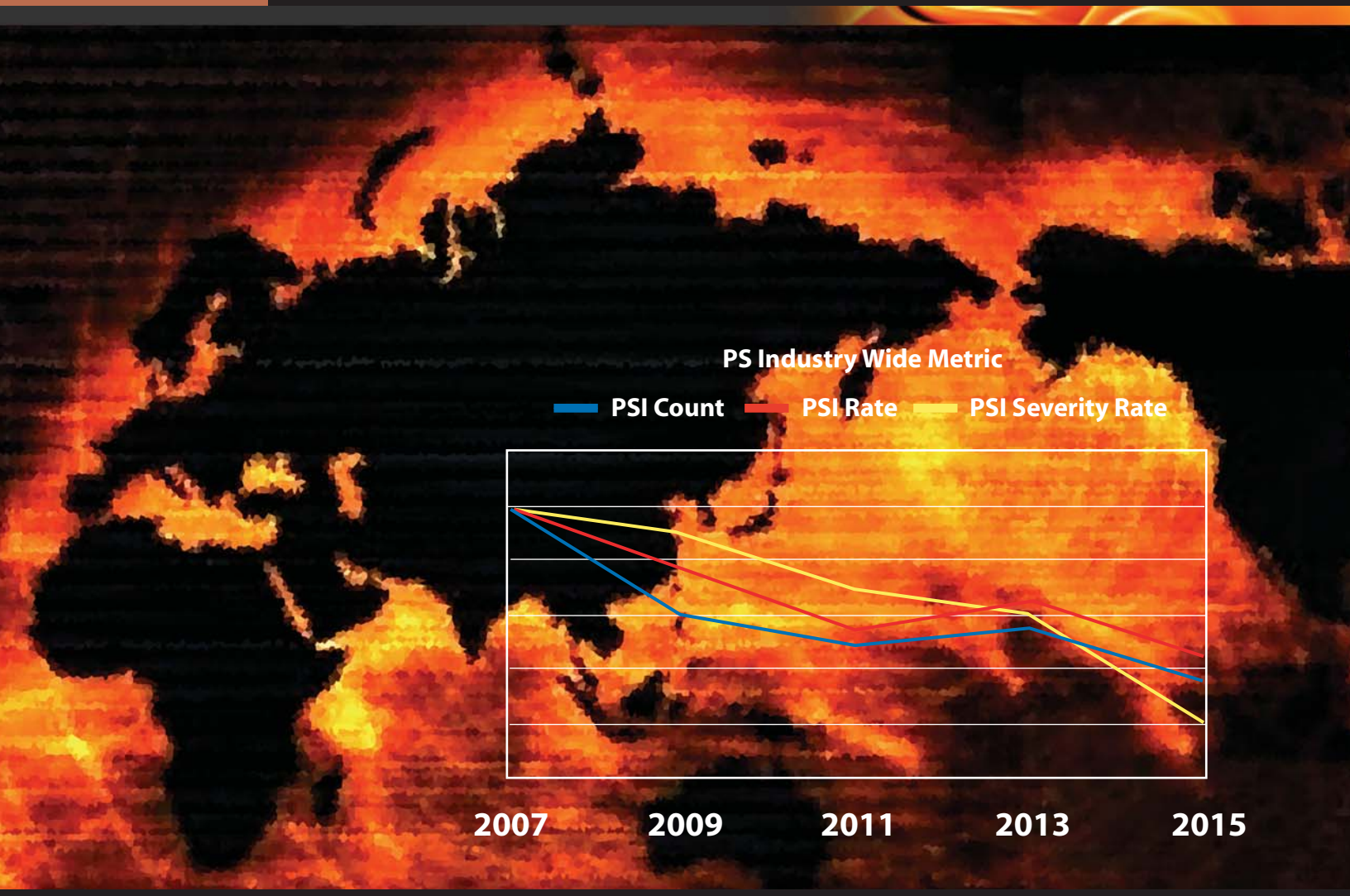
Center for Chemical Process Safety
An AIChE Technology Alliance

Process Safety Leading and Lagging Metrics

You Don't Improve What You Don't Measure



CCPS
CENTER FOR CHEMICAL PROCESS SAFETY
An AIChE Industry Technology Alliance

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 100 corporate members around the world drive the activities of CCPS.

In 2006, the CCPS Technical Steering Committee authorized a project, and the creation of a project committee, to develop a Guideline book for the development and use of Leading and Lagging Process Safety Metrics. In the initial meeting, the committee identified that the key breakthrough opportunity for industry was the development of an industry lagging metric that would become the benchmark across the chemical and petroleum industries for measuring process safety performance. To achieve this objective, it would become essential to involve representatives and members from each of the major chemical and petroleum trade associations as well as other key stakeholders. CCPS elected to extend invitations to a number of organizations, soliciting their involvement in this project.

The ultimate objective of this committee is to complete the Guideline book originally authorized by CCPS, such that additional information and guidance is available to individual companies on how to better use metrics to improve their process safety performance. This document is intended to propose an industry-wide lagging metric and suggested leading and other metrics for individual company consideration.

CCPS strongly recommends that companies around the globe adopt and implement these recommendations.

Acknowledgments

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We want to first thank the team members, and the organizations that supported their involvement in this project team:

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We also want to thank the many organizations who participated in this endeavor to harmonize the process safety lagging metric used by industry. These organizations include:

Organization*:	**Represented by:**
American Chemistry Council (ACC)	Dan Rosnowski, Debra Phillips
American Petroleum Institute (API)	Karen Haase, Ron Chittim
National Petrochemical and Refiners Association (NPRA)	Lara Swett
European Process Safety Centre (EPSC)	Richard Gowland, Ulrich Hansen
Conservation of Clean Air and Water in Europe (CONCAWE)	George Stalter

*** The listed entities participated, in whole or in part, in the development of this document. However, such participation should not be construed as endorsement of this document in its entirety.**

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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.

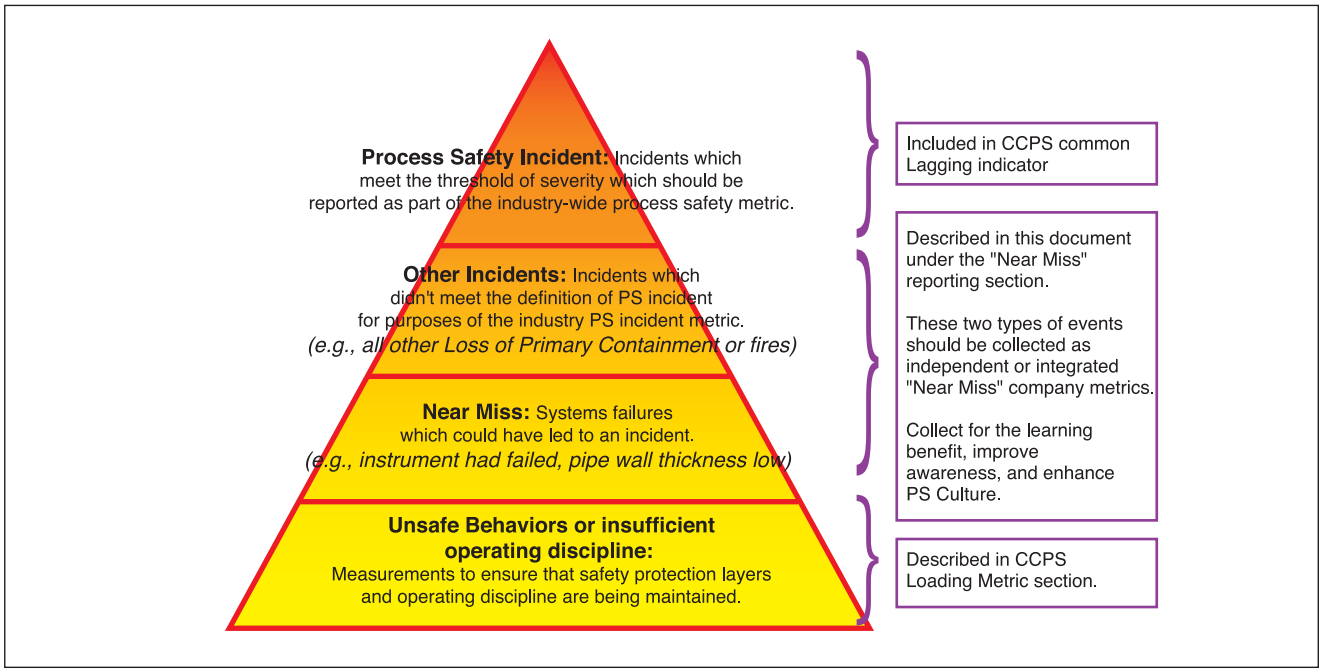
Within this document is a description of three types of metrics:

> ***"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 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.

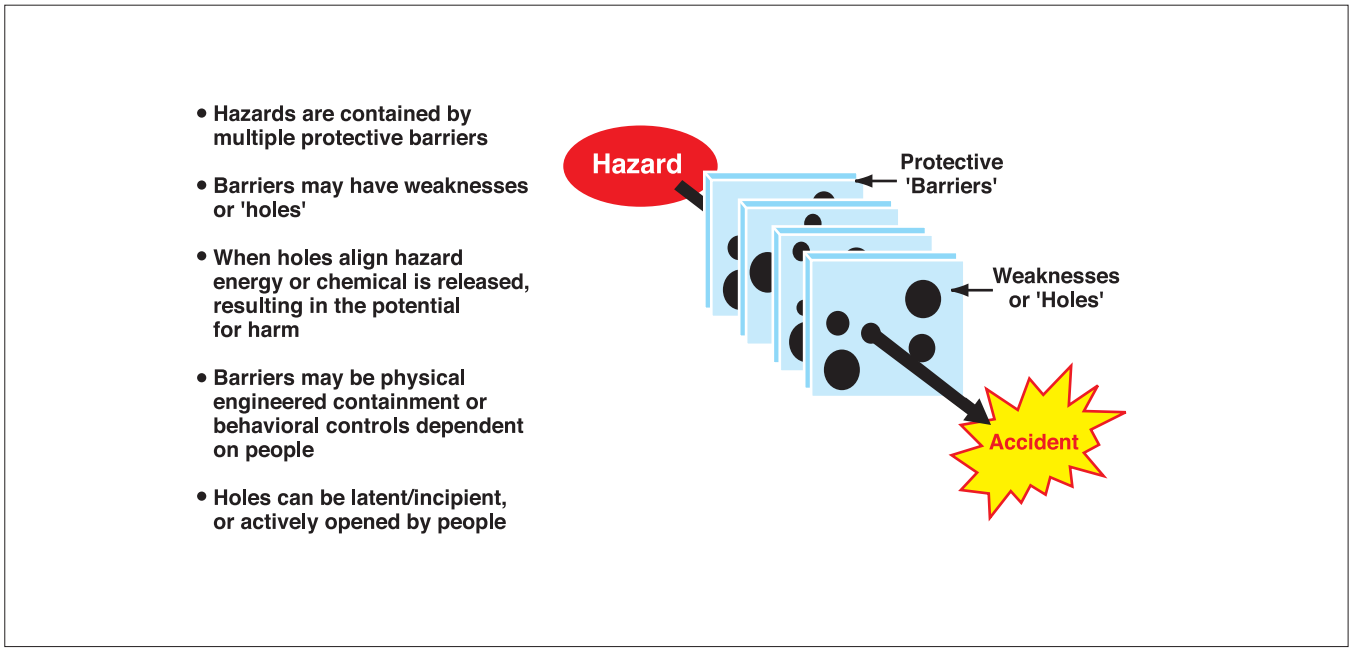
It is strongly recommended that all companies incorporate each of these three types of metrics into their internal process safety management system. Recommended metrics for each of these categories are included in the three primary sections of this document.

Figure 1: Safety and Safety Metric Pyramid



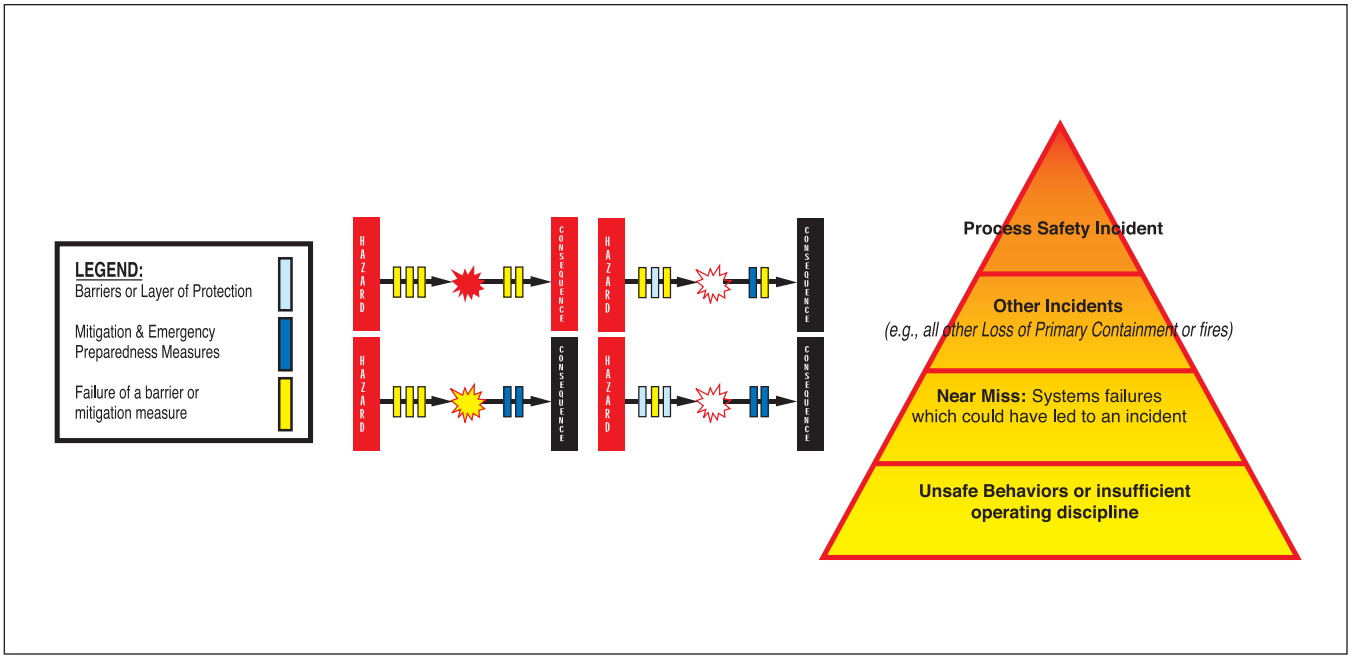
Another way to consider metrics is that the incidents at the top of the pyramid reflect situations where failures to the multiple layers of protection which are intended to prevent an incident (both physical layers and work process/operating procedure layers) have failed, while the bottom of the pyramid 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



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: Safety Pyramid/Failed Protection Layers



I. Lagging Metrics

The BP US Refineries Independent Safety Review Panel ("Baker Panel") and US Chemical Safety Board 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;
- 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):

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) Chemical or chemical process involvement
(2) Above minimum reporting threshold
(3) Location; and
(4) Acute release

Chemical or Chemical Process Involvement

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

> *A chemical or chemical 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 petrochemical 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

A release of material or energy from a chemical process, which results in any of the three situations below:

(1) An employee or contractor lost time injury and/or fatality, or hospital admission and/or fatality of a third party (non-employees/contractor)
(2) Fires or explosions resulting in greater than or equal to $25,000 of **direct cost** to the company, or;
(3) An acute release of flammable, combustible, or toxic chemicals from the primary containment (i.e., vessel or pipe) greater than the chemical release threshold quantities described on Table 1, excluding releases to properly designed and operating control device specifically designed for that event (e.g., flare, scrubber or relief devices per API Standard 521 or equivalent)

Table 1 – Process Safety Incident Threshold Values

Material Hazard Classification as Defined by United Nations as Dangerous	"Process Safety Incident"
Goods Definitions:	Threshold Quantity:
TIH Hazard Zone A materials[1]	5 kg (11 lbs.)
TIH Hazard Zone B materials[1]	25 kg (55 lbs.)
TIH Hazard Zone C materials[1]	100 kg (220 lbs.)
TIH Hazard Zone D materials[1]	200 kg (440 lbs.)
Other "Packing Group I" materials[2] & "Flammable Gases/Vapors"	500 kg (1,100 lbs.)
Other "Packing Group II" materials[2] & "Flammable Liquids"	1,000 kg (2,200 lbs.)
Other "Packing Group III" materials[2] & "Combustible Liquids" & Division 2.2 - Nonflammable, Nontoxic Gases	2,000 kg (4,400 lbs.)

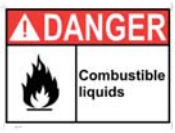
For a full list of materials cross-referenced to the UN Dangerous Goods definitions, see chemical list or spreadsheet tools posted on the http://www.aiche.org/ccps/resources/metrics web site.

For the purposes of applying these threshold values for "Flammable Gases/Vapors," "Flammable Liquids," and "Combustible Liquids," the user may use either the definitions commonly used within the petroleum refining industry (based upon National Fire Protection Association, NFPA-30 definitions), the UN Dangerous Goods (Class 2, Div. 2.1 and Class 3), or the Harmonized System of Classification and Labeling of Chemicals (GHS), Chapters 2.2 and 2.6. These different methods classify materials in a similar manner; therefore, most flammable materials will fall into the same category regardless of the definitions used.

[1] The TIH Hazard Zone A, B, C, and D designations are mentioned specifically in the US Department of Transportation regulations (49 CFR 172.101), and not in the UN Dangerous Goods definitions. However, these definitions do align with toxic vapor categories described in the Harmonized System of Classification and Labeling of Chemicals (GHS).
[2] Packing Group definitions based upon UN Dangerous Goods definitions. In the USA, these definitions are also described in US Department of Transportation regulations (49 CFR 172.101). These descriptions include several generic descriptions (e.g., "Toxic fluids") or materials which are not germane to the chemical or petroleum industries (e.g., cotton, explosive ammunition). Although the specific chemicals listed in the UN Dangerous Goods listing have been used as a basis for establishing the process safety incident threshold quantities, these generic or non-applicable materials have been excluded.

For the ease of implementation, many users may want to use the following definitions.

Definitions of Combustible and Flammable materials used in the petroleum industry (similar to NFPA-30 definitions)

	**Flammable Liquids:** Low-flash liquids [flash point below 100 deg. F (38 deg. C)], and high-flash liquids [flash point 100 deg. F (38 deg. C) or higher] at temperatures above or within 15 deg. F (8 deg. C) of their closed cup (Pensky-Martens) flash points.
	**Combustible Liquids:** High-flash liquids [flash points 100 deg. F (38 deg. C) or higher] at temperatures more than 15 deg. F (8 deg. C) below their closed cup (Pensky-Martens) flash point.

The benefit of the above definitions is that the classification is influenced by the temperature of release. When a combustible liquid with a high flash point is released at a temperature above or within 15°F (8°C) of its flash point, it has the flammability characteristics of a flammable liquid.

Over time, it is expected that industry will become more familiar with and implement the GHS definitions. For more information regarding the comparison of these methods see Appendix A.

Lost Time Injuries and Fatality Incidents Criteria[3]

Lost Time Injuries and Fatality Incidents that occur as a result of process related loss of primary containment, fire, or explosion are those that fit into one of the following categories:

- Employee (Lost time and/or Fatality)
- Contractor and Subcontractor (Lost time and/or Fatality)
- Third Party (Injury/illness resulting in Hospital Admission or Fatality)

Examples of injury or fatality cases that would be reportable include a burn injury resulting from steam released during cleaning; a physical injury from a cap blown off by pressure during a pressure test; or a chemical burn from a spill while taking a sample.

Examples of injuries or fatality cases that would not be reportable include a fall from an elevated work station while performing maintenance; a burn from a fire in a laboratory or office building; or injuries from an excavation cave-in. None of these cases are directly due to the release of energy or material from the process.

[3] Whether an injury is reportable or not reportable under these process safety metrics would make no difference in the facility's responsibility to report injuries under OSHA or other regulatory requirements.

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 1 hour or less. If a release does not exceed the TQ level over 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. The criteria for reporting incidents as a PSI described above are illustrated in the below flowchart (Figure 4).

Flowchart

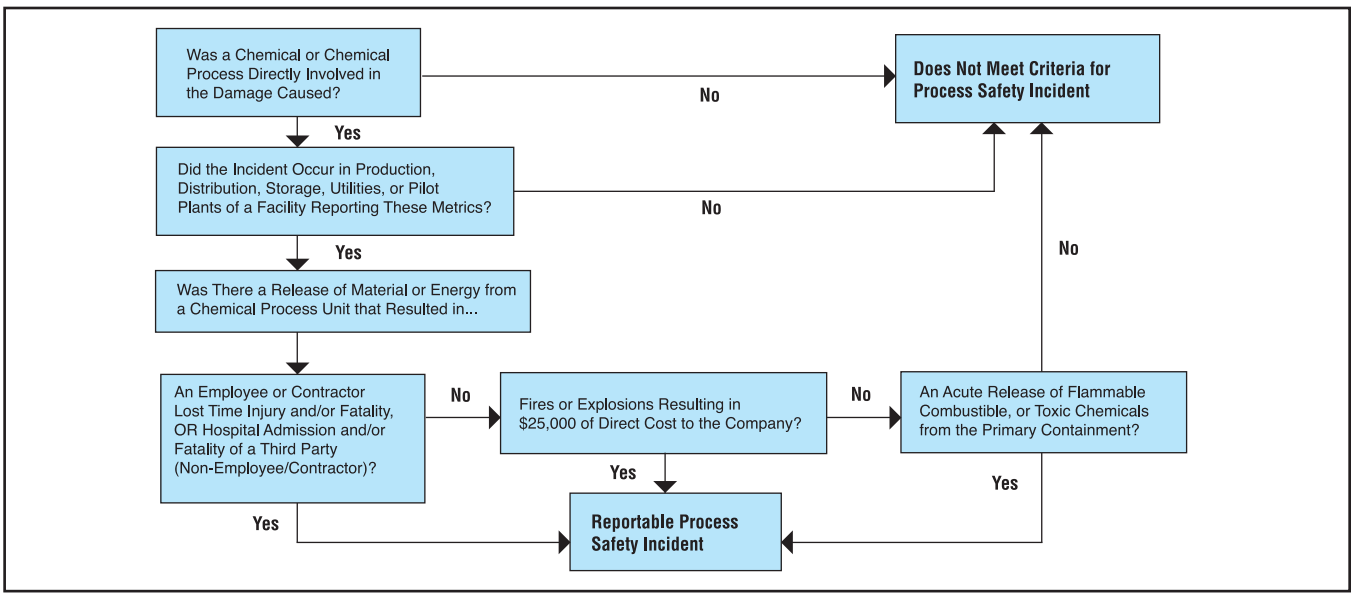


Figure 4: Determining if an incident meets definition of a reportable Process Safety Incident (PSI) under the definitions of the CCPS Industry Lagging Metric

2.0 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 and 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.

3.0 Definitions

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

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 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.

Direct Cost: Cost directly attributed to the fire and/or explosion, such as the replacement value of equipment lost, cost of repairs, cleanup, emergency response and/or fines. Direct cost does not include indirect costs, such as business opportunity losses, loss of profits due to equipment outages, cost of obtaining or operating temporary facilities or cost of obtaining replacement products to meet customer demand.

Employee: Any individual on the Company payroll and whose exposure hours, injuries and illnesses are routinely tracked by the Company. Unpaid individuals, such as government sponsored interns or secondees providing services under direct Company supervision are also included.

Explosion: The term "explosion" includes both detonations (regardless of whether or not they cause the rupture of equipment or piping) and overpressure incidents that cause the rupture of equipment or piping (regardless of whether or not they result in a chemical release or personnel injury).

Incident: An unusual or unexpected event, which either resulted in, or had the potential to result in serious injury to personnel, significant damage to property, adverse environmental impact, or a major interruption of process operations.

Loss Of Primary Containment (LOPC): An unplanned or uncontrolled release of material from primary containment.

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.

PSI: Process Safety Incident.

Third Party: Any individual other than an employee, contractor or subcontractor of the Company.

Total Employee, Contractor and 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.

UN Dangerous Goods 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). 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 on pg.12, there are a variety of rate-based metrics which can be generated. These include:

Process Safety Total Incident Rate (PSTIR):

$$\frac{\text{Total PS incidents x 200,000}}{\text{Total employees and contractor work hours in all three formulas}}$$

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

$$\textbf{PSISR} = \frac{\text{Total severity score for all PS incidents x 200,000}}{\text{Total employees and contractor work hours in all three formulas}}$$

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:

$$\frac{\text{Total Severity Level "X*" PS incidents x 200,000}}{\text{Total employees and contractor work hours in all three formulas}}$$

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.

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 4.0.

Process Safety Incident Severity Rate (PSISR): The cumulative (annual) severity-weighted rate of process safety incidents per the formula described in section 4.0.

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

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 crude 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 crude or product transfer;

(4) Routine emissions that are allowable under permit or regulation;

(5) Releases to a properly designed and operating emissions control device, such as a flare, scrubber, or relief device designed per API Standard 521 or equivalent, as long as the release did not result in (1) a liquid carryover that created a reportable PSI related to the liquid (e.g., days away from work incident, fatality, a fire or explosion that caused $25,000 or more of direct cost, liquid release or toxic aerosol release at or above threshold amounts, etc.), or (2) on-site activation of a shelter-in-place response, or (3) public protective measures being taken;

(6) Underground contamination that had no process safety consequences. [Note: The exclusion does not apply if the release resulted in an aboveground reportable PSI, such as release of toxic vapors or pooling of flammable liquids (e.g., 7 bbls or more within 1 hour)];

(7) Office building incidents (e.g., office heating equipment explosions, fires, spills, releases, personnel injury or illness, etc.);

(8) Personnel safety "slip/trip/fall" incidents that are not directly associated with evacuating from, or responding to a loss of containment incident;

(9) Loss of Primary Containment (LOPC) incidents from ancillary equipment not connected to the process (e.g., small sample containers);

(10) 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);

(11) Mechanical work being conducted outside of process units or in maintenance shops; and,

(12) Quality Assurance (QA), Quality Control (QC) and Research and Development (R&D) laboratories are excluded. (Pilot plants are not excluded.)

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 and 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

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 $25,000 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.

PSIs WITH MULTIPLE OUTCOMES

(3) 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

(4) Ten barrels of gasoline (1,400 kg, 3,100 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 1,000 kg (2,200 lbs.) or more of "Flammable Liquid."

(5) A faulty tank gauge results in the overfilling of a product tank containing "Flammable Liquids." Approximately 7,000 kg (15,500 lbs.) of liquid overflows into the tank's diked area. This incident is a reportable PSI since it is an "acute" spill greater than 2,200 lbs., regardless of secondary containment.

(6) 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.

(7) 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.

(8) A bleeder valve is left open after a plant turnaround. On startup, an estimated 10 bbls of fuel oil (1,700 kg, 3,750 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 2,000 kg or 4,400 lbs. of a "Combustible Liquid." Given the release conditions, this material would be treated as a "Combustible Liquid" (or Packing Group III Flammable Liquid under the UN DG definitions) regardless of whether the NFPA-30 or UN Dangerous Goods definitions of flammables are utilized.

(9) 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 2,000 kg or 4,400 lbs.

(10) A pipe corrodes and leaks 10 bbls (1,700 kg, 3,750 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. If the company has elected to base reporting criteria upon the NFPA-30 definitions of flammable materials described in Section 1, this would be a PSI because the HCO was released at a temperature above the flash point and it is greater then the release criteria of 1,000 kg (2,200 lbs.). If the company has elected to base reporting criteria upon the UN Dangerous Goods definitions, this would not be a PSI since the HCO would be considered a Packing Group III material, with a 2,000 kg (4,400 lbs.) threshold quantity. There will be a few situations were the NPFA definitions will have a lower TQ and other situations where the UN DG definitions will have a lower TQ. If a company consistently uses the same definitions for all reporting decisions, the annual statistics should be similar. A company should not select the definitions to use for reporting on a case-by-case basis simply to achieve the lowest overall statistics.

(11) 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 and flowed to an open drain, sewer or other collection system, it would be a reportable PSI.

ACUTE RELEASES

(12) There is a 10 bbl spill of gasoline (1,400 kg, 3,100 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 1,000 kg (2,200 lbs.) threshold exceeded in 1 hour).

(13) 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 2,060 lbs.) per hour. The spill rate was slightly less that the reporting threshold of 1,000 kg (2,200 lbs.) within "1 hour," and therefore is still not a reportable PSI.

(14) 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 per 1 hour time period).

FLARES AND EMISSION CONTROL DEVICES (e.g., scrubbers)

(15) If a chemical is routed to a flare or emission control device (e.g., scrubber), it would not be classified as a PSI as long as that flare or control device operates as designed.

(16) If a scrubber is overwhelmed by a flowrate greater than the design of the scrubber system and discharges a chemical in excess of the reporting threshold, it would be reported as a PSI.

SAFETY RELIEF DEVICE/SYSTEM

(17) 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 (1) a liquid carryover that created a reportable PSI related to the liquid (e.g., lost time incident, fatality, a fire or explosion that caused $25,000 or more of direct cost, liquid release or toxic aerosol release at or above threshold amounts, etc.), or (2) activation of a shelter-in-place response on-site, or (3) public protective measures be taken.

(18) Similar example to #17. If the relief device is not designed to API Standard 521 (e.g., the inlet pressure is less than 50 psig) or there is no documentation to validate that the installation was designed to comply with such standards. This would be a reportable PSI since the exemption only applies to vapor or gas releases from safety valves or high pressure rupture disks which comply with API Standard 521 or equivalent.

(19) 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

(20) A leak on a high pressure hydrochloric acid line results in a spill of 1,900 lbs. of hydrochloric acid. Flash calculations indicate that greater than 220 lbs. of hydrogen chloride would be released as a vapor. The 1,900 lbs. release of hydrochloric acid is not a reportable PSI since this liquid is categorized as a "Packing Group II" corrosive liquid, with a 2,200 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.

(21) 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). Further, the release is a reportable PSI since the reporting threshold for CO_2 is exceeded, as the chemical is a Division 2.2 - Nonflammable, nontoxic gas with a threshold of 2,000 kg. (Note: The incident would not be reportable if it was released from a properly designed and operating safety devices since there is a specific exclusion provided, as long as the release did not result in (1) a liquid carryover that created a reportable LOPC, or (2) on-site activation of a shelter-in-place response, or (3) public protective measures being taken.)

(22) Same as above, except that the H_2S concentration in the pipe is 50 vppm, rather than 10,000 vppm. The threshold remains unchanged at 25 kg for H_2S and 2,000 kg for CO_2.The incident would still be reportable as a PSI. However, it is now the 2,000 kg (4,400 lb.) threshold for CO_2 that triggers the reporting criteria rather than the H_2S.

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.

(23) 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.

(24) Same as above, except that the operator slipped and fell while responding to a small flammable liquid spill (e.g., less than 1,000 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 amount.

(25) Same as preceding, 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.

(26) 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.

(27) 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.

(28) 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.

(29) 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.

(30) 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

(31) An underground pipeline leaks and releases 1,000 bbls of diesel (combustible material). The spill results in contaminated soil that is subsequently remediated. This is not a reportable PSI since there were no safety consequences. If the material resulted in "acute" surface pooling 14 bbls or greater (e.g., within "1 hour"), then the event would be PSI reportable and you would report the entire amount of released material (e.g., 1,000 bbls).

(32) A pipeline leaks and releases 2,000 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.

FIRES OR ENERGY RELEASES NOT ASSOCIATED WITH CHEMICAL RELEASE

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

(33) An electrical fire impacts the operation of the process resulting in the release of 4,000 lbs. of toluene. This event would be reported as a PSI since if the chemical release exceeds the 2,200 lb. reporting threshold for toluene.

(34) An electrical fire, loss of electricity, or any other loss of utility occurs which may cause 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 create a chemical release greater than the threshold quantity, or cause a fatality or serious injury. This event would not be reported as a PSI since the equipment damage was not caused by a chemical process fire/explosion and there was not a chemical release greater than the threshold quantity.

(35) A bearing fire, lube oil system fire, electric motor failure, or similar fire occurs which damages the equipment but does not create a chemical release greater than the threshold quantity or cause a fatality or serious injury. This event would not be

reported as a PSI since no chemical release greater than the threshold quantity or injuries occurred.

(36) If in the examples #34 or #35, if either an injury or chemical release exceeding the threshold quantity had occurred these would have been reportable PSI events.

(37) An internal deflagration in a vessel causes equipment damage > $25,000. This event would be reported as a PSI since the definition of "explosion" includes detonations regardless of whether or not they cause the rupture of equipment or piping, therefore this event would be included if damages exceeded $25,000.

(38) 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 chemicals were not released and the definition of "explosion" does not include under-pressure events.

(39) If in the example #38, if a tank seam failed resulting in a spill of contents in excess of the TQ quantity for that chemical, it would have been reported as a PSI (even if the contents were captured in secondary containment dikes).

MARINE TRANSPORT VESSELS

(40) 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 refinery, petrochemical, or chemical manufacturing facility for the purposes of crude or product transfer.

(41) 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 berthed at the dock and actively involved in crude or product transfer operations.

TRUCK AND RAIL

(42) A company railcar derails and spills more than 7 bbls of gasoline while in transit. The incident is not PSI reportable since rail incidents off company property are specifically excluded.

(43) 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, it is recommended that companies also have transportation incident metrics, which would capture this event.

(44) A contract truck hauler is unloading caustic and the hose separates and generates an airborne aerosol and/or liquid caustic spill of 2,500 kg. The event is a reportable PSI since the caustic TQ of 1,000 kg was exceeded and the truck was still connected to the loading/unloading facility immediately prior to the incident.

OFFICE BUILDING

(45) 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

(46) 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 loss of containment of hazardous material.

ASSIGNMENT OF SEVERITY SCORES

(47) A leak on a high pressure hydrochloric acid line results in a spill of 4,000 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 HCL 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).

(48) 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 1,100 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).

(49) 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

(50) 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 2,000 kg (4,400 lb.) threshold quantity of a Packing Group III material, this spill would be reported as a PSI.

(51) A pipe fitting in a specialty chemicals plant fails, releasing 4,000 lbs. of a mixture of 30% formaldehyde, 45% methanol, and 25% water. This mixture is not one that is commonly transported, so the classification of the mixture has not been performed per the UN Dangerous Goods/US DOT protocols. For the purposes of this PSI metric, a simplified approach can be used by evaluating each individual component relative to the threshold value for that chemical, then determine if the total percentages exceed 100%. The pure component reporting threshold of formaldehyde is 4,400 lbs. and methanol is 2,200 lbs. This release would be reported as a PSI since the cumulative percentages of each component in the mixture exceeds 100% even though the TQs of each chemical is different, as shown below:

Component	% wt.	Release Qty, lbs	PSI TQ, lbs.	% of TQ
Formaldehyde	30%	1,200	4,400	27.2%
Methanol	45%	800	2,200	81.8%
Water	50%	1,000	n/a	0%
		4,000		109%

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 Integrity

(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
- Piping systems

- Relief and vent devices
- Instruments
- Control systems
- Interlocks and emergency shutdown systems
- Mitigation 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 and/or having approved extension of process safety action items/Total number of active or open action items) 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 and/or having approved extension of audit action items/total number of audit action items active or open) x 100 %
- (Number of past due and/or having approved extension of PHA action items/total number of PHA action items active or open) x 100 %
- (Number of past due and/or having approved extension of incident investigation action items/total number of incident investigation action items active or open) x 100 %
- (Number of outstanding incident investigation action items closed/total number of incident investigation action items raised during the period) x 100%
- (Number of past due and/or having approved extension of regulatory issue/action items/total number of PHA action items active or open) x 100 %

3.0 Management of Change

(A) Percentage of audited 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:

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

(B) Percentage of audited 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:

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

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:

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

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 Session On-time)/(Total Number of Individual PSM Training Sessions Planned) x 100%

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) x 100%

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 and discussed throughout the Baker panel 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.

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 threshold and were not recorded in the industry-wide lagging metric. 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 have 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, or damage to property, equipment or environment.

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:
- Pressure Relief Device (PRD) challenge,
- Safety Instrumented System (SIS) challenge, or
- Process deviation or excursion.

Examples of Process Safety Near Misses

Near misses for PRDs and SISs may fall into a category of either creation of a demand with successful PRD/SIS operation, and creation of a demand with failure of the PRD/SIS. 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 reach or exceed the prescribed trigger point.
- Activation of a safety instrumented system when "out of acceptable range" process variable is detected, e.g.,
  - 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).

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, and 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.

Companies who contributed PS Near Miss Reporting information/definitions for consideration in harmonizing the information in this section:

Air Products (Shakeel Kadri)
Celanese (Don Abrahamson)
Chevron Phillips Chemical (Ken Harrington)
DuPont (Harry Glidden)
ExxonMobil Chemical (Cathy Pincus)
Husky Oil (Kevin MacDougall)
Ineos (Susie Cowher)
Monsanto (Jeffrey Philiph)
Reliance Industries (Mahesh Agrawal)
Rohm & Haas (Gregory Keeports)
Shell Oil (Darren Martin)
SIS-Tech (Angela Summers)
Solutia (Kent Goddard)

Appendix A: Discussion of Flammable Material Definitions

As described in section I.1, for the purposes of applying these threshold values for "Flammable Gases/Vapors," "Flammable Liquids," and "Combustible Liquids," the user may use either the definitions commonly used within the petroleum refining industry (based upon National Fire Protection Association, NFPA-30, definitions), the UN Dangerous Goods (Class 2, Div. 2.1 and Class 3), or the Harmonized System of Classification and Labeling of Chemicals (GHS), Chapters 2.2 and 2.6. These different methods classify materials in a similar manner, but with slightly different temperature cut points. However, NPFA-based "Flammable Vapors/Gases" may be treated the same as UN "Packing Group I" flammable materials, "Flammable Liquids" may be treated the same as "Packing Group II," and "Combustible Liquids" treated the same as "Packing Group III" for the purposes of assigning the industry lagging metric release threshold quantities. The differences in definitions are illustrated below.

UN DG criteria

2.3.2.6 Hazard grouping based on Flammability

Packing Group	Flash Point (Closed-Cup)	Initial Boiling Point
I	–	≤ 35°C
II	< 23°C	> 35°C
III	≥ 23°C ≤ 60°C	> 35°C

NFPA-30 criteria:

Combustible liquid. A liquid having a closed cup flash point at or above 38°C (100°F).
Combustible liquids are subdivided:

- Class II Liquids having a closed cup flash point at or above 38°C (100°F) and below 60°C (140°F) (NFPA flammability rating 2).
- Class IIIA Liquids having a closed cup flash point at or above 60°C (140°F) and below 93°C (200°F) (NFPA flammability rating 2).
- Class IIIB Liquids having a closed cup flash point at or above 93°C (200°F)(NFPA flammability rating 1).

Flammable liquid. A liquid having a closed cup flash point below 38°C (100°F) and a Reid Vapor pressure not exceeding 276 kPa (40 psia) at 38°C. Flammable liquids do not include compressed gases or cryogenic fluids. Flammable liquids are subdivided:

- Class IA Liquids having a flash point below 23°C (73°F) and having a boiling point below 38°C (100°F) (NFPA flammability rating of 4).
- Class IB Liquids having a flash point below 23°C (73°F) and having a boiling point at or above 38°C (100°F) (NFPA flammability rating of 3).
- Class IC Liquids having a flash point at or above 23°C (73°F) and below 38°C (100°F) (NFPA flammability rating of 3).

Flammable/Combustible liquid definitions commonly used in the petroleum industry:

Flammable Liquids: Low-flash liquids [flash point below 100 deg. F (38 deg. C)], and high-flash liquids [flash point 100 deg. F (38 deg. C) or higher] at temperatures above or within 15 deg. F (8 deg. C) of their closed cup (Pensky-Martens) flash points.

Combustible Liquids: High-flash liquids [flash points 100 deg. F (38 deg. C) or higher] at temperatures more than 15 deg. F (8 deg. C) below their closed cup (Pensky-Martens) flash point.

In some situations, use of the petroleum industry definitions would result in a lower release TQ trigger due to the provision to consider the operating temperature (i.e., combustible liquids released at temperatures above or within 15 deg. F (8 deg. C) of their closed cup (Pensky-Martens) flash points) than would use of the UN DG definitions. Yet in other situations, the UN DG definitions would result in a lower TQ trigger due to the slightly lower boiling point cut points between Packing Groups. There will be little inconsistency in overall incidents reported (i.e., the Industry Lagging metric will remain valid for purposes of benchmarking or tracking industry trends) as long as companies consistently use one method or another throughout the calendar year. Companies should not select the definitions on a case-by-case basis simply to report the fewest incidents. If they wish to change from one definition basis to another, they should make the change at beginning of a new calendar year reporting period.

Appendix B: Additional Information Regarding 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

Toxic Vapors:

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

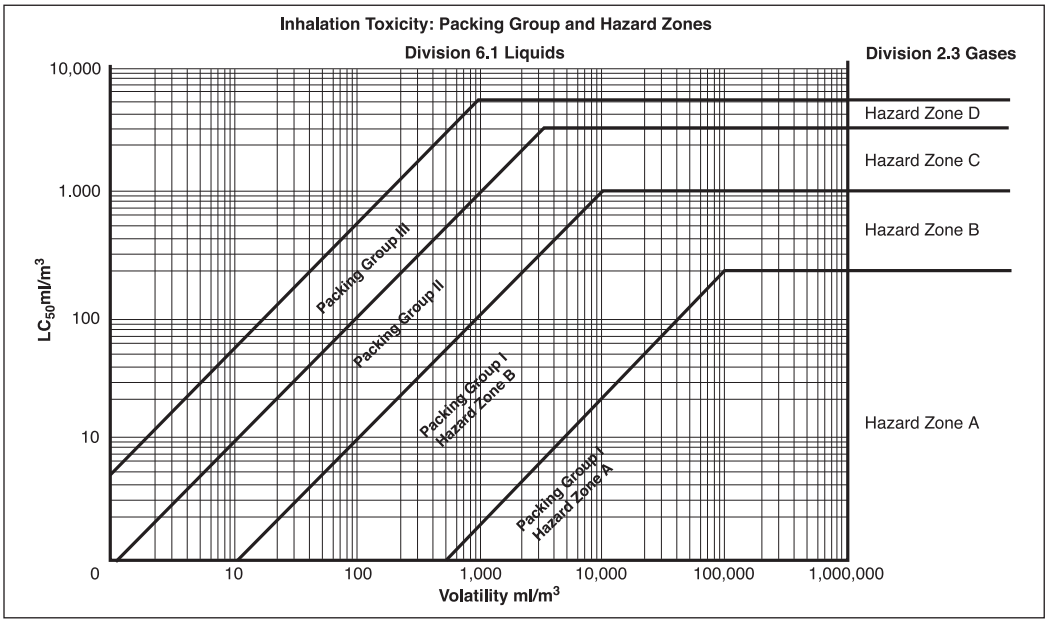
Toxic Liquids:

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)	$V \geq 500\ LC_{50}$ and $LC_{50} \leq 200$ mL/M^3
I (Hazard Zone B)	$V \geq 10\ LC_{50}$; $LC_{50} \leq 1{,}000$ mL/m^3; and the criteria for Packing Group I, Hazard Zone A are not met
II	$V \geq LC_{50}$; $LC_{50} \leq 3{,}000$ mL/m^3; and the criteria for Packing Group I, are not met
III	$V \geq .2\ LC_{50}$; $LC_{50} \leq 5{,}000$ 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/m^3at 20 °C and standard atmospheric pressure.



Appendix C: Additional Clarifications Regarding UN Dangerous Goods Lists and Exceptions

The CCPS Committee, working in conjunction with representatives of several chemical and petroleum trade associations and process safety consortia, selected the UN Dangerous Goods criteria for differentiating chemicals into a few threshold quantity categories since this approach:

- was comprehensive,
- aligned 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, Air, Argon, or Helium would be treated as a PSI if the release exceeds the 2,000 kg (4,400 lb.) threshold quantity]. But intentional releases or low pressure releases of these chemicals (e.g., nitrogen or air 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.

CCPS publishes a wide range of books useful to implement and improve process safety programs, management systems, and technologies. Please go to www.wiley.com/go/CCPS to see the full list of titles.

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