Process Safety Performance Indicators for the Refining and Petrochemical Industries

API RECOMMENDED PRACTICE 754
SECOND EDITION, APRIL 2016

AMERICAN PETROLEUM INSTITUTE

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Shall: As used in a recommended practice, “shall” denotes a minimum requirement in order to conform to the Recommended Practice (RP).

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Introduction

The purpose of this recommended practice (RP) is to identify leading and lagging indicators in the refining and petrochemical industries for nationwide public reporting as well as indicators for use at individual facilities including methods for the development and use of performance indicators. A comprehensive leading and lagging indicators program provides useful information for driving improvement and when acted upon contributes to reducing risks of major hazards (e.g. by identifying the underlying causes and taking action to prevent recurrence). This RP may augment a Company's existing practices and procedures.

This RP cannot and does not preempt any federal, state, or local laws regulating process safety. Therefore, nothing contained in this document is intended to alter or determine a Company's compliance responsibilities set forth in the Occupational Safety and Health Act of 1970 and/or the OSHA standards themselves, or any other legal or regulatory requirement concerning process safety. The use of the term or concept "process safety" in this document is independent of and may in fact be broader than the term or concept "process safety" contained in OSHA regulatory requirements, or as the term may be used in other legal or regulatory contexts. In the event of conflict between this recommended practice and any OSHA or other legal requirements, the OSHA or other legal requirements should be fully implemented.

Notes to the Second Edition

As part of the revision process, the drafting committee gathered input from companies that had adopted this RP. The committee sought comments regarding the utility and usefulness of the Tier 1 and Tier 2 indicators to drive performance improvement, as well as any comments regarding suggested improvements. The result of the input gathering exercise was a desire for continuous improvement rather than any need for fundamental change.

Although the RP was written for the U.S. Refining and Petrochemical industries, it has been widely adopted around the globe and by additional industry segments. The revision committee benefited from broad participation by parties with a direct and material interest from academia, trade associations, engineering and construction, regulators, and owner/operators both domestic and international.

The purpose of this RP is to identify leading and lagging process safety performance indicators in the refining and petrochemical industries for nationwide public reporting as well as indicators for use at individual facilities including methods for the development and use of performance indicators. A comprehensive leading and lagging indicators program provides useful information for driving improvement and when acted upon, contributes to reducing risks of major hazards (e.g. by identifying the underlying causes and taking action to prevent recurrence).

In revising this document, the drafting committee maintained a focus on indicators of process safety performance versus indicators of health, personal safety or environmental performance. Each is important and each should have its own performance indicators as part of a comprehensive and robust facility Health, Safety, and Environmental program. Process safety hazards can result in major accidents involving the release of potentially dangerous materials. Process safety incidents can have catastrophic effects such as multiple injuries and fatalities, as well as substantial economic, property, and environmental damage; and can affect workers inside the facility and members of the public who reside or work nearby.

Numerous issues including process safety indicator definitions, chemical release thresholds, data capture, statistical validity, and public reporting were again considered; this time with the benefit of four years of implementation experience. One of the most significant revision proposals was the adoption of the Globally Harmonized System for Classification and Labeling of Chemicals (GHS) for threshold release categorization. After numerous and lengthy debates, the drafting committee chose to reaffirm the U.S. DOT version of the *United Nations Dangerous Goods* (*UNDG*) hazard classification system as the most appropriate. This system is unique in the treatment of toxic chemicals in terms of both relative toxicity and relative volatility that produces a more accurate ranking of relative process safety hazards.

Other significant continuous improvement changes include:

— the addition of informative annexes specifically defining the applicability of this RP to Petroleum Pipelines and Terminals, Retail Service Stations, and Oil and Gas Drilling and Production Operations;

— the addition of an informative annex for Tier 1 PSE Severity Weighting;

— extensive additions to the informative annex of PSE Examples and Questions;

— the addition of informative annexes for Guidance for Implementation of Tier 3 and Tier 4 Indicators and Tier 4 Example Indicators;

— the revision of the Tier 1 threshold for Direct Cost Damage from Fires and Explosions from $25,000 to $100,000 to better align with the severity of the other Tier 1 consequence categories.

Process Safety Performance Indicators for the Refining and Petrochemical Industries

1 Scope

1.1 General

This recommended practice (RP) identifies leading and lagging process safety indicators useful for driving performance improvement. As a framework for measuring activity, status or performance, this document classifies process safety indicators into four tiers of leading and lagging indicators. Tiers 1 and 2 are suitable for nationwide public reporting and Tiers 3 and 4 are intended for internal use at individual facilities. Guidance on methods for development and use of performance indicators is also provided.

1.2 Applicability

NOTE At joint venture sites and tolling operations, the Company should encourage the joint venture or tolling operation to consider applying this RP.

This RP was developed for the refining and petrochemical industries, but may also be applicable to other industries with operating systems and processes where loss of containment has the potential to cause harm (see note). Applicability is not limited to those facilities covered by the OSHA Process Safety Management Standard, 29 *CFR* 1910.119, or similar national and international regulations.

NOTE To enable consistent application of this RP to other refining and petrochemical industry sub segments, informative annexes have been created to define the Applicability and Process definition for those sub segments. The user would substitute the content of those annexes for the referenced sections of this RP: Annex A—Petroleum Pipeline and Terminal Operation, Annex B—Retail Service Stations, Annex C—Oil and Gas Drilling and Production Operations.

This recommended practice applies to the responsible party. At collocated facilities (e.g. industrial park), this recommended practice applies individually to the responsible parties and not to the facility as a whole.

Events associated with the following activities fall outside the scope of this RP and shall not be included in data collection or reporting efforts:

a) releases from transportation pipeline operations outside the control of the responsible party;

b) marine transport operations, except when the vessel is connected or in the process of connecting or disconnecting to the process;

c) truck or rail transport operations, except when the truck or rail car is connected or in the process of connecting or disconnecting to the process, or when the truck or rail car is being used for on-site storage;

NOTE Active staging is not part of connecting or disconnecting to the process; active staging is not considered on-site storage; active staging is part of transportation.

d) vacuum truck operations, except on-site truck loading or discharging operations, or use of the vacuum truck transfer pump;

e) routine emissions from permitted or regulated sources;

NOTE Upset emissions are evaluated as possible Tier 1 or Tier 2 PSEs per Section 5.2 and Section 6.2.

f) office, shop, and warehouse building events (e.g. office fires, spills, personnel injury or illness, etc.);

g) personal safety events (e.g. slips, trips, falls) that are not directly associated with on-site response or exposure to a loss of primary containment (LOPC) event;

h) LOPC events from ancillary equipment not connected to the process (e.g. small sample containers);

i) quality assurance (QA), quality control (QC), and research and development (R&D) laboratories (pilot plants are included);

j) new construction that is positively isolated (e.g. blinded or air gapped) from a process prior to commissioning and prior to the introduction of any process fluids, and that has never been part of a process;

k) retail service stations; and

l) on-site fueling operations of mobile and stationary equipment (e.g. pick-up trucks, diesel generators, and heavy equipment).

1.3 Guiding Principles

Performance indicators identified in this recommended practice are based on the following guiding principles.

— Indicators should drive process safety performance improvement and learning.

— Indicators should be relatively easy to implement and easily understood by all stakeholders (e.g. workers and the public).

— Indicators should be statistically valid at one or more of the following levels: industry, company, and facility. Statistical validity requires a consistent definition, a minimum data set size, a normalization factor, and a relatively consistent reporting pool.

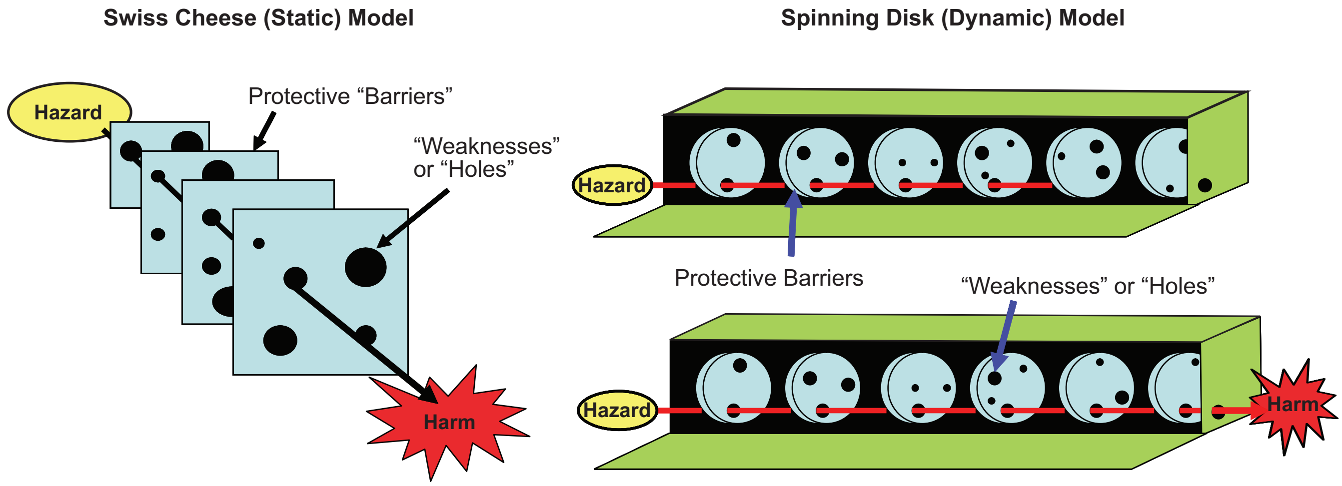
— Indicators should be appropriate for industry, company, or facility level benchmarking.

1.4 Introduction

Process safety incidents are rarely caused by a single catastrophic failure, but rather by multiple events or failures that coincide. This relationship between simultaneous or sequential failures of multiple systems was originally proposed by British psychologist James T. Reason [16] in 1990 and is illustrated by the “Swiss Cheese Model.” In the Swiss Cheese Model, hazards are contained by multiple protective barriers each of which may have weaknesses or “holes.” When the holes align, the hazard is released resulting in the potential for harm.

Christopher A. Hart in 2003 [11] represented Reason’s model as a set of spinning disks with variable size holes. This representation suggests that the relationship between the hazard and the barriers is dynamic, with the size and type of weakness in each barrier constantly changing, and the alignment of the holes constantly shifting.

Figure 1 depicts both models. In both models, barriers can be active, passive, or administrative/procedural. Holes can be latent, incipient, or actively opened by people.



- 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 harm.
- Barriers may be physical engineered containment or behavioral controls dependent upon people.
- Holes can be latent/incipient or actively opened by people.

Figure 1—“Swiss Cheese (Static) Model” and “Spinning Disk (Dynamic) Model”

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/API Standard 521/ISO 23251 [1], *Guide for Pressure-relieving and Depressuring Systems*. [1]

AiChE, Center for Chemical Process Safety [2], *Process Safety Leading and Lagging Metrics*, Appendix B: Additional Information Regarding UN Dangerous Goods Classification and Listing of Chemicals, 2008. [10]

ISO 10156:2010(E) [3], *Gases and gas mixtures—Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets - Third Edition.* [14]

IOGP, Report No. 456 [4], *Process Safety—Recommended Practice on Key Performance Indicators.* [15]

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1 American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.
2 American Institute of Chemical Engineers, Center for Chemical Process Safety, 3 Park Avenue, 19th Floor, New York, New York 10016, www.aiche.org/ccps.
3 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.
4 International Association of Oil and Gas Producers, City Tower 40 Basinghall St 14th Floor London EC2V 5DE United Kingdom, http://www.iogp.org.

UNECE [5], ECE/TRANS/202, Vol. I and II ("ADR 2009"), *European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR).* [18]

U.S. DOT [6], 49 *CFR*, Part 172, *Subpart B—Table of Hazardous Materials and Special Provisions*. [21]

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1
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. [19]

3.1.2
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. [19]

3.1.3
active staging
Truck or rail cars waiting to be unloaded where the only delay to unloading is associated with physical limitations with the unloading process (e.g. number of unloading stations) or the reasonable availability of manpower (e.g. unloading on daylight hours only, unloading Monday through Friday only), and not with any limitations in available volume within the process. Active staging is part of transportation.

Any truck or rail cars waiting to be unloaded due to limitations in available volume within the process are considered on-site storage.

3.1.4
active warehouse
An on-site warehouse that stores raw materials, intermediates, or finished products used or produced by a process.

From a process perspective, an active warehouse is equivalent to a bulk storage tank. Rather than being stored in a single large container, the raw materials, intermediates, or finished products are stored in smaller containers (e.g. totes, barrels, pails, etc.).

3.1.5
acute environmental cost
Cost of short-term cleanup and material disposal, associated with an LOPC with off-site environmental impact.

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5 United Nations Economic Commission for Europe, Information Service, Palais des Nations, CH-1211 Geneva 10, Switzerland, www.unece.org.
6 U.S. Department of Transportation,1200 New Jersey Ave, SE, Washington, D.C. 20590, www.dot.gov.

3.1.6
Company
When designated with a capital C or "the Company", refers to the operating Company in the refining and petrochemical industries, its divisions, or its consolidated affiliates. As used in this RP, the terms "Company" and "Responsible Party" are synonymous.

3.1.7
containment, primary
A tank, vessel, pipe, truck, rail car, or other equipment designed to keep material within it, typically for the purposes of storage, separation, processing, or transfer of material.

3.1.8
containment, secondary
An impermeable physical barrier specifically designed to mitigate the impact of materials that have breached primary containment. Secondary containment systems include, but are not limited to tank dikes, curbing around process equipment, drainage collection systems, the outer wall of open top double walled tanks, etc.

3.1.9
contractor and subcontractor
Any individual not on the Company payroll, whose exposure hours, injuries, and illnesses occur on site.

3.1.10
days away from work injury
Work-related injuries that result in a person being unfit for work on any day after the day of the injury as determined by a physician or other licensed health professional. "Any day" includes rest days, weekend days, vacation days, public holidays, or days after ceasing employment.

3.1.11
deflagration
Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.

3.1.12
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).

3.1.13
detonation
Propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium.

3.1.14
destructive device
A flare, scrubber, incinerator, quench drum, or other similar device used to mitigate the potential consequences of an engineered pressure relief (e.g. PRD, SIS, or manually initiated emergency depressure) device release.

3.1.15
direct cost
Cost of repairs or replacement, cleanup, material disposal, and acute environmental cost associated with a fire or explosion. 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 repairing or replacing the failed component leading to LOPC if the component is not further damaged by the fire or explosion. Direct cost does include the cost of repairing or replacing the failed component leading to LOPC if the component failed due to internal or external explosion or overpressure.

3.1.16
employee
Any individual on the Company payroll 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.).

3.1.17
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).

3.1.18
facility
The buildings, containers, or equipment that contain a process.

3.1.19
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.

3.1.20
flash point (in petroleum products)
The lowest temperature corrected to a barometric pressure of 101.3 kPa (760 mm Hg), at which application of an ignition source causes the vapors of a specimen of the sample to ignite under specified conditions of test. Test methods include ASTM D92-12b [4], ASTM D93-15 [5], D3941-14 [6], D56-05 [7], or other equivalent test methods appropriate to the material characteristics and flash point range specified in the test procedure.

3.1.21
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).

3.1.22
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."

3.1.23
loss of primary containment
LOPC
An unplanned or uncontrolled release of any material from primary containment, including non-toxic and non-flammable materials (e.g. steam, hot water, nitrogen, compressed CO_2, or compressed air).

3.1.24
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.

3.1.25
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.

3.1.26
moderate acids/bases
See acids/bases, moderate.

3.1.27
normal boiling point
The temperature at which boiling occurs under a pressure of 101.3 kPa (760 mm Hg). Test methods include ASTM E1719-12 [8], ASTM D86-12 [3], or other equivalent test method. For the purpose of this RP, the terms normal boiling point and initial boiling point are considered synonymous.

3.1.28
office building
Buildings intended to house office workers (e.g. administrative or engineering building, affiliate office complex, etc.).

3.1.29
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).

3.1.30
pilot plant
An assembly of process equipment that is intended to produce the equivalent of a salable product (whether an actual sale occurs or not). The purpose of a pilot plant is to optimize the chosen chemistry, quantify process parameters to facilitate design and construction of a commercial scale facility, and determine product purity and quality standards.

3.1.31
precautionary (evacuation, public protective measure, shelter-in-place)
A measure taken from an abundance of caution.

— For example, a company may require all workers to shelter-in-place in response to an LOPC independent of or prior to any assessment (e.g. wind direction, distance from the LOPC, etc.) of the potential hazard to those worker.

— For example, a recognized community official (e.g. fire, police, civil defense, emergency management) may order a community shelter-in-place, evacuation, or public protective measure (e.g. road closure) in the absence of information from a company experiencing a process safety event, or 'just in case' the wind direction changes, or due to the sensitive nature of the potentially affected population (e.g. school children, the elderly).

3.1.32
precautionary evacuation
See precautionary (evacuation, public protective measure, shelter-in-place).

3.1.33
precautionary public protective measure
See precautionary (evacuation, public protective measure, shelter-in-place).

3.1.34
precautionary shelter-in-place
See precautionary (evacuation, public protective measure, shelter-in-place).

3.1.35
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.).

NOTE A PRD discharge is a LOPC due to the nature of the unplanned release. The PRD discharge is evaluated against the consequence criteria to determine if it is a Tier 1 or Tier 2 PSE.

3.1.36
primary containment
See containment, primary.

3.1.37
process
Production, distribution, storage, utilities, or pilot plant facilities used in the manufacture of 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, active warehouses, ancillary support areas (e.g. boiler houses and waste water treatment plants), on-site remediation facilities, and distribution piping under control of the Company.

3.1.38
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.

It deals with the prevention and control of events that have the potential to release hazardous materials or energy. Such events can cause toxic effects, fire or explosion and could ultimately result in serious injuries, property damage, lost production, and environmental impact.

3.1.39
process safety event
PSE
An unplanned or uncontrolled release of any material including non-toxic and non-flammable materials (e.g. steam, hot water, nitrogen, compressed CO_2, or compressed air) from a process, or an undesired event or condition, that under slightly different circumstances, could have resulted in a release of material.

3.1.40
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.

3.1.41
rainout
Two-phase relief (vapor and entrained liquid) from a vent or relief device with the vapor phase dispersing to the atmosphere and the remaining liquid falling to grade or ground.

3.1.42
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. [20]

3.1.43
Research and Development (R&D) laboratory
A facility that provides controlled conditions in which scientific or technological research, experiments, and measurement may be performed.

3.1.44
responsible party
The party charged with operating the facility in a safe, compliant, and reliable manner is the responsible party. In some countries or jurisdictions, the responsible party may be called the 'duty holder' or the party with regulatory reporting responsibility. As used in this RP, the terms "Responsible Party" and "Company" are synonymous.

NOTE The responsible party is determined prior to any process safety event. The responsible party could be the facility owner or the facility operator depending upon the relationship between the two. Is the owner or the operator responsible for the performance of the facility? Who is responsible for developing and implementing prevention programs? Who is responsible for performing the investigation and identifying and implementing corrective action following a process safety event?

3.1.45
safety instrumented system
an instrumented protection layer whose purpose is to take the process to a safe state when predetermined conditions are violated.

3.1.46
secondary containment
See containment, secondary.

3.1.47
shelter-in-place
The use of a structure and its indoor atmosphere to temporarily separate individuals from a potentially hazardous outdoor atmosphere.

3.1.48
strong acids/bases
see acids/bases, strong.

3.1.49
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.].

3.1.50
tolling operation
A company with specialized equipment that processes raw materials or semi-finished goods for another company.

3.1.51
total work hours
Total employee, contractor, and subcontractor hours worked minus the hours associated with major construction projects. This is the same number typically used to calculate occupational injury and illness rates.

3.1.52
United Nations Dangerous Goods
UNDG
A classification system used to evaluate the potential hazards of various chemicals when released, which is used by most international countries as part of the product labeling or shipping information [18]. In the United States, these

hazard categories are defined in U.S. Department of Transportation (DOT) regulations 49 *CFR* 173.2a [22], and listed in 49 *CFR* 172, Subpart B. [21]

3.1.53
UNDG Class 2, Division 2.2 (non-flammable, non-toxic gases)
Non-flammable, non-toxic gases (corresponding to the groups designated asphyxiant or oxidizing) excluding air.

Asphyxiant—Gases that are non-oxidizing, non-flammable, and non-toxic that dilute or replace oxygen normally in the atmosphere.

Oxidizing—Gases that may, generally by providing oxygen, cause or contribute to the combustion of other material more than air does. These gases are pure gases or gas mixtures with an oxidizing power greater than 23.5 % as determined by a method specified in ISO 10156:2010(E). [14]

3.1.54
unsafe location
An atmospheric pressure relief device discharge point or downstream destructive device (e.g. flare, scrubber) discharge point that results in a potential hazard to personnel due to their proximity, such as the formation of flammable mixtures at ground level or on elevated work structures, presence of toxic or corrosive materials at ground or on elevated work structures, or thermal radiation effects from ignition of relief streams at the point of emission as specified in API 521 Section 5.8.4.4. [1]

3.2 Acronyms and Abbreviations

For the purposes of this publication, the following acronyms and abbreviations apply.

ACC	American Chemistry Council
AFPM	American Fuel and Petrochemical Manufacturers
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CCPS	Center for Chemical Process Safety
DOT	U.S. Department of Transportation
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
IOGP	International Association of Oil and Gas Producers
ISO	International Organization for Standardization
LEL	lower explosive limit
LOPC	loss of primary containment
LTA	less than adequate
MOC	management of change
NAICS	North American Industry Classification System
NOS	not otherwise specified

OSHA	U.S. Occupational Safety and Health Administration
PRD	pressure relief device
PSE	process safety event
PSSR	pre start-up safety review
PV	pressure/vacuum
SDS	safety data sheet
SIS	safety instrumented system
SOL	safe operating limit
SV	safety valve
TIH	toxic inhalation hazard
UK PIA	United Kingdom Petroleum Industry Association
UK HSE	United Kingdom Health and Safety Executive
UNDG	United Nations Dangerous Goods
UNECE	United Nations Economic Commission for Europe

4 Leading and Lagging Performance Indicators

In 1931, H.W. Heinrich [12] introduced the now-familiar accident pyramid based upon his experience in the insurance industry. The accident pyramid represents two key concepts. One is that safety accidents can be placed on a scale representing the level of consequence, and the second is that many precursor incidents occurred with lesser consequences for each accident that occurred with greater consequences. Heinrich's model represents a predictive relationship between lower and higher consequence personal safety events.

It is believed that a similar predictive relationship exists between lower and higher consequence events that relate to process safety. Indicators that are predictive are considered leading indicators and may be used to identify a weakness that can be corrected before a higher consequence event occurs. Figure 2 depicts a process safety pyramid with four classifications or tiers. The tiers of the pyramid represent a continuum of leading and lagging process safety indicators. Tier 1 is the most lagging and Tier 4 is the most leading.

Analysis of Tier 1 and Tier 2 process safety events can provide lessons to prevent recurrence. However, this analysis is retrospective and based upon relatively infrequent events; therefore, a company cannot rely solely on these lessons to prevent future events. It is necessary to broaden the analysis to include lessons from challenges to or weaknesses within the barrier system. Tier 3, Challenges to Safety Systems and Tier 4, Operating Discipline and Management System indicators provide an opportunity for a company to identify and correct weaknesses within the barrier system.

Implementing the full range of Tier 1 through Tier 4 indicators can dramatically enhance the process safety culture and the process safety performance of a company.

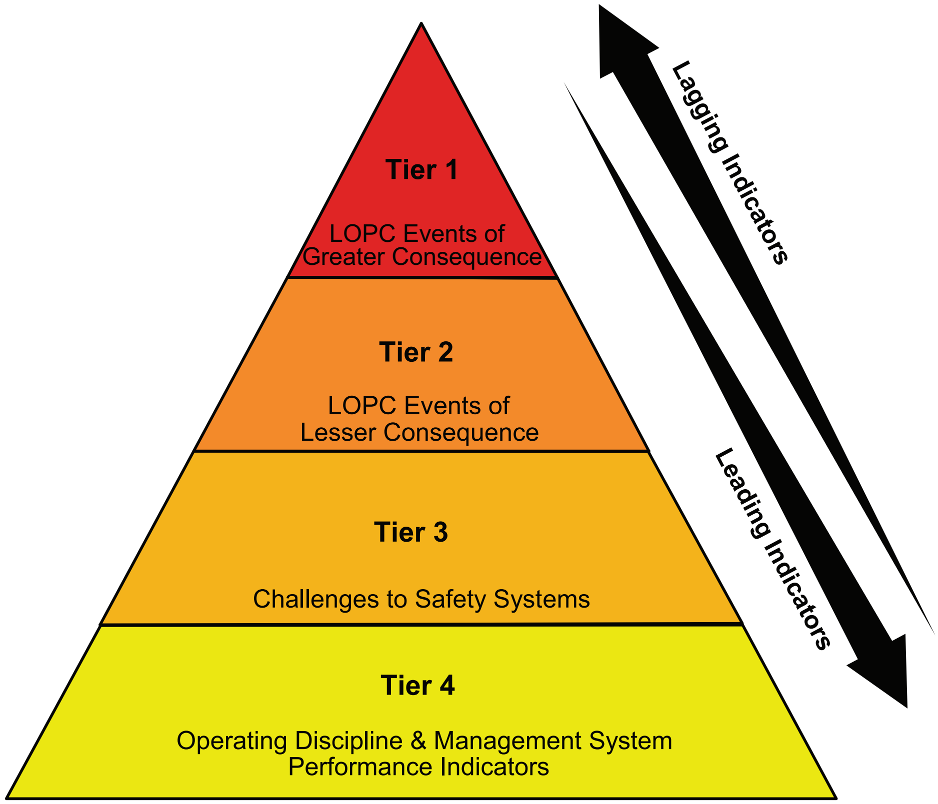


Figure 2—Process Safety Indicator Pyramid

5 Tier 1 Performance Indicator—Process Safety Event (T-1 PSE)

5.1 Tier 1 Indicator Purpose

The count of Tier 1 process safety events is the most lagging performance indicator and represents LOPC events of greater consequence. Tier 1 PSEs, even those that have been contained by secondary systems, indicate barrier system weaknesses. When used in conjunction with lower tier indicators, it can provide a company with an assessment of its process safety performance.

5.2 Tier 1 Indicator Definition and Consequences

5.2.1 Tier 1 Definition

A Tier 1 Process Safety Event (T-1 PSE) is a loss of primary containment (LOPC) with the greatest consequence as defined by this RP. A T-1 PSE is an unplanned or uncontrolled release of any material, including non-toxic and non-flammable materials (e.g. steam, hot water, nitrogen, compressed CO_2 or compressed air), from a process that results in one or more of the consequences listed below.

NOTE 1 Some non-toxic and non-flammable materials (e.g. steam, hot water, or compressed air) have no threshold quantities and are only included in this definition because of their potential to result in one of the other consequences.

NOTE 2 A pressure relief device (PRD), safety instrumented system (SIS), or manually initiated emergency depressure discharge is a LOPC due to the unplanned nature of the release. The determination of Tier 1 PSE is based upon the criteria described below.

NOTE 3 An internal fire or explosion that causes a LOPC from a process triggers an evaluation of the Tier 1 consequences. The LOPC does not have to occur first.

5.2.2 Tier 1 Consequences

- An employee, contractor or subcontractor “days away from work” injury and/or fatality.
- A hospital admission and/or fatality of a third-party.
- An officially declared community evacuation or community shelter-in-place including precautionary community evacuation or community shelter-in-place.
- A fire or explosion damage greater than or equal to $100,000 of direct cost.
- An engineered pressure relief (e.g. PRD, SIS, or manually initiated emergency depressure) discharge, of a quantity greater than or equal to the threshold quantities in Table 1 in any one-hour period, to atmosphere whether directly or via a downstream destructive device that results in one or more of the following four consequences:
  - rainout;
  - discharge to a potentially unsafe location;
  - an on-site shelter-in-place or on-site evacuation, excluding precautionary on-site shelter-in-place or on-site evacuation;
  - public protective measures (e.g. road closure) including precautionary public protective measures.
- An upset emission from a permitted or regulated source, of a quantity greater than or equal to the threshold quantities in Table 1 in any one-hour period, that results in one or more of the following four consequences:
  - rainout;
  - discharge to a potentially unsafe location;
  - an on-site shelter-in-place or on-site evacuation, excluding precautionary on-site shelter-in-place or on-site evacuation;
  - public protective measures (e.g. road closure) including precautionary public protective measures.
- A release of material greater than or equal to the threshold quantities described in Table 1 in any one-hour period.

  NOTE In determining the Threshold Release Category, a Company may choose to use either the properties of the released material based upon laboratory analysis at the time of release, or the properties documented in a safety data sheet. Companies should be consistent in their approach for all LOPCs.

Annex E, PSE Examples and Questions provides a wide variety of examples to assist companies in determining the proper classification of Tier 1.

Annex F, Listing of Chemicals Sorted by Threshold Quantity provides a link to a comprehensive list of chemicals with associated release threshold quantities that has been adopted for this RP. Annex F also describes the thought process used to assign Packing Groups, Hazard Zones, and threshold quantities for flammable and toxic materials.

Annex G, Application of Threshold Release Categories to Multicomponent Releases provides guidance on threshold release category determination for a variety of multicomponent streams.

Annex H, PSE Tier 1/Tier 2 Determination Decision Logic Tree provides a flowchart to assist companies in determining if a loss of primary containment is a Tier 1 or Tier 2 process safety event.

5.3 Calculation of Tier 1 PSE Rate

The Tier 1 PSE Rate shall be calculated as follows:

$$\text{Tier 1 PSE Rate}_{200,000} = (\text{Total Tier 1 PSE Count / Total Work Hours}) \times 200,000\text{, or}$$

$$\text{Tier 1 PSE Rate}_{1,000,000} = (\text{Total Tier 1 PSE Count / Total Work Hours}) \times 1,000,000$$

NOTE Total Work Hours was chosen as the normalizing factor for PSE Rate as a balance between ready availability of the value, relevance to harm, and applicability to various refining and petrochemical operations. Other suggested normalizers such as throughput, Dow Fire and Explosion Index, etc. did not strike this balance. Total work hours includes employees and contractors (see 3.1.51 for definition).

The choice of calculating PSE Rate utilizing either a 200,000 or 1,000,000 man hour multiplier should be consistent with the basis for calculating the Company's occupational injury rate or public reporting conventions.

5.4 Optional Tier 1 PSE Severity Weighting

Severity weighting, whether Company defined or industry association defined, can provide additional useful information about Tier 1 PSEs that may help drive performance improvement. Annex D provides an example methodology for calculating a severity weight for Tier 1 PSEs that a company may find beneficial.

6 Tier 2 Performance Indicator—Process Safety Events (T-2 PSE)

6.1 Tier 2 Indicator Purpose

The count of Tier 2 process safety events represents LOPC events of lesser consequence. 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 events. In that sense, Tier 2 PSEs act as a leading indicator for Tier 1 PSEs and can provide a company with opportunities for learning and improvement of its process safety performance.

6.2 Tier 2 Indicator Definition and Consequences

6.2.1 Tier 2 Definition

A Tier 2 Process Safety Event (T-2 PSE) is a LOPC with lesser consequence. A T-2 PSE is an unplanned or uncontrolled release of any material, including non-toxic and non-flammable materials (e.g. steam, hot water, 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 as a Tier 1 PSE.

NOTE 1 Some non-toxic and non-flammable materials (e.g. steam, hot water, or compressed air) have no threshold quantities and are only included in this definition because of their potential to result in one of the other consequences.

NOTE 2 A pressure relief device (PRD), safety instrumented system (SIS), or manually initiated emergency depressure discharge is a LOPC due to the unplanned nature of the release. The determination of Tier 2 PSE is based upon consequences and threshold quantities described below.

NOTE 3 An internal fire or explosion that causes a LOPC from a process triggers an evaluation of the Tier 2 consequences. The LOPC does not have to occur first.

Table 1—Tier 1 Material Release Threshold Quantities

Threshold Release Category	Material Hazard Classification [a,c,d,e,f]	Threshold Quantity (outdoor release)	Threshold Quantity (indoor[b] release)
T1-1	TIH Zone A Materials	≥5 kg (11 lb)	≥0.5 kg (1.1 lb)
T1-2	TIH Zone B Materials	≥25 kg (55 lb)	≥2.5 kg (5.5 lb)
T1-3	TIH Zone C Materials	≥100 kg (220 lb)	≥10 kg (22 lb)
T1-4	TIH Zone D Materials	≥200 kg (440 lb)	≥20 kg (44 lb)
T1-5	Flammable Gases or Liquids with Normal Boiling Point ≤35 °C (95 °F) and Flash Point <23 °C (73 °F) or Other Packing Group I Materials (excluding acids/bases)	≥500 kg (1100 lb)	≥50 kg (110 lb)
T1-6	Liquids with Normal Boiling Point >35 °C (95 °F) and Flash Point <23 °C (73 °F) or Other Packing Group II Materials (excluding acids/bases)	≥1000 kg (2200 lb) or ≥7 bbl	≥100 kg (220 lb) or ≥0.7 bbl
T1-7	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 (see definition 3.1.2) or UNDG Class 2, Division 2.2 (non-flammable, non-toxic gases) excluding air or Other Packing Group III Materials	≥2000 kg (4400 lb) or ≥14 bbl	≥200 kg (440 lb) or ≥1.4 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.

In determining the Threshold Release Category for a material, one should first use the toxic (TIH Zone) or flammability (Flash Point and Boiling Point) or corrosiveness (Strong Acid or Base vs. Moderate Acid or Base) characteristics. Only when the hazard of the material is not expressed by those simple characteristics (e.g. reacts violently with water) is the UNDGL Packing Group used.

[a] Many materials exhibit more than one hazard. [22] Correct placement in Hazard Zone or Packing Group shall follow the rules of DOT 49 *CFR* 173.2a [22] or UN Recommendations on the Transportation of Dangerous Goods, Section 2. [18] See Annex F.

[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 E, PSE Examples and Questions 49 through 53.

[e] A LOPC of Liquids with Flash Point >60 °C (140 °F) and ≤93 °C (200 °F) released at a temperature below Flash Point cannot be Tier 1 PSE based upon quantity released no matter the volume.

[f] A LOPC of a moderate acid/base cannot be Tier 1 PSE based upon quantity released no matter the volume.

6.2.2 Tier 2 Consequences

— An employee, contractor or subcontractor recordable injury.

— A fire or explosion damage greater than or equal to $2500 of direct cost.

NOTE Some companies rather than performing a detailed estimate use a simple rule-of-thumb to determine if the direct cost exceeded $2500: If the damage requires repair, then the direct cost is often at least $2500.

— An engineered pressure relief (PRD, SIS, or manually initiated emergency depressure) device discharge, of a quantity greater than or equal to the threshold quantities in Table 2 in any one-hour period, to atmosphere whether directly or via a downstream destructive device that results in one or more of the following four consequences:

  — rainout;

  — discharge to a potentially unsafe location;

  — an on-site shelter-in-place or on-site evacuation excluding precautionary on-site shelter-in-place or on-site evacuation;

  — public protective measures (e.g. road closure);

  — including precautionary public protective measures.

— An upset emission from a permitted or regulated source, of a quantity greater than or equal to the threshold quantities in Table 2 in any one-hour period, that results in one or more of the following four consequences:

  — rainout;

  — discharge to a potentially unsafe location;

  — an on-site shelter-in-place or on-site evacuation, excluding precautionary on-site shelter-in-place or on-site evacuation;

  — public protective measures (e.g. road closure) including precautionary public protective measures.

— A release of material greater than or equal to the threshold quantities described in Table 2 in any one-hour period.

NOTE In determining the Threshold Release Category, a Company may choose to use either the properties of the released material based upon laboratory analysis at the time of release, or the properties documented in a safety data sheet. Companies should be consistent in their approach for all LOPCs.

Annex E, PSE Examples and Questions provides a wide variety of examples to assist companies in determining the proper classification of Tier 2.

Annex F, Listing of Chemicals Sorted by Threshold Quantity provides a link to a comprehensive list of chemicals with associated release threshold quantities that has been adopted for this RP. Annex F also describes the thought process used to assign Packing Groups, Hazard Zones, and threshold quantities for flammable and toxic materials.

Annex G, Application of Threshold Release Categories to Multicomponent Releases provides guidance on threshold release category determination for a variety of multicomponent streams.

Table 2—Tier 2 Material Release Threshold Quantities

Threshold Release Category	Material Hazard Classification [a,c,d,e,f]	Threshold Quantity (outdoor release)	Threshold Quantity (indoor[b] release)
T2-1	TIH Zone A Materials	≥0.5 kg (1.1 lb)	≥0.25 kg (0.55 lb)
T2-2	TIH Zone B Materials	≥2.5 kg (5.5 lb)	≥1.25 kg (2.75 lb)
T2-3	TIH Zone C Materials	≥10 kg (22 lb)	≥5 kg (11 lb)
T2-4	TIH Zone D Materials	≥20 kg (44 lb)	≥10 kg (22 lb)
T2-5	Flammable Gases or Liquids with Normal Boiling Point ≤35 °C (95 °F) and Flash Point <23 °C (73 °F) or Other Packing Group I Materials (excluding acids/bases)	≥50 kg (110 lb)	≥25 kg (55 lb)
T2-6	Liquids with Normal Boiling Point >35 °C (95 °F) and Flash Point <23 °C (73 °F) or Other Packing Group II Materials (excluding acids/bases)	≥100 kg (220 lb) or ≥0.7 bbl	≥50 kg (110 lb) or ≥0.35 bbl
T2-7	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 (see definition 3.1.2) or UNDG Class 2, Division 2.2 (non-flammable, non-toxic gases) excluding air or Other Packing Group III Materials	≥200 kg (440 lb) or ≥1.4 bbl	≥100 kg (220 lb) or ≥0.7 bbl
T2-8	Liquids with Flash Point >60 °C (140 °F) and ≤93 °C (200 °F) released at a temperature below Flash Point or Moderate acids/bases (see definition 3.1.1)	≥1000 kg (2200 lb) or ≥7 bbl	≥500 kg (1100 lb) or ≥3.5 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.

In determining the Threshold Release Category for a material, one should first use the toxic (TIH Zone) or flammability (Flash Point and Boiling Point) or corrosiveness (Strong Acid or Base vs. Moderate Acid or Base) characteristics. Only when the hazard of the material is not expressed by those simple characteristics (e.g. reacts violently with water) is the UNDGL Packing Group used.

[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 [22] or UN Recommendations on the Transportation of Dangerous Goods, Section 2 [18]. See Annex F.

[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 E, PSE Examples and Questions 49 through 53.

[e] A LOPC of Liquids with Flash Point >60 °C (140 °F) and ≤93 °C (200 °F) released at a temperature below Flash Point cannot be Tier 1 PSE based upon quantity released no matter the volume.

[f] A LOPC of a moderate acid/base cannot be Tier 1 PSE based upon quantity released no matter the volume.

Annex H, PSE Tier 1/Tier 2 Determination Decision Logic Tree provides a flowchart to assist companies in determining if a loss of primary containment is a Tier 1 or Tier 2 process safety event.

6.3 Calculation of Tier 2 PSE Rate

The Tier 2 PSE rate shall be calculated as follows:

$$\text{Tier 2 PSE Rate}_{200{,}000} = (\text{Total Tier 2 PSE Count / Total Work Hours}) \times 200{,}000\text{, or}$$

$$\text{Tier 2 PSE Rate}_{1{,}000{,}000} = (\text{Total Tier 2 PSE Count / Total Work Hours}) \times 1{,}000{,}000$$

NOTE Total Work Hours was chosen as the normalizing factor for PSE Rate as a balance between ready availability of the data, relevance to harm, and applicability to various refining and petrochemical operations. Other suggested normalizers such as throughput, Dow Fire and Explosion Index, etc. did not strike this balance. Total work hours includes employees and contractors (see 3.1.51 for definition).

The choice of calculating PSE Rate utilizing either a 200,000 or 1,000,000 man hour multiplier should be consistent with the basis for calculating the Company's occupational injury rate.

7 Tier 3 Performance Indicators—Challenges to Safety Systems

7.1 Purpose of Indicator

A Tier 3 PSE typically represents a challenge to the barrier system that progressed along the path to harm, but is stopped short of a Tier 1 or Tier 2 PSE consequence. Indicators at this level provide an additional opportunity to identify and correct weaknesses within the barrier system.

Tier 3 indicators are too facility-specific for benchmarking or developing industry applicable criteria. They are intended for internal company use and can be used for local (facility) public reporting. A company may use all or some of the example indicators below:

— safe operating limit excursions,

— primary containment inspection or testing results outside acceptable limits,

— demands on safety systems,

— other LOPCs;

or identify others that are meaningful to its operations.

A Company shall develop and use Tier 3 Indicators.

7.2 Examples of Tier 3 PSEs

7.2.1 Safe Operating Limit Excursions

7.2.1.1 Indicator Definition

A process parameter deviation that exceeds the safe operating limit (SOL) applicable to the phase of operation. Different operating phases (e.g. regeneration or steps in a batch process) may have different SOLs for the same equipment. Figure 3 depicts the relationship between normal operating limits, high/low alarm limits, and the SOL. Exceeding the SOL represents the point beyond which troubleshooting ends and pre-determined action occurs to return the process to a known safe state. The predetermined action may range from manually executed operating procedures to a fully automated safety instrumented system.

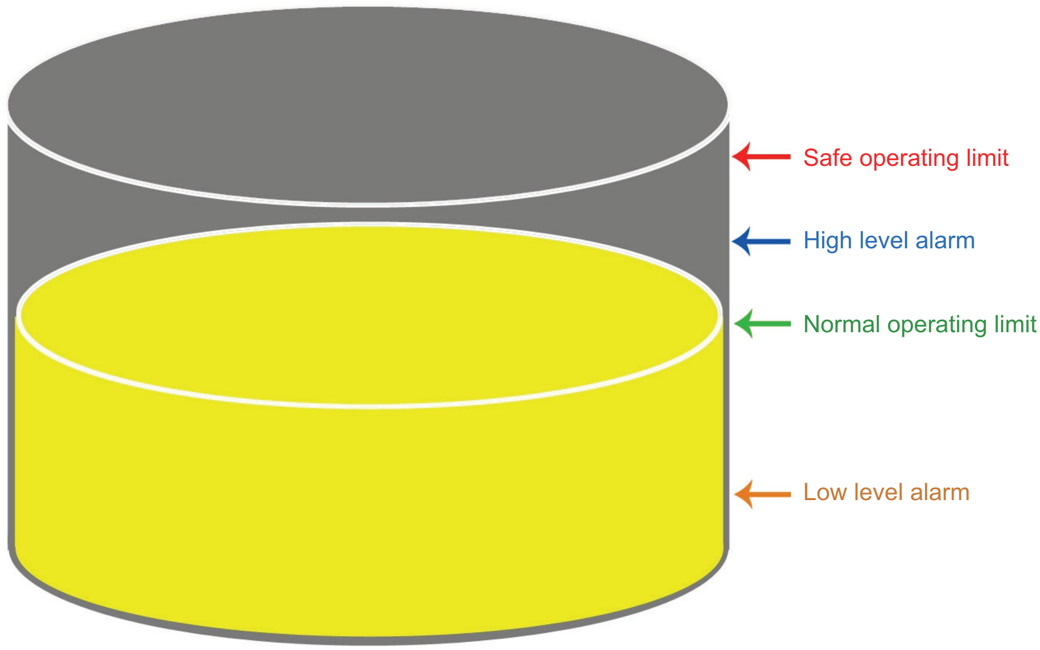


Figure 3—Example of Safe Operating Limit for Tank Level

7.2.1.2 Indicator Data Capture

A Tier 3 PSE is counted for each SOL excursion that occurred in a specified time period.

A company may want to record the duration of individual SOL excursions and may even calculate the total duration of all SOL excursions.

A single initiating event may result in multiple SOL excursions (e.g. facility-wide failure of a utility) and each excursion should be counted as a separate Tier 3 PSE. A process condition that hovers near the SOL value may result in multiple excursions. These excursions should be counted as a single Tier 3 PSE.

7.2.2 Primary Containment Inspection or Testing Results Outside Acceptable Limits

7.2.2.1 Indicator Definition

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.

7.2.2.2 Indicator Data Capture

A Tier 3 PSE is counted for vessels, atmospheric tanks, piping, or machinery when previous operating pressures or levels exceed the acceptable limits based upon wall thickness inspection measurements.

A single Tier 3 PSE 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 Tier 3 PSE 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.

7.2.2.3 Calculation

Number of equipment pieces found to have operated outside fitness-for-service rating per 100 or 1000 inspections or tests. Equipment types (e.g. pressure vessels, pipes, atmospheric tanks, machinery) should be calculated separately.

7.2.3 Demands on Safety Systems

7.2.3.1 Indicator Definition

A demand on a safety system designed to prevent a LOPC or to mitigate the consequences of a LOPC.

An emphasis is placed on the “system” approach to recognize that many safety systems consist of multiple elements. For example, a system may include sensors, logic solvers, actuators, and final control devices designed to prevent a LOPC, or it may include a PRD and flare or scrubber that function together to mitigate the consequences of a LOPC. All of these elements function together as a system and when a demand is placed on the system, a single event is counted, regardless of the number of devices that must function within the system. An example is a process vessel that uses multiple PRDs to either handle large relief loads or to minimize the potential for chattering. Activation of these multiple PRDs constitutes activation of one safety system and would be recorded as one Demand on Safety Systems.

7.2.3.2 Indicator Data Capture

7.2.3.2.1 General

A Tier 3 PSE is counted for each Demand on Safety Systems event when one of the following occurs:

1) activation of a safety instrumented system;

2) activation of a mechanical shutdown system;

3) activation of a PRD not counted as Tier 1 or Tier 2, regardless of the phase of operation (e.g. start-up, shutdown, normal, temporary, emergency shutdown, regeneration, batch mode).

A demand resulting from intentional activation of the safety system during periodic device testing, or manual activation as a part of the normal shutdown process is excluded.

7.2.3.2.2 Activation of a Safety Instrumented System

A safety instrumented system is considered to have been activated when called upon to function by a valid signal regardless of whether or not the SIS responds. A single initiating event may result in multiple SIS activations (e.g. facility-wide power failure) with each SIS activation being counted separately. Inadvertent or intentional activation during maintenance activities should not be counted as a Tier 3 PSE, but may be counted in Tier 4.

SIS activation that is configured for equipment protection with no related LOPC protection should not be counted as a Tier 3 PSE.

7.2.3.2.3 Activation of Mechanical Shutdown System

A mechanical shutdown system is considered to have been activated when called upon to function by a valid signal, regardless of whether or not the mechanical shutdown system responds. Inadvertent or intentional activation during maintenance activities should not be counted as a Tier 3 PSE, but may be counted in Tier 4.

Mechanical shutdown system activation that is configured for equipment protection with no related LOPC protection should not be counted as a Tier 3 PSE.

7.2.3.2.4 Activation of Pressure Relief Device (PRD) Not Counted as Tier 1 or Tier 2

A PRD is considered to have been activated when the system pressure reaches the device set point whether or not the PRD performs as designed. A single initiating event may result in activation of multiple PRDs (e.g. facility-wide power failure) with each PRD activation being counted separately. Multiple PRDs that function as a system (e.g. to either handle large relief loads or to minimize the potential for chattering, Safety Valve (SV) and rupture disk combinations) are to be counted as a single device. Activation of PRDs to be counted as Tier 3 PSEs includes the following:.

— Safety Valve (SV)—If activation is known it should be counted. Exclude times when the SV lifts early or leaks when the pressure is below the SV set point.

— Rupture Disc—Count each time the disc is replaced excluding regularly scheduled preventive maintenance.

— Rupture Pin Device—Count each time a pin is replaced excluding regularly scheduled preventive maintenance.

— Deflagration Vent—Count each time the vent must be re-seated excluding regularly scheduled preventive maintenance.

— Pressure/Vacuum (PV) Vents (e.g. on tanks)—Count only events in which the PV vent fails to function. This is typically indicated by damage to the tank.

7.2.3.3 Calculation

The count of Demands on Safety Systems is typically segregated by system type (e.g. SIS, PRD, and Mechanical Trip). Some Companies may find that a rate of demands per safety system type provides a more useful indicator than a simple count. Tier 3 Demands on Safety Systems may be subcategorized as follows:

— number of SIS activations;

— number of mechanical trip activations;

— number of Tier 3 PRDs directly to atmosphere;

— number of Tier 3 PRDs to atmosphere via a downstream destructive device.

7.2.4 Other LOPC Events

7.2.4.1 General

Companies may find it useful to collect information on LOPC incidents with a consequence less than Tier 2 PSEs (e.g. any fire or explosion, small releases). Companies that choose to collect this information will need to establish consequence thresholds meaningful to its operations and meaningful to its process safety goals. Consequences should reflect potential process safety hazards rather than health (e.g. personnel exposure limits) or environmental (e.g. fugitive emissions) hazards.

7.2.4.2 Indicator Definition

LOPC events not counted as Tier 1 or Tier 2 PSEs.

7.2.4.3 Indicator Data Capture

Count of other LOPCs defined by facility determined categories.

8 Tier 4 Performance Indicators—Operating Discipline and Management System Performance

8.1 General

The example indicators presented in this section represent a starting point for the thought process that must take place within each company and at each facility. Tier 4 performance indicators must reflect facility-specific barrier systems, facility-specific performance objectives, and the maturity of any existing performance indicators. The thought process for creating appropriate and useful performance indicators is given in Section 9.

8.2 Purpose of Indicator

Tier 4 indicators typically represent performance of individual components of the barrier system and are comprised of operating discipline and management system performance. Indicators at this level provide an opportunity to identify and correct isolated system weaknesses. Tier 4 indicators are indicative of process safety system weaknesses that may contribute to future Tier 1 or Tier 2 PSEs. In that sense, Tier 4 indicators may identify opportunities for both learning and systems improvement. Tier 4 indicators are too facility-specific for benchmarking or developing industry applicable criteria. They are intended for internal company use and for local (facility) reporting.

A company shall develop and use Tier 4 performance indicators. A company may use all or some of the example indicator topics below, or identify others that are meaningful to its operations.

8.3 Examples of Tier 4 Indicators

The choice of Tier 4 performance indicators should be limited to the meaningful few that are representative of the barrier systems in place at a particular facility. The indicators should be those with the highest predictive ability and those that provide actionable information. The following list of operating discipline and management system performance indicators may be considered.

1) Process Hazard Evaluations Completion—Schedule of process area retrospective and revalidation hazard evaluations completed on time by fully qualified teams.

2) Process Safety Action Item Closure—Percentage and/or number of past-due process safety actions. This may include items from incident investigations, hazard evaluations or compliance audits.

3) Training Completed on Schedule—Percentage of process safety required training sessions completed with skills verification.

4) Procedures Current and Accurate—Percent of process safety required operations and maintenance procedures reviewed or revised as scheduled.

5) Work Permit Compliance—Percent of sampled work permits that meet all requirements. This may include permit to enter, hot work, general work, lockout/tagout, etc.

6) Safety Critical Equipment Inspection—Percent of inspections of safety critical equipment completed on time. This may include pressure vessels, storage tanks, piping systems, pressure relief devices, pumps, instruments, control systems, interlocks and emergency shutdown systems, mitigation systems, and emergency response equipment.

7) Safety Critical Equipment Deficiency Management—Response to safety critical equipment inspection findings (e.g. non-functional PRDs and SISs). This may include proper approvals for continued safe operations, sufficient interim safeguards, and timeliness of repairs, replacement, or rerate.

8) Management of Change (MOC) and Pre Start-up Safety Review (PSSR) Compliance—Percent of sampled MOCs and PSSRs that meet all requirements and quality standards.

9) Completion of Emergency Response Drills—Percentage of emergency response drills completed as scheduled.

10) Fatigue Risk Management—Key measures of fatigue risk management systems may include: percentage of overtime, number of open shifts, number of extended shifts, number of consecutive shifts worked, number of exceptions, etc.

Annex J, Tier 4 Example Indicators provides additional details that a company may find useful if it chooses to implement any of the above operating discipline and management system performance indicators.

9 Guidelines for Selection of Process Safety Indicators

9.1 General

This section provides a high-level overview of some key aspects of process safety indicator selection and development; additional guidance can be found in Annex J. A more complete treatment of this topic can be found in references such as:

— Center for Chemical Process Safety, *Guidelines for Process Safety Metrics,* American Institute of Chemical Engineers, New York, 2009; [9]

— UK Health and Safety Executive (UK HSE), “Step-By-Step Guide to Developing Process Safety Performance Indicators, HSG254,” Sudbury, Suffolk, UK, 2006; [17]

— Hopkins, Andrew, “Thinking About Process Safety Indicators,” Working Paper 53, Paper prepared for the Oil and Gas Industry Conference, Manchester, UK, 2007; [13]

9.2 Purpose of Indicators

The purpose of process safety indicators is to identify events or conditions that could ultimately lead to higher-level consequences. Indicators provide a means to measure activity, status, or performance against requirements and goals. Monitoring and analyzing performance enables Companies to take corrective action as needed. Properly defined and understood indicators can give Companies confidence that the right things are being managed and tracked.

Selection of indicators is important since some indicators may not provide the needed insights to ensure desired performance. Poorly selected or poorly crafted indicators can result in knowledge gaps or may result in unwarranted confidence. More than one indicator and more than one type of indicator are needed to monitor the different dimensions of process safety operating discipline and management system performance.

9.3 Lagging versus Leading Indicators

Lagging indicators tend to be outcome-oriented and retrospective; they describe events that have already occurred and may indicate potential recurring problems and may include fires, releases, and explosions.

Leading indicators tend to be forward-looking and indicate the performance of the key work processes, operating discipline, or protective barriers that prevent incidents. They are designed to give an indication of potential problems or deterioration in key safety systems early enough that corrective actions may be taken.

The differentiation or classification of indicators as lagging or leading is not important. The important point is to capture information that can be acted upon to correct a situation, to identify lessons learned, and to communicate this knowledge.

9.4 Characteristics of Effective Indicators

Credible and useful indicators exhibit certain characteristics or meet certain criteria.

— Reliable: They are measurable using an objective or unbiased scale. To be measurable, an indicator needs to be specific and discrete.

— Repeatable: Similar conditions will produce similar results and different trained personnel measuring the same event or data point will obtain the same result.

— Consistent: The units and definitions are consistent across the Company. This is particularly important when indicators from one area of the Company will be compared with those of another.

— Independent of Outside Influences: The indicator leads to correct conclusions and is independent of pressure to achieve a specific outcome.

— Relevant: The indicator is relevant to the operating discipline or management system being measured; they have a purpose and lead to actionable response when outside the desired range.

— Comparable: The indicator is comparable with other similar indicators. Comparability may be over time, across a company, or across an industry.

— Meaningful: The indicator includes sufficient data to measure positive or negative change.

— Appropriate for the Intended Audience: The data and indicators reported will vary depending upon the needs of a given audience. Information for senior management and public reporting usually contains aggregated or normalized data and trends, and is provided on a periodic basis (e.g. quarterly or annually). Information for employees and employee representatives is usually more detailed and is reported more frequently.

— Timely: The indicator provides information when needed based upon the purpose of the indicator and the needs of the intended audience.

— Easy to Use: Indicators that are hard to measure or derive are less likely to be measured or less likely to be measured correctly.

— Auditable: Indicators should be auditable to ensure they meet the above expectations.

9.5 Selection of Indicators

There are various ways to identify the critical few indicators that can be used to drive process safety performance improvement.

— Use process hazard evaluation and risk assessment findings to identify potential high impact events and the process safety barriers intended to prevent such incidents.

  — What can go wrong?

- — What are the consequences?
- — What is the likelihood?
- — Which are the most critical barriers?
- — How vulnerable are the barriers to rapid deterioration?

— Use incident investigation and analysis findings to identify process safety barrier failures that contributed to incidents.

— Use shared external learnings to determine what others have successfully used.

Involving employees and employee representatives, process safety professionals, and engineers in the identification process can yield a more complete picture of process safety performance that will aid in indicators selection. Selecting appropriate indicators using unbiased and broad-based input will lead to a high-performing program.

Annex I, Guidance for Implementation of Tier 3 and Tier 4 Indicators discusses the various issues and concerns that a company may experience when implementing Tier 3 and Tier 4 indicators.

10 Reporting Performance Indicators

10.1 Format and Forum

The purpose of data collection, data analysis, and reporting is to facilitate learning and improvement. The format and forum for reporting data varies depending upon the target audience. Local reporting to employees and employee representatives, community groups and emergency management officials may occur in small group formats where details can be shared and dialog facilitated. Nationwide public reporting for the purpose of trending over time and comparison may occur through industry trade groups.

10.2 Transparency

Companies should have a philosophy of openness and transparency to satisfactorily demonstrate ongoing process safety performance to employees and employee representatives, community groups, government agencies and other key stakeholders. Openness and transparency build credibility among stakeholders and the public at large.

Transparency and self-disclosure require a trust among those reporting and all interested and affected parties that data will be used in good faith to promote performance improvement and learning and not for "disciplinary action" or litigation.

10.3 Stakeholder

10.3.1 Broad Access (Nationwide) Public Reporting

Annually, each Company shall publicly report Tier 1 and Tier 2 PSE information specified in Table 3. It should also include other appropriate information based upon the data capture specified in 10.4. The information should be continuously available for at least five years.

Table 3—Stakeholder Report Information

		Industry	Company
Tier 1	Current Year PSE Count + 5-Year Rolling Average	X	See Note
	Current Year PSE Rate + 5-Year Rolling Average	X	X
Tier 2	Current Year PSE Count + 5-Year Rolling Average	X	See Note
	Current Year PSE Rate + 5-Year Rolling Average	X	X
NOTE Comparisons among companies and industries are only statistically valid on a rate basis; therefore, Company PSE counts should not be reported publicly.			

Reporting may be directly from an individual company or through industry trade groups, government agencies or other means. Options for public reporting include the following.

a) Company Specific Reports or Web Sites—When reporting information directly to the public or to other interested parties, Companies may make Tier 1 and Tier 2 PSE information readily available on a publicly accessible web site, or as a written report provided upon request by any interested party.

b) Industry Association or Professional Society Reports or Web Sites—API, ACC, AFPM, CCPS, UK PIA, or other petroleum or petrochemical industry associations may collect and report Tier 1 and Tier 2 PSE information. These reports may be in the form of publicly accessible web sites, or as written reports provided upon request by any interested party. The advantage of association or society reporting is that it allows interested parties to view information in one place and enables benchmarking of performance.

c) Government Agency or Other Organizations—Local, state, or national government agencies, or other organizations may elect to establish reporting web sites.

10.3.2 Local (Facility) Public Reporting

Each company's facility should determine the appropriate methods to communicate PSE information to its employees and employee representatives, the local community, and emergency management officials.

Annually, each company's facility shall report a summary of its facility-specific Tier 1, 2, 3, and 4 PSE information to its employees and employee representatives. Unattended, remote-operated or minimum-manned facilities are exempt from this requirement. Minimum manning would include one or two operators, performing limited duration daily checks at a facility.

Annually, each company's facility shall make available a summary of facility-specific Tier 1 and 2 PSE information and can report facility-specific Tier 3 and 4 PSE information to the local community and emergency management officials along with information regarding measures taken to improve performance. This includes any communities that could reasonably be affected by a LOPC event. Remote facilities where the maximum credible LOPC cannot impact any public receptors are exempt from this requirement.

10.4 PSE Data Capture

10.4.1 Facility Information

The following information shall be captured for each facility:

a) type of facility (NAICS or equivalent international code);

b) corporate name;

c) company name (if different);

d) facility location/name (country, state/province, city, facility name);

e) facility identifier(s) (unique number(s) assigned by data collection groups);

f) total work hours:

   1) total hours worked by employees, and

   2) total hours worked by contractors and subcontractors.

10.4.2 Tier 1 PSE Information

The following information shall be captured for each Tier 1 PSE:

a) facility identifier;

b) Tier 1 PSE consequences/triggers—each Tier 1 PSE will have one or more of the following consequences (check all that apply):

   NOTE Since a Tier 1 Process Safety Event can result in one or more consequences, the total count of consequences will be equal to or greater than the total count of Tier 1 PSEs.

   1) an employee, contractor, or subcontractor "days away from work" injury and/or fatality:

      i) number of employee days away from work injuries,

      ii) number of employee fatalities,

      iii) number of contractor or subcontractors days away from work injuries,

      iv) number of contractor or subcontractor fatalities;

   2) a third party (non-employees/contractor, community members) hospital admission and/or fatality:

      i) number of third-party hospital admissions,

      ii) number of third-party fatalities;

   3) an officially declared community evacuation or community shelter-in-place including precautionary community evacuation or community shelter-in-place;

   4) a fire or explosion causing $100,000 or more in direct cost:

i) fire,

ii) explosion;

5) an engineered pressure relief (e.g. PRD, SIS, or manually initiated emergency depressure) discharge, of a quantity greater than or equal to the threshold quantities in Table 1 in any one-hour period, to atmosphere whether directly or via a downstream destructive device (check one):

i) PRD, SIS, or manually initiated emergency depressure device directly to atmosphere,

ii) PRD, SIS, or manually initiated emergency depressure device to atmosphere via a downstream destructive device;

that results in one or more of the following four consequences (check all that apply):

i) rainout,

ii) discharge to a potentially unsafe location,

iii) an on-site shelter-in-place or on-site evacuation, excluding precautionary on-site shelter-in-place or on-site evacuation,

iv) public protective measures (e.g. road closure) including precautionary public protective measures;

6) an upset emission from a permitted or regulated source, of a quantity greater than or equal to the threshold quantities in Table 1 in any one-hour period, that results in one or more of the following four consequences (check all that apply):

i) rainout;

ii) discharge to a potentially unsafe location;

iii) an on-site shelter-in-place or on-site evacuation, excluding precautionary on-site shelter-in-place or on-site evacuation;

iv) public protective measures (e.g. road closure) including precautionary public protective measures;

7) a release of flammable, combustible, toxic, corrosive, or UNDG Class 2, Division 2.2 material from primary containment (check one):

i) Tier 1 (Table 1) Threshold Release Category 1,

ii) Tier 1 (Table 1) Threshold Release Category 2,

iii) Tier 1 (Table 1) Threshold Release Category 3,

iv) Tier 1 (Table 1) Threshold Release Category 4,

v) Tier 1 (Table 1) Threshold Release Category 5,

vi) Tier 1 (Table 1) Threshold Release Category 6,

vii) Tier 1 (Table 1) Threshold Release Category 7;

release location (check one):

i) outdoor release,

ii) indoor release;

8) Tier 1 PSE severity weight (optional).

10.4.3 Tier 2 PSE Information

The following information shall be captured for each Tier 2 PSE:

a) facility identifier;

b) Tier 2 PSE consequences/triggers—each Tier 2 PSE will have one or more of the following consequences (check all that apply):

NOTE Since a Tier 2 Process Safety Event can result in one or more consequences, the total count of consequences will be equal to or greater than the total count of Tier 2 PSEs.

1) an employee, contractor, or subcontractor recordable injury:

i) number of employee recordable injuries,

ii) number of contractor or subcontractor recordable injuries;

2) a fire or explosion causing $2500 or more in direct cost:

i) fire,

ii) explosion;

3) an engineered pressure relief (PRD, SIS, or manually initiated emergency depressure) discharge, of a quantity greater than or equal to the threshold quantities in Table 2 in any one-hour period, to atmosphere whether directly or via a downstream destructive device (check one):

i) PRD, SIS, or manually initiated emergency depressure device directly to atmosphere,

ii) PRD, SIS, or manually initiated emergency depressure device to atmosphere via a downstream destructive device;

that results in one or more of the following four consequences (check all that apply):

i) rainout,

ii) discharge to a potentially unsafe location,

iii) resulted in an on-site shelter-in-place or on-site evacuation excluding precautionary on-site shelter-in-place or precautionary on-site evacuation,

iv) resulted in public protective measures (e.g. road closure) including precautionary public protective measures;

4) an upset emission from a permitted or regulated source, of a quantity greater than or equal to the threshold quantities in Table 2 in any one-hour period, that results in one or more of the following four consequences (check all that apply):

   i) rainout,

   ii) discharge to a potentially unsafe location,

   iii) an on-site shelter-in-place or on-site evacuation, excluding precautionary on-site shelter-in-place or on-site evacuation,

   iv) public protective measures (e.g. road closure) including precautionary public protective measures;

5) a release of flammable, combustible, toxic, corrosive, or UNDG Class 2, Division 2.2 material from primary containment (check one):

   i) Tier 2 (Table 2) Threshold Release Category 1,

   ii) Tier 2 (Table 2) Threshold Release Category 2,

   iii) Tier 2 (Table 2) Threshold Release Category 3,

   iv) Tier 2 (Table 2) Threshold Release Category 4,

   v) Tier 2 (Table 2) Threshold Release Category 5,

   vi) Tier 2 (Table 2) Threshold Release Category 6,

   vii) Tier 2 (Table 2) Threshold Release Category 7.

   viii) Tier 2 (Table 2) Threshold Release Category 8;

   release location (check one):

   i) outdoor release,

   ii) indoor release.

10.4.4 PSE Related Information

The following information is useful in data analysis and shall be captured for each Tier 1 and Tier 2 PSE.

a) Type of process:

   1) Refining Processes (check one):

      i) active warehouse,

      ii) alkylation, HF

      iii) alkylation, sulfuric

iv) bitumen/resid/asphalt,

v) calcining,

vi) coking,

vii) crude/vacuum distillation,

viii) fcc,

ix) flares/flare systems/flare gas recovery

x) gas and liquid desulfurization/treating (H_2S absorbers, amine systems, Merox),

xi) hydrogen,

xii) hydrotreating,

xiii) hydrocracking,

xiv) isomerization,

xv) loading/unloading (truck or rail)

xvi) marine/jetty/wharf,

xvii) pilot plant,

xviii) reforming,

xix) sulfur recovery,

xx) tank farm/storage facility/offsites/storage and transfer piping,

xxi) utilities/steam plant/cogeneration,

xxii) vapor recovery/light ends,

xxiii) waste/wastewater handling, treatment or disposal,

xxiv) other (describe);

2) Petrochemical and Other Processes (check one):

i) active warehouse,

ii) synthesis gas (CO, H2),

iii) LNG,

iv) methane,

v) methanol,

vi) methyl mercaptan,

vii) formaldehyde and derivatives,

viii) acetic acid and derivatives,

ix) dehydrogenation (propylene, butylenes),

x) ethane,

xi) ethylene and derivatives,

xii) ethanol,

xiii) ethylene oxide,

xiv) flares/flare systems/flare gas recovery

xv) glycols (ethylene, propylene),

xvi) NGL fractionation,

xvii) polyethylene,

xviii) ethylene dichloride and derivatives,

xix) ethyl benzene and derivatives,

xx) polystyrene,

xxi) styrene-butadiene,

xxii) phenol,

xxiii) propane,

xxiv) propylene,

xxv) polypropylene,

xxvi) isopropanol,

xxvii) propylene oxide and derivatives,

xxviii) butane,

xxix) isobutane,

xxx) isobutene,

xxxi) butadiene,

xxxii) MTBE,

xxxiii) ETBE,

xxxiv) pentane,

xxxv) hexane,

xxxvi) cyclohexane,

xxxvii) hexanol,

xxxviii) aromatics derivatives (cumene, dis-proportionation, aromatic isomerization, linear alkylbenzene),

xxxix) benzene,

xl) toluene,

xli) xylene,

xlii) paraxylene,

xliii) amines derivatives,

xliv) diisocyanates (TDA, MDA, IPDA, etc.),

xlv) isocyanates,

xlvi) specialty chemicals,

xlvii) loading/unloading (truck or rail),

xlviii) pilot plant,

xlix) tank farm/storage facility/offsite/storage and transfer piping,

l) utilities/steam plant/cogeneration,

li) waste/wastewater handling, treatment or disposal,

lii) other (describe);

b) Date and time of event;

c) Mode of operation (check one):

i) start-up,

ii) planned shutdown,

iii) emergency shutdown,

iv) normal (check one):

a) sampling,

b) loading/unloading,

c) equipment preparation/taking out of service for maintenance,

d) equipment commissioning/putting in service following maintenance,

e) switching equipment (e.g. pumps, filters),

f) filling/draining,

g) mixing/handling chemicals,

h) operator performed maintenance,

i) changing lineups,

j) steady state operation,

k) other (describe),

v) upset,

vi) turnaround,

vii) routine maintenance,

viii) temporary,

ix) other (describe);

d) Point of release (check one):

i) pump,

ii) compressor,

iii) blower/fan,

iv) pressure vessel (drum, tower, pressurized storage),

v) filter/coalescer,

vi) furnace/fired heater,

vii) fired boiler,

viii) heat exchanger,

ix) instrumentation,

x) cooling tower,

xi) piping system, small bore ≤50 mm (2 in.) (piping, gaskets, sight glasses, expansion joints, tubing, valves),

xii) piping system, large bore >50 mm (2 in.) (piping, gaskets, sight glasses, expansion joints, tubing, valves),

xiii) reactor,

xiv) atmospheric tank (fixed roof or internal/external floating roof),

xv) flare/relief system,

xvi) other (describe);

e) Type of material released (check one):

i) flammable,

ii) combustible,

iii) toxic,

iv) corrosive,

v) UNDG Class 2, Division 2.2

vi) utilities (e.g. air, water, steam, nitrogen, etc.)

vii) other (describe).

f) Event description:

Briefly describe “what happened” and “why”. For example: “Leak on a fractionator reflux line due to external corrosion caused from a leak in a process water line dripping on the reflux line.” Another example: “LOPC from overfilling a small caustic tank due to malfunctioning level indication.”

g) Comments (optional);

h) Causal factors (check all that apply):

i) change management LTA,

ii) communication LTA,

iii) design LTA,

iv) equipment reliability LTA,

v) fixed equipment inspection LTA,

vi) human factors LTA,

vii) knowledge and skills LTA,

viii) operating limits LTA,

ix) procedures LTA,

x) risk assessment LTA,

xi) safe work practices or procedures LTA,

xii) work monitoring LTA,

xiii) other (describe).

Annex A
(informative)

Application to Petroleum Pipeline and Terminal Operations

A.1 General

API 754 was developed for the refining and petrochemical industries, but may also be applicable to other industries with operating systems and processes where loss of containment has the potential to cause harm such as petroleum pipeline and terminal operations. API 754 may be applied to petroleum pipeline and terminal operations by substituting the following sections for those used in the body of this RP.

A.2 Applicability

This RP applies to the responsible party. At collocated facilities (e.g. industrial park), this recommended practice applies individually to the responsible parties and not to the facility as a whole.

Events associated with the following activities fall outside the scope of this RP and shall not be included in data collection or reporting efforts:

a) marine transport operations, except when the vessel is connected or in the process of connecting or disconnecting to the process;

b) truck or rail operations, except when the truck or rail car is connected or in the process of connecting or disconnecting to the process, or when the truck or rail car is being used for on-site storage;

NOTE Active staging is not part of connecting or disconnecting to the process; active staging is not considered on-site storage; active staging is considered part of transportation.

c) vacuum truck operations, except on-site truck loading or discharging operations, or use of the vacuum truck transfer pump;

d) routine emissions from permitted or regulated sources;

NOTE Upset emissions are evaluated as possible Tier 1 or Tier 2 PSEs per Section 5.2 and Section 6.2.

e) office, shop, and warehouse building events (e.g. office fires, spills, personnel injury or illness, etc.);

f) personal safety events (e.g. slips, trips, falls) that are not directly associated with on-site response or exposure to a loss of primary containment (LOPC) event;

g) LOPC events from ancillary equipment not connected to the process (e.g. small sample containers);

h) quality assurance (QA) and quality control (QC) laboratories; and

i) on-site fueling operations of mobile and stationary equipment (e.g. pick-up trucks, diesel generators, and heavy equipment).

A.3 Terms and Definitions

The following terms and definitions apply to Annex A.

process
Distribution, storage, utilities, or loading facilities used store and transport petrochemical and petroleum refining feedstocks, and products. This includes process equipment (e.g. vessels, piping, process sumps, vapor recovery systems, pumps, compressors, exchangers, pigging stations, metering stations, refrigeration systems, etc.), storage tanks, active warehouses, ancillary support areas (e.g. waste water and ballast water treatment plants), on-site remediation facilities, and on-site and off-site distribution piping under control of the Company.

Annex B
(informative)

Application to Retail Service Stations

B.1 General

API 754 was developed for the refining and petrochemical industries, but may also be applicable to other industries with operating systems and processes where loss of containment has the potential to cause harm such as retail service stations. API 754 may be applied to retail service stations by substituting the following sections for those used in the body of this recommended practice. Retail service stations dispense gasoline, diesel, biofuels, propane, compressed natural gas, and hydrogen to the public.

This RP applies to the responsible party. At collocated facilities (e.g. industrial park), this RP applies individually to the responsible parties and not to the facility as a whole.

B.2 Applicability

Events associated with the following activities fall outside the scope of this RP and shall not be included in data collection or reporting efforts:

a) truck operations, except when the truck is connected or in the process of connecting or disconnecting to the process, or when the truck is being used for on-site storage;

NOTE Active staging is not part of connecting or disconnecting to the process; active staging is not considered on-site storage; active staging is part of transportation.

b) routine emissions from permitted or regulated sources;

NOTE Upset emissions are evaluated as possible Tier 1 or Tier 2 PSEs per Section 5.2 and Section 6.2.

c) office, shop, and convenience store events (e.g. office fires, spills, personnel injury or illness, etc.);

d) personal safety events (e.g. slips, trips, falls) that are not directly associated with on-site response or exposure to a loss of primary containment (LOPC) event;

e) LOPC events from ancillary equipment not connected to the process (e.g. small sample containers); and releases caused by the actions of retail customers.

NOTE Failure of the auto shutoff, in countries where 'latch' filling is permitted, that causes a spill is not considered an action of the retail customer.

B.3 Terms and Definitions

The following terms and definitions apply to Annex B.

process
Storage and dispensing facilities used for retail sales of petroleum refining products and biofuels. This includes process equipment (e.g. LPG vessels, piping, hoses, pumps, compressors, exchangers, etc.), above or below ground storage tanks, active warehouses, dispensers, and LPG exchange cylinders under control of the Company.

Annex C
(informative)

Oil and Gas Drilling and Production Operations

API 754 was developed for the refining and petrochemical industries, but may also be applicable to other industries with operating systems and processes where loss of containment has the potential to cause harm such as oil and gas drilling and production activities. API 754 may be applied to oil and gas drilling and production operations by following the guidance provided in *IOGP Report No. 456*. [15]

Annex D
(informative)

Tier 1 PSE Severity Weighting

Severity weighting, whether Company-defined or industry association-defined, can provide additional useful information about Tier 1 PSEs that may help drive performance improvement. Table D.1 is an example of a methodology for calculating a severity weight for Tier 1 PSEs that a company may find beneficial. The severity weighting is not intended to produce an ordinal ranking of Tier 1 PSEs, but rather a relative differentiation between one Tier 1 PSE and another. There is no intended or implied equating of consequences from one category to the next. Also, there is no intended or implied value judgment that a Tier 1 PSE with a higher severity score is "worse" than another Tier 1 PSE with a lower severity score.

Using Table D.1, a severity weight for each Tier 1 PSE may be calculated by summing the points associated with each consequence category.

Example 1

During startup following a maintenance outage, a distillation column was overfilled resulting in a release of 1200 bbls of flammable liquid in six minutes from an atmospheric relief device. The liquid release formed a flammable cloud that exploded killing 8 people, injured 47 people, and caused $80 M in damage. An officially declared shelter-in-place order was issued for the nearby community for 2 hours.

Example 1 PSE Severity Weight

Safety/Human Health	Multiple Fatalities	27 Points
Direct Cost	$80 M	9 Points
Material Release	≥ 27× Tier 1 TQ	27 Points
Community Impact	Shelter-in-Place < 3 hours	1 Point
Off-Site Environmental Impact	No Environmental Impact	0 Points
Tier 1 PSE Severity Weight Total		64 Points

Example 2

An uncontrolled exothermic reaction resulted in the venting of 20 tons of toxic gas in 45 minutes. The toxic cloud drifted into the nearby community killing 3500 people. An officially declared community evacuation was ordered; residents were not permitted to return for 7 days.

Example 2 PSE Severity Weight

Safety/Human Health	Multiple Fatalities	27 Points
Direct Cost	< $25,000	0 Points
Material Release	≥ 27× Tier 1 TQ	27 Points
Community Impact	Community Evacuation > 48 Hours	27 Points
Off-Site Environmental Impact	No Environmental Impact	0 Points
Tier 1 PSE Severity Weight Total		81 Points

Table D.1—Tier 1 Process Safety Event Severity Weighting

Severity Points	Consequence Categories				
	Safety/Human Health [a]	Direct Cost from Fire or Explosion	Material Release Within Any 1-Hr Period [a]	Community Impact	Off-Site Environmental Impact [b, c]
1 point	— Injury requiring treatment beyond first aid to an employee, contractor, or subcontractor. (Meets the definition of a US OSHA recordable injury.)	— Resulting in \$100,000 ≤ Direct Cost Damage <\$1,000,000.	— Release volume 1× ≤ Tier 1 TQ < 3× outside of secondary containment.	— Officially declared shelter-in-place or public protective measures (e.g. road closure) for <3 hours, or — Officially declared evacuation <3 hours.	— Resulting in \$100,000 ≤ Acute Environmental Cost <\$1,000,000.
3 points	— Days Away From Work injury to an employee, contractor, or subcontractor, or — Injury requiring treatment beyond first aid to a third party.	— Resulting in \$1,000,000 ≤ Direct Cost Damage <\$10,000,000.	— Release volume 3× ≤ Tier 1 TQ < 9× outside of secondary containment.	— Officially declared shelter-in-place or public protective measures (e.g. road closure) for > 3 hours, or — Officially declared evacuation > 3 hours < 24 hours.	— Resulting in \$1,000,000 ≤ Acute Environmental Cost <\$10,000,000, or — Small-scale injury or death of aquatic or land-based wildlife.
9 points	— A fatality of an employee, contractor, or subcontractor, or — A hospital admission of a third party.	— Resulting in \$10,000,000 ≤ Direct Cost Damage <\$100,000,000.	— Release volume 9× ≤ Tier 1 TQ < 27× outside of secondary containment.	— Officially declared evacuation > 24 hours < 48 hours.	— Resulting in \$10,000,000 ≤ Acute Environmental Cost <\$100,000,000, or — Medium-scale injury or death of aquatic or land-based wildlife.
27 points	— Multiple fatalities of employees, contractors, or subcontractors, or — Multiple hospital admission of third parties, or — A fatality of a third party.	— Resulting in ≥\$100,000,000 of direct cost damages.	— Release volume ≥ 27× Tier 1 TQ outside of secondary containment.	— Officially declared evacuation > 48 hours.	— Resulting in ≥ \$100,000,000 of Acute Environmental Costs, or — Large-scale injury or death of aquatic or land-based wildlife

[a] Where there is no secondary containment, the quantity of material released from primary containment is used. Where secondary containment is designed to only contain liquid, the quantity of the gas or vapor being released and any gas or vapor evolving from a liquid must be calculated to determine the amount released outside of secondary containment.

[b] Judging small, medium or large scale injury or death of aquatic or land-based wildlife should be based on local regulations or Company guidelines.

[c] The severity weighting calculation includes a category for "Off-Site Environmental Impact" and injury beyond first aid (i.e. OSHA "recordable injury") level of Safety/Human Health impact that are not included in the Tier 1 PSE threshold criteria. However, the purpose of including both of these values is to achieve greater differentiation of severity points for events that result in any form of injury or environmental impact.

Example 3

A 10-in. process furnace outlet line failed due to undetected corrosion. The rupture released a flammable liquid that ignited immediately; the fire burned for 3 hours and caused $30 M in equipment damage. There were no injuries, no community impact, and no off-site environmental impacts.

Example 3 PSE Severity Weight

Safety/Human Health	No injuries	0 Points
Direct Cost	$30 M	9 Points
Material Release	All material consumed in the fire	0 Points
Community Impact	No community impact	0 Points
Off-Site Environmental Impact	No Environmental Impact	0 Points
Tier 1 PSE Severity Weight Total		9 Points

Example 4

A 6-in. process line ruptures due to external corrosion releasing mixture of hydrogen sulfide and flammable gas. One worker is exposed and becomes ill resulting in a recordable injury. The hydrogen sulfide in the mixture exceeds it Tier 1 threshold quantity by 4×; the flammable gas in the mixture exceeds its Tier 1 threshold release quantity by 2.3×. There were no other impacts from this event.

Example 4 PSE Severity Weight

Safety/Human Health	A recordable injury	1 Points
Direct Cost	No fire or explosion damage	0 Points
Material Release	Hydrogen sulfide exceeded it Tier 1 threshold release quantity by 4×	3 Points
Community Impact	No community impact	0 Points
Off-Site Environmental Impact	No Environmental Impact	0 Points
Tier 1 PSE Severity Weight Total		4 Points

Some Companies have found it useful to represent the severity weighting of each PSE in a bar chart (see Figure D.1).

Some Companies have found it beneficial to calculate a severity weighting rate (see Figure D.2). The Tier 1 PSE Severity Weighting Rate may be calculated as follows:

Tier 1 PSE Severity Weighting Rate $_{200,000}$ = (Total Tier 1 PSE Severity Points for All Events / Total Work Hours) × 200,000, or

Tier 1 PSE Severity Weighting Rate $_{1,000,000}$ = (Total Tier 1 PSE Severity Points for All Events / Total Work Hours) × 1,000,000

NOTE Total Work Hours was chosen as the normalizing factor for PSE Rate as a balance between ready availability of the data, relevance to harm, and applicability to various refining and petrochemical operations. Other suggested normalizers such as throughput, Dow Fire and Explosion Index, etc. did not strike this balance. Total work hours includes employees and contractors (see 3.1.51 for definition).

The choice of calculating Tier 1 PSE Severity Weighting Rate utilizing either a 200,000 or 1,000,000 man hour multiplier should be consistent with the basis for calculating the Company's occupational injury rate.

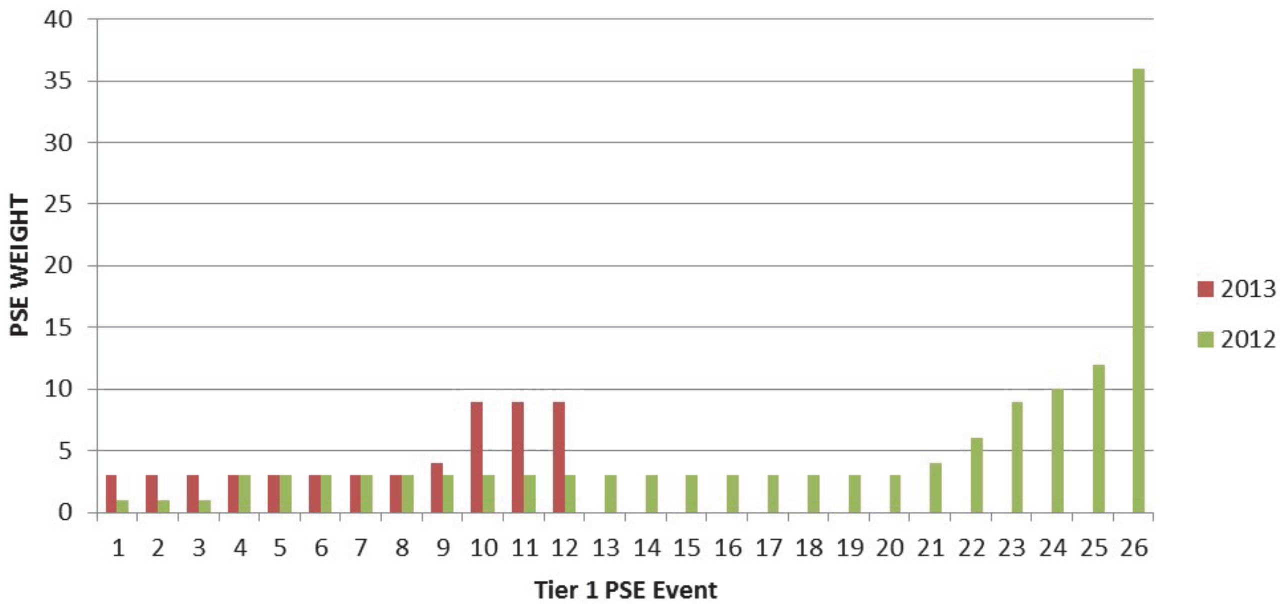


Figure D.1—Tier 1 PSE Severity Weighting

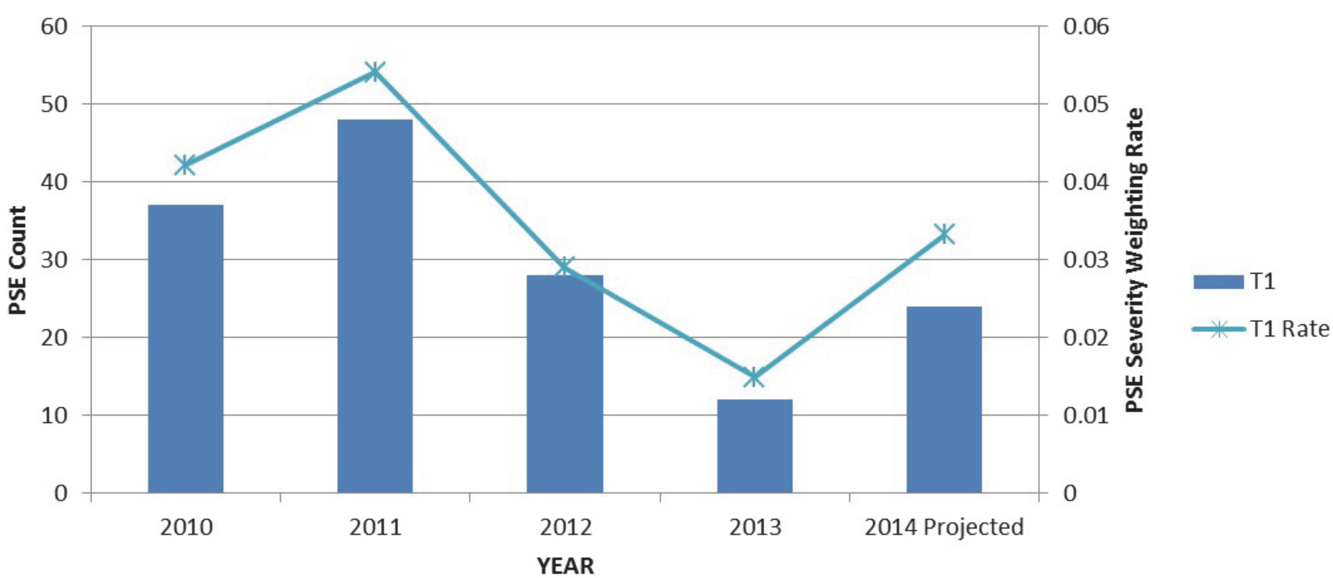


Figure D.2—Tier 1 PSE Trend

Annex E
(informative)

PSE Examples and Questions

Table E.1—PSE Examples and Questions: Injury

Example / Question	Tier 1/2
1) An operator walks through a process unit and slips and falls to the ground and suffers a days away from work injury. The slip/fall is due to weather conditions, "chronic" oily floors and slippery shoes. This is not a PSE. Personal safety "slip/trip/fall" incidents that are not directly associated with evacuating from or responding to a LOPC are specifically excluded from PSE reporting.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability §5.2, Tier 1 Definition
2) Same as above, except that the operator slipped and fell while responding to a small spill of liquid with a flash point <23 °C (73 °F) (e.g. less than 7 bbl in 1 hour) resulting in a days away from work injury. This would be a Tier 1 PSE since the operator was responding to a LOPC.	Tier 1 §5.2, Tier 1 definition
3) Same as above, except that the operator slipped and fell several hours after the incident had concluded. This would not be a reportable PSE. Personal safety events (e.g. slips, trips, and falls) that are not directly associated with on-site response to a LOPC are excluded. Slips/trip/falls after the LOPC has concluded (such as "after-the-fact" clean-up and remediation) is not directly associated with on-site response.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability
4) A scaffold builder experiences a days away from work injury after falling from a scaffold ladder while evacuating from a LOPC on nearby equipment. This is a Tier 1 PSE.	Tier 1 §1.2, Applicability § 5.1, Tier 1 Definition
5) An operator walks past a steam trap and the operator's ankle is burned by the steam resulting in a days away from work injury. This is a Tier 1 PSE because even though the LOPC was steam (vs hydrocarbon or chemical), the physical state of the material was such that it caused a day away from work injury. Unplanned or uncontrolled releases of non-toxic and non-flammable materials are within the scope of this recommended practice.	Tier 1 §5.2, Tier 1 Definition
6) A reactor vessel has been intentionally purged with nitrogen. A contractor bypasses safety controls, enters the enclosure and dies. This is not a PSE because there was no unplanned or uncontrolled LOPC, but it would be recorded on the Company's injury and illness log. Same as above, except that nitrogen inadvertently leaked into the enclosure. This would be a Tier 1 PSE because there was a fatality associated with an unplanned or uncontrolled LOPC.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition Tier 1 §5.2, Tier 1 Definition
7) During a routine, planned catalyst recharge activity, steam is introduced into the reactor at a specified pressure and a slide valve below the tray is opened to dump the catalyst. During the catalyst dump a worker stepped up to the reactor flange to pull out the slide valve-pin from the reactor and some hot catalyst came out through the pin sleeve/flange resulting in the worker receiving a recordable thermal burn injury from the hot catalyst. The injured worker was not the one assigned to perform this task, so was not wearing all the appropriate PPE. The release of the hot catalyst was planned, but it was not controlled since it contacted an unprotected worker; therefore, this would be a Tier 2 PSE based upon the recordable injury.	Tier 2 §5.2, Tier 2 Definition
8) A maintenance technician is turning a bolt on a process flange with a wrench. Due to improper body positioning, the wrench slips and hits the employee in the mouth, requiring dental surgery and two days off work. This is not a PSE because there was no unplanned or uncontrolled LOPC involved with the injury.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition

Table E.1—PSE Examples and Questions: Injury (Continued)

Example / Question	Tier 1/2
9) A recordable injury occurred as a result of hot water coming out of a sewer (person standing in vicinity received thermal injury to feet). Is this a Tier 2 PSE since the sewer system is secondary not primary containment? The sewer system can be considered a part of a different process (i.e. waste water treatment), or the introduction of hot water into the sewer system could be viewed as unplanned or uncontrolled manner resulting in the injury. Therefore, this would be a Tier 2 PSE.	Tier 2 §6.2, Tier 2 Definition
10) As part of a new construction project, equipment was being hydrotested using potable water when a 2 in. ball valve suddenly became disconnected. The hose whipped and struck a worker in the head and caused his death. Is this a Tier 1 PSE? A hydrotest using potable water for new construction is not considered a "process"; therefore, this tragic event is not a PSE. It is an occupational safety related fatality and an appropriate investigation should be conducted to prevent a recurrence.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability §3.1.37, Definition of Process
11) During the draining of a gas line, a fire begins. The worker performing the draining operation was not hurt; however, another worker near the draining operation began running and fell down a flight of stairs injuring his ankle. The injury resulted in 8 days away from work. The facility Evacuation Protocol wasn't activated because the fire was incipient (minor deflagration) and the fire damage was less than $2500. Is this event considered a PSE, or is it considered an occupational safety incident? If there was any reason to believe that the person began running because of fear of the potential consequences of a fire occurring in their work area, then the injury would be related to the LOPC. Since the LOPC resulted in a day away from work injury, this would be a Tier 1 PSE.	Tier 1 §5.2, Tier 1 Definition

Table E.2—PSE Examples and Questions: Fire or Explosion

Example/Question	Tier 1/2
12) 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. Is this a PSE? This is not a PSE since there was no unplanned or uncontrolled LOPC.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 definition §6.2, Tier 2 definition
13) An internal deflagration in a vessel causes equipment damage $100,000, but there was no loss of containment. Is this a PSE? While this is a serious process event and should be investigated as such, it does not meet the definition of a Tier 1 PSE because there was no LOPC involved. Rare or unique events with actual serious consequences that do not meet the strict definition of a Tier 1 or 2 PSE, may be classified and reported at a company's discretion. A company may also want to determine if a Tier 3 indicator was triggered by this event.	Not a Tier 1 PSE §5.2, Tier 1 Definition
14) An electrical fire impacts the operation of the process resulting in a release of 4000 lb of toluene within a one-hour period. Is this a PSE? This is a Tier 1 PSE since the LOPC exceeds the 2200 lb reporting threshold for toluene.	Tier 1 PSE §5.1, Table 1

Table E.2—PSE Examples and Questions: Fire or Explosion (Continued)

Example/Question	Tier 1/2
15) An electrical fire, loss of electricity, or any other loss of utility may occur that causes a plant shutdown and possibly incidental equipment damage (e.g. damage to reactors or equipment due to inadequate shutdown), however if it does not create a LOPC release it is not a PSE. It is likely that during a shutdown, one or more safety devices are activated; therefore, a company may choose to record a Tier 3 Demand on Safety System.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition
16) A pump lube oil system fire from a leak causes damage greater than $100,000, but does not create a LOPC greater than the threshold quantity or cause a fatality or serious injury. This is a Tier 1 PSE since the damage was greater than $100,000.	Tier 1 §5.2, Tier 1 Definition
17) A forklift truck delivering materials inside a process unit knocks off a bleeder valve leading to the release of isopentane and a subsequent vapor cloud explosion with asset damage greater than $100,000. This is a Tier 1 PSE since an unplanned or uncontrolled LOPC resulted in a fire or explosion causing greater than $100,000 damage.	Tier 1 §5.2, Tier 1 Definition
18) There is a boiler fire at the Main Office complex, and direct cost damages totaled $75,000. The incident is not a PSE since office building events are specifically excluded.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability
19) 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. This incident is a Tier 2 PSE since the LOPC was from the process and resulted in a Tier 2 consequence (a fire that results in a direct cost greater than $2500).	Tier 2 §6.2, Tier 2 Definition
20) The rundown temperature on a #6 fuel oil was much higher than normal going into tankage. One tank reached its fill volume, and the rundown was swapped to a second tank. The heel in this second tank was extremely low and there was free water on top of the product in the tank, presumably caused by condensation. The high temperature of the product entering the second tank caused the water to vaporize, over-pressuring the tank, causing the roof to buckle, the top seam to rip in a couple of places, and vapors to escape. Damage to the tank exceeded $100k. Is this a Tier 1 event? The rapid vaporization of the water resulted in a pressure discontinuity that satisfies the API 754 definition of explosion, and since the direct cost exceeded the Tier 1 threshold of $100k, this event would be a Tier 1 PSE.	Tier 1 §3.1.17, Explosion Definition §3.1.15, Direct Cost Definition §5.2, Tier 1 Definition
21) A motor trip in one portion of the process unit resulted in hydrogen reverse flowing from a common vent header into another portion of the process resulting in an internal explosion with greater than $100,000 damage. There was no LOPC to atmosphere. During normal operations, the pressure balance keeps hydrogen from entering this portion of the process. Is this a Tier 1 event? Because there was no Loss of Primary Containment (hydrogen appears to have moved from one form of primary containment into another) this is not a Tier 1 PSE. It appears to be a significant process upset and likely triggered one or more criteria for being characterized as a Tier 3 PSE that should be fully investigated based upon potential consequence.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition

Table E.2—PSE Examples and Questions: Fire or Explosion (Continued)

Example/Question	Tier 1/2
22) In the case of a release that results in a fire/explosion, do you calculate the amount of material released AND the fire damage? If the material released ignites immediately, the fire/explosion direct cost damage represents the LOPC's full potential for harm; therefore, only the direct cost from the fire/explosion is used to determine the Tier classification of the event. If the ignition of the material is not immediate, both the quantity released and the fire/explosion direct cost damage would be evaluated to determine the appropriate PSE classification. For example: A crack on a furnace tube that releases material that burns in the firebox. If the release quantity were counted the event might be a Tier 1 even though it had no damage caused by the fire and essentially zero potential for escalation from the fire event. A small flange fire on a stream in excess of auto-ignition temperature could exceed the Tier 1 LOPC quantity over an hour even though little damage is caused by the fire and the event has little potential for escalation However, if the fire/explosion results in secondary releases, those releases must be independently evaluated against the Tier 1 and Tier 2 criteria.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition §6.2, Tier 2 Definition
23) A water surge drum is filled with no discharge pumps operating; the drum is over pressured and large crack opens on the bottom of the drum releasing water. There are no injuries, but the damage to the drum is $35,000. Does this over pressure meet the definition of an explosion meaning this would be a Tier 2 PSE? This overpressure does not meet the definition of an explosion because there was no release of energy that causes a pressure discontinuity or blast wave. A company may choose to record this event as a Tier 3 Other LOPC.	Not a Tier 1 or Tier 2 PSE §3.1.17, Explosion Definition

Table E.3—PSE Examples and Questions: Loss of Primary Containment

Example/Question	Tier 1/2
24) Ten bbl of gasoline (1150 kg, 2530 lb) leak from piping onto concrete and the gasoline doesn't reach soil or water. Facility personnel estimate that the leak occurred within one hour. This is a Tier 1 PSE because there was a LOPC of 7 bbl (1000 kg, 2200 lb) or more of liquid with a flash point <23 °C (73 °F) in any one-hour period. If the spill had been less than 7 bbl, but equal to or greater than 0.7 bbl (100 kg 220 lb), it would be a Tier 2 PSE.	Tier 1 §5.2, Tier 1 Definition and Table 1 Tier 2 §6.2, Table 2
25) A spill of 20 barrels of weak bleach occurred in less than one hour due to a mechanical failure of a valve on a day storage tank. The SDS sheet lists the pH of the material as a range between 13-14 (i.e., a strong base per API 754 definition 3.1.2). Using the SDS listed property, this would be classified as a Tier 1 PSE due to the rate exceeding 14 barrels in one hour for a strong base. However, in this case, the actual pH for the material was measured at 11.2 on the day of the release per tests performed on bleach remaining within the day tank. At a pH of 11.2, the material would not meet the definition of a strong or moderate base; therefore, there would be no Tier 1 or 2 TQ. Should this event be classified as a Tier 1 PSE based upon the SDS properties of the material? Use of the analysis of the material as spilled (pH value in this case) is permitted. A company may choose to use either the properties of the released material based upon laboratory analysis at the time of release, or the properties documented in a SDS. Companies should be consistent in their approach for all LOPCs.	Not a Tier 1 or Tier 2 PSE §3.1.1 Moderate Base Definition §3.1.2 Strong Base Definition

Table E.3—PSE Examples and Questions: Loss of Primary Containment (Continued)

Example/Question	Tier 1/2
26) A faulty tank gauge results in the overfilling of a product tank containing liquid with a normal boiling point > 35 °C (95 °F) and a flash point < 23 °C (73 °F). Approximately 50 bbl (7000 kg, 15,500 lb) of liquid overflows into the tank's diked area. This incident is a Tier 1 PSE since it is a release of 2200 lb or more within any one-hour period, regardless of secondary containment. If the spill had been λεσσ τηαν 2200 lb (7 bbl), but equal to or greater than 220 lb (1 bbl), it would be a Tier 2 PSE.	Tier 1 §5.2, Tier 1 Definition and Table 1 Tier 2 §6.2, Table 2
27) A maintenance contractor opens a process valve and gets sprayed with less than the Tier 1 or Tier 2 TQ of sulfuric acid resulting in a severe burn and days away from work injury. This is a Tier 1 PSE because it is an unplanned or uncontrolled LOPC that resulted in a days away from work injury. If this incident had resulted in a recordable injury, it would be a Tier 2 PSE.	Tier 1 §5.2, Tier 1 Definition Tier 2 §6.2, Tier 2 Definition
28) A portion of piping is being prepared for maintenance. The line is drained and isolation is verified. At some point prior to the first flange break, the line accumulated liquid due to a leaking valve. If the volume of material that leaked back into the isolated line is greater than the Tier 1 Table 1 or Table 2 TQs in any one-hour period, would this be considered a LOPC and subsequently a Tier 1 or Tier 2 PSE? Since there was no LOPC, this is not a Tier 1 or Tier 2 PSE. The material remained within the piping designed to contain it. If the flanges were opened and the LOPC resulted in injury, fire/explosion, or a TQ release, then it would be classified as a PSE.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition §6.2, Tier 2 Definition
29) An operator opens a quality control sample point to collect a routine sample of product and material splashes on him. The operator runs to a safety shower leaving the sample point open and a Tier 2 threshold quantity is released. This is a Tier 2 PSE since the release of a threshold quantity was unplanned or uncontrolled. Same as above, however, the operator catches the sample, blocks in the sample point and later drops and breaks the sample container resulting in exposure and injury from the sample contents. This is not a PSE because the LOPC is from a piece of ancillary equipment not connected to a process.	Tier 2 §6.2, Tier 2 Definition Not a PSE §1.2, Applicability
30) A bleeder valve is left open after a plant turnaround. On start-up, an estimated 15 bbl of fuel oil, a liquid with a flashpoint above 60 °C (140 °F), is released at 38 °C (100 °F) (below its flashpoint) onto the ground within an hour and into the plant's drainage system before the bleeder is found and closed. This is a Tier 2 PSE. Same as above, except the release temperature is above the flashpoint; thus, it would be a Tier 1 PSE. Per the UNDG classification system, fuel oil is considered a Packing Group III material. If that is true, why doesn't the event in the first example above qualify the LOPC as a Tier 1 PSE per Tier 1 Release Category 7? In determining the Threshold Release Category of a material one should first use the toxic (TIH Zone), flammability (Flash Point and Boiling Point) or corrosiveness (Strong Acid or Base vs. Weak Acid or Base) characteristics. Only when the hazard of the material is not expressed by those simple characteristics (e.g. reacts violently with water) is the UNDGL Packing Group used. In the case of fuel oil, the hazard of flammability is the primary hazard so the boiling point and flash point should be the features used to determine the Threshold Release Category. In that case, the Threshold Release Category would be Tier 2 TRC 8 (Liquids with Flash point >60 °C (140 °F) and ≤93 °C (200 °F) released at a temperature below Flash Point).	Tier 2 §6.2, Table 2 Tier 1 §5.2, Table 1

Table E.3—PSE Examples and Questions: Loss of Primary Containment (Continued)

Example/Question	Tier 1/2
31) 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 $100,000 in damages to the internals of the heater. There was no release outside of the fire box. This would be a Tier 1 PSE 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. If this same incident had resulted in less than $100,000 in damages, but greater than $2500 in damages, it would be a Tier 2 PSE since there was an explosion resulting in greater than $2500 in damages.	Tier 1 §5.2, Definition Tier 2 §6.2, Tier 2 Definition
32) The regenerative thermal oxidizer (RTO) is typically fed materials with low concentrations of flammable gas (LEL). For the incident in question, materials with higher than normal LEL were fed into the RTO. The combustion of the higher LEL materials caused an overpressure of the outer structure of the RTO, resulting in a rupture of the box. The direct cost of the incident exceeds $100,000. Is this a Tier 1 PSE even though the explosion was not specifically caused by an LOPC? The event did result an LOPC; therefore, the definition of a PSE is satisfied. The $100,000 direct cost damage classifies the PSE as a Tier 1 event. The LOPC does not have to occur first.	Tier 1 §5.2, Definition
33) There is a tube rupture in a fired heater causing a fire (contained in the heater) resulting in greater than $100,000 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 $100,000 makes this a Tier 1 PSE. Same as above, except the operator detects the tube cracking with only a small flame from the tube and subsequently shuts down the heater with no resultant damage from the tube flame. This would not be a Tier 1 or Tier 2 PSE since the LOPC did not result in any of the defined consequences. A company may choose to record this as a Tier 3 “Other LOPC Event.”	Tier 1 §5.2, Definition Tier 3
34) An operator is draining water off a flammable crude oil tank with a flash point of 60 °C (140 °F) or less into an open drainage system designed for that purpose. The operator leaves the site and forgets to close the valve. Twenty bbl of crude oil are released into the drainage system within an hour. This would be a Tier 1 PSE because the release of crude oil is unplanned or uncontrolled and it is greater than the release criteria of 14 bbl. If the drainage system goes to an API separator and the oil is recovered (secondary containment), this would still be a Tier 1 event because the crude oil was released from primary containment. In the example above, if a crude oil with a flash point above 60 °C (140 °F) is released at a temperature below the flash point, it would be a Tier 2 PSE.	Tier 1 §5.2, Definition and Table 1 Tier 1 §5.2, Tier 1 Definition and Table 1 Tier 2 §6.2, Table 2
35) An operator purposely drains 20 bbl of material with a flash point > 60 °C (140 °F) at a temperature below its flash point into an oily water collection system within one hour as part of a vessel cleaning operation. Since the drainage is planned and controlled and the collection system is designed for such service, this is not a reportable Tier 1 or 2 PSE. If the material released had been unplanned or uncontrolled and flowed to an open drain, sewer, or other collection system, it would be a reportable Tier 2 PSE based on the threshold quantity and material below its flash point.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition Tier 2 §6.2, Table 2
36) If an internal or external floating roof partially sinks and material gets above it, but remains within the tank, is this a LOPC? Material on top of the floating roof is an LOPC. Material stored within a floating roof tank is expected to be inside the tank walls and beneath the floating roof. Depending upon the volume of material released, this may be a Tier 1 or Tier 2 PSE.	§3.1.17, LOPC Definition

Table E.3—PSE Examples and Questions: Loss of Primary Containment (Continued)

Example/Question	Tier 1/2
37) Oil-water/process wastewater is collected a cone roof tank with an internal floating roof (IFR). The tank contains both oil and water; the oil can vary in flash point and normal boiling point depending on what is collected and transferred to the tank at any given time. The IFR sank for unknown reasons that allowed the tank contents to go above the internal floating roof. Vapor from the low flash material was released through the cone roof vent, but the liquid was all contained within the tank shell. For the purposes of Tier 1 and 2 PSE reporting, is this a LOPC? The LOPC occurs as a result of liquid on top of the floating roof (the roof, tank walls, and tank floor are primary containment). When a floating roof sinks or is flooded, the volume used for determining whether an event is Tier 1 or Tier 2 is the amount of hydrocarbon liquid that goes above the floating roof, regardless of whether the floating roof in internal or external.	Tier 1 PSE §5.2, Tier 1 Definition Tier 2 §6.2, Tier 2 Definition
38) A cold rain on a hot summer day results in the thermal contraction of the flare header. As the result of a less than adequate purge design, air is ingested into the system that by calculation results in an explosive mixture. Is this a PSE? The purge system was intended to keep air from entering the system; therefore, the ingestion of air is a LOPC. However, this is not a PSE since none of the Tier 1 or Tier 2 consequences was realized. A company may choose to record this event as a Tier 3 Other LOPC. What if the explosive mixture ignites as the result of pyrophoric iron sulfide deposits and causes $100,000 in damage to the flare system? In this instance, this would be a Tier 1 PSE since the LOPC of air into the flare system resulted in a fire/explosion causing $100,000 in direct cost.	Not a Tier 1 or Tier 2 PSE Tier 1 PSE §5.2, Tier 1 Definition
39) A flammable gas was released from a pipe and immediately ignited (a jet fire) causing $3500 in damage before it could be isolated and extinguished. All of the gas was consumed in the fire; however, the Company engineers were able to calculate that 800 kg (1800 lb) was released. Is this a Tier 1 or Tier 2 PSE? Since the release immediately ignited, the fire damage represents the LOPC's full potential for harm; therefore, the $3500 direct cost damage would govern and the event would be classified as a Tier 2 PSE. Alternate Scenario: Same as above, except ignition was not immediate; therefore, the quantity released would be evaluated as well as the direct cost damage to determine the appropriate classification. Since the 800 kg (1800 lb) LOPC exceeds the Tier 1 threshold quantity for a flammable gas, the event would be classified as a Tier 1 PSE.	Tier 2 §6.2, Tier 2 Definition
40) There was a leak from the flange of a heat exchanger. The leak was properly classified as a Tier 2 PSE based upon quantity released. Rather than shutting down, a sealant was used as a temporary repair. After few days, the sealant failed and another Tier 2 threshold quantity was released. Is the second LOPC a separate Tier 2 PSE, or is it a continuation of the first Tier 2 PSE? Since the original event was concluded by application of the sealant, the LOPC due to the loss of the temporary sealant would be considered a separate event and a second Tier 2 PSE should be recorded. From a lessons learned or root cause perspective, the first event would focus on the cause of the gasket leak; the second event would focus on the cause of the sealant failure.	Tier 2 §6.2, Tier 2 Definition
41) Steam is used to purge a hydrogen header during a brief shutdown. Steam flow is discontinued prior to startup; however, the header cools down creating a slight vacuum. Air leaks into hydrogen header resulting in a hydrogen/air explosion during startup. The hydrogen header and electrolyzers are breached and badly damaged resulting in $300,000 in repairs and $4 million in lost production. Is this a PSE? This is a Tier 1 PSE. There was a LOPC of air into the system and a LOPC from the breached header that resulted in direct cost damage in excess of the Tier 1 threshold of $100,000. Note: the $4 million in lost production is by definition excluded from the calculation of direct cost damage.	Tier 1 §5.2, Tier 1 Definition §3.1.15, Direct Cost Definition

Table E.3—PSE Examples and Questions: Loss of Primary Containment (Continued)

Example/Question	Tier 1/2
42) The suction control system on a hydrogen compressor malfunctions resulting in a negative pressure to the compressor. Air leaks into the inlet piping and subsequently causes an explosion in the discharge side of the compressor. The compressor, piping, and after cooler are badly damaged but remain intact. Repair costs exceed $1,000,000. Is this a PSE? This is a Tier 1 PSE. There was a LOPC of air into the system that resulted in an explosion with direct cost damage in excess of the Tier 1 threshold. Note: the direction of the LOPC is governed by the pressure differential; it does not have to be from internal to external.	Tier 1 §5.2, Tier 1 Definition §3.1.15, Direct Cost Definition
43) Operations was troubleshooting issues with the pressure control on a vacuum distillation unit when they discovered a corrosion leak that was allowing air to leak into the process. Is this a PSE? This is not a PSE. Air leaking into the process is considered a LOPC; however, API 754 excludes air from the UNDG Division 2.2, Class 2 category so there is no threshold quantity consequence associated with the LOPC and none of the other consequences was realized. A company may choose to record a Tier 3 Other LOPC for this event.	Not a Tier 1 or Tier 2 PSE§5.2, Tier 1 Definition §3.1.53, Direct UNDG Division 2.2, Class 2 Definition
44) A company decides to undertake live flare work to repair a malfunctioning relief valve. The relief valve does not have a discharge block valve that can be used to isolate it from the refinery flare system. The company reduces any ongoing venting and flare usage as much as possible before the work starts, introduces nitrogen to create a positive pressure, and takes appropriate precautions to protect the workers. During the 10 minutes it takes to remove the relief valve and install a blind flange, an estimated 350 kg (770 lbs) of nitrogen escapes the flare line. There were no injuries and no community impact from the escaping gas. Is this a PSE? Although the quantity of nitrogen released exceeds the Tier 2 threshold quantity for a UNDG Class 2, Division 2.2 material, the release was both planned and controlled; therefore, there was no LOPC as defined in this RP; therefore, this is not a Tier 1 or Tier 2 PSE. In this example, the consequences of the nitrogen release were anticipated and safeguards put in place to protect the workers (planned), and the quantity released did not exceed the anticipated volume and there were no injuries or community impact (controlled). NOTE Performing live flare work involves a number of potential hazards and is generally discouraged. Any planned release of potentially harmful material needs to be to a safe location and/or workers need to be appropriately protected.	Not a Tier 1 or Tier 2 PSE §3.1.23, LOPC Definition

Table E.4—PSE Examples and Questions: A Release Within Any One-hour Period

Example/Question	Tier 1/2
45) There is a 10 bbl spill of gasoline that steadily leaks from piping onto soil over a two-week time period. Simple calculations show the spill rate was approximately 0.03 bbl per hour. This is not a Tier 1 or Tier 2 PSE since the spill event did not exceed the threshold quantity in any one-hour period. A company may choose to count this as a Tier 3 other LOPC event.	Not a Tier 1 or Tier 2 PSE
Alternate Scenario: 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 bbl per hour. The spill rate was less than the reporting threshold of 7 bbl within 1 hour for a Tier 1 PSE but it does meet the threshold of 1 bbl within 1 hour, thus it is a Tier 2 PSE.	§6.2, Tier 2 Definition Table 2
Alternate Scenario: Same example as above, except the 10 bbl leak was estimated to have spilled at a rate of 8 bbl/hr during the first hour and 4 bbl/hr during the last 30 minutes. Since the spill rate of 8 bbl/hr exceeds the Tier 1 threshold within any one-hour period, this event would be a Tier 1 PSE.	§5.2, Tier 1 Definition Table 1
46) 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 Tier 1 PSE because the solvents involved are flammable liquids consistent with the boiling and flash points of TRC 6 in Table 1 and the threshold quantity of 7 bbl is exceeded if the time period is estimated to be less than one hour.	Tier 1 §5.2, Tier 1 Definition, Table 1
47) While troubleshooting a higher-than-expected natural gas flow rate, operating personnel find an open block valve on the natural gas line releasing to an elevated vent location. Upon further investigation, it is determined that a total of 1 million lb of natural gas was relieved at a steady rate over a 6-month period. This is not a Tier 1 PSE as the release rate (~100 kg per hour) did not exceed the threshold quantity of 500 kg or more within one hour); however, it is a Tier 2 PSE because it did exceed the threshold of 50 kg or more within 1 hour. NOTE This size release may be reportable under environmental regulations.	Tier 2 §6.2, Tier 2 Definition

Table E.4—PSE Examples and Questions: A Release Within Any One-hour Period (Continued)

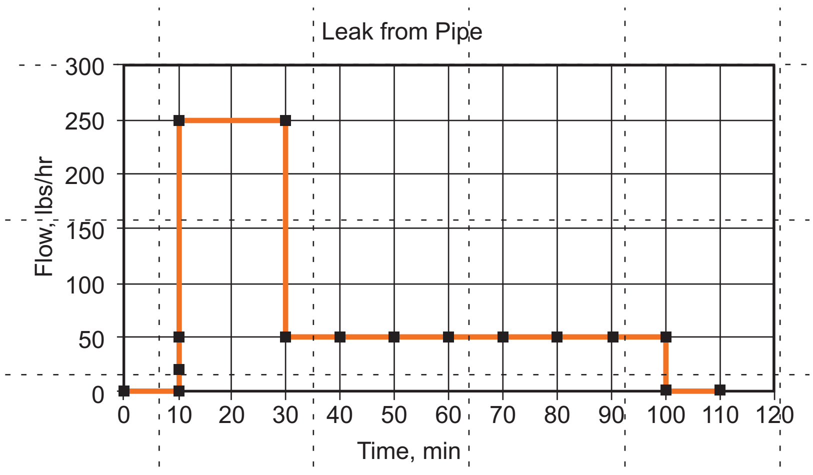
Example/Question	Tier 1/2
48) A flammable gas (propylene) is found leaking from a pipe at 250 lbs/hr. After 20 minutes, operations personnel were able to partially isolate the line reducing the leak rate to 50 lbs/hr. The line continued to leak at 50 lbs/hr for an additional 70 minutes before the line could be completely isolated. See chart below:  What is the appropriate way to assess the quantity released? The threshold quantity is compared against the greatest release volume in "any one-hour period". In this case, the release rate profile is known, and the greatest release volume in any one-hour period occurs during the first hour. First Hour of Incident Amount Released: 20 min = 0.33 hrs @ 250 lbs/hr = 82.50 lbs Amount Released: 40 min = 0.67 hrs @ 50 lbs/hr = 33.50 lbs Total release in first hour = 116 lbs; therefore, this a Tier 2 PSE since the volume release in "any one hour period" exceeds the Tier 2 threshold quantity for flammable gases.	Tier 2 §6.2, Tier 2 Definition Table 2

Table E.5—PSE Examples and Questions: Mixtures and Solutions

<table>
<tr><th>Example/Question</th><th>Tier 1/2</th></tr>
<tr><td>49) A pipe fitting in a specialty chemicals plant fails, releasing 4000 lb 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 2200 lb.
<table>
<tr><th>Component</th><th>wt. %</th><th>Release Qty (lb)</th><th>PSE TQ (lb)</th><th>% of TQ</th></tr>
<tr><td>Formaldehyde</td><td>30 %</td><td>1200</td><td>4400</td><td>27.3 %</td></tr>
<tr><td>Methanol</td><td>45 %</td><td>1800</td><td>2200</td><td>81.8 %</td></tr>
<tr><td>Water</td><td>25 %</td><td>1000</td><td>n/a</td><td>0 %</td></tr>
<tr><td></td><td></td><td></td><td></td><td>109.1 %</td></tr>
</table>
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 [22] or UN Recommendations on the Transportation of Dangerous Goods, Section 2. [18]</td>
<td>Tier 1
§5.2, Tier 1 Definition
Table 1, Footnote d</td></tr>
<tr><td>50) A leak from a superheated hydrochloric acid line results in a spill of 1900 lb of hydrochloric acid. Flash calculations indicate that greater than 220 lb of hydrogen chloride is released as a vapor. The 1900 lb liquid release is not a reportable Tier 1 PSE since it does not exceed the Tier 1 threshold release quantity.

However, since the liquid flashed or was sprayed out as an aerosol, and anhydrous hydrogen chloride is a TIH Zone D material, the 220 lb of hydrogen chloride released as a vapor would be a reportable Tier 1 PSE since it exceeded the Tier 1 Release Category 4 threshold quantity within a one-hour period.

Although the 1900 lb liquid release exceeded the Tier 2 threshold release quantity, the event is classified based upon the more serious Tier 1 release of a toxic material.</td>
<td>Tier 1
§5.2, Tier 1 Definition</td></tr>
<tr><td>51) A pipe containing CO_2 and 10,000 vppm H_2S (1 % by volume) leaks and 7000 kg (15,400 lb) of the gas is released within an hour. Calculations show that the release involved about 55 kg (121 lb) of H_2S, a TIH Zone B chemical, and 6945 kg (15,279 lb) of CO_2, a UNDG Class 2, Division 2.2 non-flammable, non-toxic gas. The release is a Tier 1 PSE because it exceeds the Tier 1 threshold quantity for both Release Category 2 and 7.

Alternate Scenario:

If the H_2S concentration is 50 vppm, then the calculated release quantity would be 0.3 kg (0.66 lb) of H_2S and 6999 (15,398 lb) of CO_2. The release would still be a Tier 1 PSE since this Release Category 7 threshold quantity is exceeded even though the Release Category 2 quantity falls below the Tier 1 and Tier 2 thresholds for H_2S.</td>
<td>Tier 1
§5.2, Tier 1 Definition
Table 1</td></tr>
<tr><td>52) Do you use the PG (Packing Group) or the “moderate/strong acid” definition when classifying the following three substances: spent sulfuric acid; fresh sulfuric acid; and hydrochloric acid? The threshold release quantity is different depending on which classification method is used.

Since the predominant hazard associated with these three substances is corrosivity, the moderate/strong acid definition should be used for the materials listed above; however, if there is a contaminant in the spent sulfuric acid whose hazard is not reflected by the pH, then the packing group should be used if it results in a lower threshold release quantity.</td>
<td>§3.1.2 Definition Acids/Bases, Strong

§Annex F</td></tr>
</table>

Table E.5—PSE Examples and Questions: Mixtures and Solutions (Continued)

Example/Question	Tier 1/2
53) A hose connection leaked and approximately 1000 kg of a water treatment chemical was released outdoors. There were no injuries, fire, or community impact as a result of the spill. The water treatment chemical is approximately 25 % diethylamine, which is a UNDG PG II (Hazard Class 8—Corrosive) material. The SDS does not classify the solution as hazardous, and the physical properties do not indicate a toxic, flammable, or corrosive hazard. Is this a Tier 2 PSE? The 25 % diethlyamine solution does not separate into distinct components when released; therefore, the properties of the solution as a whole are considered. Since a thorough review of the SDS does not indicate any hazards that fall into the material hazard classification (e.g. toxicity, flammability, corrosivity) associated with a threshold release quantity, this is not a Tier 1 or Tier 2 PSE. A Company may choose to count this LOPC as a Tier 3 Other LOPC.	Not a Tier 1 or Tier 2 PSE §6.2, Tier 2 Definition Table 2

Table E.6—PSE Examples and Questions: Pressure Relief Device

Example/Question	Tier 1/2
54) There is a unit upset and the PRD opens to an atmospheric vent that has been designed per API 521 for that scenario, resulting in a release of 300 lb of propane to the atmosphere with no adverse consequences. Although the release exceeded the Tier 2 threshold quantity, because it did not result in one of the defined negative consequences, it is not a Tier 2 PSE. A company may choose to count this as a Tier 3 event since it is an activation of a PRD that was not counted in Tier 1 or 2. Alternate Scenario: Same as above, but there was an on-site shelter-in-place. This is not a Tier 1 PSE because it did not exceed the threshold quantity requirement. This is a Tier 2 PSE because it both exceeded the threshold quantity and resulted in one of the defined negative consequences.	Not a Tier 1 or Tier 2 PSE Tier 2 §6.2, Tier 2 Definition
55) A chlorine vessel has a 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 rainout, on-site shelter-in-place, public protective measure or other indication of discharge to an unsafe location. A company may count this as a Tier 3 PSE since it was an atmospheric release from a PRD.	Not a Tier 1 or Tier 2 PSE §5.2 Tier 1 Definition Table 1 §6.2, Tier 2 Definition Table 2
56) If a PRD activates/opens at 30 % of its set point due to a frozen pilot and the release is greater than the TQ for a Tier 1 event, is this a Tier 1 PSE event since the PRD failed to perform as designed? The criteria for PRD releases is independent of whether the PRD opened at, above or below its set point or other factors associated with design and installation. Releases from PRDs are only classified at Tier 1 or 2 if one or more of the listed consequences occurs (e.g. rainout, discharge to a potentially unsafe location; an on-site shelter-in-place; public protective measures). None of those consequences is identified in the question. PRDs have a designed discharge location that is intended to safely disperse the release without forming a hazard. If it does create the hazard (i.e. any one of the four consequences), then it is treated like a release from any other location (TQ determines the Tier).	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition Table 1 §6.2, Tier 2 Definition Table 2
57) There is a unit upset and the PRD fails to open, resulting in overpressure of the equipment and a 10-minute release of 2000 lb of butane (flammable gas) from a leaking flange before it can be blocked in. This is a Tier 1 PSE.	Tier 1 PSE §5.1, Definition and Table 1

Table E.6—PSE Examples and Questions: Pressure Relief Device (Continued)

Example/Question	Tier 1/2
58) A facility had an event where the hot oil system over pressured and the relief valve lifted with a small amount of heating oil going to secondary containment. There were no injuries or other consequences and the amount released did not exceed the Tier 1 or Tier 2 release thresholds. Should this event be included as a Tier 3 metric for PRD activation since this was a utility material and was not in the process, even though the material itself is a hydrocarbon? Utility systems, inclusive of hot oil systems, are included within the definition of “process” as it applies to API 754 reporting; therefore, a company may choose to record this event as a Tier 3 Other LOPC and a Tier 3 Demand on Safety Systems.	Not a Tier 1 or Tier 2 PSE
59) What is the proper way to classify PRD release events where the PRD (and any associated downstream destructive device) was actually designed for liquid relief or for two-phase relief? For example: a) A PRD on a condensate pump discharge lifts and condensate is relieved back to the condensate tank. The PRD is designed for liquid relief and the downstream piping is designed for liquids. b) A PRD on a two-phase gas/condensate piping segment (upstream of separation) lifts and sends gas and condensate to the flare knockout where the liquids are removed and the gas is sent to flare. The PRD is designed for two-phase relief and the flare system was designed to handle the liquids. c) PRD on a two-phase gas/condensate piping segment (upstream of separation) lifts and sends gas and condensate to a pop tank where liquids are captured in the pop tank and the gas is vented to a safe location. The PRD is designed for two-phase relief and the pop tank is designed to handle the liquids. Single phase or two-phase flow and PRD design are not the determinants for classifying a PRD discharge is a Tier 1 or Tier 2 PSE. All PRD discharges are LOPCs by definition; therefore, each PRD discharge to atmosphere (whether directly or via a downstream destructive device) has to be evaluated against the four negative consequences [(1) rainout, (2) discharge to a potentially unsafe location, (3) an on-site shelter-in-place or evacuation, excluding precautionary shelter-in-place or evacuation, (4) public protective measures (e.g. road closure) including precautionary public protective measures]. In Example 1, the PRD discharge is not to atmosphere or to a downstream destructive device; it is recycled back to the condensate tank; therefore, it is not a PSE. In Example 2, the two-phase PRD discharges to a downstream destructive device. The liquid phase is contained in the flare knockout drum and the gas is combusted in the flare; therefore, it is not a PSE since none of the four negative consequences was realized. Example 3 is similar to Example 2. The two-phase PRD discharges to a pop tank that captures the liquids and the gas is vented to a safe location. Since none of the four negative consequences associated with a PRD discharge is realized, this is not a PSE. A company may choose to record these events as a Tier 3 Demand on Safety System.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition §6.2, Tier 2 Definition

Table E.7—PSE Examples and Questions: Company Premises, PSEs with Multiple Outcomes, Pipelines

Example/Question	Tier 1/2
60) A pipeline leaks and releases 2000 lb of flammable vapor above ground within one hour; however, the release occurred in a remote location within the facility. This is a Tier 1 PSE since the release occurred within the process or storage areas of the facility ("remoteness" is not a consideration) and it exceeds a Tier 1 threshold quantity.	Tier 1 PSE §5.1, Definition and Table 1
61) 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 facility's property in the short segment of piping that runs over the public road. Although the leak technically occurs off-site, this is a Tier 1 PSE since the facility owns and operates the entire segment of pipeline.	Tier 1 PSE §1.2, Applicability §5.1, Definition and Table 1
62) A third-party truck loaded with a flammable product is traveling on Company premises and experiences a leak and subsequent fire and property damages of $75,000 (direct costs). The incident would not be a Tier 1 or Tier 2 PSE because truck incidents are excluded, except when they are connected to the process for the purposes of feedstock or product transfer. Same as above except, the third party truck is parked and being used for temporary on-site storage. This would be a Tier 1 PSE since the applicability exclusion does not include the use of trucks or railcars for on-site storage.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability Tier 1 1.2 Applicability
63) There is a 200 bbl spill of liquid with a flash point <23 °C (73 °F) that ignites and results in damages to other equipment, a toxic gas release above the reporting threshold, along with three days away from work injuries and one fatality. This is a Tier 1 PSE. The facility would record a single event with multiple consequences (e.g. one fatality, three day away from work injuries, fire, and threshold quantity of liquid with a flash point <23 °C (73 °F) and toxic gas).	Tier 1 §5.1, Definition
64) An underground pipeline operated by the facility leaks and releases 1000 bbl of diesel (flash point >60 °C (140 °F)) at a temperature below its flash point within the facility over a period of three days (13.9 bbl/hr). The spill results in contaminated soil that is subsequently remediated. This is a Tier 2 PSE since the leak rate was greater than the Tier 2 threshold quantity in any one-hour period.	Tier 2 §6.2, Table 2
65) 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 $100,000 damage to Company A's equipment. This is not a PSE for Company B since the pipeline is not owned, operated or maintained by Company B. This would be a transportation incident for Company A.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability

Table E.8—PSE Examples and Questions: Marine Transport

Example/Question	Tier 1/2
66) A marine transport vessel that had just disconnected from the process has an onboard 14 bbl spill of material with a flash point >60 °C (140 °F) released at a temperature below its flash point. The event is not a PSE since marine transport operation incidents are specifically excluded, except when the vessel is connected to the process for the purposes of feedstock or product transfer. If the marine transport vessel was still connected to the process when the spill occurred, it would be a Tier 2 PSE.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability Tier 2 §1.2, Applicability §6.2, Tier 2 Definition and Table 2

Table E.8—PSE Examples and Questions: Marine Transport (Continued)

Example/Question	Tier 1/2
67) A third-party barge is being pushed by a tug and hits the dock. A barge compartment is breached and releases 50 bbl of diesel to the water. The event is not a PSE since the barge was not connected to the process for the purpose of feedstock or product transfer.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability

Table E.9—PSE Examples and Questions: Truck and Rail

Example/Question	Tier 1/2
68) A Company railcar derails and spills more than 7 bbl of gasoline while in transit. The incident is not a PSE since it is not connected to the process for the purpose of feedstock or product transfer.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability
69) Two chlorine railcars were delivered to the single railcar unloading rack at the facility; the receiving tank has sufficient available volume to receive both railcars. One railcar is connected to the process, and the other is staged at the unloading rack but is not connected to the process. The second railcar develops a leak and releases 6 lb of chlorine in less than an hour. Is this a PSE? This is not a Tier 1 or Tier 2 PSE since the second railcar satisfies the definition of 'active staging'. Active staging is part of transportation and is expressly excluded from the scope of this RP. Alternate Scenario: Same as above, except the receiving tank does not have sufficient available volume to receive the second railcar. This is a Tier 2 PSE. The second railcar does not satisfy the definition of 'active staging' and is considered on-site storage. The 6 lb chlorine release exceeds the Tier 2 threshold for a TIH Zone B material (TRC T2-2).	Not a Tier 1 or Tier 2 PSE §1.2, Applicability §3.1.3, Definition of Active Staging
70) A third-party truck/trailer on Company Premises has a spill of gasoline greater than 7 bbl in less than an hour while loading. The incident is a Tier 1 PSE since the truck was connected to the process for the purpose of feedstock or product transfer.	Tier 1 §1.2, Applicability §5.1, Definition
71) A truck enters the refinery, parks and is connected to the filling bay. After loading the product, the truck disconnects and leaves the filling bay and an accident occurs leading to a LOPC on the refinery premises. Is this a PSE? This would not be a PSE per API 754; the truck was not connected nor in the process of disconnecting from the process; therefore, the subsequent LOPC should be counted as a transportation event. Even though it is not a PSE per API 754, it should be investigated and corrective action taken to prevent a recurrence.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability

Table E.9—PSE Examples and Questions: Truck and Rail (Continued)

Example/Question	Tier 1/2
72) Background: Caustic and aluminum react exothermically and generate hydrogen gas. As with most reactions, as the temperature increases, the rate of gas generation also increases. Company X contracted its normal transport company for a routine delivery of 50% caustic. The transport company inadvertently selected an aluminum trailer and drove it to the caustic supplier's facility for loading. The supplier did not identify the trailer as aluminum and loaded the caustic. The trailer was delivered (dropped) at the Company X facility at 2:00 p.m. on Sunday; the trailer was subsequently moved to the unloading spot early Monday morning (~5:00 a.m.). The Company X loader noticed that something was wrong (e.g. the trailer was hotter than it should have been); subsequent sampling and investigation revealed the aluminum trailer. By ~7:00 a.m., the area was evacuated and barricaded, and a stainless steel trailer was ordered for transloading. Before the transfer could take place, the aluminum trailer ruptured and spilled the entire contents, which were well above the Tier 1 threshold amount. There were no injuries and the material was contained to prevent environmental impact. Is this is considered a Company X PSE? Although the aluminum trailer was not connected to the process for the purpose of unloading, it had been moved to the unloading station and would therefore be considered "in the process of connecting" to the process; therefore, this event falls within the applicability of API 754. Since the Tier 1 release quantity was exceeded, this would be considered a Tier 1 PSE. Alternate Scenario: The aluminum trailer ruptures and spills the entire contents while still in the delivery yard of Company X. This would not be a PSE for Company X since the circumstances satisfy the definition of active staging, and active staging events are considered part of the transportation process and not part of on-site storage or connected to the process. The transport company may choose to record this as transportation event. Alternate Scenario: The Company X loader recognizes the problem while the trailer is still located in the delivery yard. After careful evaluation, Company X determines the trailer can be safely moved to an unloading bay to take advantage of secondary containment. While in the unloading bay, the trailer ruptures before transloading to a stainless steel trailer. This would not be a PSE for Company X since the trailer was moved to the unloading bay as a mitigation measure rather than for the purpose of unloading. The trailer is still considered in the process of being transported; therefore, the transport company may choose to record this as a transportation event. Alternate Scenario: The aluminum trailer ruptures while awaiting pickup at the caustic manufacturer's facility. Since the release did not occur while filling the trailer, and since the caustic manufacturer does not maintain an active warehouse of filled trailers, the release occurred while in the process of being transported. The transport company may choose to record this as a transportation event.	Tier 1 §1.2, Applicability §3.1.3, Active Staging Definition §5.1, Tier 1 Definition
73) In preparation for an Alkylation Unit turnaround, the unit inventory of olefins is loaded into four railcars and moved to a spur on the north side of the property for storage during the turnaround. While at the spur, one of the railcars develops a leak and releases a Tier 1 threshold quantity. Is this a Tier 1 PSE? While at the spur, the rail cars are classified as on-site storage, which is part of the 'process'; therefore, the olefin spill in excess of the Tier 1 threshold quantity is a Tier 1 PSE. Alternate Scenario: After the turnaround, the four rail cars are moved to the unloading rack; the unloading rack can only accommodate two rail cars. A leak of a Tier 1 threshold quantity occurs in one of the cars outside the loading rack and awaiting unloading. Is this a Tier 1 PSE? The two rail cars outside the loading rack awaiting unloading satisfy the definition of 'active staging'. Active staging is excluded from the scope of API 754; therefore, this event is not a Tier 1 PSE. The Company may choose to record the LOPC as a transportation event.	Tier 1 §1.2, Applicability §3.1.37, Process Definition §5.1, Tier 1 Definition

Table E.10—PSE Examples and Questions: Downstream Destructive Devices

Example/Question	Tier 1/2
74) 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 PRD is greater than the Tier 1 threshold and it results in the formation of a flammable mixture at grade. This would be classified as a Tier 1 PSE since the relief valve discharge is greater than the threshold quantity in Table 1 and resulted in an unsafe release. Same as above except, the vapor is dispersed into the atmosphere without creating any one of the four listed consequences. This is not a Tier 1 or Tier 2 PSE. A company may count this as a Tier 3.	Tier 1 §5.2, Tier 1 Definition and Table 1 Tier 3
75) 100 bbl of naphtha liquid are inadvertently routed to the flare system through a PRD. The flare knockout drum contains most of the release; however, there is minimal naphtha rainout from the flare. This is a Tier 1 PSE since the volume released from the PRD to a downstream destructive device does exceed the threshold quantity in Table 1 and resulted in one of the four listed consequences (i.e. rainout).	Tier 1 §5.2, Tier 1 Definition and Table 1
76) A PRD release less than Tier 1 threshold quantity is routed to a scrubber that 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 Tier 1 PSE since an LOPC resulted in a days away from work injury. The rules for PRD discharges are superseded by the actual harm caused. Alternate Scenario: Same as above, except the release quantity is greater than the Tier 2 threshold quantity but less than the Tier 1 threshold and the toxic material was observed or detected, without injury, at an elevated work structure. This is a Tier 2 PSE since the release quantity from a PRD to a downstream destructive device exceeds a Tier 2 threshold quantity and results in an unsafe release (potential exposure to toxic material) as specified in the list of Tier 2 consequences.	Tier 1 §5.2, Tier 1 Definition Tier 2 §6.2, Definition
77) A propane tank over-pressures through a PRD 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. Due to the height and location of the flare, the release dissipated into the atmosphere above grade and above any working platforms. Even though the PRD release exceeded the Tier 1 threshold quantity, this is not a Tier 1 PSE since the PRD release did not result in any of the consequences listed under Tier 1. This release may be reportable under environmental regulations and the company may choose to capture it as a Tier 3 other LOPC and as a Tier 3 demand on a safety system.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition and Table 1
78) An upset causes a PRD to open and release fuel gas to the facility flare system. The flare system works properly and combusts the vapor release that came from the PRD. This is not a Tier 1 or Tier 2 PSE since the PRD release was routed to a downstream destructive device that functioned as intended (i.e. did not cause one of the four listed consequences). A company may record this as a Tier 3 challenge to the safety system.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition and Table 1 §6.2, Tier 2 Definition and Table 2
79) If a relief valve releases a Tier 1 or 2 threshold quantity and liquid is carried over to the flare drum knockout, but no release to atmosphere in the form of rainout occurs, would you count it as Tier event? The four consequences associated with a release to a downstream destructive device are assessed at the discharge point of the downstream destructive device. In this case, there was no rainout from the flare stack, and assuming none of the other three consequences was realized, then this event would not be a PSE. A company may choose to record this event as a Tier 3 challenge to a safety system.	Not a Tier 1 or Tier 2 PSE §5.2, Definition

Table E.11—PSE Examples and Questions: Vacuum Truck Operations

Example/Question	Tier 1/2
80) 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 PSE since vacuum truck operations are excluded unless loading, discharging, or using the truck's transfer pump.	Not a Tier 1 or Tier 2 PSE §1.2, Applicability
81) 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 $10,000 in damage to the vacuum truck. This is a Tier 2 PSE since the original spill of hydrocarbons constitutes the LOPC and the response to the LOPC results in one of the Tier 2 consequences. Same as above except the vacuum truck is connected to the process. This is a Tier 2 PSE due to $10,000 fire damage. The excess of hydrocarbon vapors absorbed by the carbon canister is the uncontrolled LOPC.	Tier 2 §1.2, Applicability §6.2, Definition Tier 2 §1.2, Applicability
82) During the routine cleaning of sludge from a tank with the use of a 3rd party vacuum truck, one of the cyclone separators mounted on the truck was ejected from its housing ($10,000 damage). The vacuum truck's transfer pump was being used to move material from the tank to an external containment bin. The separator landed a few feet from the vacuum truck and no personnel were injured or equipment damaged. Preliminary investigation results determined that the over pressurization was a due to a deflagration inside the cyclone separator. Would this event be classified as a Tier 3 LOPC because of the use of the vacuum truck transfer pump, or would it be excluded as a truck operation where the truck was not connected to the process for the purpose of feedstock or product transfer? As described, the vacuum truck would be considered part of the process since the vacuum truck transfer pump was being used. When the cyclone separator was 'ejected from its housing', there would have been a release of material; therefore, this would be a Process Safety Event. Based upon the direct cost damage of $10,000 from the explosion, the event would be classified as a Tier 2 PSE.	Tier 2 PSE §1.2 Applicability §6.2 Tier 2 Definition

Table E.12—PSE Examples and Questions: Direct Cost

Example/Question	Tier 1/2
83) 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 Tier 1 PSE. 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. This is, however, a Tier 2 PSE since the direct costs exceeded $2500.	Tier 2 §6.2, Tier 2 Definition

Table E.12—PSE Examples and Questions: Direct Cost (Continued)

Example/Question	Tier 1/2
84) A 4 in. pipeline carrying hydrogen passed through an area where drift from a cooling tower caused external corrosion that resulted in a pinhole leak that immediately ignited. When the small blue flame was identified on a night shift the line was isolated and depressured with the fire causing no damage because the flame was pointed upward and did not impinge on any other equipment. When the line was inspected to determine the appropriate temporary repair, it was determined that over 300 ft of pipe was in such bad shape that it had to be replaced and could not be returned to service. The replacement cost of that segment of the line exceeded \$100,000. Is this a Tier 1 PSE? This is not a Tier 1 or Tier 2 PSE. The damage to the pipeline was not caused by the fire, and by definition the cost of repairing or replacing the failed component leading to the LOPC is excluded if the component is not further damaged by the fire. A company may choose to record this event as a Tier 3 Other LOPC.	Not a Tier 1 or Tier 2 PSE §3.1.13, Definition of Direct Cost
85) A specialty chemicals reactor normally operates at 250 °C (480 °F) and high pressure. When operators observed the reactor temperature falling (indicative of a stalled reaction), they added more catalyst and reduced cooling water flow. A few moments later, the exothermic reaction became uncontrollable even with full flow of cooling water. The pressure and temperature rose with the temperature peaking at 650 °C (1200 °F) well above the design limit of the steel. Fortunately, there was no LOPC; however, it is believed that with a little more heat release the reactor would have ruptured with significant consequences. The reactor and some other overheated equipment had to be replaced at a cost of \$1.5 million. Is this a Tier 1 PSE? Even though the direct cost damage exceeded the \$100,000 Tier 1 consequence level, since there was no loss of primary containment this event is not a Tier 1 PSE. However, rare or unique events with actual serious consequences that do not meet the strict definition of a Tier 1 or 2 PSE, may be classified and reported at a Company's discretion. A company may choose to record this event as a Tier 3 safe operating limit excursion and possibly a Tier 3 demand on safety systems.	Not a Tier 1 or Tier 2 PSE §5.1 Tier 1 Definition
86) Upon shutdown of a H2/CO partial oxidizer (gasifier), the high pressure nitrogen purge failed to sweep the O2 supply line. Hot syngas from the gasifier reacted with the oxygen still remaining in the oxygen feed line between the check valve and gasifier, resulting in an explosion inside the oxygen feed piping and check valve that ruptured the line. The loss of syngas was approximately 350 lbs, (less than Tier 1 threshold quantity) and one first aid injury from thermal burns and pipe fragments. The cost to repair the piping and check valve from the internal explosion was \$175,000. There was no other damage beyond the failed piping that lead to LOPC of syngas. This is a Tier 1 PSE since the Direct Cost damage exceeded the Tier 1 threshold of \$100,000. By definition, Direct Cost includes the cost of repairing the failed component leading to LOPC if the component failed due to an internal or external explosion or overpressure.	Tier 1 §3.1.13, Definition of Direct Cost §5.2, Tier 1 Definition
87) A reactor heating an organometallic chemical overheats causing an exothermic decomposition resulting in a BLEVE of the reactor. The resulting LOPC was less than the Tier 1 threshold release quantity; there were no injuries and no damages beyond destroyed reactor (\$225,000 to replace/repair). This is a Tier 1 PSE since the Direct Cost damage exceeded the Tier 1 threshold of \$100,000. By definition, Direct Cost includes the cost of repairing the failed component leading to LOPC if the component failed due to an internal or external explosion or overpressure.	Tier 1 §3.1.13, Definition of Direct Cost §5.2, Tier 1 Definition

Table E.13—PSE Examples and Questions: Officially Declared Evacuation or Shelter-in-Place

Example/Question	Tier 1/2
88) 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 Tier 1 or Tier 2 PSE. The facility may choose to capture this event as a Tier 3 other LOPC.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition §6.2, Tier 2 Definition
89) 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 Tier 1 or Tier 2 PSE. The facility may choose to capture this event as a Tier 3 other LOPC.	Not a Tier 1 or Tier 2 PSE §5.2, Tier 1 Definition §6.2, Tier 2 Definition
90) A refinery has a hydrocarbon LOPC event that results in off-site odors. Many students and faculty at the local high school claim they are ill from the odors and several go to the local emergency room, but all are evaluated and released without treatment or hospital admissions. The school administration evacuates the school and students/faculty are dismissed for the day. The estimated quantity of hydrocarbon released does not exceed the Tier 1 or 2 threshold quantities. The evacuation was not declared by the police, local emergency responders, local emergency management administration officials or by refinery emergency management personnel. Is this event a Tier 1 PSE? Is the evacuation of a school by school administration due to odor from a LOPC considered "an officially declared community evacuation?" School administrator does not have authority to declare a "community" evacuation or shelter-in-place; therefore, not a Tier 1 PSE.	Not a Tier 1 or Tier 2 PSE §3.1.24, Officially Declared Definition

Table E.14—PSE Examples and Questions: Routine Emissions

Example/Question	Tier 1/2
91) Hydrocarbon vapor are routinely released from the Pressure Vacuum Valve (PVV) or vent of a fixed roof tank when the tank fills or when contents are warmed in the sun. Do these releases constitute a LOPC and possible PSE? These type of routine emissions associated with tank filling and changes in atmospheric temperature are typically permitted. Routine emissions from permitted or regulated sources fall outside the scope of this RP; therefore, this type of routine emissions is not a PSE.	Not a Tier 1 or Tier 2 PSE §1.2 Applicability

Table E.14—PSE Examples and Questions: Routine Emissions (Continued)

Example/Question	Tier 1/2
92) A process furnace is permitted for SOx emissions. A process upset result in a higher than normal sulfur concentration in the fuel gas used to fire the furnace, which in turn results in the permit limit for SOx to be exceeded, but no other consequences. Is this a LOPC and possible PSE? Routine emissions from permitted or regulated sources are excluded from the scope of API 754. Upset emissions are evaluated against four criteria to determine if the event is a PSE. If the event resulted in (1) rainout, (2) discharge to a potentially unsafe location, (3) an on-site shelter-in-place or on-site evacuation, excluding precautionary shelter-in-place or precautionary evacuation, or (4) public protective measures (e.g. road closure) including precautionary public protective measures, then it is considered a PSE. If the volume of the upset emissions exceeded the TQ values in Table 1 in any one-hour period, then the event would be a Tier 1 PSE. If the volume of the upset emissions exceeded the TQ values in Table 2 in any one-hour period, then it would be a Tier 2 PSE. Since the upset emissions of SOx did not result in any of the negative consequences, it does not constitute a PSE. The purpose of the applicability exclusion for routine emissions is intended to address process upsets or maintenance issues that may result in changes to the quantity released from a permitted emissions stream from a permitted source. The intent of Process Safety Event recording is to identify those events that pose a relatively immediate hazard as a result of an unplanned or uncontrolled release of any material. Routine emissions from permitted or regulated sources typically do not pose an immediate hazard; however, upset emissions have the potential for harm and need to be assessed against the Tier 1 and Tier 2 PSE consequences. However, if the excess emissions resulted in harm to people, impact to the community, or fire damage, then the event should be evaluated against the Tier 1 and Tier 2 PSE criteria (excluding the threshold quantity criteria).	Not a Tier 1 or Tier 2 PSE §1.2 Applicability §5.2 Tier 1 Definition §6.2 Tier 2 Definition
93) During routine monitoring by the facility Leak Detection and Repair (LDAR) contractor, a valve was determined to have emissions greater than 10,000 ppmv of Volatile Organic Compound (VOC) from the valve packing. Is this leak a LOPC and possible PSE? By definition, this leak would be considered a fugitive emission and is regulated under the LDAR program. Routine emissions from permitted or regulated sources fall outside the scope of this RP; therefore, this type of regulated emissions is not a PSE. The “leaking” component should be recorded and repaired consistent with EPA requirements for the LDAR program.	Not a Tier 1 or Tier 2 PSE §1.2 Applicability

Table E.15—PSE Examples and Questions: Ancillary Equipment

Example/Question	Tier 1/2
94) A tote is located adjacent to a tank for the purpose of unloading but is not yet connected to the process. A forklift runs into the tote causing a LOPC. Is this a PSE? Even though the tote is not connected to the process, it would still be considered part of the process since it is in position ready to be connected (on-site storage). Therefore, this LOPC may be a Tier 1 or Tier 2 PSE if one of the consequences was realized.	Possible Tier 1 or Tier 2 PSE §1.2 Applicability §5.2 Tier 1 Definition §6.2 Tier 2 Definition

Table E.15—PSE Examples and Questions: Ancillary Equipment (Continued)

Example/Question	Tier 1/2
95) Does the definition of “process” include consumables for the equipment (e.g. hydraulic fluids for hydraulic actuator, lubricating oil for engine/motor). Should LOPC of such consumables be included in the reporting scope? Is the reporting scope limited to material processed (e.g. hydrocarbon gas) and chemicals added to aid the processing of the material, or does it include all materials as long as they are all part of the “process”? The definition for the scope of “process” has been made as broad as possible while still recognizing that there are pieces of equipment that operate and activities that occur within a facility that are not involved with the “process”. Many refrigeration systems are part of the “process”, but the refrigerator that keeps lunches cold in the control center are not part of the “process”. Hydraulic fluids for hydraulic actuators, lubricating oil for motors, and instrument air are part of the “process” when the actuator, motor and instrument air are used by the process equipment, but not when the hydraulic actuator or engine are on a piece of mobile equipment. Similarly, the air in use by a sand blaster is not part of the process.	§3.1.28, Definition of Process
96) During a process unit turnaround, a Tier 2 threshold quantity of crude oil was spilled from a frac tank that had been used for equipment draining. At the time of the spill, the frac tank was in the process area but was not connected to the process. Is this a Tier 2 PSE? Since the frac tank was not connected to the process and was awaiting transport for disposal or recycle, the LOPC would not be a Tier 2 PSE. This example is analogous to the use of a vacuum truck to transport material that was not actively loading, discharging, or using its transfer pump. A company may choose to record this as a transportation event. However, if the crude oil was to be transferred back into the process after the turnaround, then the frac tank would be considered on-site storage even though it was not connected to the process, and the LOPC would qualify as a Tier 2 PSE.	Not a Tier 1 or Tier 2 PSE §1.2 Applicability

Table E.16—PSE Examples and Questions: Responsible Party

Example / Question	Tier 1/2
97) Regarding LOPC events associated with marine transport, truck and rail operations: A company has 1) met the requirement of “connected to the process for the purposes of feedstock or product transfer,” and 2) exceeded either a Tier 1 or Tier 2 threshold quantity. When classifying the event, is ownership or operation of the transport additional criteria? If the transport (vessel, barge, truck, or rail car) was owned or operated by a third-party, would it still be a PSE? The ownership of the transport equipment involved in marine transport, truck and rail operations has no bearing on what constitutes a PSE, nor does the involvement of contract workers. Where a facility is a joint venture operated by others, the PSE is reported by the responsible party.	§1.2 Applicability §3.1.44, Responsible Party Definition
98) The facility experienced a Tier 1 PSE. The facility is owned by Company A, but is operated by Company B. Who is the responsible party, who should count the PSE? The answer depends on the nature of the contract between the two parties. As the contract operator, does Company B also have responsibility for the performance of the facility (i.e. In this case would they be expected to perform the investigation and identify and implement corrective action?). If ‘yes’, Company B is the responsible party and they would record the PSE. If ‘no’ and Company B is simply acting upon the instructions of Company A, then the Company A is the responsible party and they would record the PSE.	§3.1.44, Responsible Party Definition

Table E.16—PSE Examples and Questions: Responsible Party (Continued)

Example / Question	Tier 1/2
99) A 3rd party tank truck operator begins filling his tanker at an unstaffed loading rack. The belly valve of the tanker truck was left open and when the operator disconnected the loading hose, a Tier 1 quantity of flammable liquid was spilled. This is a Tier 1 PSE since the LOPC occurred while disconnecting from the process (i.e., the loading rack). Although the 3rd party tank truck operator has an obligation to follow the operating procedures (i.e. close the belly valve before disconnecting the loading hose), he is not the operator of the facility and therefore he is not the responsible party. The Company that owns or operates the loading rack is the responsible party. The Company establishes the operating procedures, installs prevention measures, authorizes 3rd parties to use the facility, etc.	§1.2 Applicability §3.1.44, Responsible Party Definition
100) A contractor performing work overpressured the contractor supplied tank. The tank roof blew off and traveled 45 ft where it landed on the cab of the contractor's CO_2 supply truck causing $15,000 in damage. Since this was a turn-key job by the contractor, the Company had no contractual liability for the incident or the damage. Is this a PSE? Although the contractor is performing a turn-key job on behalf of the Company, the Company is still the responsible party (i.e. the party responsible for delivering safe, compliant and reliable operations) and the Company should record this event as a Tier 2 PSE.	Tier 2 §1.2 Applicability §3.1.44, Responsible Party Definition §6.2, Tier 2 Definition
101) The custody transfer meter for a refined products pipeline that is owned, operated, and maintained by a pipeline Company is physically located inside the fence line of a refinery. On a quarterly basis, the pipeline Company checks and calibrates the meter. During the proving operation, a lineup error results in a Tier 1 threshold quantity release of a flammable liquid. Even though the LOPC occurred inside the fence line of the refinery, the Tier 1 PSE is recorded by the pipeline Company since they own, operate, and maintain the custody transfer meter and the portable meter proving station. The pipeline Company is the responsible party.	Tier 1 §1.2 Applicability §5.2, Tier 1 Definition §3.1.44, Responsible Party Definition

Annex F
(informative)

Listing of Chemicals Sorted by Threshold Quantity (Based on UN Dangerous Goods Hazard Class or Grouping)

As part of its efforts to develop an industry lagging metric, the CCPS created a comprehensive list of chemicals with associated release threshold quantities that has been adopted for this recommended practice. A copy of the list of chemicals can be found on the CCPS web site.

CCPS web site:

Step 1: http://www.aiche.org/ccps/knowledgebase/measurement.aspx

Step 2: download the Process Safety Incident Evaluation Tool

Step 3: search “Chemical List and View Chemical Details

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 Dangerous Goods list complete with UN numbers in PDF format:

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

Alphabetical cross reference in PDF format:

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

The following discussion, extracted from the CCPS [10] leading and lagging metrics document, provides the thought process used to assign the Packing Groups, Hazard Zones, and threshold quantities for flammable and toxic materials.

Flammable Materials:

UNDG Criteria

2.2.3.1.3 Hazard Grouping Based on Flammability		
Packing Group	**Flash Point (Closed-Cup)**	**Normal Boiling Point**
I	—	≤35 °C (95 °F)
II	<23 °C (73 °F)	>35 °C (95 °F)
III	≥23 °C (73 °F) ≤60 °C (140 °F)	>35 °C (95 °F)

Toxic Vapors:

TIH Hazard Zones A, B, C, and D per U.S. DOT regulations. [21]

UNDG 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 1000 ppm
C	LC_{50} greater than 1000 ppm and less than or equal to 3000 ppm
D	LC_{50} greater than 3000 ppm or less than or equal to 5000 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 ≤1000	>2.0 and ≤4.0

The packing group and hazard zone assignments for liquids based on inhalation of vapors is defined in the following table (also see Figure F.1):

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} ≤1000 mL/m^3; and the criteria for Packing Group I, Hazard Zone A are not met
II	V ≥LC_{50}; LC_{50} ≤3000 mL/m^3; and the criteria for Packing Group I, are not met
III	V ≥0.2 LC_{50}; LC_{50} ≤5000 mL/m^3; and the criteria for Packing Groups I and II, are not met
NOTE V is the saturated vapor concentration in air of the material in mL/m^3 at 20 °C and standard atmospheric pressure.	

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 UNDG 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.

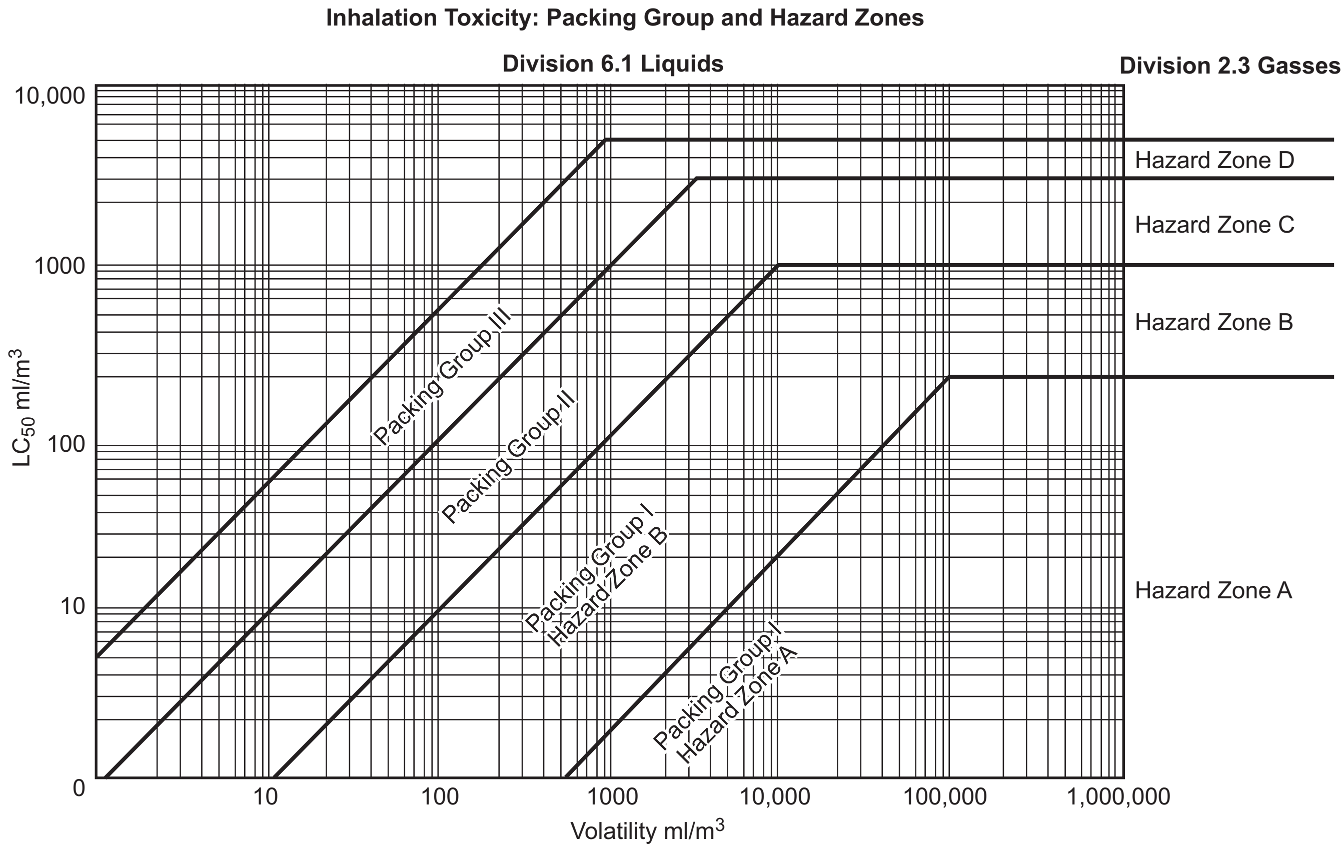


Figure F.1—Inhalation Toxicity: Packing Group and Hazard Zones

However, the UNDG list 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” (NOS), which may require further evaluation to assign to a specific chemical (e.g. “*Amines, liquid, corrosive, NOS*”, *or* “*Hydrocarbons, liquid, NOS*.”).

Furthermore, there are many low hazard materials that are excluded (e.g. solid polyethylene pellets) and are not the subject of this recommended practice. 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 UNDG list 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 UNDG list. 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 performance indicators. 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 their web site.

Annex G
(informative)

Application of Threshold Release Categories to Multicomponent Releases

G.1 General

Many streams involved in Loss of Primary Containment (LOPC) scenarios contain multiple components that may cover more than one Threshold Release Category. The following sections provide guidance on the determination of the Threshold Release Category for these streams.

In determining the Threshold Release Category, a company may choose to use either the properties of the released material based upon laboratory analysis at the time of the release, or the properties documented in a safety data sheet. Companies should be consistent in their approach for all LOPCs.

G.2 Gases or Vapors with Toxic Components

Toxic Inhalation Hazard (TIH) materials are often present as only a component in the LOPC of a gas or vapor stream. TIH materials affect, for the most part, human health independent of the other components in a released stream. The effect of multiple TIH materials in a stream is assumed to be additive.

Therefore, for an LOPC of a gas or vapor stream that contains a component that is a TIH material, the quantity of that TIH component material released is used to determine if a Tier 1 or Tier 2 threshold quantity release has occurred. If there are multiple TIH components in a stream, the percentage of the threshold release quantity for each individual component may be calculated and summed. When the summed percentages exceed 100 %, a threshold quantity release has occurred consistent with Example 49.

Example 51 demonstrates this principle.

G.3 Flammable Gases

A gas is either flammable when mixed with air or it is not. Multicomponent streams are not separated into flammable and non-flammable components to determine if the flammable components have exceeded a threshold quantity for flammable gas releases. Gases that contain inert components may have a more limited flammable range when mixed with air than the pure flammable components, but so long as there is any ratio of the stream that is flammable when mixed with air, the stream is treated as a flammable gas (Threshold Release Category 5). A graph (see Figure G.1) showing the flammable limits of methane-nitrogen mixtures can be used to show that any mixture of methane and nitrogen that contains greater than about 81 % nitrogen cannot be mixed in any concentration with air to form a flammable mixture.

Methods for estimating the flammability zone boundaries for complex mixtures with multiple components have been published. See T. J. Hansen and D. A. Crowl, Estimation of the Flammability Zone Boundaries for Flammable Gases, Process Safety Progress Volume 29, Issue 3, Pages 209-215, December 2009. [23]

G.4 Asphyxiant Gases (UNDG Class 2, Division 2.2 [Non-flammable, Non-toxic Gases])

Loss of Primary Containment of some gases have the ability to create atmospheres insufficient in oxygen for human life without being Toxic Inhalation Hazards or Flammable Gases. The ability of humans to survive oxygen deficient atmospheres is a function of both the oxygen concentration and the length of time exposed. Temporary impairment of mental capability may occur at concentrations less than 12 % oxygen. Multi-component streams containing less than 12 % oxygen by volume is considered an Asphyxiant Gas [UNDG Class 2, Division 2.2 (non-flammable, non-toxic gases)] for determination of Threshold Release Category 7 for Tier 1 and Tier 2.

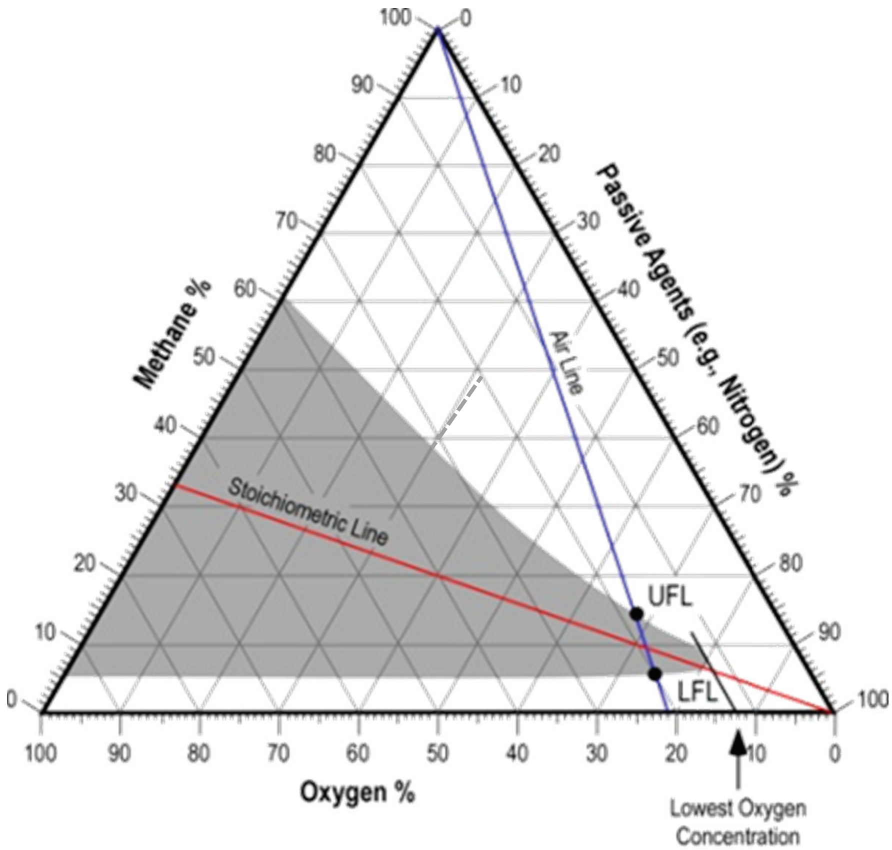


Figure G.1—Flammability Limits of Methane, Nitrogen, Oxygen Mixtures

An example could be a mixture of 95 % Freon 22 and 5 % oxygen. Neither Freon nor oxygen represent a hazard expressed by any of the other threshold release categories, but the mixture has the ability to create an asphyxiating atmosphere around a release. A release of greater than 2000 kg of this mixture in a period of one hour or less would be considered a Tier 1 PSE.

G.5 Flashing Liquid Streams Containing Toxic Inhalation Hazards (TIH)

Multicomponent liquid streams may release TIH materials into the air upon LOPC to atmospheric conditions. A flash calculation is necessary to determine if a threshold quantity of a TIH material has been released independent of the threshold quantity of the liquid itself. See Annex E, PSE Examples and Questions 50.

G.6 Flammable Liquids

The flash point, normal boiling point and release temperature of multicomponent liquid streams are used to determine the applicable threshold release quantity in Table 1 and Table 2. It is not necessary to determine the fraction of individual components in a stream to determine its flammability characteristics.

G.7 Multicomponent Streams Containing Flammable and Inert Liquids (e.g. Water)

G.7.1 Liquid Steams with a Distinct Liquid Phase of Flammable Liquid

When the released stream contains a distinct liquid phase of a flammable liquid, the threshold quantity applicable to that liquid phase applies for the quantity of that phase. This is often the case for mixtures of hydrocarbons and water, which will quickly separate into two distinct phases, one hydrocarbon phase and one water phase.

An example would be the distinct water and oil phases that are released from a de-watering valve left open on an oil-water separator tank.

G.7.2 Liquid Streams Containing Flammable Components Dissolved in Inert Liquids (e.g. Water)

Where the released stream contains flammable components dissolved in an inert liquid, the flammability of the liquid, in total, is used to determine the applicability of threshold release quantities for the stream. The stream is not separated into its components to determine if a threshold quantity has been released for an individual component.

As an example, water and methanol are completely miscible; they will not separate due to the action of gravity. A stream with 3 % contamination of methanol has no flash point. This stream may not have any of the hazards represented by the threshold release categories in Tier 1 and Tier 2 and therefore have no threshold release quantity. If the methanol concentration of the stream were increased to about 15 %, the stream would have a flashpoint below 93 °C (200 °F) and qualify for a Tier 2 threshold release quantity of 1000 kg (2200 lb) or 7 barrels. In that case the volume of the entire release would be compared to the 1000 kg (2200 lb) or 7 barrel threshold.

G.7.3 Liquid Streams Containing Stable Emulsions of Flammable Components and Inert Liquids (e.g. Water)

Where the released stream contains a stable emulsion (i.e. stable for a period of one hour or more at released conditions) of flammable components and inert liquids, the flammability of the emulsion, in total, is used to determine the applicability of threshold release quantities for the stream. The stream is not separated into its components to determine if a threshold quantity has been released for an individual component.

The discharge stream of a centrifugal pump handling a mixture of water and oil along with an emulsification agent (e.g. soap) can form a stable emulsion that may not separate into its component layers over a very long time. If that stream is involved in a release, the characteristics of the entire emulsified stream ares used to characterize the stream in Tables 1 and 2 rather than a comparison of individual stream components.

G.8 Solutions

A solution is a homogeneous mixture composed of only one phase. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent.

The properties of the solution are used to determine the Threshold Release Category that applies to the released stream as a whole. When the properties or hazards of a solution are unknown, a company may use the properties or hazards of the solute and solvent separately and the released quantities to determine the applicable Threshold Release Category and threshold release quantity.

Annex H
(informative)

PSE Tier 1/Tier 2 Determination Decision Logic Tree

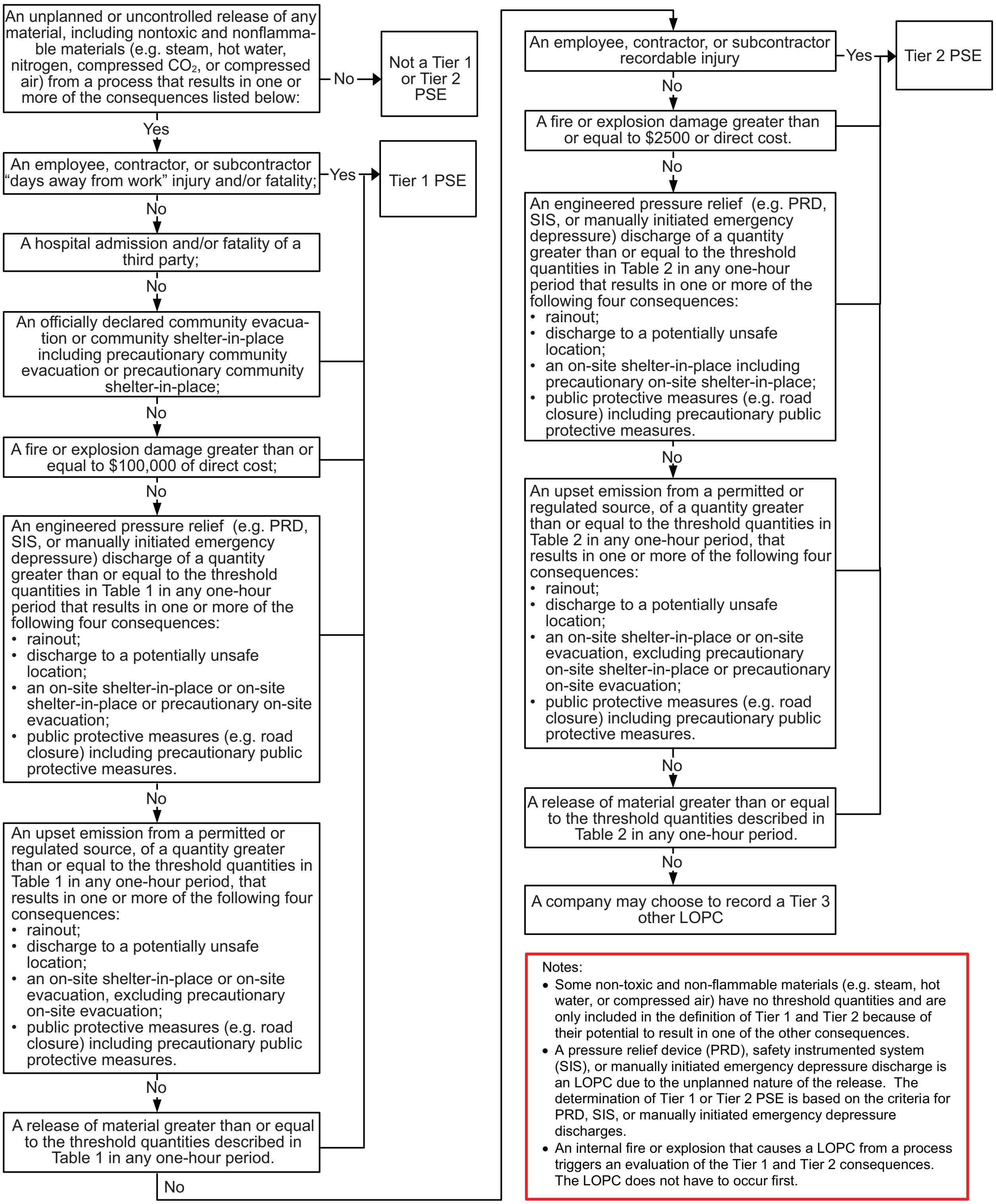


Figure H.1—PSE Tier 1/Tier 2 Determination Decision Logic Tree

Annex I
(informative)

Guidance for Implementation of Tier 3 and Tier 4 Indicators

I.1 Case for Change—Implementing Tier 3 and Tier 4 Indicators in an Organization

Process safety failures can result in harm to people, the environment, property, reputation, and financial stability of a company. Root cause analysis of Tier 1 and Tier 2 process safety events can provide lessons to prevent recurrence. However, this analysis is retrospective and based upon relatively infrequent events; therefore, a company cannot afford to rely solely on these lessons to prevent future events. It is necessary to broaden the analysis to include lessons from challenges to or weaknesses within the barrier system.

Tier 3, Challenges to Safety Systems and Tier 4, Operating Discipline and Management System indicators provide the opportunity for a company to identify and correct weaknesses within the barrier system. Indicators that are implemented well can dramatically enhance the process safety culture and the process safety performance of a company.

> The Baker Panel Report [24] stated "The passing of time without a process accident is not necessarily an indication that all is well and may contribute to a dangerous and growing sense of complacency."

Indicators for indicators' sake will not drive improvement. Indicators must be implemented in a way that effectively engages critical stakeholders and those stakeholders must diligently respond to the information if performance improvement is to occur.

I.2 Lessons Learned from Implementing Tier 3 and Tier 4 Indicators

I.2.1 General

Tier 1 and Tier 2 PSE indicators, as defined by ANSI/API 754, provide base-line data on industry and company performance, facilitate trend analysis and benchmarking, and are intended for nationwide public reporting. Tier 3 and Tier 4 indicators are company defined; they reflect a company's facility-specific barriers and processes, and the facility-specific performance objectives. Tier 3 and Tier 4 indicators are not intended for nor are they suitable for nationwide public reporting.

The decision to adopt Tier 1 and 2 indicators may be easier for a company because they are fully defined and they represent infrequent events that likely require analysis and action by the company per existing policies and procedures. The decision to adopt Tier 3 and Tier 4 indicators may be more difficult since the company must select and define the appropriate indicators at each level, create the mechanism to measure, analyze, and respond to events that occur more frequently and for events that historically may not have required any follow-up.

From an implementation and performance improvement perspective, it may be advantageous for a company to begin with Tier 3 indicators. Tier 3 indicators are relatively easy to identify and define, and many process control systems can automatically collect the data. Operators and maintenance personnel can often respond directly and promptly to the identified weakness (e.g. process parameter exceeding a safe operating limit, repair or recalibration for equipment, and a failed or out-of-tolerance condition) while the underlying cause of the challenge to the safety system is analyzed.

Tier 4 indicators represent operating discipline and management system barriers. Indicators at this level are the most leading and represent fundamental processes and activities that prevent or mitigate process safety events. Identifying, defining, and measuring Tier 4 indicators is more challenging. Each facility and perhaps each process unit within a company may require unique variations of a given Tier 4 indicator to achieve the maximum performance improvement benefit of having an indicator.

Indicators at all levels may drive wrong or unintended behaviors if the purpose of the indicator is misunderstood. For example, release volumes may be underestimated; operating limit excursions may be deemed invalid; preventive maintenance may be deferred without appropriate review; “easy” but ineffective action item resolution may be implemented to meet deadlines, etc. Each of the examples represents a desire to improve the indicator results rather than a desire to strengthen the underlying barriers.

I.2.2 Potential Pitfalls and Obstacles to Implementation

I.2.2.1 Commitment/Support

Senior leadership support and commitment are essential for the implementation and sustainability of a successful indicators program. Indicators must be chosen in support of a company’s business plan, objectives, and culture. Too many indicators or meaningless indicators may result in information overload making it more difficult for senior leaders to understand and to respond to the information presented.

I.2.2.2 Definitions

Vague wording or incomplete definitions may make indicators difficult to understand, difficult to implement, difficult to achieve consistent interpretation, and difficult to aggregate to higher levels within the company (if appropriate). Taking the time to clearly define indicators and gaining agreement amongst affected group results in meaningful indicators that provide useful information in the pursuit of performance improvement.

I.2.2.3 Data Collection

Existing data systems may not collect or readily produce the information a company wants to monitor. Indicator development often involves creating, changing, or standardizing data collection systems. Automated data collection is preferable to manual collection for larger data sets, for more complicated indicators, analysis or formatting, and for more timely presentation.

Indicator data must be presented in a format that can be readily understood by those expected to respond to it. Simplified charts, graphics, and summaries may be best for one level within a company while details may be necessary for another level.

Data collection that depends upon manual input by individuals requires time and effort to communicate the specifics of the data collection, the mechanics of the data collection, and the importance of the data collection. The process of communicating and training may need to be repeated to ensure consistency in the data collection and to reinforce the importance of the activity.

I.2.2.4 Resources

Indicators require resources (e.g. time, money, people) to achieve their purpose consistently over time. Identifying these resources must be part of the defining process and must be supported by leadership throughout the life cycle of the indicator.

I.2.2.5 Reluctance to Implement

A company may choose to tie indicator results to performance management and compensation systems. If a company’s history is punitive toward rather than supportive of individuals, there may be a natural reluctance to implement indicators. Focusing on the root cause of poor performance or lack of progress represented by indicator results rather than automatically or solely blaming the individual will overcome the company history and the reluctance to implement.

I.3 Education for Stakeholders Regarding Tier 1-4 Indicators

I.3.1 Employees and Employee Representatives

I.3.1.1 Purpose

Indicators should drive process safety performance improvement and learning. Indicators should also be relatively easy to implement and easily understood by all stakeholders including employees and their representatives. If employees and their representatives don't understand the basis or purpose for an indicator, it is much less likely the indicator will drive sustainable improvement.

I.3.1.2 Suggested Methods

For employees to learn the intent of process safety indicators, they must first understand process safety and their role in achieving positive process safety performance.

a) Distinguish between process and personal safety: Often employees are very familiar with the goals and requirements of personal safety but may be unclear on the goals and requirements of process safety. Explaining this difference serves as an excellent starting point.

b) Show employees their connection to process safety: Pointing out the many ways employees can impact process safety at their facility, along with potential consequences, is a key step to creating a positive process safety culture. Methods may include pictorial role-by-role representations of key responsibilities organized by process safety elements.

c) Highlight for employees that process safety indicators often reflect the functioning of layers of defense (Implementation, operation within, maintenance of, or correcting as a result of a PSE 1, 2, or 3).

d) Use past company or industry incidents and investigation results to illustrate how process safety events have impacted the facility.

e) Explain the process safety indicators, then make them highly visible on a regular basis using the facility's existing communication methods.

I.3.1.3 Examples

a) Distinguish between Personal and Process Safety.

It may be helpful to use a simple graphic to visually demonstrate the differences between personal and process safety (see Figure I.1).

Figure I.1—Personal Safety/Process Safety Graphic

b) Show employees their connection to Process Safety.

Figure I.2 demonstrates the relationship between process safety elements and a single piece of equipment. A similar graphic could be created for other pieces of equipment or for various operating or maintenance roles.

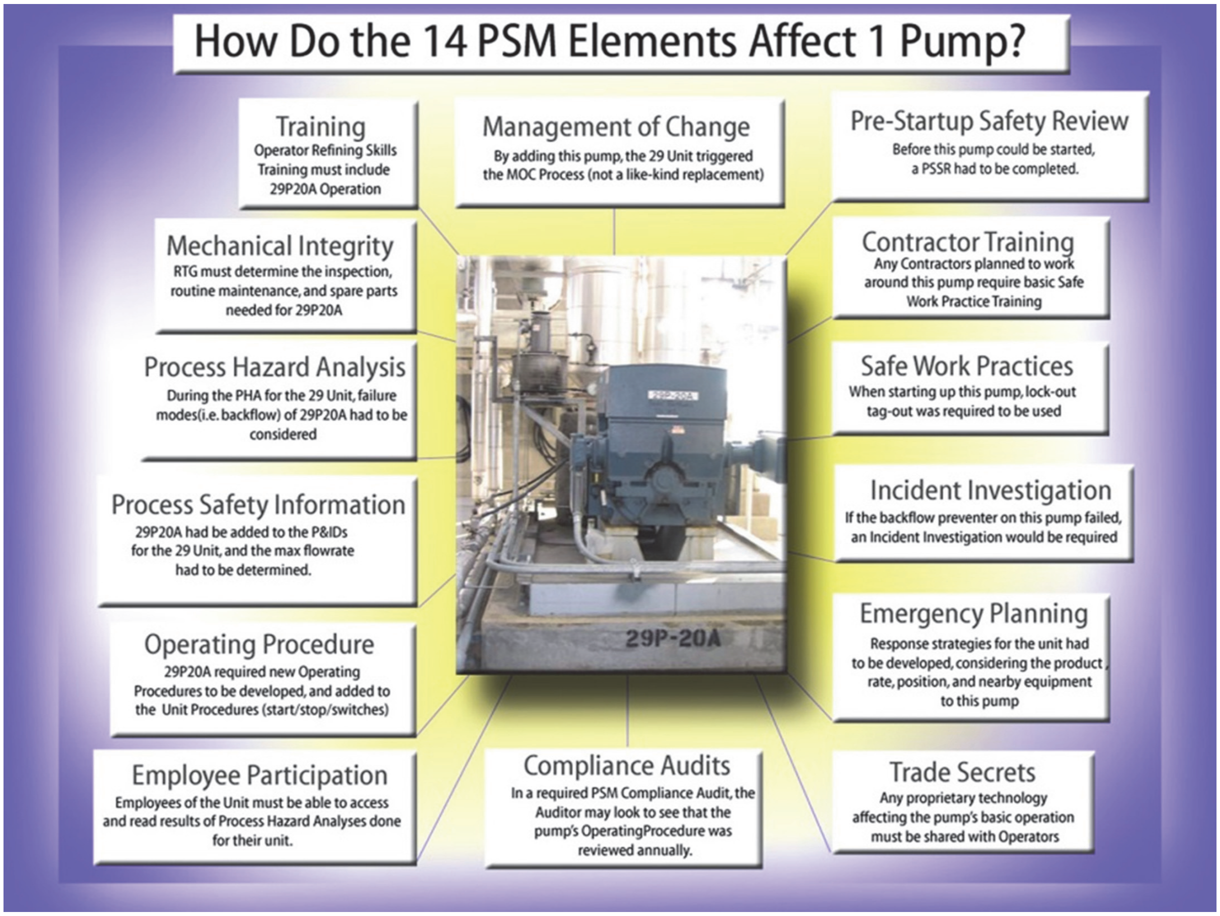


Figure I.2—Illustration of Process Safety Elements Relating to Equipment

c) Use past company or industry incidents and investigation results to illustrate how process safety events have impacted the facility. The U.S. Chemical Safety Board[7] investigations are an excellent resource.

The 2005 Texas City Isom incident resulted in an industry-wide action to move occupied trailers and temporary structures away from potentially hazardous areas, and the publication of API 753, *Management of Hazards Associated with Location of Process Plant Portable Buildings*.

d) Explain the process safety indicators, and then make them highly visible on a daily basis using the facility's existing communication methods. See Figure I.3.

7 http://www.csb.gov/investigations/

Plays of the Week			
Date	**Description**		
12-Feb	Outstanding coordination while executing startup of temp API at WWTP.		
14-Feb	Great attention to detail by Operator during walk down, identifying improper gasket.		
Safety			
Date	**Description**	**Type**	**PSE**
15-Feb	Employee received some insulation in the eye.	Injury I	N/A
15-Feb	Heater trip when switching vent gas between heaters H1 and H2.	Near Miss	TIER 3
15-Feb	Employee slipped on ice when exiting vehicle injuring left shoulder.	Follow-up	N/A

Figure I.3—Daily Indicator Listing Example

I.3.2 Facility Leadership

I.3.2.1 Purpose

Facility Leaders play a critical role in the successful use of process safety indicators. The intent of the indicators must be understood by the facility leadership team so they can reinforce learnings from events, as well as drive actions to improve performance in areas that do not meet the expectations of the facility.

I.3.2.2 Suggested Methods

Basic process safety education for leadership team members is a precursor to successful indicators implementation. Face-to-face presentations on the elements of process safety, including application examples and connections to past facility incidents, establish the need for improvement in process safety performance.

Additional presentations are useful to clearly differentiate process safety indicators from potentially more familiar environmental and personal safety indicators.

I.3.2.3 Examples

A Facility Leadership Team Orientation may include the following.

a) Definition of process safety and explanation of process safety culture.

b) Significant industry incidents that influenced process safety regulation.

c) Explanation of each of the process safety elements with examples that apply to the site.

d) Discussion of roles and responsibilities of each facility leadership team member with respect to process safety.

e) Review of the company and facility’s risk profile with respect to process safety.

f) Overview of process safety indicators, with connections back to the site. Discussion to include review of past incidents and how they would be classified using these indicators.

I.3.3 Company Leadership

I.3.3.1 Purpose

Because company leadership typically sets the risk profile for the organization, it is critical that they understand the impact that process safety has on people, the environment, the public, and their business. Once the role of process safety is understood, company leadership can drive improvement in targeted areas at specific facilities, and positively recognize those facilities with sustained positive performance.

I.3.3.2 Suggested Methods

The same or similar basic education presentations regarding process safety used for facility leadership can be used for company leadership as well.

I.3.3.3 Examples

See I.3.2.3 for suggested content of the orientation material.

I.3.4 Local Community Leaders and Local Emergency Management Officials

I.3.4.1 Purpose

Local community leaders, local emergency management officials, and interested citizens are key stakeholders of the facility's process safety performance. Because community leaders and citizens, including emergency management personnel, are much less likely to be familiar with the hazards, safeguards, and daily activities of the facility than employees, it is suggested that targeted efforts be made to educate these groups about process safety as part of the indicators communication process. Indicators without context and understanding are not useful.

I.3.4.2 Suggested Methods

Local Community Advisory Committees (CACs) and Local Emergency Planning Commissions (LEPCs) are natural audiences for process safety orientation and process safety indicator presentations. For example, if annual updates on the facility's personal safety or environmental performance are already given to these groups, adding a session on process safety is a natural progression. If one of these venues doesn't already exist, a company could propose a specific session and then schedule it to reoccur on an annual basis.

The knowledge and interests of CACs/LEPCs vary with the experience and background of the members and sometimes with the dynamics of a particular geographic location. While Tier 3 and Tier 4 indicators can be extremely valuable indicators for a company, the detailed definitions, data sets, calculations, results, etc. may be inappropriate for community groups. The details may actually confuse the audience and contribute to misunderstanding.

While API 754 requires that a summary of facility-specific Tier 1 and Tier 2 PSE information be made available to community groups, communication to CACs/LEPCs on Tier 3 and Tier 4 indicators should be tailored to the needs of the audience. It may be best to limit or concentrate the discussion to the "story" that the indicators are telling. Sharing a summary of indicator data, trends, and actions taken may fulfill the interests of the CACs/LEPCs, and demonstrate that the company is actively measuring, monitoring, and making corrections to improve performance.

Reporting summary data and trends also avoids the possibility that "raw numbers" get into the public domain where they can be misunderstood, misused, and reported out of context.

I.3.4.3 Examples

A Community Members or Local Emergency Management Officials Orientation may include the following.

a) Definition of process safety, including the distinction between personal and process safety.

b) Review of the company and facility's vision with respect to process safety.

c) Discussion of the barriers (e.g. basic controls, alarms, safety instrumented systems, relief devices) and processes (e.g. inspection and testing, training, MOC) in place to prevent or mitigate process safety events.

d) Overview of process safety indicators, explaining how they relate back to the barriers and processes already discussed.

e) High level review of criteria used in the indicators to calibrate the audience's ideas of what is being measured.

I.4 Selection of Tier 3 and Tier 4 Indicators

I.4.1 General

Selecting effective indicators is a challenge, particularly the more leading Tier 3 and Tier 4 indicators that aim to proactively identify barrier system weaknesses that contribute to higher consequence Tier 1 and Tier 2 process safety events. Properly selected, defined, and understood indicators can give a company the confidence that the right things are being managed and tracked. This requires companies to develop knowledge and understanding of the most critical risk control barriers.

At a company or facility level, there are three types of inputs that can be used together to help identify critical barriers that are weak or subject to rapid deterioration.

I.4.2 Proactive Identification of Critical Barriers or Processes

Proactive identification makes use of recent Process Hazards Analysis (PHA) and other risk assessment techniques to identify initiating causes and likelihoods, prevention and mitigation barriers, and consequences. Employees and their representatives, process safety committees, and process safety surveys may also contribute to the proactive identification of critical barriers.

I.4.3 Reactive Identification of Critical Barriers or Processes

Reactive identification makes use of root cause analysis from incident investigations to identify weaknesses in or missing prevention and mitigation barriers or processes critical to the prevention of future process safety events. Internal or external audits and regulatory challenges may also contribute to the reactive identification of critical barriers.

I.4.4 External Identification of Critical Barriers or Processes

External identification makes use of experience and input from external sources such as industry benchmarking, conference presentations, and published text to identify what others have found beneficial.

I.4.5 Identification of Critical Barrier or Process Weaknesses

I.4.5.1 General

Once the critical barriers and processes have been identified, the next step is to identify potential weaknesses that could result in a failure of the barrier or process. It is helpful to examine each barrier or process from three perspectives: 1) Design and Installation, 2) Operation, and 3) Maintenance and Inspection. The potential weaknesses that are dynamic are more suitable choices for identification and monitoring through indicators, while potential weaknesses that are static are more suitable for identification through quality assurance/quality control efforts or auditing.

I.4.5.2 Barrier or Process Design and Installation

Design and installation weaknesses tend to be latent defects that do not change over time.

EXAMPLE Safety Related Alarm with Operator Intervention

The alarm set point does not provide enough time for the operator's action to take affect before the consequence is realized, or the physical installation is incorrect in some way.

EXAMPLE Management of Change

The management of change procedure does not identify temporary change as an item to be managed.

I.4.5.3 Barrier or Process Operation

Operation weaknesses tend to be defects that deteriorate over time.

EXAMPLE Safety Related Alarm with Operator Intervention

Completion of initial and refresher training on the operator response procedure, or, the alarm is bypassed without proper authorization or is not reinstated at the prescribed time.

EXAMPLE Management of Change

Required actions are not completed before commissioning of the change.

I.4.5.4 Barrier or Process Maintenance and Inspection

Maintenance and inspection weaknesses tend to be "as found" defects.

EXAMPLE Safety Related Alarm with Operator Intervention

The maintenance test or inspection discovered the alarm device in a failed or non-functioning state, or the schedule maintenance test or inspection is past due.

EXAMPLE Management of Change

A temporary change is in service past its removal date.

I.5 Tier 3 and Tier 4 Indicator Monitoring, Aggregation, and Analysis

I.5.1 General

Any PSE Tier 3 or Tier 4 indicator identified by a company should be analyzed; otherwise the indicator may not be worth collecting. This informative Annex is designed to provide guidance for companies in performing periodic analysis of Tier 3 and Tier 4 PSEs toward recommending improvements in either facility or company-wide process safety programs.

I.5.2 Methods for Monitoring, Aggregation, and Analysis of Process Safety Event Tier 3 and 4 Indicators

Companies should establish internal methods to collect, aggregate, analyze, and trend Tier 3 and Tier 4 PSE indicator data. The results should be periodically reviewed with selected leadership groups at various levels within the organization for the purpose of developing improvement plans, setting strategic objectives/targets, and assignment of appropriate resources. A simplified method could include the following five steps.

1) Establish systems to consistently collect indicator data for analysis.

2) Select data for deeper analyses, and determine appropriate aggregation for trending, including management review.

3) Periodically analyze the data and review results, making recommendations for improvement.

4) Report the recommendations to leaders and assign owners to specific action plans.

5) Audit the data collection and analysis process for improvement opportunities.

Sections I.5.3 through I.5.5 provide additional discussion for each step in the process safety indicators analysis methodology.

I.5.3 Systems to Consistently Collect Process Safety Event Information

I.5.3.1 General

A company should evaluate what analysis of PSEs should be performed and at what level within the organization. How will the data be collected, categorized and sorted, what electronic tools are available and/or may be required? What data is "tactical" versus "strategic" and what format should be used to report the analysis? Each of these considerations is explored further below.

I.5.3.2 Data to be Analyzed and Trended, Including Organizational Level of Tracking/Trending

As with selection of Tier 3 and Tier 4 indicators, what a company will elect for further data analysis, the level of analysis to be conducted, and the appropriate organizational level to analyze and trend the data will be unique for each company. Questions for companies to consider may include the following.

— What data should be analyzed and trended company-wide?

— What data should be analyzed and trended at the site-level?

— What data should be analyzed and trended at the unit-level?

— What data should be analyzed and trended at the work group and/or shift-level?

While companies may decide to aggregate data from Tier 3 and Tier 4 indicators, care must be taken to ensure that similar facilities or activities form the basis of the aggregation; otherwise, comparisons may lead to erroneous judgments.

I.5.3.3 Categorization of Data

Subject to a company's decision on what data to analyze and trend, data needs should be identified by categories and sub-categories in an effort to understand how best to collect the data. Existing database systems may require some modification or configuration to add fields, modify data hierarchy structures, etc. to facilitate ease of collection and reporting.

Performing a mapping exercise for Tier 3 and 4 PSEs that a company will want to analyze and trend at a company, site, or unit level is valuable as it may provide insight how best to categorize data for collection. Figure I.4 illustrates mapping of an example company's targeted analyses for Tier 3 Loss of Primary Containment (LOPC) PSEs. Since this company desires to analyze and trend Tier 3 LOPC PSE at the company-level, it becomes important that each facility categorize their units using common terminology (e.g. "Alkylation", "FCC", etc.). However, since facilities will be analyzing data by equipment involved, physical causes and management system root causes, each facility will want to ensure at a minimum their terminology for these sub-categories is standardized (otherwise a data analyst may be required to take additional time to manipulate and interpret data for their analysis).

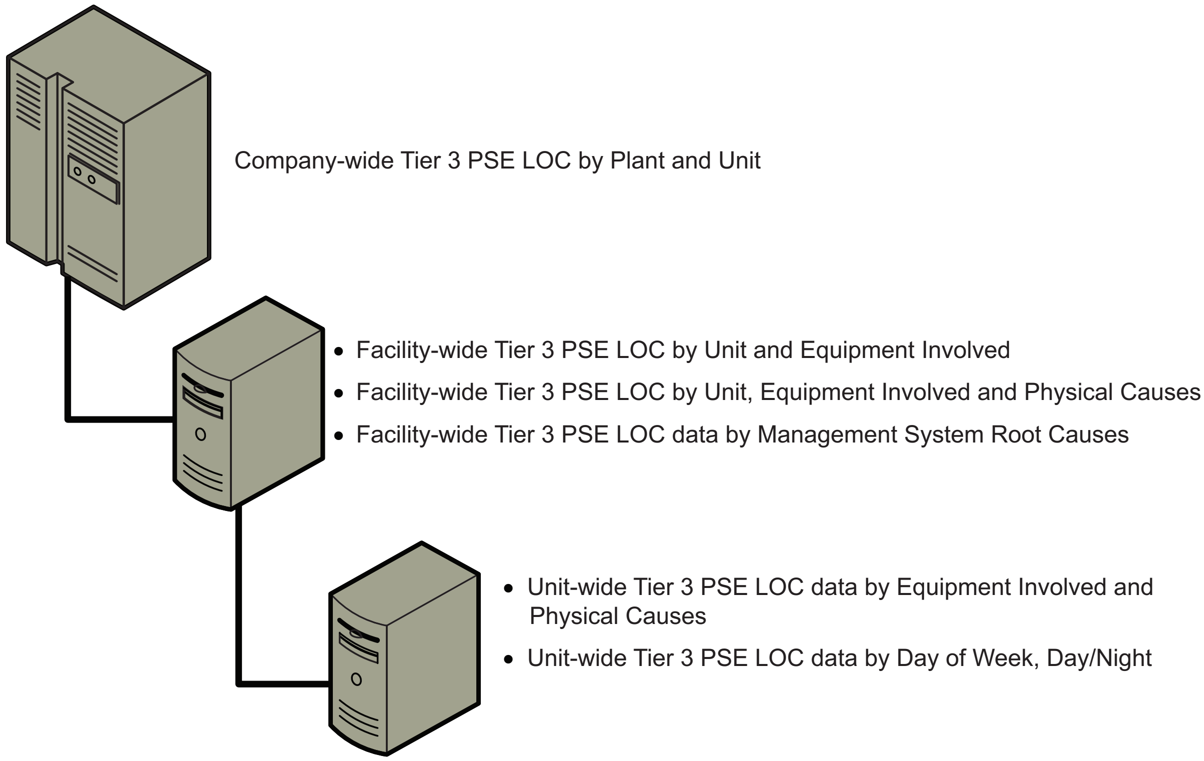


Figure I.4—Illustration of Data Flow and Need for Categorization

A good starting point for potential categories and sub-categories would be use of the information in Section 10.4.4 of ANSI/API RP 754.

Based on the size of the company, organization, data collection capabilities, operating philosophy, etc., the data selected for deep dive analysis is expected to vary. In addition, companies may elect to perform a one-time analysis, or a limited number of deep dive data analyses for a particular set of groupings/subgroupings (often referred to as "buckets" or categories of information) based on whether they can extract valuable information to recommend process safety improvements. The list below provides examples of Tier 3 and Tier 4 deep dive data analyses, however the categories and subcategories may not be appropriate for every company. Additionally, other categories or "buckets" may be appropriate based on criteria unique to the company.

— Comparison of all Process Safety Indicators by Operating Unit.

— Comparison of Process Safety Indicators by Tier and Operating Unit.

— Process Safety Indicators by Tier and Day of Week/Time.

— Process Safety Indicators by Tier and Equipment Type/Failure.

— Process Safety Indicators by Tier and Mode of Operation.

— Process Safety Indicator by investigated Root Cause(s).

— Process Safety Indicator by Tier and Investigation Root Cause(s).

— Tier 3 Loss of Primary Containment PSEs by Site.

— Tier 3 Loss of Primary Containment PSEs by Site and Unit.

— Tier 3 Loss of Primary Containment PSEs by Equipment.

— Tier 3 Loss of Primary Containment PSEs by Equipment and Physical Cause(s).

— Tier 3 Loss of Primary Containment PSEs by Equipment, Physical Cause(s) and Management System Root Cause(s).

— Tier 3 Fire and/or Explosion PSEs by Site.

— Tier 3 Fire and/or Explosion PSEs by Site and Unit.

— Tier 3 Fire and/or Explosion PSEs by Equipment.

— Tier 3 Fire and/or Explosion PSEs by Equipment and Physical Cause(s).

— Tier 3 Fire and/or Explosion PSEs by Equipment, Physical Cause(s) and Management System Root Cause(s).

— Tier 4 Action Item Closure by Site.

— Tier 4 Action Item Closure by Site and Unit.

— Tier 4 MOC/PSSR Compliance by Site.

— Tier 4 MOC/PSSR Compliance by Site and Unit.

— Tier 4 Completion of Safety Critical Equipment Inspection Performance by Site.

— Tier 4 Completion of Safety Critical Equipment Inspection Performance by Site and Unit.

— Tier 4 Work Permit Compliance by Site.

— Tier 4 Work Permit Compliance by Site and Unit.

Select examples of trended deep dive data analyses are included in Section I.5.4 of this Annex.

I.5.3.4 Quality Control of Data/Information Collection

Whether data will be collected, trended and analyzed at a site level or rolled-up for company-wide analysis, it becomes important to establish a quality control (QC) plan for information collection. As part of the QC planning, a company may elect to establish clear rules and procedures for data collection, training for those involved in collection and reporting data, and work processes for data analysis/peer review.

I.5.3.5 Rules and Procedures for Data Collection

Tier 3 and Tier 4 PSE data is often collected from a combination of automated systems and manual processes. Automated systems are typically the most consistent and reliable. Procedures or descriptions on how these systems are queried to obtain the category and subcategory information may be beneficial to ensure consistency between analysts executing these queries.

For manual processes dependent on people to collect and report the Tier 3 and 4 data, companies should establish clear procedures to aid in consistent collection of data. The procedures should define specific roles and responsibilities for data collection, techniques and practices, and rules for reporting the data. Checklists and protocols are beneficial tools used to ensure consistency in data collection.

As an example, Tier 4 indicator data for work permit compliance is likely to be collected through a process of field inspections and audits; therefore, the rules defining what constitutes “meeting all permit requirements” should be clear. If the rules are not clear, this could result in inconsistencies in the data that may result in false conclusions and non-productive recommendations.

I.5.3.6 Training for Individuals Involved in Data Collection

The success of any data analysis will depend on the quality of the data collected and reported. To ensure high integrity data, each individual involved in the data collection should be trained. Some individuals, such as technical experts experienced in analyzing data, may need limited training specific to the data collection tools, organizational requirements, company-specific procedures, etc. to successfully perform their work. Other individuals, particularly those involved in more manual work processes to collect data, may require additional classroom and on-the-job training to understand how to collect and report data.

I.5.3.7 Work Processes for Data Analysis and Peer Review

Companies should establish clear work processes for data analysis and peer review to ensure the data and analysis is not only accurate, but meaningful. As part of this quality review, a company should ensure the integrity of the systems used to collect and analyze the data. For example, spreadsheet formulas used to analyze data should be checked for accuracy. Aggregation protocols for data reported at a company level or reported externally should be verified.

Peer review processes take advantage of multiple individuals reviewing the information, questioning the results and interpretations, and challenging the analyst to confirm information accuracy. These reviews, particularly when they include other technical experts familiar with the data, can catch errors both small and large before the analysis is finalized and presented to leadership.

I.5.3.8 Management of the Data in Tracking Systems and Reporting

Tier 3 and 4 PSE information is often derived from large volumes of data, most effectively collected and tracked by sophisticated databases. A company may find their ability to analyze Tier 3 and 4 indicator data is limited by their ability to assimilate the data by category and subcategory. Before investing in expensive data management systems, a company may consider performing a one-time manual analysis to determine the value of the analysis. If meaningful information for action is realized, then the company may decide to investigate more effective and efficient data collection tools (i.e. database) for future use. The decision to use automated tools will be dependent on the time required to manually collect the data, the frequency of the analysis, and the continued future benefit of the specific analysis.

The frequency of data analysis will depend on the availability of the data and its overall usefulness. For example, collecting the bulk number of PSE Tier 3 LOPC events for a company from each plant may require only a modest effort making it practical to collect/analyze on a quarterly basis. This data could then be compared against prior quarters to determine positive or negative trends. Negative trends may trigger further and more immediate analysis. Positive trends may call for a review of cause and effect against improvement action progress. Additional reviews may require a higher level of effort that is more practically conducted on a periodic basis, such as semi-annual or annual basis. Examples of data deep dives that may be more complex, conducted less frequently, are illustrated in Section I.5.4.

Finally, a company should consider how the data is best presented. For example, some data and analysis may be more tactical in nature, resulting in the need to know more immediately by a broad audience. This may best be communicated through more automated means of data collection and presentation (e.g. dashboards). Other data may be more important for strategic planning and could be formalized and communicated through less automated means, such as presentation and written reports to appropriate leadership levels for decision making purposes. A company should select which data is tactical versus strategic, the best means for reporting the data, and who in the organization should receive the final analysis however it may be presented.

I.5.4 Analyze and Interpret

I.5.4.1 General

A deep dive data analysis could begin with a simplistic review of Tier 3 and/or Tier 4 data to screen what additional areas may warrant further interrogation. A common technique is to funnel from a high-level review of a large volume of common data to a smaller focused subset. This Section illustrates an approach to funneling specific Tier 3 Loss of Primary Containment (LOPC) events. The same or similar approach may be employed based for other Tier 3 and Tier 4 indicators, such as Tier 3 fires and explosions, Tier 3 demands on safety systems, etc.

Funneling is a common technique of starting with a larger group of data with key categories identified, then continuing to go deeper into the data to analyze whether worthwhile recommendations can be made for improvement action plans. Success of the funneling technique is often dependent on the tools and data available (e.g. sophistication of the database and ability to query by categories and subcategories) as well as the individual analyst performing the assessment. A skilled analyst should be able to start with a large data set and continue to drill down and determine if trends may exist, then present the data in such a manner prompting recommendations and actions. Figure I.5 illustrates the high-level decision making process an analyst may use starting with a large data set, then continue to drill down to make recommendations or end the analysis.

Below is an example of how an analyst may drill down into data by categories and subcategories.

I.5.4.2 Examples

Company X decided to perform a deep dive analysis of Tier 3 Other LOPC events once each calendar year as part of its strategic planning and budgeting activities. Company X has four refineries having similar process units at each refinery. The Company tracks all PSEs in a common database (PSE Tier 1 to 4 events) and has collected PSE related information per the ANSI/API 754, Section 10.4, as well as other data of value in performing data analysis.

Based on the Company’s unique considerations, an initial data analysis is performed for total Tier 3 Other LOPCs by Plant. The result is shown in Figure I.6.

A basic high-level review of total Tier 3 Other LOPCs indicates two plants account for most of these types of events. The initial analysis may lead to further interrogation as to why Plants 1 and 2 have higher Tier 3 Other LOPC totals than Plants 3 and 4 (e.g. better reporting by Plants 1 and 2, more non-routine work at Plants 1 and 2, size and complexity of facilities, etc.).

While the initial basic high-level review provides some valuable information, it lacks the detail needed to begin to understand what resources should be assigned to improvement projects. To dive deeper into the data, the Company elects to look at the Tier 3 Other LOPCs not only by plant, but also by process unit (Figure I.7).

Figure I.8 now provides additional information of potential interest. For example, of the four reporting plants, over 70 percent of the Tier 3 Other LOPC events occurred in three units (FCC, Alkylation, and Asphalt) suggesting a more focused interrogation of common causes in these areas may be advisable. Additionally, Plants 1, 2, and 3 all experienced the most Tier 3 PSE LOPC events in the FCC and Alkylation process units.

Since Plants 1 and 2 FCC and Alkylation units account for over 50 % of the total Tier 3 Other LOPC events, analysis of the data may go deeper into these specific units to evaluate other contributing common causes. Figure I.9 illustrates a focused review of the data for the Plant 1 FCC and Alkylation units based on the equipment involved subcategory.

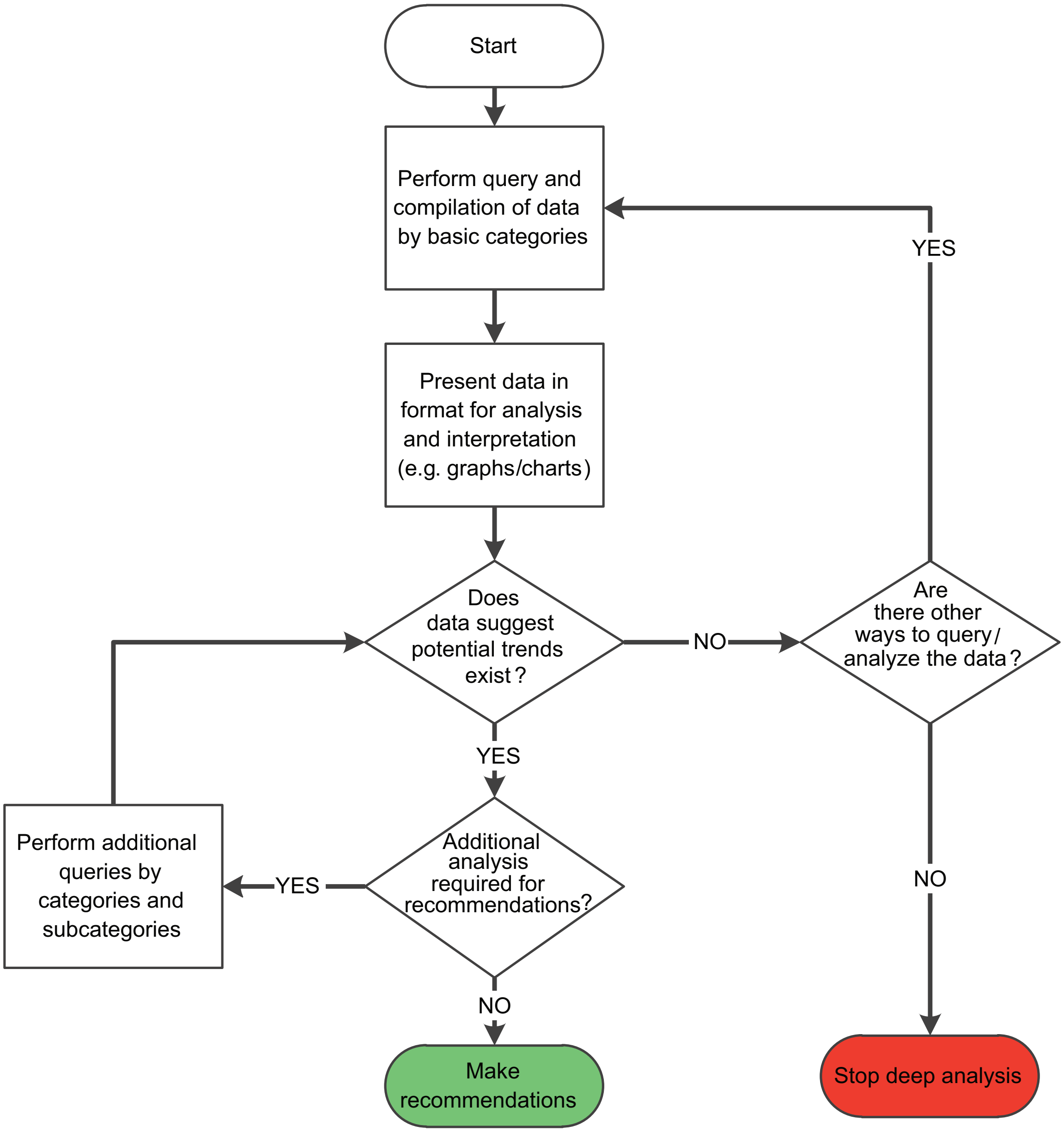


Figure I.5—Example of Data Funneling Flow Diagram

As illustrated in the Figure I.7, over 80 percent of the Tier 3 Other LOPCs involved pumps in the FCC and Alkylation units. Similar analyses can be conducted for the remaining Plants 2 to 4 to understand if Tier 3 Other LOPCs are a localized issue at Plant 1 or a more wide-spread problem within Company X.

Many other types of data analysis may be performed for the Tier 3 Other LOPCs, with each being assessed for a further deep dive. Figure I.9, Figure I.10, and Figure I.11 are additional examples of initial analyses that could then be evaluated for additional interrogation.

I.5.4.3 Additional Data Analysis Method

It is important to consider the volume of data necessary to yield a valid analysis. For example, at least 20 data points are needed to establish valid control limits. Moving averages are best for data that comes in slowly; monthly data is considered very slow and would benefit from moving average charts. The chart below was chosen with a moving

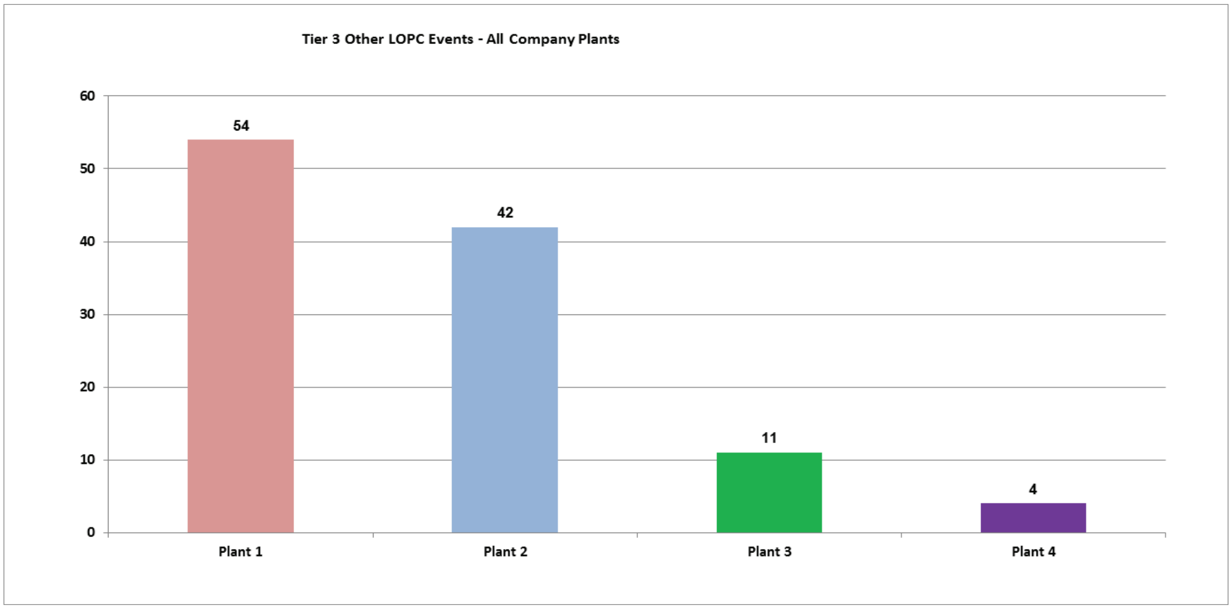


Figure I.6—Example PSE Tier 3 Other LOPC Graph

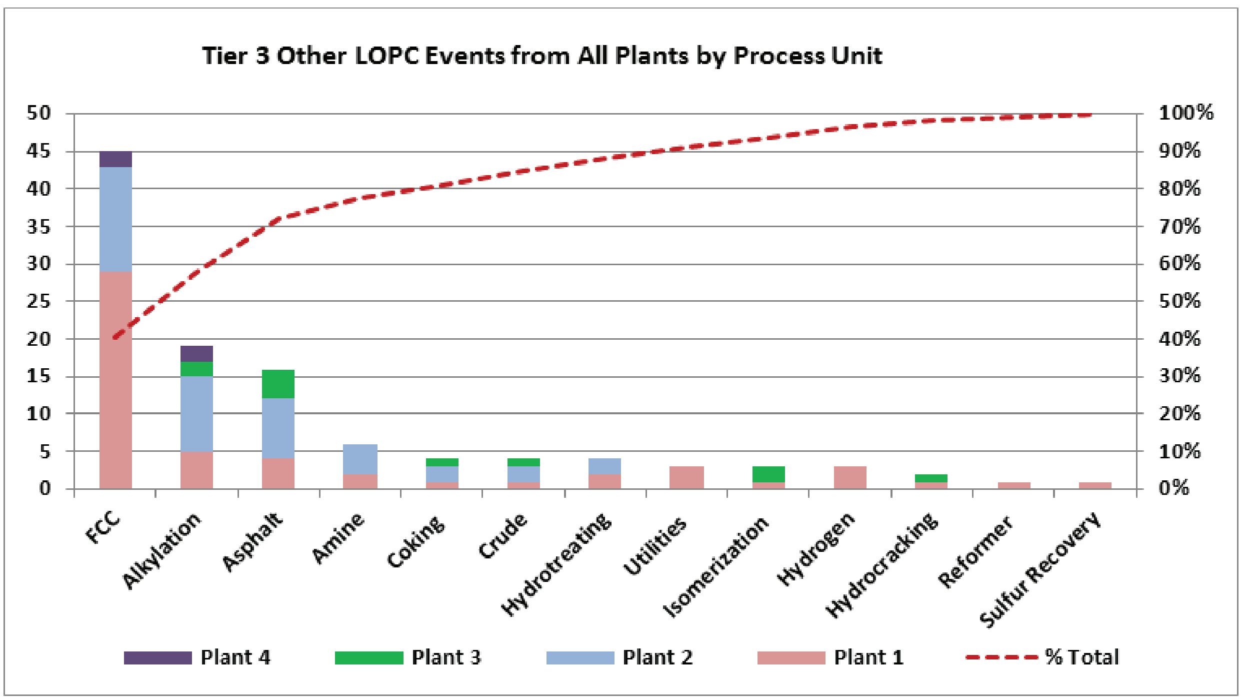


Figure I.7—Example PSE Tier 3 Other LOPC Graph by Plant and Process Unit

average of 3 months. Three was chosen because a quarter of a year is a natural subset that is commonly used in businesses.

In Figure I.12, the red lines are upper and lower control limits, the green line is the average. The red highlighted dots on the right hand side show "out of control" points. Data outside the control limits has a 99.73 % chance of being a change in the underlying system. In this case, it is a change in the downward direction, always a good thing in terms of demands on safety systems. To get a better idea of how the change looks on its own, one can separate the data into stages (see Figure I.13).

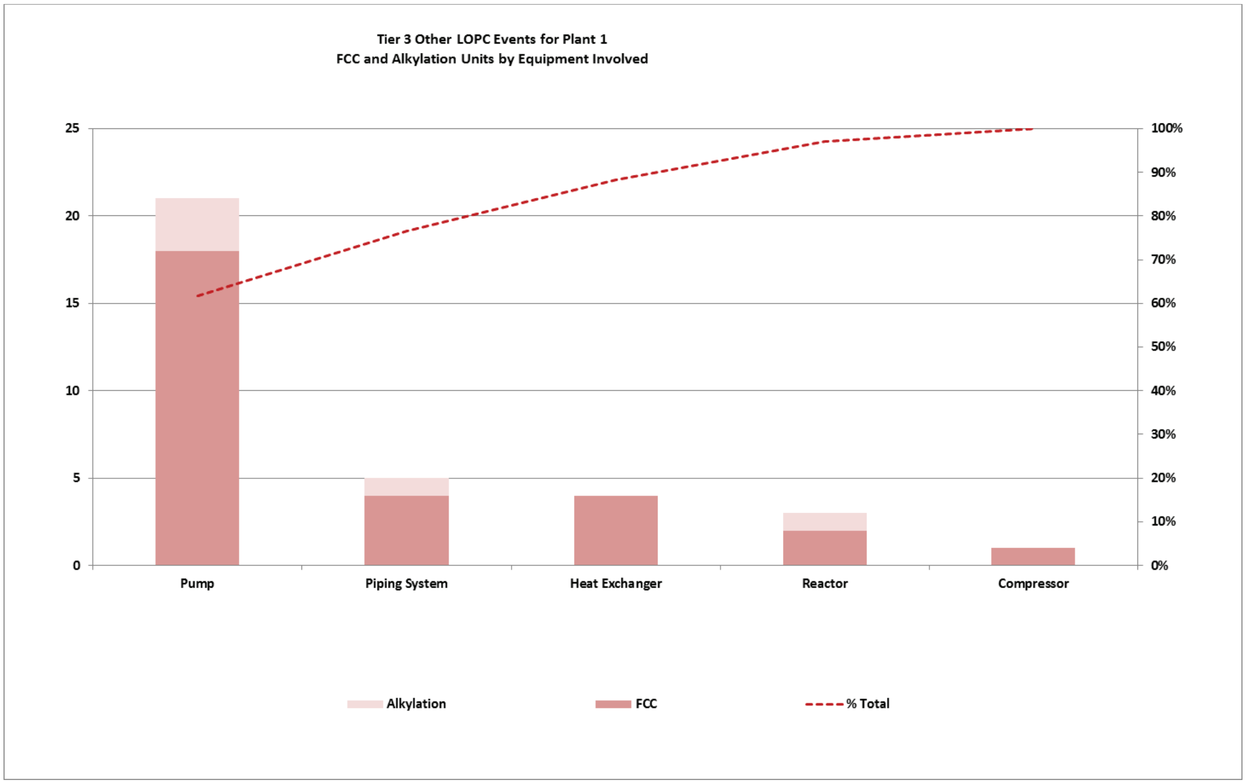


Figure I.8—Example PSE Tier 3 Other LOPC Graph for Plant 1 FCC and Alkylation Units by Equipment Involved

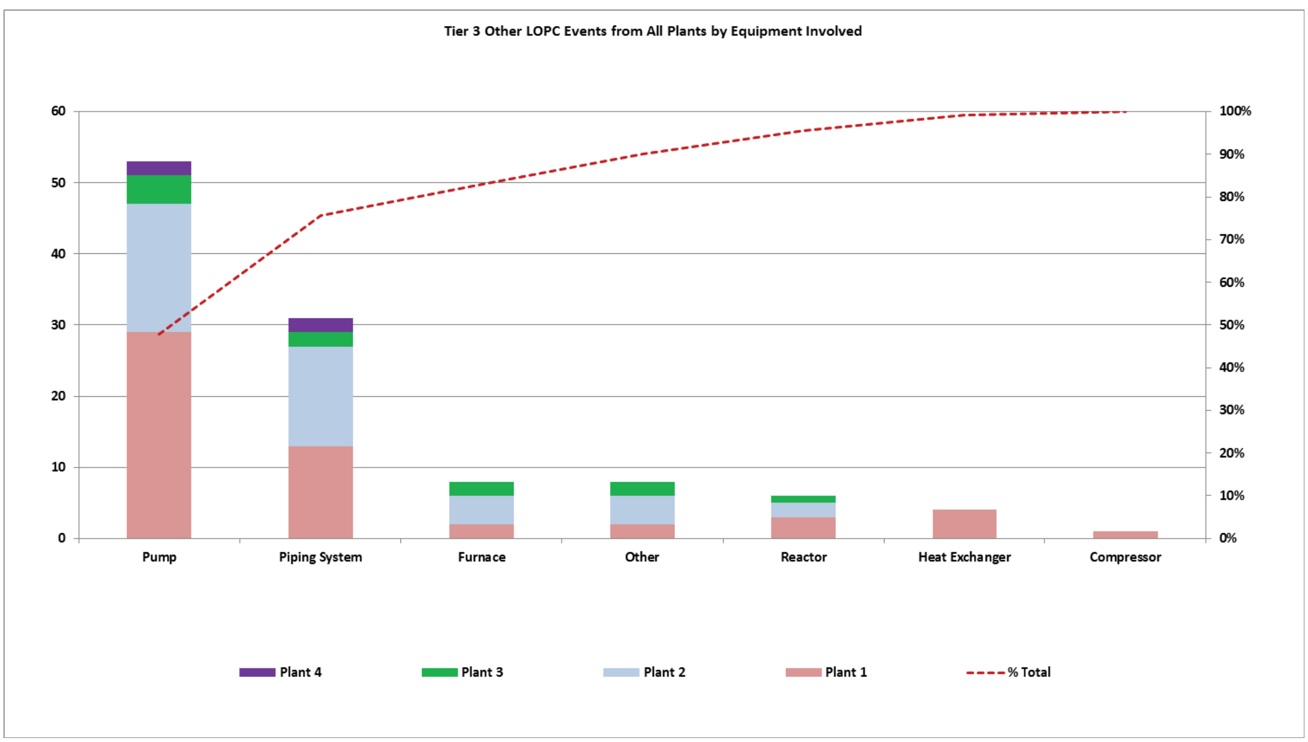


Figure I.9—Example PSE Tier 3 Other LOPC Graph by Plant and Equipment Involved

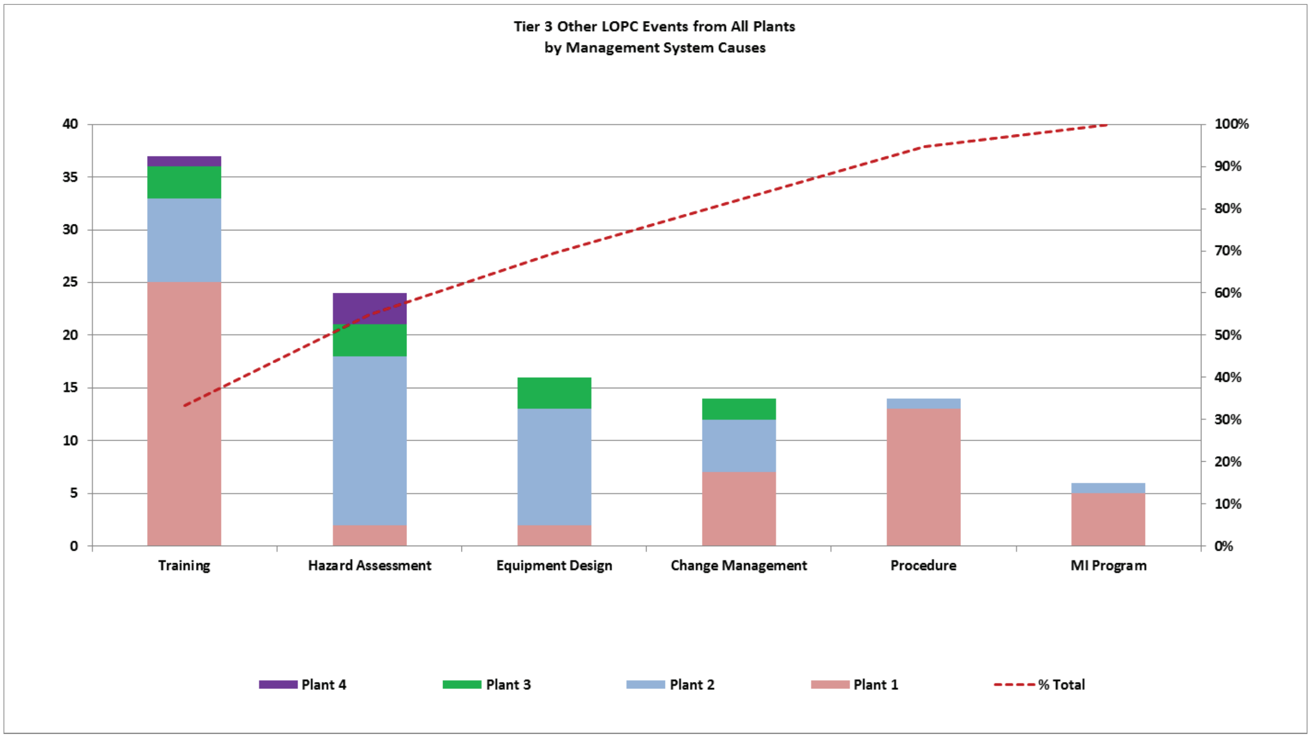


Figure I.10—Example PSE Tier 3 Other LOPC Graph by Plant and Management System Root Causes

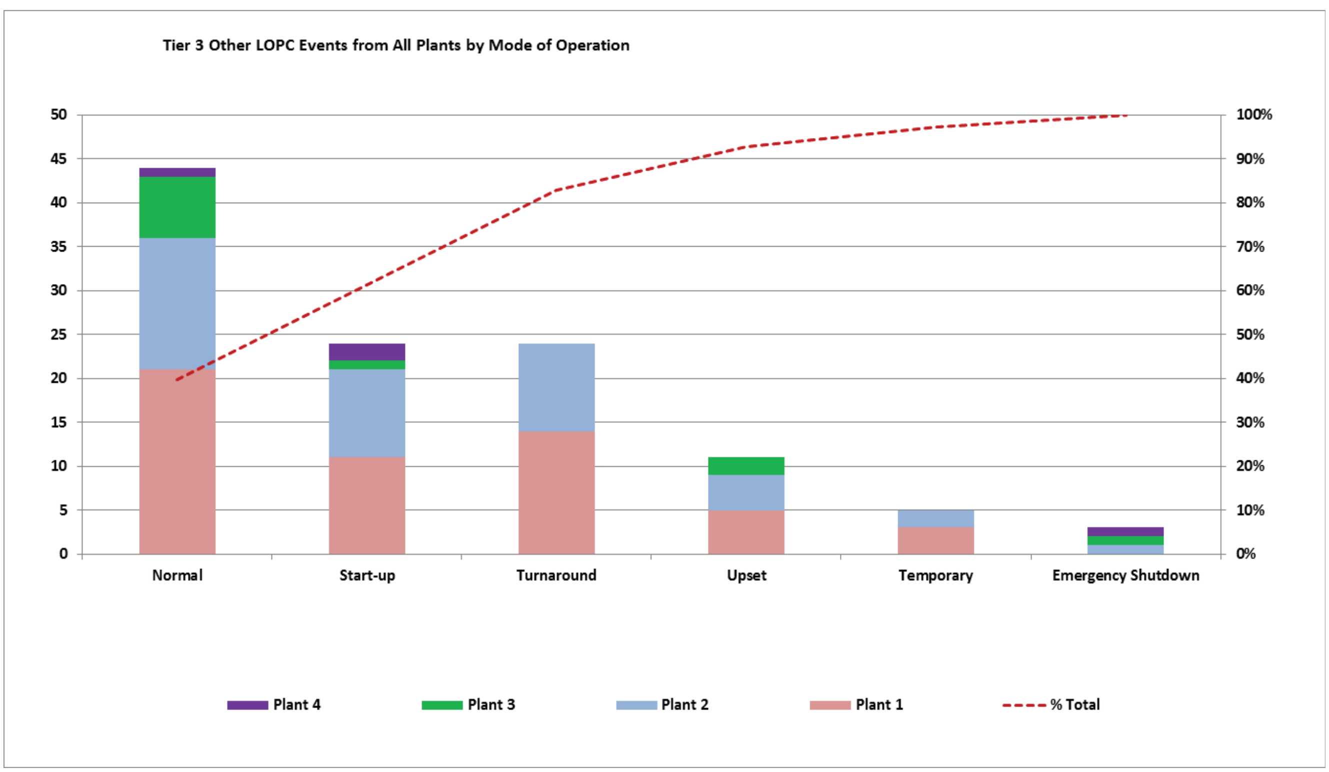


Figure I.11—Example PSE Tier 3 Other LOPC Graph by Plant and Mode of Operation

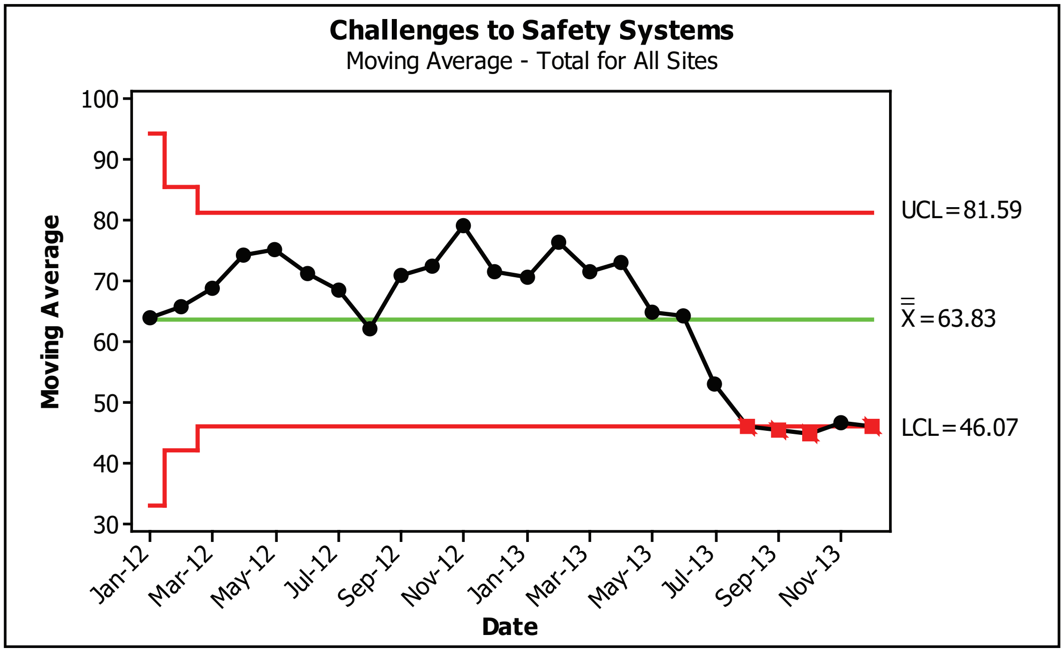


Figure I.12—Example of Moving Average for Demands on Safety Systems

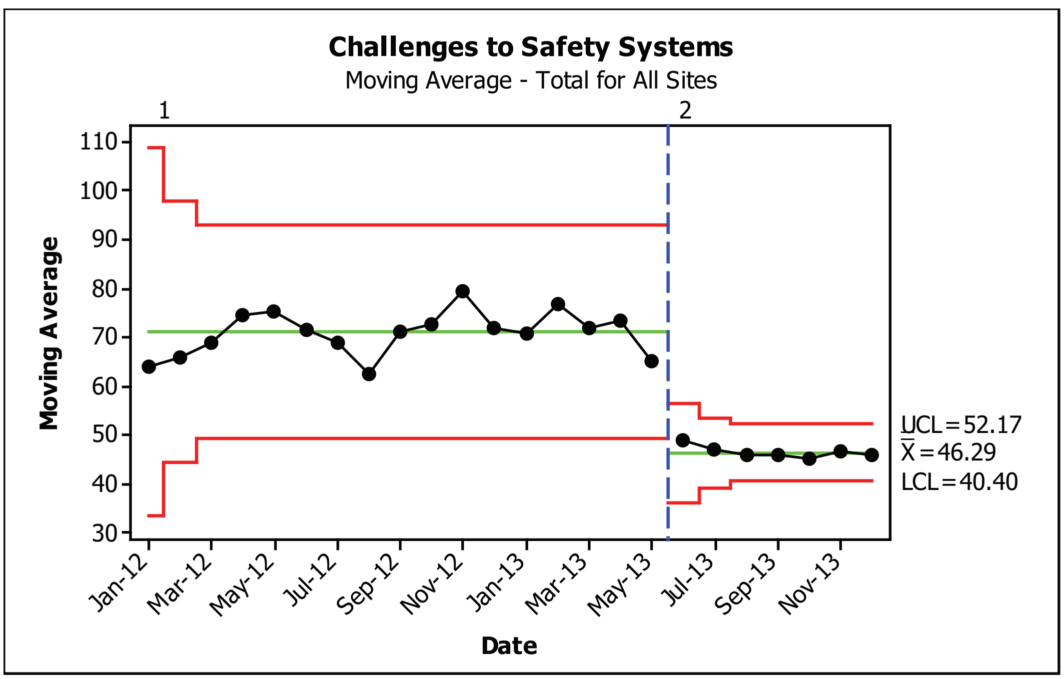


Figure I.13—Example of Moving Average for Demands on Safety Systems—Separated into Stages

The data now has a better fit to the control limits and the average in both stages. The different sets of data were skewing the statistics incorrectly for each other. The first data set (Jan–May) has an upper control limit of 93 and a lower limit of 49. The second data set (Jun–Dec) is different in two ways: 1) the average is substantially lower, and 2) the spread of the control limits is much smaller. This is positive in two ways: 1) fewer demands on safety systems is indicative of safer plant operations, and 2) tighter control limits means the chart will be more sensitive to changes. This means a team can react faster and solve problems before the issues escalate.

I.5.5 Recommend and Improve

The value of any deep dive analysis will be the recommendations and related action plans to improve performance.

Recommendations should apply the principles of being specific, measurable, time-limited and include accountable individual(s) for implementation. As a deep dive analysis of Tier 3 and 4 PSE data progresses, those reviewing and interpreting the information should evaluate whether they have reached a point to draw conclusions and make recommendations. For example, the funneling of Tier 3 Other LOPC data to a stopping point as depicted in Figure I.9 may result in a recommendation for further investigation into the causes of LOPCs from pumps at Company X Plant 1. However, an analyst may want to further interrogate the actual causes of the pump LOPCs to make a more specific recommendation (e.g. common types of pumps failing, mode of operation impacts, etc.).

I.5.6 Management Review

Periodically a management review of the deep dive data analysis should be performed at appropriate levels in a company's organization. Some analysis is best reported and reviewed at a facility-level only, while other analysis should be reviewed with appropriate leaders at a company level. The level of detail presented to various leadership groups should reflect the company's unique organizational structure and operating philosophy.

During the management review sessions, several items may be covered:

a) overview of the process to collect and analyze data;

b) results of the analysis, including important trends and common causes;

c) recommendations developed based on the observed trends;

d) resource requirements to resolve recommendations;

e) results of audits conducted on the data analysis work processes, rules and procedures;

f) other lessons learned from the analysis.

Finally, as part of the management review, it may be beneficial to discuss the overall strategy for Tier 3 and Tier 4 indicators, including challenges with data collection and interpretation, value of individual indicators and whether any changes should be considered. If an indicator is identified as not adding value, communicating that learning to leadership could result in a redeployment of resources to other indicators and process safety improvement activities of greater value.

I.5.7 Audit of Data Collection, Reporting, Analysis, Recommendations

Deep dive data analysis is conducted to provide company leaders with information to identify specific process safety improvement opportunities, to develop action plans, and to assign appropriate resources. Since the deep dive analysis is used for strategic and tactical decision making, it is important to periodically audit the activities involved. This may include audits of the following:

a) Audits of data collection tools, such as databases, spreadsheets, etc. for accuracy.

b) Review of rules and procedures developed for data collection, reporting and aggregation within a site or company.

c) Review of training for individual participants in the data collection and reporting, including an evaluation of their competency and if the initial training was effective.

d) Review of analysis work products, such as formal reports, presentations, calculations, etc. used for recommendation development and management review.

e) Other activities as defined by the company.

In addition, a company may elect to perform focused audits for areas of inconsistency observed during a particular deep dive analysis. For example, Figure I.6 appeared to indicate greater reporting of Tier 3 Other LOPCs at Company X Plants 1 and 2. The Company may consider auditing Plants 3 and 4 to ensure the Tier 3 Other LOPC criteria is well understood and is being properly collected, reported and/or categorized. Conversely, the Company may also consider auditing Plants 1 and 2 to ensure over-reporting and counting of events not meeting the Company's criteria for Tier 3 Other LOPC is not occurring.

Annex J
(informative)

Tier 4 Example Indicators

J.1 Process Hazard Evaluations Completion

Indicator Definition:

Schedule of process area retrospective and revalidation hazard evaluations completed on time by fully qualified teams.

Intent of Indicator:

Process hazards evaluations are foundational studies for effective process safety management. The systematic identification of initiating causes, process deviations, consequences, and prevention and mitigation barriers enables an evaluation of risk, and provides input into other elements of process safety (e.g. operating procedures, mechanical integrity). Completing process hazards evaluations as scheduled using competent teams provides assurance that hazards are understood and that leaders have the information needed for managing risks and making decisions for improving process safety.

Indicator Data Capture:

The count of scheduled retrospective and revalidation process hazard evaluation studies completed on time and by fully qualified teams, and the count of studies scheduled or the count of studies not completed on time or by fully qualified teams for the defined period.

A company will need to define “on time”, “fully qualified teams”, and the measurement period (e.g. quarterly, annual, 5-year).

Indicator Calculation:

Percentage of studies completed on time and by fully qualified teams for the defined period, or

Count of studies not completed on time or not by fully qualified teams for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to identify which process units did not complete the scheduled study on time or by a fully qualified team.

Primary Audience for Indicator:

Site leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of on time and fully qualified teams.

Indicator Frequency:

Quarterly, semi-annually, or annually dependent upon the number of scheduled process hazards evaluations.

Unintended Consequences:

Completion schedules could be changed (authorized or unauthorized) to prevent a study from being overdue. A team could be staffed based upon function rather than competence (e.g. a new rather than an experienced operator could fill the operations team member role).

J.2 Process Safety Action Item Closure

Indicator Definition:

Percentage and/or number of past-due process safety actions.

This may include items from incident investigations, hazard evaluations, or compliance audits.

Intent of Indicator:

Provide assurance that process safety actions are completed in a timely manner. Process safety actions come from a number of sources including, but not limited to process hazard evaluation studies, incident investigations, and compliance audits.

Indicator Data Capture:

The count of process safety actions overdue and the total count of process safety actions expected to be complete within the defined period.

A company will need to define “overdue”, “completion”, and the measurement period (e.g. quarterly, annual, 5-year).

A company may also choose to count the number of process safety actions that are awaiting a shutdown for implementation.

Indicator Calculation:

Percentage of process safety actions overdue for the defined period, or

Cumulative count of process safety actions overdue.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit, by action source (e.g. hazard study, incident investigation, compliance audit), by risk ranking, by consequence type (e.g. safety, environment, operability), by shutdown required, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company-level aggregation will require a consistent facility-to-facility definition of on time, completion, and shutdown required.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of process safety actions.

Unintended Consequences:

Completion dates could be changed (authorized or unauthorized) to prevent an action from being overdue. An action could be marked for implementation during a shutdown if that excludes it from the count of overdue. An action could be marked complete without satisfying the company's definition of completion.

J.3 Training Completed on Schedule

Indicator Definition:

Percentage of process safety required training sessions completed with skills verification.

Intent of Indicator:

Provide assurance that personnel assigned to process safety critical roles have satisfactorily completed required process safety training.

Indicator Data Capture:

The count of required process safety training sessions completed with skills verification and the total count of required process safety training sessions scheduled during the defined period.

A company will need to define "required process safety training", "completion with skills verification", safety critical roles, and the measurement period (e.g. quarterly, annual, 3-year).

Indicator Calculation:

Percentage of process safety required training sessions completed with skills verification for the defined period, or

Count of process safety required training sessions not completed with skills verification for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit, by safety critical role, by required training module, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of required process safety training and safety critical roles.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of process safety required training sessions.

Unintended Consequences:

Completion dates could be changed (authorized or unauthorized) to prevent a required process safety training module from being overdue.

J.4 Procedures Current and Accurate

Indicator Definition:

Percent of process safety required operations and maintenance procedures reviewed or revised as scheduled.

Intent of Indicator:

Provide assurance that process safety related operating and maintenance procedures are current and accurate.

Indicator Data Capture:

The count of required process safety operations and maintenance procedures reviewed or revised and the total count of required process safety operations and maintenance procedures scheduled for review or revision during the defined period.

A company will need to define “required process safety operations and maintenance procedures”, “review or revised” including quality standards, review or revision frequency based upon procedure priority, and the measurement period (e.g. quarterly, annual, 3-year).

Indicator Calculation:

Percentage of required process safety operations and maintenance procedures reviewed or revised for the defined period, or

Count of process safety operations and maintenance procedures not reviewed or revised for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit or maintenance area/type, by procedure priority, by operations or maintenance procedure, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of process safety related operations and maintenance procedures and review or revised including quality standards, and review or revised frequency based upon procedure priority.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of process safety required training sessions.

Unintended Consequences:

Review or revision dates could be changed (authorized or unauthorized) to prevent a required procedure review or revision from being overdue. Quality standards with respect to review or revision could be relaxed to prevent a procedure review or revision from being overdue.

J.5 Work Permit Compliance

Indicator Definition:

Percent of sampled work permits that meet all requirements.

This may include permit to enter, hot work, lockout/tagout, etc.

Intent of Indicator:

Provide assurance that work permits are being issued consistent with company expectations.

Indicator Data Capture:

The count of sampled work permits that meet all requirements and the total count of sampled work permits during the defined period.

A company will need to define which permit types to sample, the minimum sample size by permit type, “meeting all requirements” (e.g. scope of work, hazards identified, PPE, precautions, authorizing signatures) by permit type, and the measurement period (e.g. monthly, quarterly, annual).

Indicator Calculation:

Percentage of sampled work permits that meet all requirements for the defined period, or

Count of sampled work permits that did not meet all requirements for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit or work area, by permit type, by requirement, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of which work permits are included, and meeting all requirements including quality standards.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of work permits.

Unintended Consequences:

Quality standards could be relaxed to satisfy the definition of meeting permit requirements.

J.6 Safety Critical Equipment Inspection

Indicator Definition:

Percent of inspections of safety critical equipment completed on time.

This may include pressure vessels, storage tanks, piping systems, pressure relief devices, pumps, instruments, control systems, interlocks and emergency shutdown systems, mitigation systems, and emergency response equipment.

Intent of Indicator:

Provide assurance that defined inspections of safety critical equipment are being completed on time consistent with company expectations.

Indicator Data Capture:

The count of safety critical equipment inspections completed on time and the total count of safety critical equipment inspections scheduled during the defined period.

A company will need to define the categories of safety critical equipment, the types of inspections or tests, inspection or testing quality standards, and the measurement period (e.g. monthly, quarterly, annual).

Indicator Calculation:

Percentage of safety critical equipment inspections completed on time for the defined period, or

Count of safety critical equipment inspections not completed on time for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit, by equipment type, by inspection or test priority, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of equipment types, inspection or test types, inspection or testing quality standards, and methodology for establishing inspection or testing frequencies.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of safety critical equipment inspections or tests.

Unintended Consequences:

Inspection or testing dates could be changed (authorized or unauthorized) to prevent an inspection or test from being overdue. Inspection or tests could be grouped to skew the results (e.g. piping circuits inspected versus individual piping inspection points). Inspection or testing quality standards could be relaxed to qualify an inspection or test as complete.

J.7 Safety Critical Equipment Deficiency Management

Indicator Definition:

Response to safety critical equipment inspection findings (e.g. non-functional PRDs and SISs).

This may include proper approvals for continued safe operations, sufficient interim safeguards, and timeliness of repairs, replacement, or rerate.

Intent of Indicator:

Provide assurance that the risk associated with non-functional safety critical equipment is managed consistent with company expectations.

Indicator Data Capture:

The count of safety critical equipment inspection findings managed consistent with company expectations and the total count of safety critical equipment inspection findings.

A company will need to define the categories of safety critical equipment, the types of inspections or tests, inspection, “findings” (e.g. degree of impairment), company equipment deficiency management expectations, and the measurement period (e.g. monthly, quarterly, annual).

Indicator Calculation:

Percentage of safety critical equipment inspections findings managed consistent with company expectations for the defined period, or

Count of safety critical equipment inspection findings not managed consistent with company expectations for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit, by equipment type, by management expectation (e.g. authorization for continued operation, timeliness of repair), etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of safety critical equipment, inspection or test findings (e.g. degree of impairment), company equipment deficiency management expectations.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of safety critical equipment inspections or tests.

Unintended Consequences:

The definition of an inspection or test finding could be relaxed to exclude impairment from the data set. Company equipment deficiency management expectations could be relaxed to qualify a finding as properly managed.

J.8 Management of Change (MOC) and Pre Start-up Safety Review (PSSR) Compliance

Indicator Definition:

Percent of sampled MOCs and PSSRs that meet all requirements and quality standards.

Intent of Indicator:

Provide assurance that the MOC and PSSR processes are being executed consistent with company expectations.

Indicator Data Capture:

The count of MOCs and PSSRs that meet all company requirements and quality standards and the total count of MOCs and PSSRs completed within the defined period.

A company will need to define the MOC and PSSR company requirements, quality standards, and the measurement period.

Indicator Calculation:

Percentage of completed MOCs and PSSRs that meet all company requirements and quality standards for the defined period, or

Count of completed MOCs and PSSRs that did not meet all company requirements and quality standards for the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by process unit, by MOC versus PSSR, by temporary or permanent MOC, by company requirements, by quality standards, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of MOC and PSSR company requirements and quality standards.

Indicator Frequency:

Monthly, quarterly, or annually dependent upon the number of completed MOCs and PSSRs.

Unintended Consequences:

The assessment of MOC or PSSR completion could be relaxed to exclude an impairment from the data set. The review of company requirements or quality standards could be relaxed to qualify an MOC or PSSR as meeting expectations.

J.9 Completion of Emergency Response Drills

Indicator Definition:

Percentage of emergency response drills completed as scheduled.

Intent of Indicator:

Provide assurance that emergency response plans and personnel are in place and well drilled.

Indicator Data Capture:

The count of emergency response drills completed and the total count of emergency response drills scheduled within the defined period.

A company will need to define the expectations for emergency response drills (e.g. table top, simulated action, live action, external involvement, etc.), the frequency of emergency response drills, and the measurement period.

Indicator Calculation:

Percentage of emergency response drills completed within the defined period, or

Count of emergency response drills that were not completed within the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by emergency response drill type (e.g. table top, simulated action), by emergency response drill topic (e.g. fire, toxic gas, community impact), by emergency response scope (e.g. unit, multi-unit, facility, off-site), etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of emergency response drill expectations and frequency.

Indicator Frequency:

Quarterly or annually dependent upon the number of scheduled emergency response drills.

Unintended Consequences:

The assessment of whether an exercise meets the company definition of an emergency response drill could be relaxed to inflate the number of completed drills.

J.10 Fatigue Risk Management

Indicator Definition:

Key measures of fatigue risk management systems may include: percentage of overtime, number of open shifts, number of extended shifts, number of consecutive shifts worked, number of exceptions, etc.

Fatigue is reduced mental and physical functioning caused by sleep deprivation and/or being awake during normal sleep hours. This may result from extended work hours, insufficient opportunities for sleep, failure to use available sleep opportunities, or the effects of sleep disorders, medical conditions or pharmaceuticals that reduce sleep or increase sleepiness.

Intent of Indicator:

Provide assurance that fatigue issues are being managed and that the personnel are alert and unimpaired due to fatigue.

Indicator Data Capture:

The count of overtime hours, the count of regularly scheduled hours, the count of open shift positions, the count of consecutive shifts worked, and the count of fatigue management exceptions (e.g. acceptable work shift patterns, minimum rest periods, etc.) within the defined period.

A company will need to define fatigue parameters and terms (e.g. positions covered by the company fatigue management program, extended shift, work pattern, minimum rest, open shift, etc.) and the measurement period. Reference API RP 755, *Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries.* [2]

Indicator Calculation:

Percentage of overtime within the defined period, or

Count of open shifts within the defined period, or

Count of extended shifts within the defined period, or

Count of consecutive shifts worked within the defined period, or

Count of company fatigue management expectations that were not followed within the defined period.

Indicator Drill Down:

A company may choose to configure its management information system to provide a drill down of the indicator by unit or work area, by work group (e.g. operations, maintenance, and engineering) or individual, by fatigue management expectation, etc.

Primary Audience for Indicator:

Facility leadership with possible aggregation at a company level.

Company level aggregation will require a consistent facility-to-facility definition of fatigue management parameters.

Indicator Frequency:

Quarterly, annually, or within defined periods of heavy overtime (e.g. shutdown preparation, shutdown, startup).

Unintended Consequences:

Indicator data is viewed as averages (over a work group or a work period) rather than an indicator of individual worker impairment due to fatigue.

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