdown systems that are configured for equipment protection with no related loss of containment protection should be excluded from the process safety near miss count.

Near misses involving primary containment inspection or testing results outside acceptable limits:

An inspection or test finding that indicates primary containment equipment has been operated outside acceptable limits. These findings typically trigger an action, such as replacement-in-kind, repairs to restore fitness-for-service, replacement with other materials, increased inspection or testing, or de-rating of process equipment. Examples include:

- An inspection or test finding that indicates vessels, atmospheric tanks, piping, or machinery when previous operating pressures or levels exceed the acceptable limits based upon wall thickness inspection measurements.

  A single event is recorded for each pressure vessel or atmospheric tank regardless of the number of individual test measurements found to be below the required wall thickness.

  A single event is recorded for each pipe circuit regardless of the number of individual test measurements below its required wall thickness as long as it is the same line, constructed of the same material, and is in the same service.

Near misses involving a process deviation or excursion include:

- Excursion of parameters such as pressure, temperature, flow outside operating window but remaining within the process safety limits.
- Excursions of process parameters beyond pre-established critical control points or those for which emergency shutdown or intervention is indicated.
- Operation outside of equipment design parameters.
- Unusual or unexpected runaway reaction whether or not within design parameters.

Near Misses associated with Management System Failures/Issues:

These types of observations should be captured to understand where there are opportunities for improving a facility's process safety management systems.

Discovery of a failed safety system upon testing

- Relief devices that fail bench tests at setpoints
- Interlock test failures
- Uninterruptible power supply system malfunctions
- Fire, gas, & toxic gas detectors found to be defective during routine inspection/testing
- During inspection of an emergency vent line header, the header was found to be completely blocked with iron scale because moisture from the emergency scrubber had migrated back into the header
- During testing of an emergency shutdown system, a Teflon-lined emergency shutdown valve was found stuck open because the Teflon had cold flowed and jammed the valve
- During inspection of a conservation vent, found the vent blocked by process material that had condensed and frozen

Discovery of a defeated safety system

- Process upset with interlock in bypass condition,
- Defeated critical instrument / device not in accordance with defeat procedure
- Bypasses left on after leaving block valve site

"Errors of Omission / Commission"

- Failure to remove line blanks in critical piping or failure to introduce the correct batch ingredients in the proper sequence
- During replacement of a rupture disk, the disk was found with the shipping cover still in place
- Process control engineer accidentally downloaded the wrong configuration to a process unit DCS

Unexpected / Unplanned Equipment Condition

- Equipment discovered in "unexpected" condition due to damage or premature / unexpected deterioration
- Wrong fittings used on steam system
- Failure of equipment like heat exchanger tubes leading to mix up and / or contamination of fluids

Physical Damage to Containment Envelope

- Dropping loads / falling objects within range of process equipment
- Truck backed into wellhead
- Snow plow grazed gas line

Maximizing Value of Near Miss Reporting

Near miss reporting provides valuable data for improving the process safety management systems at a facility. The following processes can maximize the benefits from a process safety near miss program.

➢ Use process safety lagging indicator, process safety near miss, and management system leading indicators to build a process safety performance pyramid.

➢ When evaluating process safety near misses, consider the potential adverse impacts. The level of response to a near miss (i.e. investigation, analysis, and follow-up) should be determined using the potential as well as the actual consequences of the event.

➢ Tie the near miss data to the deficient management system in order to drive system improvements from near misses as well as from actual incidents.

➢ Place value upon reporting near misses. Consider reward / recognition for reporting near misses as well as rewards for bottom line performance.

Appendix A: UN Dangerous Goods Classification and Listing of Chemicals

A comprehensive listing of chemicals, along with the threshold values for reporting as defined by this metric will be posted on the CCPS web site: http://www.aiche.org/ccps/resources/metricsproject

Additional information regarding the UN Dangerous Goods Classification System can be found at the following web sites:

UNECE web site:

http://www.unece.org/trans/danger/publi/adr/adr2007/07ContentsE.html

The PDF Dangerous Goods list complete with UN numbers:

http://www.unece.org/trans/danger/publi/adr/adr2007/English/03-2%20E_tabA.pdf

Alphabetical cross reference:

http://www.unece.org/trans/danger/publi/adr/adr2007/English/03-3%20E_alphablist.pdf

UN or DOT definitions

UN DG criteria

Flammable Liquids

Packing Group	Flash Point (closed-cup)	Initial boiling point
I	–	≤ 35 °C (≤ 95 °F)
II	< 23 °C (< 73 °F)	>35 °C (> 95 °F)
III	≥23 °C ≤ 60 °C (≥ 73 °F ≤ 140 °F	>35 °C (> 95 °F)

Toxic Liquids

TIH Hazard Zones A, B, C and D per US DOT regulations (Note: UN Dangerous Goods definitions do not include these definitions, but the following do align with definitions in the UN GHS definitions).

Hazard Zone	Inhalation toxicity
A	LC_{50} less than or equal to 200 ppm
B	LC_{50} greater than 200 ppm and less than or equal to 1,000 ppm
C	LC_{50} greater than 1,000 ppm and less than or equal to 3,000 ppm
D	LC_{50} greater than 3,000 ppm or less than or equal to 5,000 ppm

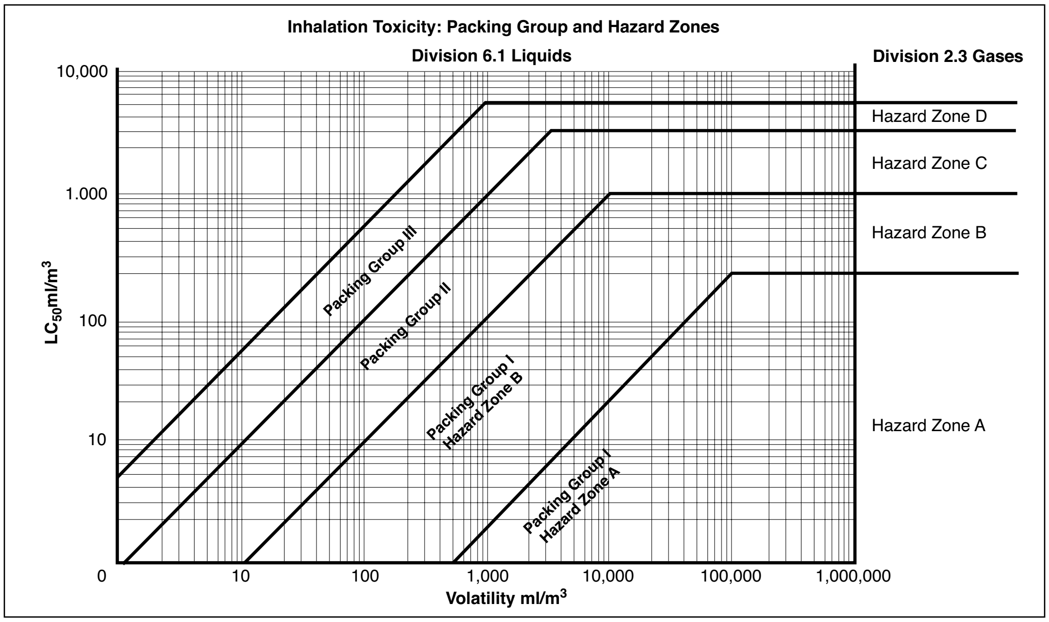
Toxic Liquids

Packing Group	Oral toxicity LD_{50}(mg/kg)	Dermal toxicity LD_{50}(mg/kg)	Inhalation toxicity by dusts and mists LC_{50}(mg/L)
I	≤ 5.0	≤ 50	≤ 0.2
II	> 5.0 and ≤ 50	> 50 and ≤ 200	> 0.2 and ≤ 2.0
III	> 50 and ≤ 300	> 200 and ≤ 1,000	> 2.0 and ≤ 4.0

The packing group and hazard zone assignments for liquids based on inhalation of vapors shall be in accordance with the following table:

Packing group	Vapor concentration and toxicity
I (Hazard Zone A)	V ≥ 500 LC_{50} and LC_{50} ≤ 200 mL/M^3
I (Hazard Zone B)	V ≥ 10 LC_{50}; LC_{50} ≤ 1,000 mL/m^3; and the criteria for Packing Group I, Hazard Zone A are not met
II	V ≥ LC_{50}; LC_{50} ≤ 3,000 mL/m^3; and the criteria for Packing Group I, are not met
III	V ≥ .2 LC_{50}; LC_{50} ≤ 5,000 mL/m^3; and the criteria for Packing Groups I and II, are not met

Note 1: V is the saturated vapor concentration in air of the material in mL/m3at 20 °C and standard atmospheric pressure.



Appendix B: Additional Clarifications regarding UN Dangerous Goods lists & Exceptions

The CCPS Committee, working in conjunction with representatives of several chemical and petroleum trade associations and process safety consortiums, selected the UN Dangerous Goods criteria for differentiating chemicals into a few threshold quantity categories since this approach:
was comprehensive, aligns with the new *Globally Harmonized System of Classification and Labeling of Chemicals (GHS)*, and resulted in excellent differentiation of hundreds of chemicals into a few groupings that aligned well with perceived risk when toxicity, flammability, and volatility were considered.

However, the UN DGL does contain a few materials that are either:

- not of general concern from a petrochemical process safety perspective (e.g., Cotton);
- described as a generic category with the associated label "not otherwise specified" (n.o.s.) which may require further evaluation to assign to a specific chemical (e.g., "Amines, liquid, corrosive, n.o.s.", or "Hydrocarbons, liquid, n.o.s."); or
- may contain chemicals in a specific physical property state (e.g., "Nitrogen, compressed", or "Nitrogen, cryogenic liquid") which may be confused for a less hazardous state which is not designated under the UN DGL. [Note: an acute and unintended release of "compressed" or "cryogenic" Nitrogen, Argon, or Helium would be treated as a PSI if the release exceeds the 2000 kg (4400 lb.) threshold quantity. But the planned, controlled, slow, and safe, releases of these chemicals (e.g., nitrogen used for purging) would not be reportable.

Furthermore, there are many low hazard materials which are excluded (e.g., solid polyethylene pellets); therefore, are not subject to reporting under this metric. However, it may not be apparent to the user if those chemicals are intentionally excluded or if covered under the generic categories described above.

Overall, the benefits of this expanded list of chemicals considered in the CCPS Lagging Metric due to the UN DGL outweigh the negatives of potential initial complexity in training or interpretation of these definitions. However, it is likely that initially there will need to be interpretations or exceptions for some specific chemicals listed in the UN DGL. To maintain the consistency in reporting between companies or trade groups, it is recommended that communication and collaboration between the trade groups continue with regard to any interpretations or exceptions needed to facilitate consistent and efficient reporting of the process safety lagging metric. If trade groups mutually agree to exclude specific chemicals from the metric, or apply other implementation guidelines, they are encouraged to communicate their decision to CCPS. CCPS can collect and post those agreed exceptions on the web site where these metrics documents will be available.

Acknowledgements

Thanks to:

Sanjay Choudhary, *Tata Chemicals, Ltd.*
Elroy Christle, *Honeywell, Inc.*
Jeff Fox, *Dow Corning*
Eric Freiburger, *Praxair, Inc.*
Wayne Garland, *Eastman Chemical Company*
Andrew Goddard, *Arkema*
Shakeel Kadri, *Air Products and Chemicals, Inc.*
Darrell Loewe, *Formosa Plastics Corporation*
Steve Marwitz, *Formosa Plastics Corporation*
Louisa Nara, *CCPS*
Tim Overton, *CCPS Emeritus*
Jeff Philiph, *Monsanto Company*
Philip Rasch, *BASF*
Daniel Sliva, *CCPS*
Kenan Stevick, *The Dow Chemical Company*

If your company is interested in process safety metrics and strengthening its process safety program, you should also:

- **Join CCPS**

  STRENGTHEN Your Corporate Process Safety Culture
  CONTRIBUTE to the Overall Safety of the Industry
  JOIN CCPS, the Global Community Committed to Process Safety

  For information about membership, call +1.646.495.1371 Or email ccps@aiche.Org
  For a complete member list, please see www.Aiche.Org/ccps/about/members.Aspx

- **Read "Guidelines for Process Safety Metrics"**

  For more information, please see www.wiley.com/go/CCPS

- **Attend the Global Congress on Process Safety**

  For more information, please see www.aiche.org/GCPS

- **Read and share the "Process Safety Beacon"**

  For more information, please see www.aiche.org/CCPS/Publications/Beacon/index.aspx

- **Advance basic awareness of Process Safety with the Process Safety Boot Camp**

  For more information, please see www.aiche.org/ccps/Education/BootCamp.aspx

CCPS An AIChE Technology Alliance

CENTER FOR CHEMICAL PROCESS SAFETY
AIChE 3 Park Avenue, New York, New York 10016-5991 USA ■ Tel: (+1) 646.495.1370
www.ccpsonline.org ■ E-mail: ccps@aiche.org

The Global Community Committed to Process Safety