

Process Safety Performance Indicators for the Refining and Petrochemical Industries

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Introduction

The purpose of this recommended practice (RP) is to identify leading and lagging indicators for the refining and petrochemical industries, suitable for nationwide public reporting, as well as performance indicators for use at individual facilities including methods for their development and use. 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 trends and 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 RP and any OSHA or other legal requirements, the OSHA or other legal requirements should be fully implemented.

Notes to the Third 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 for the refining and petrochemical industries, suitable for nationwide public reporting, as well as indicators for use at individual facilities including methods for their development and use. 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 trends and underlying causes and taking action to prevent recurrence).

In revising this document, the drafting committee maintained a focus on indicators of process safety performance vs 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 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 10 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. The drafting committee chose to include the equivalent GHS classifications in parallel to the U.S. DOT version of the United Nations Dangerous Goods (UNDG) hazard classifications. The GHS system offers analogous categories to nearly all toxic, flammable, and corrosive characteristics identified by the U.S. DOT version of UNDG hazard classification. In addition, a variety of GHS categories were aligned to specific packing group material classifications. Another significant change was regarding how corrosives are viewed in relation to process safety events. Given the localized effects of corrosive loss of primary containments (LOPCs) compared to flammables and toxics, the committee chose to reduce the material hazard classification for corrosive agents to better align with the other hazard classes.

Other significant continuous improvement changes include:

- clarifications to the definitions of primary and secondary containment, direct cost, indoor release, and unsafe location;
- making process safety event (PSE) severity weighting reporting mandatory;
- expanding the resolution and usefulness of causal data collected by adding an additional layer of causes under each primary cause;
- expanded the data collection capability to include non-petroleum-based chemical facilities.

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 subsegments, informative annexes have been created to define the Applicability and Process definition for those subsegments. 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 RP applies to the responsible party. At co-located facilities (e.g. industrial park), this RP 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;

NOTE The boundary between marine transport operations and in the process of connecting to or disconnecting from the process is the first/last step in loading/unloading procedure (e.g. first line ashore, last line removed, etc.).

- 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 1 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.

NOTE 2 The boundary between truck or rail transport operations and in the process of connecting to or disconnecting from the process is the first/last step in loading/unloading procedure (e.g. wheel chocks, set air brakes, disconnect master switch, etc.).

- 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 5.2 and 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 LOPC event;
- h) LOPC events from ancillary equipment not connected to the process;
- 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 RP 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 prevent or mitigate incidents. Barriers can also be classified as active, passive, or administrative/procedural. Holes can be latent, incipient, or actively opened by people.

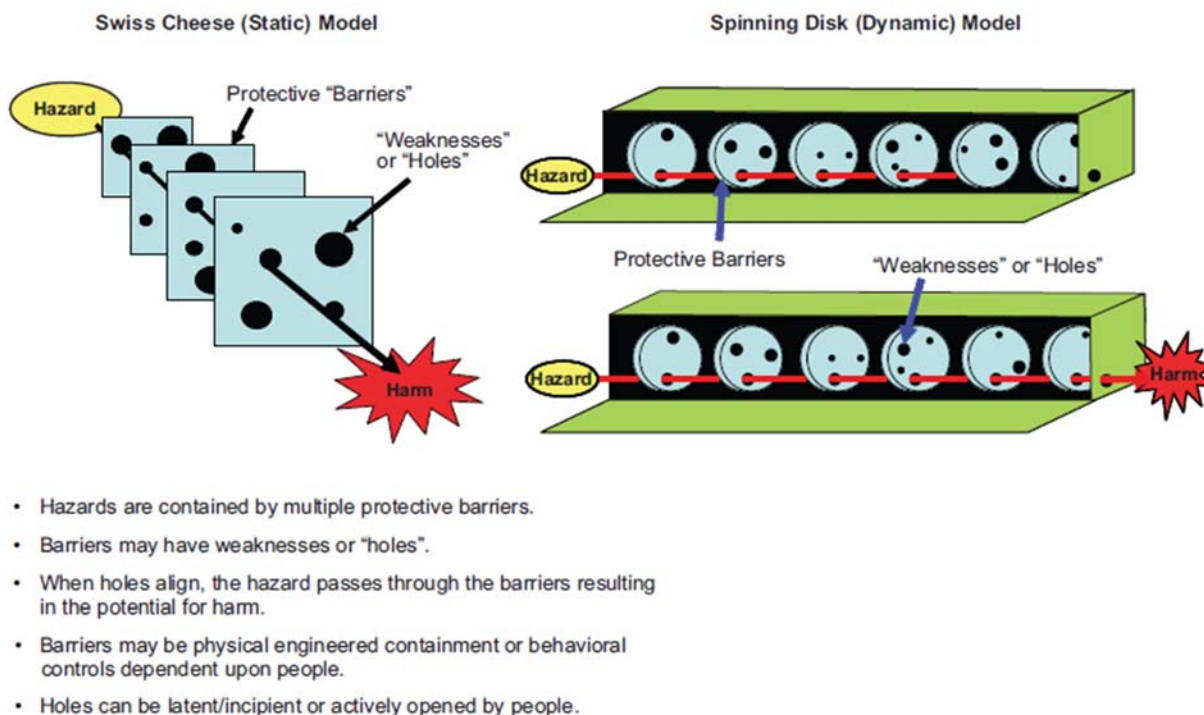


Figure 1—"Swiss Cheese (Static) Model" and "Spinning Disk (Dynamic) Model"

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.

There are no normative references.

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 *Globally Harmonized System of Classification and Labeling of Chemicals* (GHS) Skin Corrosion Category 1B^[19] or substances with $\text{pH} \geq 1$ and < 2 , or $\text{pH} > 11.5$ and ≤ 12.5 . Either definition may be used for classification. The GHS definition is considered more precise for skin corrosion classification; however, the availability of this measurement may preclude its use.

NOTE GHS Skin Corrosion Category 1B^[19] is defined as substances that cause destruction of skin tissue, namely visible necrosis through the epidermis and into the dermis in at least one animal following exposure > 3 minutes and ≤ 1 hour and observations ≤ 14 days.

3.1.2

acids/bases, strong

Substances with GHS Skin Corrosion Category 1A^[19] or substances with $\text{pH} < 1$ or $\text{pH} > 12.5$. Either definition may be used for classification. The GHS definition is considered more precise for skin corrosion classification; however, availability of this measurement may preclude its use.

NOTE GHS Skin Corrosion Category 1A ^[19] is defined as substances that cause destruction of skin tissue, namely visible necrosis through the epidermis and into the dermis in at least one animal after exposure ≤ 3 minutes during an observation period ≤ 1 hour.

3.1.3

acids/bases, weak

Substances with GHS Skin Corrosion Category 1C ^[19] or substances with a $\text{pH} \geq 2$ or $\text{pH} \leq 11.5$. Either definition may be used for classification. The GHS definition is considered more precise for skin corrosion classification; however, availability of this measurement may preclude its use.

NOTE GHS Skin Corrosion Category 1C ^[19] is defined as substances that cause destruction of skin tissue, namely, visible necrosis through the epidermis and into the dermis in at least one animal after exposures > 1 hour and ≤ 4 hours and observations ≤ 14 days.

3.1.4

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.

3.1.5

active warehouse

An on-site building, structure, or designated area 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.).

3.1.6

acute environmental cost

Cost of short-term cleanup and material disposal associated with a LOPC with off-site environmental impact.

3.1.7

ancillary equipment

Equipment necessary to support the purpose and function of process equipment (e.g. lubricating systems, process seal barrier fluid, additive injection, hydraulic or pneumatic actuators, sample containers, etc.).

3.1.8

Company

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

3.1.9

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.

Primary containment also includes closed systems that have a pressure boundary such that there is no exposure of process material to the atmosphere. Where there is a pressure boundary, liquids and vapors are recovered or controlled, and at no time is material directly in contact with the atmosphere. Examples include closed drainage or collection systems, rapid deinventory systems, double-walled tanks, etc.

3.1.10**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, open drainage collection systems, trenches, pits, open sumps, the outer wall of open-top double-walled tanks, etc.

3.1.11**contractor and subcontractor**

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

3.1.12**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.

3.1.13**deflagration**

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

3.1.14**deflagration vent**

An opening in a vessel or duct that when activated 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).

3.1.15**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. pressure-relief device (PRD), safety instrumented system (SIS), or manually initiated emergency depressure] device release.

3.1.16**detonation**

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

3.1.17**direct cost**

Fire or explosion direct cost includes the material and labor cost of (1) in-kind repairs, replacement, or restoration of process and non-process equipment and tangible public or private property to pre-event condition whether completed or not, (2) aftermath cleanup, (3) material disposal, and (4) short-term cleanup and material disposal associated with fire/explosion emergency response efforts that result in off-site environmental impact (e.g. fire-fighting foam/water runoff).

Direct cost does not include the cost of (1) emergency response personnel, equipment, materials, and supplies utilized to manage the event or incidental damage caused by the emergency response, (2) engineering or inspection assessments to determine the extent of damage or necessary repairs, (3) opportunity upgrades to materials or technology, (4) superficial or cosmetic only damage that does not affect function or performance to company-owned process and non-process equipment, (5) indirect costs, such as business opportunity, business interruption, fines, and feedstock/product losses, (6) loss of profits due to equipment outages, costs of obtaining or operating temporary facilities, or (7) 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 fire or explosion.

3.1.18**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.).

3.1.19**explosion**

A release of energy that causes a pressure discontinuity or blast wave (e.g. detonations, deflagrations, and rapid releases of high pressure, e.g. a sudden phase change of material).

3.1.20**facility**

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

3.1.21**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.

3.1.22**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).

3.1.23**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], ASTM D3941-14 ^[6], ASTM D56-05 ^[7], or other equivalent test methods appropriate to the material characteristics and flash point range specified in the test procedure.

3.1.24**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."

3.1.25**indoor release**

A release within a structure composed of four walls, floor, and roof.

NOTE The potential consequences of indoor releases are magnified due to hazards associated with congestion, confinement, personnel proximity, and limitations on egress. Open doors or windows and powered or natural ventilation systems do not change the definition of indoor.

3.1.26**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 CO₂, or compressed air).

NOTE The duration of the material release is assessed from the beginning of the release to the end of the release, not from the beginning of the release to the containment or mitigation of the release.

3.1.27**major construction projects**

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

3.1.28**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.

3.1.29**moderate acids/bases**

See **acids/bases, moderate**.

3.1.30**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.

3.1.31**office building**

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

3.1.32**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).

3.1.33**oil barrel**

1 oil barrel = 42 gallons = 0.159 M³.

3.1.34**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.

3.1.35**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 a LOPC independent of or prior to any assessment (e.g. wind direction, distance from the LOPC, etc.) of the potential hazard to the 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 PSE, 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).

3.1.36**pressure-relief device****PRD**

A device designed to open and relieve excess pressure [e.g. safety valve (SV), thermal relief, rupture disk, rupture pin, deflagration vent, pressure/vacuum (PV) 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.

3.1.37**primary containment**

See **containment, primary**.

3.1.38**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, associated ancillary equipment, etc.), storage tanks, active warehouses, support areas (e.g. boiler houses and wastewater treatment plants), on-site remediation facilities, and distribution piping under control of the Company.

3.1.39**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.

3.1.40**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 CO₂, 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.

3.1.41**public receptors**

Off-site 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.

3.1.42**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 or the evidence that the remaining liquid has fallen to grade or ground.

3.1.43**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]

3.1.44**research and development laboratory****R&D laboratory**

A facility that provides controlled conditions in which scientific or technological research, experiments, and measurement may be performed.

3.1.45**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 PSE. 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 PSE?

3.1.46**safety instrumented system****SIS**

An instrumented protection layer whose purpose is to take the process to a safe state when predetermined conditions are violated.

3.1.47**secondary containment**

See **containment, secondary**.

3.1.48**shelter-in-place**

The use of a structure or portion of a structure and its indoor atmosphere to temporarily separate individuals from a potentially hazardous outdoor atmosphere.

3.1.49**strong acids/bases**

See **acids/bases, strong**.

3.1.50**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.].

3.1.51**tolling operation**

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

3.1.52**total work hours**

Total employee, contractor, and subcontractor hours at a facility worked minus the hours associated with any major construction projects (see 3.1.27 for definition) at that facility. This is the same number typically used to calculate a facility occupational injury and illness rate.

NOTE Total work hours is used as a normalizing factor to calculate a process safety event rate. The normalized rate data can then be used to compare the performance of various size and complexity facilities, the performance of different industry sectors, and performance over time. Subtracting major construction hours from the total work hours for a facility prevents an anomaly in the rate data due to these limited duration projects with work hours that could significantly exceed the traditional work hours at a facility.

3.1.53**turnaround**

A work activity where an entire process unit or a major section of a unit is shut down for a period of time for the purpose of inspection, maintenance, or modification.

3.1.54**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. DOT 49 *CFR* 173.2a ^[22] and listed in U.S. DOT 49 *CFR* 172, Subpart B ^[21].

3.1.55**United Nations Dangerous Goods (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]

3.1.56**unsafe location**

An atmospheric PRD or upset emission discharge or a downstream destructive device (e.g. flare, scrubber) discharge that results in a potential hazard to personnel, whether present or not, due to the formation of flammable mixtures at ground level or on elevated work structures, presence of toxic or corrosive materials at ground level or on elevated work structures, or thermal radiation effects at ground level or on elevated work structures from ignition of relief streams at the point of emission as specified in API 521, Section 5.8.4.4. ^[1]

Excluded from the definition of an unsafe location are those ground level and elevated work structure locations that have a known potential for exposure of personnel to flammable mixtures, toxic substances, corrosive materials, or thermal radiation effects if access to those locations is controlled by virtue of authorized access or hard barriers with appropriate warning signs.

NOTE The term “unsafe location” is used in the description of one of the four potential Tier 1 or Tier 2 consequences associated with an engineered pressure relief or an upset emission from a permitted or regulated source. The assumption is the discharge from the engineered pressure relief whether directly to atmosphere or via a downstream destructive device or the emission from a permitted or regulated source are engineered for safe dispersion of the release.

3.1.57**upset emission**

Any condition that exceeds the documented permit parameters or conditions associated with routine emission from a permitted or regulated source. This could include process parameters such as temperature, pressure, volume, rate, concentration, and duration or release conditions such as timing, location, day/night, wind speed/direction, and simultaneous operations.

NOTE Upset emission applies to specific identified assets (e.g. furnace stacks) and not general or fugitive emission sources (e.g. seals, packing) that are covered under blanket or site-wide permitting.

3.1.58**weak acids/bases**

See **acids/bases, weak**.

3.2 Acronyms and Abbreviations

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

CCPS	Center for Chemical Process Safety
FCC	fluid catalytic cracking
GHS	<i>Globally Harmonized System of Classification and Labeling of Chemicals</i>
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
PRD	pressure-relief device
PSE	process safety event
PSSR	pre-start-up safety review
PV	pressure/vacuum
QA	quality assurance
QC	quality control
R&D	research and development
SDS	safety data sheet
SIS	safety instrumented system
SOL	safe operating limit
SV	safety valve
TIH	toxic inhalation hazard
TRC	threshold release category
UNDG	United Nations Dangerous Goods

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 incidents.

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 incident 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 PSEs 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.

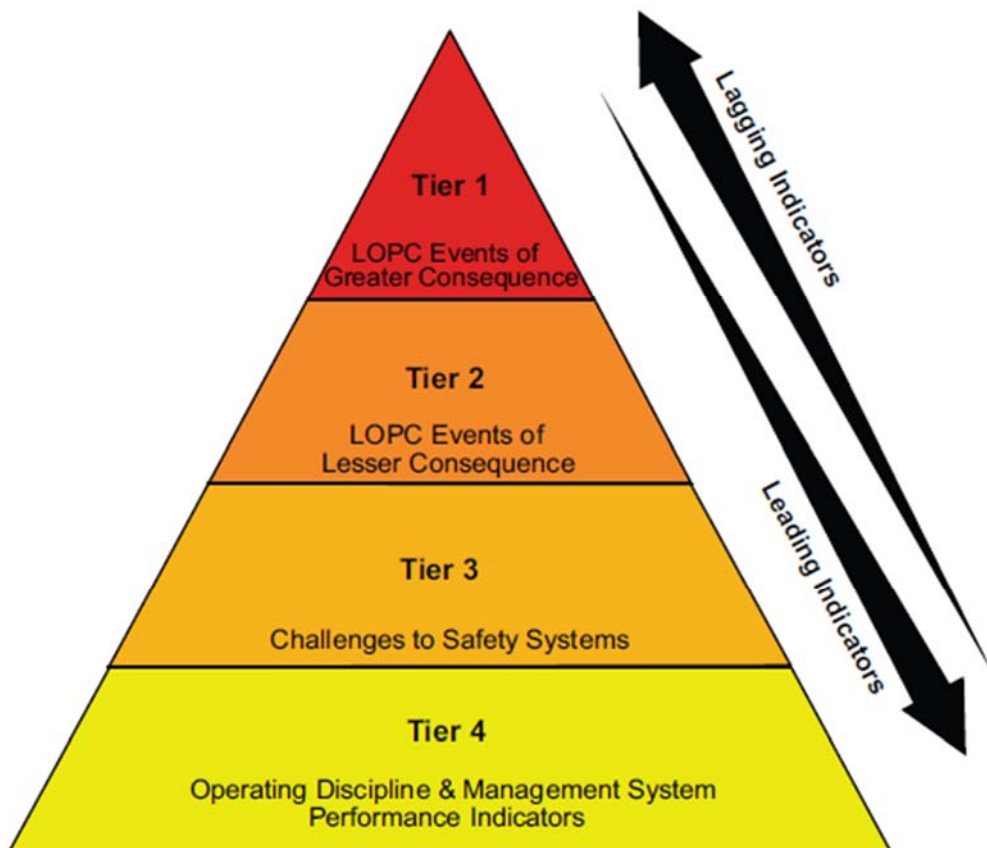


Figure 2—Process Safety Indicator Pyramid

5 Tier 1 Performance Indicator—Process Safety Event

5.1 Tier 1 Indicator Purpose

The count of Tier 1 PSEs is the most lagging performance indicator and represents LOPC events of greater consequence. Tier 1 PSEs, even those that have been captured within secondary containment, 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 PSE is a LOPC with the greatest consequence as defined by this RP. A Tier 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 CO₂ 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 PRD, 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 1-hour period, to atmosphere whether directly or via a downstream destructive device that results in one or more of the following four consequences. The threshold quantity determination is made at the discharge of the engineered PRD, while the consequence is determined when the material reaches atmosphere whether directly or via a downstream destructive device.
 - 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 1-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.
- An unignited release of material greater than or equal to the threshold quantities described in Table 1 in any 1-hour period, excluding engineered pressure-relief discharges and upset emissions from permitted or regulated sources.

NOTE 1 In determining the threshold release category (TRC), 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 (SDS). Companies should be consistent in their approach for all LOPCs.

NOTE 2 The material hazard classification in this document is not related to piping service classes in API 570 nor any other material class descriptions in other API documents.

NOTE 3 Engineered pressure-relief discharges and upset emissions from permitted or regulated sources are special-case LOPCs with their own criteria for classification as a Tier 1 PSE.

Tables E.1 through E.16 in Annex E, PSE Examples and Questions, provide a wide variety of examples to assist companies in determining the proper classification of Tier 1.

Figure H.1 in Annex H, PSE Tier 1/Tier 2 Determination Decision Logic Tree, provides a flowchart to assist companies in determining if a LOPC is a Tier 1 or Tier 2 PSE.

5.2.3 Table 1 TRCs

Table 1 (Tier 1 and Tier 2 threshold release quantities) is organized by TRCs. Each TRC lists the specific materials included in that category using one of two material hazard classification descriptions. Option 1 primarily uses toxic inhalation hazard (TIH), DOT, and UNDG language, while Option 2 primarily utilizes GHS language. For each material involved in a LOPC, a company will determine the TRC and the corresponding threshold release quantity using one of these two descriptors. The two material hazard classification options are substantially, but not exactly, equivalent for some materials. As a result, a company may choose either option, but once chosen, they should apply that option consistently to all LOPC classifications.

When using material hazard classification Option 1 to determine the TRC, a company should first use the toxic, flammable, or corrosive characteristic of the material. If the TRC cannot be determined from these characteristics, then and only then is the packing group descriptor used.

Released materials may represent more than one hazard type (e.g. toxic, flammable, corrosive) dependent upon its composition and physical state. Annex G, Application of TRCs to Multicomponent Releases, describes the rule set for determining the TRC for a variety of multicomponent streams. When a single component has multiple hazards (e.g. toxic and flammable), the TRC category that gives the most severe tier rating should be used. Additionally, Annex F describes the process for assigning packing groups and TIH zones based upon flammability and toxicity information.

In determining the TRC, 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.

Annex E, Table E.5 provides a number of examples for determining the TRC of mixtures and solutions.

Annex F, Listing of Chemicals Sorted by Threshold Quantity, provides a link to the Center for Chemical Process Safety (CCPS) comprehensive list of chemicals with associated release threshold quantities.

5.3 Calculation of Tier 1 PSE Rate

The Tier 1 PSE Rate shall be calculated as follows:

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

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

NOTE 1 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 3.1.52 for definition).

NOTE 2 If a company chooses to calculate an aggregated PSE Rate for their organization (e.g. segment, region, corporate), they would do so by aggregating the Total Work Hours and the PSE Count of the facilities included in the aggregation.

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

5.4 Tier 1 PSE Severity Weighting

A severity weight for each Tier 1 PSE shall be calculated by summing the points associated with each consequence category utilizing the methodology shown in Annex D.

Table 1—Material Release Threshold Quantities

Threshold Release Category	Material Hazard Classification Option 1	Material Hazard Classification Option 2	Tier 1		Tier 2	
			Threshold Quantity (Outdoor)	Threshold Quantity (Indoor)	Threshold Quantity (Outdoor)	Threshold Quantity (Indoor)
TRC 1	TIH Zone A materials	H330 Fatal if inhaled, acute toxicity, inhalation (ch. 3.1) (cat. 1)	≥ 5 kg (11 lb)	≥ 0.5 kg (1.1 lb)	≥ 0.5 kg (1.1 lb)	≥ 0.25 kg (0.55 lb)
TRC 2	TIH Zone B materials	H330 Fatal if inhaled, acute toxicity, inhalation (ch. 3.1) (cat. 2)	≥ 25 kg (55 lb)	≥ 2.5 kg (5.5 lb)	≥ 2.5 kg (5.5 lb)	≥ 1.25 kg (2.75 lb)
TRC 3	TIH Zone C materials	H331 Toxic if inhaled, acute toxicity, inhalation (ch. 3.1) (cat. 3)	≥ 100 kg (220 lb)	≥ 10 kg (22 lb)	≥ 10 kg (22 lb)	≥ 5 kg (11 lb)
TRC 4	TIH Zone D materials	H332 Harmful if inhaled, acute toxicity, inhalation (ch. 3.1) (cat. 4)	≥ 200 kg (440 lb)	≥ 20 kg (44 lb)	≥ 20 kg (44 lb)	≥ 10 kg (22 lb)
TRC 5	Flammable gases	H220 Extremely flammable gas, flammable gases (ch. 2.2) (cat. 1A) H221 Flammable gas, flammable gases (ch. 2.2) (cat. 1B,2)	≥ 500 kg (1100 lb)	≥ 50 kg (110 lb)	≥ 50 kg (110 lb)	≥ 25 kg (55 lb)
	Liquids with normal boiling point ≤ 35 °C (95 °F) and flash point < 23 °C (73 °F)	H224 Extremely flammable liquid and vapor, flammable liquids (ch. 2.6) (cat. 1)				
	Other Packing Group I materials (excluding acids/bases and excluding UNDG Class 1; Class 2.2; Class 4.2; Class 4.3; Class 7; and Class 9 materials)	H228 Flammable solid, flammable solids (ch. 2.7) (cat. 1,2) H230 May react explosively even in the absence of air, flammable gases (ch. 2.2) (chemically unstable gas cat. A) H231 May react explosively even in the absence of air at elevated pressure and/or temperature, flammable gases (ch. 2.2) (chemically unstable gas cat. B) H232 May ignite spontaneously if exposed to air, flammable gases (ch. 2.2) (cat. 1A pyrophoric gas) H250 Catches fire spontaneously if exposed to air, pyrophoric liquids and pyrophoric solids (ch. 2.9 & 2.10) (cat. 1) H310 Fatal in contact with skin, acute toxicity, dermal (ch. 3.1) (cat. 1)				

			Tier 1		Tier 2	
Threshold Release Category	Material Hazard Classification Option 1	Material Hazard Classification Option 2	Threshold Quantity (Outdoor)	Threshold Quantity (Indoor)	Threshold Quantity (Outdoor)	Threshold Quantity (Indoor)
TRC 6	Liquids with normal boiling point > 35 °C (95 °F) and flash point < 23 °C (73°F)	H225 Highly flammable liquid and vapor, flammable liquids (ch. 2.6) (cat. 2)	≥ 1000 kg (2200 lb) or ≥ 7 oil bbl	≥ 100 kg (220 lb) or ≥ 0.7 oil bbl	≥ 100 kg (220 lb) or ≥ 0.7 oil bbl	≥ 50 kg (110 lb) or ≥ 0.35 oil bbl
	Crude oil ≥ 15 API Gravity (unless actual flash point available)	Crude oil ≥ 15 API Gravity (unless actual flash point available)				
	Other Packing Group II materials (excluding acids/bases and excluding UNDG Class 1; Class 2.2; Class 4.2; Class 4.3; Class 7; and Class 9 materials)	H240 Heating may cause an explosion, self-reactive substances and mixtures and organic peroxides (ch. 2.8 & 2.15) (type A) H241 Heating may cause a fire or explosion, self-reactive substances and mixtures and organic peroxides (ch. 2.8 & 2.15) (type B) H242 Heating may cause a fire, self-reactive substances and mixtures and organic peroxides (ch. 2.8 & 2.15) (types C–F) H271 May cause fire or explosion; strong oxidizer, oxidizing liquids and oxidizing solids (ch. 2.13 & 2.14) (cat. 1) H310 Fatal in contact with skin, acute toxicity, dermal (ch. 3.1) (cat. 2)				
TRC 7	Liquids with flash point ≥ 23 °C (73 °F) and ≤ 60 °C (140 °F)	H226 Flammable liquid and vapor, flammable liquids (ch. 2.6) (cat. 3)	≥ 2000 kg (4400 lb) or ≥ 14 oil bbl	≥ 200 kg (440 lb) or ≥ 1.4 oil bbl	≥ 200 kg (440 lb) or ≥ 1.4 oil bbl	≥ 100 kg (220 lb) or ≥ 0.7 oil bbl
	Liquids with flash point > 60 °C (140 °F) released at a temperature at or above flash point	H227 Combustible liquid, flammable liquids (ch. 2.6) (cat. 4) [**Released at a temperature at or above flash point **] Liquids with flash point > 93 °C (200 °F) released at a temperature at or above flash point				
	Crude oil < 15 API Gravity (unless actual flash point available)	Crude oil < 15 API Gravity (unless actual flash point available)				
	UNDG Class 2, Division 2.2 (non-flammable, non-toxic gases) excluding air	H270 May cause or intensify fire; oxidizer oxidizing gases (ch. 2.4) (cat. 1) UNDG Class 2, Division 2.2 (non-flammable, non-toxic gases) excluding air				
	Other Packing Group III materials (excluding acids/bases and excluding UNDG Class 1; Class 2.2; Class 4.2; Class 4.3; Class 7; and Class 9 materials)	H272 May intensify fire; oxidizer, oxidizing liquids and oxidizing solids (ch. 2.13 & 2.14) (cat. 2,3) H311 Toxic in contact with skin, acute toxicity, dermal (ch. 3.1) (cat. 3)				

			Tier 1		Tier 2	
Threshold Release Category	Material Hazard Classification Option 1	Material Hazard Classification Option 2	Threshold Quantity (Outdoor)	Threshold Quantity (Indoor)	Threshold Quantity (Outdoor)	Threshold Quantity (Indoor)
TRC 8	Liquids with flash point > 60 °C (140 °F) and ≤ 93 °C (200 °F) released at a temperature below flash point	H227 Combustible liquid, flammable liquids (ch. 2.6) (cat. 4) [**Released at a temperature below flash point **]	N/A	N/A	≥ 1000 kg (2200 lb)	≥ 500 kg (1100 lb)
	Strong acids/bases (see definition 3.1.2)	H314 Causes severe skin burns, skin corrosion/irritation (ch. 3.2) (cat. 1A)			or	or
	No equivalent	H370 Causes damage to organs, specific target organ toxicity, single exposure (ch. 3.8) (cat. 1)			≥ 7 oil bbl	≥ 3.5 oil bbl
NOTE 1 It is recognized that threshold quantities given in kg or lb and bbl are not exactly equivalent. Companies should select one of the pair and use it consistently for all recordkeeping activities.						
NOTE 2 Refer to 5.2.3 for guidance on selecting the correct TRC and the use of material hazard classification Option 1 and Option 2.						

6 Tier 2 Performance Indicator—Process Safety Events

6.1 Tier 2 Indicator Purpose

The count of Tier 2 PSEs represents LOPC events of lesser consequence. Tier 2 PSEs, even those that have been captured within secondary containment, 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 PSE is a LOPC with lesser consequence. A Tier 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 CO₂, 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 PRD, 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.

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 1 in any 1-hour period, to atmosphere whether directly or via a downstream destructive device that results in one or more of the following four consequences. The threshold quantity determination is made at the discharge of the engineered PRD, while the consequence is determined when the material reaches atmosphere whether directly or via a downstream destructive device.
 - 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 1-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.
- An unignited release of material greater than or equal to the threshold quantities described in Table 1 in any 1-hour period, excluding engineered pressure-relief discharges and upset emissions from permitted or regulated sources.

NOTE 1 In determining the TRC, 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.

NOTE 2 The material hazard classification in this document is not related to piping service classes in API 570 nor any other material class descriptions in other API documents.

NOTE 3 Engineered pressure-relief discharges and upset emissions from permitted or regulated sources are special-case LOPCs with their own criteria for classification as a Tier 2 PSE.

Tables E.1 through E.16 in Annex E, PSE Examples and Questions, provide a wide variety of examples to assist companies in determining the proper classification of Tier 2.

Figure H.1 in Annex H, PSE Tier 1/Tier 2 Determination Decision Logic Tree, provides a flowchart to assist companies in determining if a LOPC is a Tier 1 or Tier 2 PSE.

6.3 Calculation of Tier 2 PSE Rate

The Tier 2 PSE rate shall be calculated as follows:

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

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

NOTE 1 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 3.1.52 for definition).

NOTE 2 If a company chooses to calculate an aggregated PSE Rate for their organization (e.g. segment, region, corporate), they would do so by aggregating the Total Work Hours and the PSE Count of the facilities included in the aggregation.

The choice of calculating PSE Rate utilizing either a 200,000 or 1,000,000 work 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 (SOL) 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 SOL Excursions

7.2.1.1 Indicator Definition

A process parameter deviation that exceeds the 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 SIS.

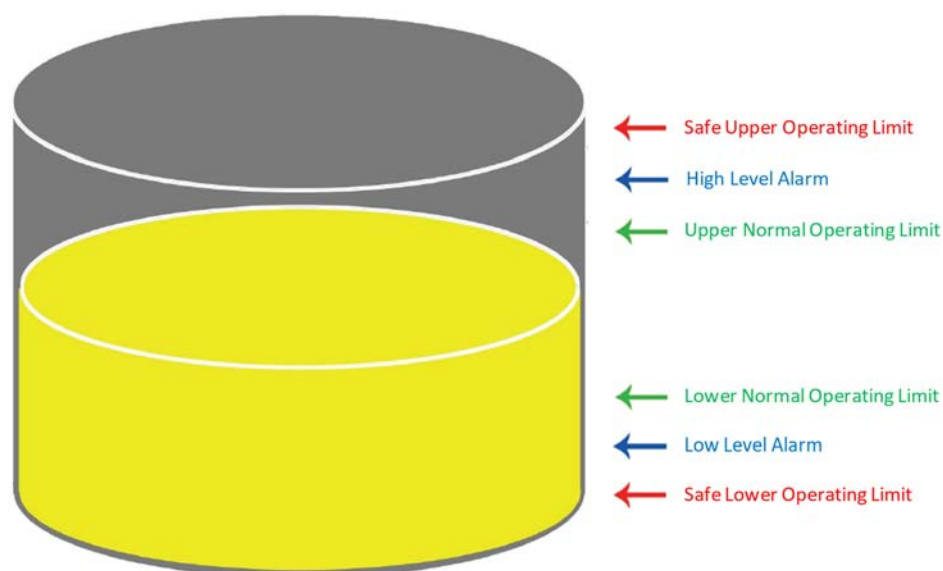


Figure 3—Example of Safe Operating Limit for Tank Level



Documents

Document Sharing Hub

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 demands on safety systems.

7.2.3.2 Indicator Data Capture

7.2.3.2.1 General

A Tier 3 PSE is counted for each demands on safety systems event when one of the following occurs:

- activation of a SIS;
- activation of a mechanical shutdown system;
- 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 SIS

A SIS 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 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 to protect the same equipment are to be counted as a single device (e.g. multiple SVs sized to handle large relief loads or staged to minimize the potential for chattering, SV and rupture disk combinations). 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 shutdown system). 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 shutdown system 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 events 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 Operating Discipline and Management System, 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 Operating Discipline and Management 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 Operating Discipline and Management System 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.

- *Process Hazard Evaluations Completion*—Schedule of process area retrospective and revalidation hazard evaluations completed on time by fully qualified teams.
- *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.
- *Training Completed on Schedule*—Percentage of process safety required training sessions completed with skills verification.
- *Procedures Current and Accurate*—Percent of process safety required operations and maintenance procedures reviewed or revised as scheduled.
- *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.
- *Safety Critical Equipment Inspection*—Percent of inspections of safety critical equipment completed on time. This may include pressure vessels, storage tanks, piping systems, PRDs, pumps, instruments, control systems, interlocks and emergency shutdown systems, mitigation systems, and emergency response equipment.
- *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.
- *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.
- *Completion of Emergency Response Drills*—Percentage of emergency response drills completed as scheduled.
- *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:

- AIChE CCPS, *Guidelines for Process Safety Metrics*, New York, 2009; ^[9]
- UK HSE, *Developing Process Safety Indicators: A Step-by-Step Guide for Chemical and Major Hazard Industries*, Series Code HSG254, Sudbury, Suffolk, UK, 2006; ^[17]

- Hopkins, A., “Thinking About Process Safety Indicators,” Working Paper 53 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 vs 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 or mitigate 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 2. 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 5 years.

Table 2—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 nationwide public reporting include the following.

- Company Specific Reports or Websites*—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 website or as a written report provided upon request by any interested party.
- Industry Association or Professional Society Reports or Websites*—API, American Chemistry Council (ACC), American Fuel and Petrochemical Manufacturers (AFPM), Center for Chemical Process Safety (CCPS), United Kingdom Petroleum Industry Association (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 websites 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.
- Government Agency or Other Organizations*—Local, state, or national government agencies, or other organizations may elect to establish reporting websites.

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 PSE 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 1-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 1-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) TRC 1,
 - ii) Tier 1 (Table 1) TRC 2,

- iii) Tier 1 (Table 1) TRC 3,
- iv) Tier 1 (Table 1) TRC 4,
- v) Tier 1 (Table 1) TRC 5,
- vi) Tier 1 (Table 1) TRC 6,
- vii) Tier 1 (Table 1) TRC 7;

release location (check one):

- i) outdoor release,
- ii) indoor release;

8) Tier 1 PSE severity weight.

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 PSE 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 1 in any 1-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 1 in any 1-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 1) TRC 1,
 - ii) Tier 2 (Table 1) TRC 2,
 - iii) Tier 2 (Table 1) TRC 3,
 - iv) Tier 2 (Table 1) TRC 4,
 - v) Tier 2 (Table 1) TRC 5,
 - vi) Tier 2 (Table 1) TRC 6,
 - vii) Tier 2 (Table 1) TRC 7,
 - viii) Tier 2 (Table 1) TRC 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, hydrofluoric (HF),

- iii) alkylation, sulfuric,
 - iv) bitumen/resid/asphalt,
 - v) calcining,
 - vi) coking,
 - vii) crude/vacuum distillation,
 - viii) fluid catalytic cracking (FCC),
 - ix) flares/flare systems/flare gas recovery
 - x) gas and liquid desulfurization/treating (H₂S absorbers, amine systems, Merox),
 - xi) hydrogen,
 - xii) hydrotreating,
 - xiii) hydrocracking,
 - xiv) isomerization,
 - xv) loading/unloading/truck/rail/transport vessel,
 - xvi) marine/jetty/wharf,
 - xvii) pilot plant,
 - xviii) polymerization,
 - xix) reforming,
 - xx) sulfur recovery,
 - xxi) tank farm/storage facility/off-sites/storage and transfer piping,
 - xxii) utilities/steam plant/cogeneration,
 - xxiii) vapor recovery/light ends,
 - xxiv) sewer/lift station/wastewater handling, treatment, or disposal,
 - xxv) other (describe);
- 2) petrochemical processes (check one):
- i) active warehouse,
 - ii) synthesis gas (CO, H₂),
 - iii) liquified natural gas (LNG),
 - iv) methane,
 - v) methanol,