Process Safety Performance Indicators for the Refining and Petrochemical Industries

ANSI/API RECOMMENDED PRACTICE 754
THIRD EDITION, AUGUST 2021

American
Petroleum
Institute

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed. The use of API publications is voluntary. In some cases, third parties or authorities having jurisdiction may choose to incorporate API standards by reference and may mandate compliance.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the standard.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the standard.

May: As used in a standard, "may" denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, "can" denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

Page

1 Scope . . . 1
1.1 General . . . 1
1.2 Applicability . . . 1
1.3 Guiding Principles . . . 2
1.4 Introduction . . . 2

2 Normative References . . . 3

3 Terms, Definitions, Acronyms and Abbreviations . . . 3
3.1 Terms and Definitions . . . 3
3.2 Acronyms and Abbreviations . . . 11

4 Leading and Lagging Performance Indicators . . . 11

5 Tier 1 Performance Indicator-Process Safety Event . . . 12
5.1 Tier 1 Indicator Purpose . . . 12
5.2 Tier 1 Indicator Definition and Consequences . . . 13
5.3 Calculation of Tier 1 PSE Rate . . . 14
5.4 Tier 1 PSE Severity Weighting . . . 15

6 Tier 2 Performance Indicator-Process Safety Events . . . 19
6.1 Tier 2 Indicator Purpose . . . 19
6.2 Tier 2 Indicator Definition and Consequences . . . 19
6.3 Calculation of Tier 2 PSE Rate . . . 20

7 Tier 3 Performance Indicators-Challenges to Safety Systems . . . 21
7.1 Purpose of Indicator . . . 21
7.2 Examples of Tier 3 PSEs . . . 21

8 Tier 4 Performance Indicators-Operating Discipline and Management System Performance . . . 24
8.1 General . . . 24
8.2 Purpose of Indicator . . . 24
8.3 Examples of Tier 4 Indicators . . . 25

9 Guidelines for Selection of Process Safety Indicators . . . 25
9.1 General . . . 25
9.2 Purpose of Indicators . . . 26
9.3 Lagging vs Leading Indicators . . . 26
9.4 Characteristics of Effective Indicators . . . 26
9.5 Selection of Indicators . . . 27

10 Reporting Performance Indicators . . . 27
10.1 Format and Forum . . . 27
10.2 Transparency . . . 28
10.3 Stakeholder . . . 28
10.4 PSE Data Capture . . . 29

Contents

Page

Annex A (informative) Application to Petroleum Pipeline and Terminal Operations. 43

Annex B (informative) Application to Retain Service Stations 45

Annex C (informative) Oil and Gas Drilling and Production Operations 46

Annex D (normative) Tier 1 PSE Severity Weighting 47

Annex E (informative) PSE Examples and Questions 51

Annex F (informative) LIsting of Chemicals Sorted by Threshold Quantity
(Based on UNDG Hazard Class or Grouping) 84

Annex G (informative) Application of TRCs to Multicomponent Releases 87

Annex H (informative) PSE Tier 1/Tier 2 Determination Decision Logic Tree. 90

Annex I (informative) Guidance for Implementation of Tier 3 and Tier 4 Indicators 92

Annex J (informative) Tier 4 Example Indicators 112

Bibliography 123

Figures
1 “Swiss Cheese (Static) Model” and “Spinning Disk (Dynamic) Model” 3
2 Process Safety Indicator Pyramid. 12
3 Example of Safe Operating Limit for Tank Level 21
D.1 Tier 1 PSE Severity Weighting 50
D.2 Tier 1 PSE Trend 50
F.1 Inhalation Toxicity: Packing Group and Hazard Zones. 86
G.1 Flammability Limits of Methane, Nitrogen, Oxygen Mixtures 88
H.1 PSE Tier 1/Tier 2 Determination Decision Logic Tree 91
I.1 Personal Safety/Process Safety Graphic 94
I.2 Illustration of Process Safety Elements Relating to Equipment 95
I.3 Daily Indicator Listing Example. 96
I.4 Illustration of Data Flow and Need for Categorization. 101
I.5 Example of Data Funneling Flow Diagram 105
I.6 Example PSE Tier 3 Other LOPC Graph 106
I.7 Example PSE Tier 3 Other LOPC Graph by Plant and Process Unit 106
I.8 Example PSE Tier 3 Other LOPC Graph for Plant 1 FCC and Alkylation Units
by Equipment Involved. 107
I.9 Example PSE Tier 3 Other LOPC Graph by Plant and Equipment Involved 107
I.10 Example PSE Tier 3 Other LOPC Graph by Plant and Management System Root Causes 108
I.11 Example PSE Tier 3 Other LOPC Graph by Plant and Mode of Operation 108
I.12 Example of Moving Average for Demands on Safety Systems 109
I.13 Example of Moving Average for Demands on Safety Systems—Separated into Stages. 109

Tables
1 Material Release Threshold Quantities. 16
2 Stakeholder Report Information 28
D.1 Tier 1 PSE Severity Weighting 48
E.1 Process Safety Event Examples and Questions: Injury 51
E.2 Process Safety Event Examples and Questions: Fire or Explosion 54
E.3 Process Safety Event Examples and Questions: Loss of Primary Containment 57

Contents

Page

E.4 Process Safety Event Examples and Questions: A Release Within Any 1-hour Period 64
E.5 Process Safety Event Examples and Questions: Mixtures and Solutions 66
E.6 Process Safety Event Examples and Questions: Pressure-relief Device, Unsafe Location 68
E.7 Process Safety Event E Examples and Questions: Company Premises, Process Safety Event with Multiple Outcomes, Pipelines 71
E.8 Process Safety Event Examples and Questions: Marine Transport 71
E.9 Process Safety Event Examples and Questions: Truck and Rail 72
E.10 Process Safety Event Examples and Questions: Downstream Destructive Devices 74
E.11 Process Safety Event Examples and Questions: Vacuum Truck Operations 75
E.12 Process Safety Event Examples and Questions: Direct Cost 76
E.13 Process Safety Event Examples and Questions: Officially Declared Evacuation or Shelter-in-Place 77
E.14 Process Safety Event Examples and Questions: Upset Emissions 78
E.15 Process Safety Event Examples and Questions: Ancillary Equipment/Active Staging/Active Warehouse 80
E.16 Process Safety Event Examples and Questions: Responsible Party 82

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.

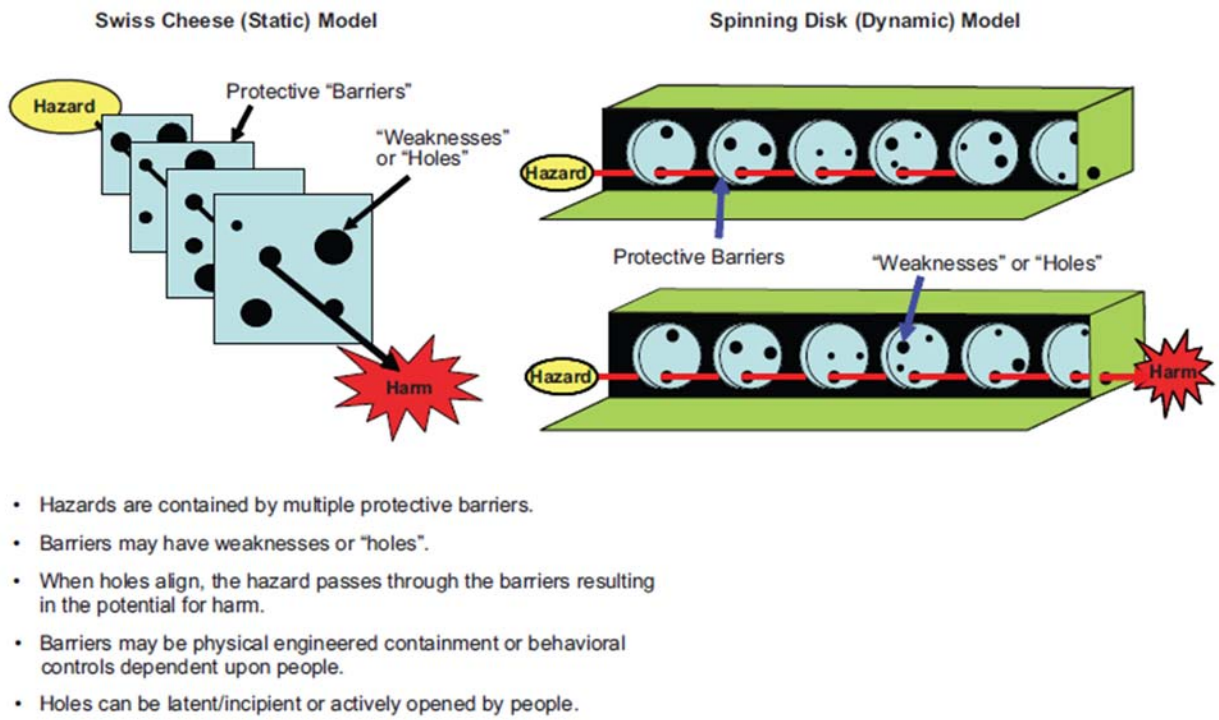


Figure 1—"Swiss Cheese (Static) Model" and "Spinning Disk (Dynamic) Model"

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 pH ≥ 1 and < 2, or 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 pH < 1 or 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 pH ≥ 2 or pH ≤ 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 CO_2, 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 M^3.

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 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.

3.1.41
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	*Globally Harmonized System of Classification and Labeling of Chemicals*
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.

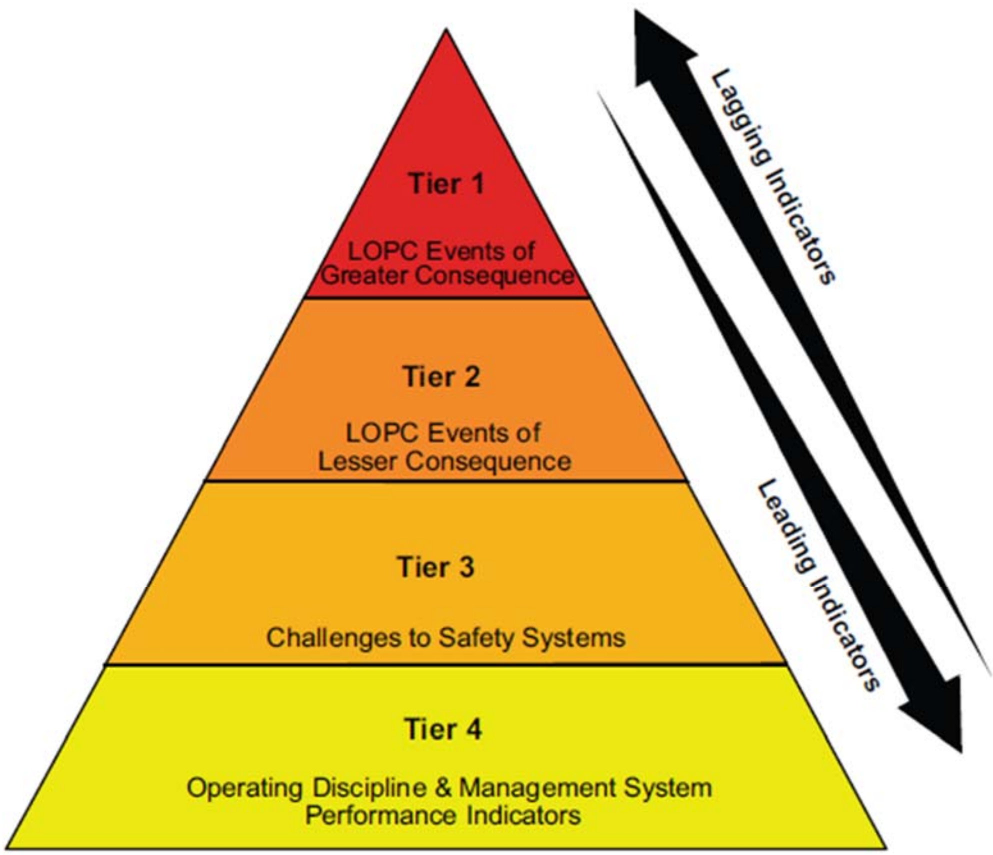


Figure 2—Process Safety Indicator Pyramid

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 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 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:

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

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

NOTE 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 Threshold Quantity (Outdoor)	Tier 1 Threshold Quantity (Indoor)	Tier 2 Threshold Quantity (Outdoor)	Tier 2 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) or ≥ 7 oil bbl	≥ 500 kg (1100 lb) or ≥ 3.5 oil bbl
	Strong acids/bases (see definition 3.1.2)	H314 Causes severe skin burns, skin corrosion/irritation (ch. 3.2) (cat. 1A)				
	No equivalent	H370 Causes damage to organs, specific target organ toxicity, single exposure (ch. 3.8) (cat. 1)				

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 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 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.

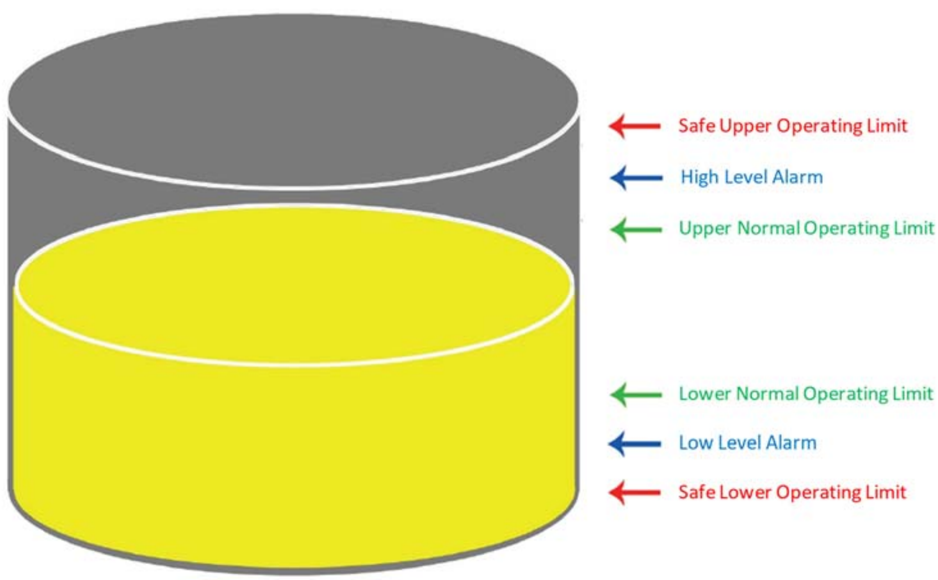


Figure 3—Example of Safe Operating Limit for Tank Level

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.

a) *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.

b) *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.

c) *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 (H_2S 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, H_2),

iii) liquified natural gas (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/rail/transport vessel,

xlviii) pilot plant,

xlix) tank farm/storage facility/off-site/storage and transfer piping,

l) utilities/steam plant/cogeneration,

li) sewer/lift station/wastewater handling, treatment or disposal,

lii) other (describe);

3) general chemical sector processes (check one):

i) absorption,

ii) boilers,

iii) centrifuging/dewatering,

iv) compounding/extrusion,

v) compression,

vi) desorption/vacuum stripping,

vii) distillation,

viii) drying,

ix) dust handling,

x) evaporation,

xi) filtering/coalescing,

xii) fired equipment/burner management,

xiii) heat exchange,

xiv) liquefaction,

xv) loading/unloading,

xvi) marine/jetty/wharf,

xvii) milling/size reduction,

xviii) mixing/blending,

xix) other,

xx) pilot plant,

xxi) pumping/transferring,

xxii) reactor,

xxiii) refrigeration,

xxiv) relief systems,

xxv) repacking/transloading,

xxvi) scrubbing/flaring,

xxvii) separation (other),

xxviii) solids handling,

xxix) tank farm/storage,

xxx) utilities,

xxxi) warehousing,

xxxii) wastewater treatment;

b) date and time of event;

c) mode of operation (check one):

1) start-up,

2) planned shutdown,

3) emergency shutdown,

4) normal (check one):

   i) sampling,

   ii) loading/unloading,

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

   iv) equipment commissioning/putting in service following maintenance,

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

   vi) filling/draining,

   vii) mixing/handling chemicals,

   viii) operator performed maintenance,

   ix) changing lineups,

   x) steady state operation,

   xi) other (describe);

5) upset,

6) turnaround,

7) routine maintenance,

8) temporary,

9) other (describe);

d) point of release (check one):

1) pump,

2) compressor,

3) blower/fan,

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

5) filter/coalescer,

6) furnace/fired heater,

7) fired boiler,

8) heat exchanger,

9) instrumentation,

10) cooling tower,

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

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

13) reactor,

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

15) flare/relief system,

16) other (describe);

e) type of material released (check one):

1) flammable,

2) combustible,

3) toxic,

4) corrosive,

5) UNDG Class 2, Division 2.2,

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

7) 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 (select up to three primary causal factors. It is also desired to select at least one sub-causal factor for each primary causal factor):

1) change management/MOC/PSSR:

i) action items implementation less than adequate (LTA),

ii) commissioning not authorized or LTA,

iii) informing/training personnel LTA,

iv) MOC hazard analysis LTA,

v) no MOC,

vi) QA/QC design and construction LTA,

vii) temporary MOC past removal date,

viii) updating procedures/process safety information LTA,

ix) other (describe);

2) communication:

i) ambiguous,

ii) language barrier,

iii) misunderstood,

iv) no communication,

v) not timely,

vi) prework safety review LTA,

vii) shift turnover LTA,

viii) signs, warnings, or labels LTA,

ix) other (describe);

3) design/construction:

i) codes and standards, specifications, or practices LTA,

ii) construction not consistent with design,

iii) engineering LTA,

iv) fabrication or installation LTA,

v) wrong material(s) of construction,

vi) other (describe);

4) equipment reliability:

i) maintenance methodology LTA,

ii) premature failure,

iii) preventive maintenance/testing frequency LTA,

iv) repair methodology LTA,

v) testing methodology LTA,

vi) other (describe);

5) fixed equipment inspection:

i) corrective action not timely,

ii) frequency LTA,

iii) knowledge/experience of inspector LTA,

iv) location LTA,

v) no inspection,

vi) QA/QC LTA,

vii) records LTA,

viii) technique LTA,

ix) other (describe);

6) human performance:

i) ergonomics LTA,

ii) human machine interface LTA,

iii) physiologically related—fatigue, illness, impairment,

iv) time constraint/pressure,

v) work environment,

vi) workload—physical/mental,

vii) other (describe);

7) knowledge, skills, and experience:

i) experience LTA,

ii) knowledge LTA,

iii) skills LTA,

iv) other (describe);

8) operating limits:

i) no operating limits,

ii) not alarmed,

iii) not monitored,

iv) operating limits exceeded,

v) operating limits not correct,

vi) other (describe);

9) procedures:

   i) operating:

      — no procedure available,

      — procedure available but not used/followed,

      — procedure followed incorrectly (e.g. steps out of order),

      — procedure not accurate/clear,

      — situation not covered,

      — used wrong procedure,

      — other (describe);

   ii) maintenance:

      — no procedure available,

      — procedure available but not used/followed,

      — procedure followed incorrectly (e.g. steps out of order),

      — procedure not accurate/clear,

      — situation not covered,

      — used wrong procedure,

      — other (describe);

   iii) contractor:

      — no procedure available,

      — procedure available but not used/followed,

      — procedure followed incorrectly (e.g. steps out of order),

      — procedure not accurate/clear,

      — situation not covered,

      — used wrong procedure,

      — other (describe);

   iv) other (describe);

10) risk assessment or incident investigation:

   i) action item closure LTA or not timely,

   ii) incident investigation LTA,

iii) no risk assessment,

iv) risk assessment not accurate,

v) risk assessment not adequate,

vi) other (describe);

11) safe work practices or procedures:

i) confined space practice or procedure problem LTA,

ii) energy control/isolation practice or procedure LTA,

iii) hot work practice or procedure LTA,

iv) line breaking/equipment opening practice or procedure LTA,

v) other (describe);

12) work monitoring:

i) insufficient oversight,

ii) QA/QC LTA,

iii) rules not enforced,

iv) rules not followed,

v) scheduling LTA,

vi) simultaneous operations,

vii) working on wrong location,

viii) other (describe);

13) other (please 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 *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) 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 connecting to/disconnecting from the process is the first/last step in loading/unloading procedure (e.g. first line ashore, last line removed, etc.).

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 1 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.

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

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 5.2 and 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 LOPC event;

g) LOPC events from ancillary equipment not connected to the process;

h) QA and 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, associated ancillary equipment, etc.), storage tanks, active warehouses, support areas (e.g. wastewater 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 RP. Retail service stations dispense gasoline, diesel, biofuels, propane, compressed natural gas, and hydrogen to the public.

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.

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 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 connecting to/disconnecting from the process is the first/last step in loading/unloading procedure (e.g. wheel chocks, set air brakes, disconnect master switch, etc.).

a) 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.

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

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

d) LOPC events from ancillary equipment not connected to the process, 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.), aboveground or belowground 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
(normative)

Tier 1 PSE Severity Weighting

Severity weighting provides additional useful information about Tier 1 PSEs that may help drive performance improvement. Table D.1 describes the methodology for calculating a severity weight for Tier 1 PSEs. 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 shall be calculated by summing the points associated with each consequence category.

EXAMPLE 1

During start-up following a maintenance outage, a distillation column was overfilled, resulting in a release of 1200 bbl of flammable liquid in six minutes from an atmospheric relief device. The liquid release formed a flammable cloud that exploded, killing 8 people, injuring 47 people, and causing $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 PSE Severity Weighting

Severity Points	**Consequence Categories**				
	Safety/Human Health [c]	**Direct Cost from Fire or Explosion**	**Material Release Within Any 1-hr Period** [a d e]	**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 U.S. 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.

[d] For the purpose of severity weighting, general paving or concrete under process equipment, even when sloped to a collection system, is not credited as secondary containment.

[e] Material release is not tabulated for fires or explosions. These events severity will be determined by the other consequence categories in this table.

EXAMPLE 3

A 10-in. process furnace outlet line failed due to undetected corrosion. The rupture released a flammable liquid that ignited; 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	N/A for Fire (see Table D.1, footnote e)	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 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 is calculated as follows:

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

Tier 1 PSE Severity Weighting $\text{Rate}_{1,000,000}$ = (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 3.1.52 for definition).

The choice of calculating Tier 1 PSE Severity Weighting 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.

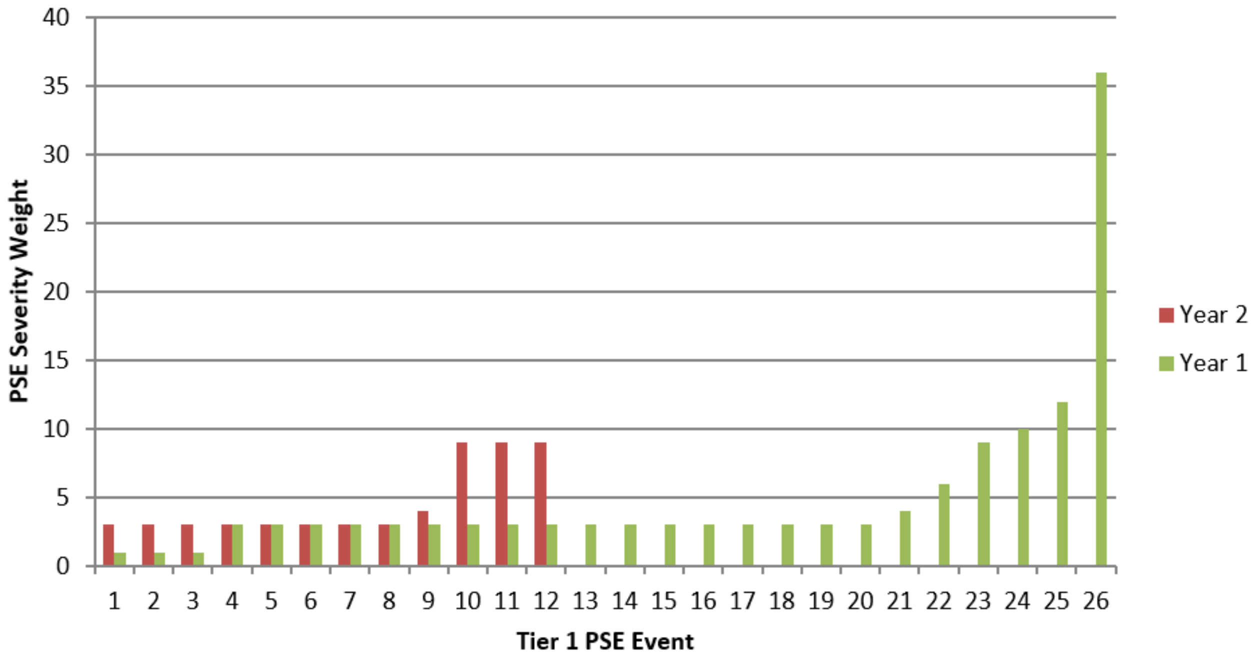


Figure D.1—Tier 1 PSE Severity Weighting

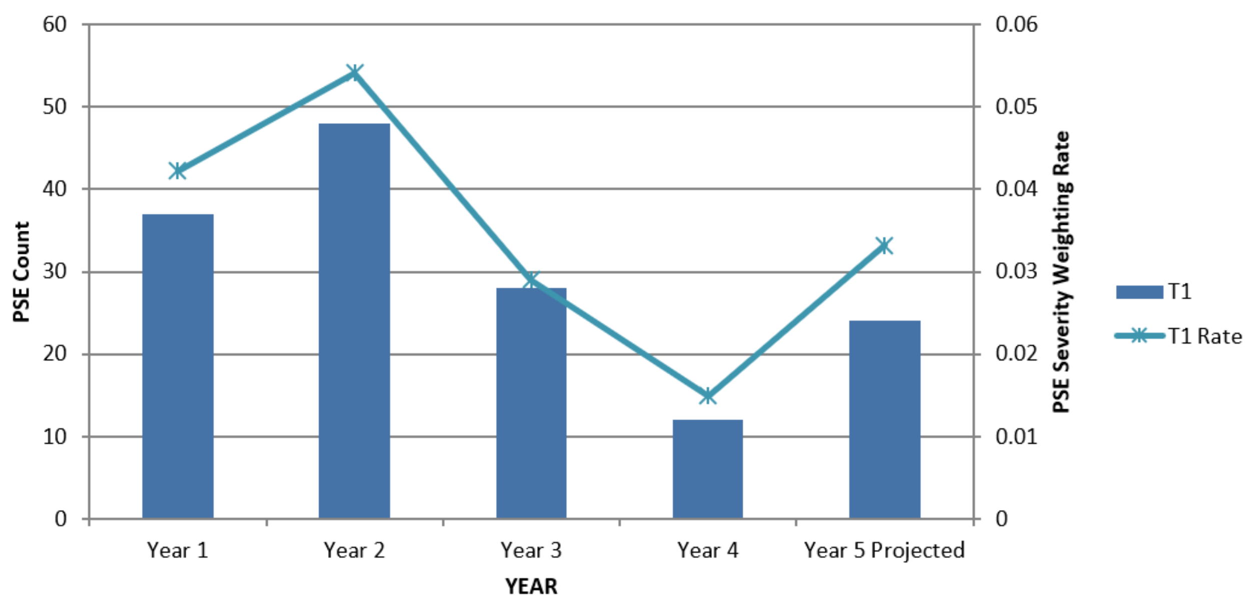


Figure D.2—Tier 1 PSE Trend

Annex E
(informative)

PSE Examples and Questions

Table E.1—Process Safety Event Examples and Questions: Injury

Example/Question	Tier 1/2
E.1-1 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” events 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
E.1-2 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 PSE 5.2, Tier 1 definition
E.1-3 Same as above, except that the operator slipped and fell several hours after the event 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” cleanup and remediation) are not directly associated with on-site response.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability
E.1-4 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 PSE 1.2, Applicability 5.2, Tier 1 definition
E.1-5 An operator walks past a steam trap located near a common walkway just as the steam trap discharges. The operator’s ankle is burned by the discharge, resulting in a days away from work injury. Is this a PSE? This is a Tier 1 PSE. While a steam trap is designed to periodically discharge hot flashing water, the timing is unplanned and the discharge location in this instance near a common walkway is uncontrolled; therefore, this was both an unplanned and uncontrolled LOPC that resulted in one of the Tier 1 consequences. The material released does not have to be a hydrocarbon or chemical; a Tier 1 PSE can result from the unplanned or uncontrolled release of any material from a process, including non-toxic and non-flammable materials.	Tier 1 PSE 5.2, Tier 1 definition

Example/Question	Tier 1/2
E.1-6 A reactor vessel has been intentionally purged with nitrogen. Strict controls regarding entry, including PPE, have been specified as part of the confined space entry permit process. Unattended vessel manways that are not used for entry are controlled with a hard barrier and signage and a barricaded hot zone around the potentially oxygen deficient atmosphere where nitrogen is exiting the vessel. For an unknown reason, at one of the unattended vessel manways, a contractor bypasses safety controls, enters the reactor vessel, and dies. Is this a Tier 1 PSE? This is not a Tier 1 PSE. The release of nitrogen from the vessel was planned and controlled, and the PPE, the physical barriers, and signage were appropriate for the hazard. It was the intentional act of the contract worker to bypass and defeat these controls that results in the fatality and not an unplanned or uncontrolled LOPC. This tragic event is a personal safety event that would be recorded on the Company's injury and illness log. Alternate Scenario: Individuals are working inside a standard confined space (no inert purge). A nitrogen hose is inadvertently connected to the pneumatic tools being used inside the vessel. The nitrogen creates an oxygen-deficient atmosphere and a worker collapses, strikes their head, and unfortunately dies. Is this a Tier 1 PSE? This is a Tier 1 PSE. There was an unplanned release of any material (nitrogen) that resulted in a fatality.	Not a Tier 1 PSE 5.2, Tier 1 definition Tier 1 PSE 5.2, Tier 1 definition
E.1-7 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 a worker and caused an injury; therefore, this would be a Tier 2 PSE based upon the recordable injury.	Tier 2 PSE 6.2, Tier 2 definition
E.1-8 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 2 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
E.1-9 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. wastewater 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 PSE 6.2, Tier 2 definition
E.1-10 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/her 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 3.1.38, Process definition

Example/Question	Tier 1/2
E.1-11 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/her ankle. The injury resulted in 8 days away from work. The facility Evacuation Protocol was not 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 event? 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 PSE 5.2, Tier 1 definition
E.1-12 A worker was sprayed in the eyes with caustic while draining it into a container, resulting in a lost workday injury. The worker was wearing eye goggles, but the caustic was drained from the wrong location, where it was at a higher pressure than expected. Is this a PSE? The caustic draining was planned, but it became uncontrolled when the operator was injured.	Tier 1 PSE 5.2, Tier 1 definition
E.1-13 Two (2) contractors were tasked with removing a level transmitter from a vessel. A third contractor was assigned general tasks in the area. The work permit for the two contractors performing the level transmitter removal were required to wear PPE (e.g. goggles, chemical suits, gloves, etc.) to protect them from residual chemicals. The third contractor performing general duties was only required to wear standard PPE (safety glasses, FRC, hardhat, etc.). Having completed her general tasks, the third contractor in standard PPE went to assist the other two contractors removing the level transmitter. When the level transmitter was removed, residual chemical drained from the nozzle into a drip pan and splashed on the three contractors. The contractor wearing standard PPE ran to a nearby safety shower. The chemical contact resulted in a recordable injury to the third contractor. Is this a PSE? This is a Tier 1 PSE. Recognizing that exposure to residual chemical could result in a worker injury, the planned and controlled release of material involved the use of PPE. The contractor that was injured was not wearing the appropriate PPE for this job; therefore, the release was uncontrolled. A release of material that results in a lost work day injury is a Tier 1 PSE, because it was uncontrolled, regardless of the PPE being worn.	Tier 1 PSE 5.2, Tier 1 definition
E.1-14 While an employee was blowing down a salt water strainer, the PVC piping failed, resulting in the employee being forcibly sprayed with salt water causing the employee to stumble backwards and hit his/her head on adjacent equipment, resulting in a recordable injury. The salt water is non-hazardous, and the operating temperature is ~60 °F (~15 °C). Is this a PSE? This is a Tier 2 PSE. To qualify as a Tier 1 or Tier 2 PSE, there must be an unplanned or uncontrolled release of any material, even non-hazardous material, from a process that results in one of the defined consequences. The definition of “material” (see 3.1.28), states that the substance released must have the “potential to cause harm due to its chemical (e.g. flammable, toxic, corrosive, reactive, asphyxiate) or physical (e.g. thermal, pressure, slippery) properties.” In this case, the salt water had the ability to cause harm because the system pressure was sufficient to cause harm. Therefore, this example illustrates an uncontrolled release of material from a process that resulted in a Tier 2 PSE consequence.	Tier 2 PSE 6.2, Tier 2 definition 3.1.26, LOPC definition 3.1.28, Material definition

Table E.2—Process Safety Event Examples and Questions: Fire or Explosion

Example/Question	Tier 1/2
E.2-1 A scaffold board is placed near a high-pressure steam pipe and subsequently begins to burn, but it 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
E.2-2 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. 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
E.2-3 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 demands on safety systems.	Not a Tier 1 or Tier 2 PSE 5.2, Tier 1 definition
E.2-4 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 direct cost damage was greater than $100,000.	Tier 1 PSE 5.2, Tier 1 definition
E.2-5 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 PSE 5.2, Tier 1 definition
E.2-6 There is a fire in the steam heat boiler at the Main Office complex, and direct cost damages totaled $75,000. The event is not a PSE since office building events are specifically excluded.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability
E.2-7 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 event 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 PSE 6.2, Tier 2 definition
E.2-8 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, overpressuring 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 $100,000. 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 $100,000, this event would be a Tier 1 PSE.	Tier 1 PSE 3.1.19, Explosion definition 3.1.17, Direct cost definition 5.2, Tier 1 definition

Example/Question	Tier 1/2
E.2-9 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 LOPC (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
E.2-10 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, 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. For example: A crack on a furnace tube releases material that ignites and burns in the firebox until the leak can be isolated. The burning material causes $75,000 direct cost damage to the furnace. The engineers calculate that from start to finish 13,000 lb of flammable gas is released before the leak can be isolated. An evaluation of the direct cost damage would result in this event being classified as a Tier 2 PSE. An evaluation of the material release quantity indicates an amount greater than a Tier 1 threshold quantity of flammable gas was released; however, since the release ignited, only the direct damage costs are considered making this event a Tier 2 PSE. Alternate Case: If everything in the example is the same, except the burning material only causes $2,000 in direct cost damage, this event is neither a Tier 1 nor Tier 2 PSE; however, a company may choose to count this event in their Tier 3 metric.	Tier 2 PSE 5.2, Tier 1 definition 6.2, Tier 2 definition
E.2-11 A water surge drum is filled with no discharge pumps operating; the drum is overpressured and a 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 overpressure meet the definition of an explosion, meaning this would be a Tier 2 PSE? This is not a Tier 2 PSE. The overpressure in this example 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 2 PSE 3.1.19, Explosion definition
E.2-12 A line catastrophically fails due to vibration induced fatigue. The release ignites, resulting in a jet fire. The jet fire impinges on a crane parked nearby, destroying the crane, but does not cause any significant damage to process equipment. The cost to replace the crane is $350,000. Is this a Tier 1 PSE? This is a Tier 1 PSE since the direct cost fire damage from the LOPC exceeded the Tier 1 PSE threshold of $100,000. By definition, direct cost fire/explosion damage includes the cost to repair or replace process and non-process equipment and tangible public or private property.	Tier 1 PSE 3.1.17, Direct cost definition

Example/Question	Tier 1/2
E.2-13 A corrosion-related leak results in a large fire that damaged piping and an out-of-service vessel (abandoned in place). The company spends $15,000 in engineering and inspection costs to determine the extent of the fire damage, $95,000 to replace the damaged pipework with an upgraded metallurgy resistant to the corrosion damage mechanism, and $50,000 to make the out-of-service vessel safe to remain in place. To replace the pipework with in-kind metallurgy would have cost $45,000. To restore the functionality of the out-of-service (abandoned in place) vessel would have cost $125,000. Is this a Tier 1 or Tier 2 PSE? This is a Tier 2 PSE. The definition of direct cost excludes the cost of engineering or inspection assessments to determine the extent of damage or necessary repairs, and it also excludes the cost of opportunity upgrades to materials or technology. The definition of direct cost does include the cost to restore equipment to pre-event condition whether or not the repairs are made. In this example, the out-of-service vessel has been abandoned in place (i.e. no expectation of future functionality); therefore, only the post fire cost to make the equipment safe is included in the direct cost calculation. This is a Tier 2 PSE based upon $50,000 to make the vessel safe and $45,000 for the in-kind metallurgy piping replacement for a total direct cost of $95,000.	Tier 2 PSE 3.1.17, Direct cost definition
E.2-14 A small flange fire impinges upon some instrument cable before being quickly extinguished. It is determined that the equipment functions afterwards, but maintenance recommends replacing the small section of fire damaged cable to avoid any future reliability issues. When executing the job, maintenance determines that replacing 50 ft of cable was easier than repairing the small section. Is the cost of replacing the 50 ft of cable included in the total direct cost damage for this fire? The definition of direct cost includes in-kind repairs, replacement, or restoration to pre-event condition. Direct cost does not include superficial- or cosmetic-only damage that does not affect function or performance. Direct cost also does not include opportunity upgrades to materials or technology. So, in this case, the cost of repairing the small section of cable recommended by maintenance to assure reliable function is included; however, the ease of repair replacement of 50 ft of cable is excluded as an opportunity upgrade.	3.1.17, Direct cost definition
E.2-15 A furnace tube inside a hydrogen furnace develops a leak. The material released is a blend of hydrogen and steam and is consumed inside the box. During the release, the pressure of the leak causes some refractory to spall off the side of the furnace and fall onto a burner. The flame from the burner is redirected to where it comes out of the register and causes damage to an electrical conduit feeding a temperature instrument. The cost of the repairs to the conduit exceed $2500. No repairs to the furnace skin are necessary and the refractory repairs are less than $2500. No other negative consequences occurred. Is this a Tier 2 PSE? This is a Tier 2 PSE. It does not matter that there was a complicated chain of events that led to the ultimate consequence. There was an unplanned release of hydrogen and steam from a tube leak that resulted in greater than $2500 direct cost fire damage. The Tier 1 and Tier 2 PSE categorization requires that there be an unplanned or uncontrolled LOPC from a process and that one of the negative consequences was realized. It does not require the LOPC to directly cause one of the consequences.	Tier 2 PSE 3.1.17, Direct cost definition 6.2, Tier 2 definition
E.2-16 A portable diesel-driven pump was being used to transfer material from one tank to another. The hot exhaust of the diesel engine ignited a fire in the soundproofing exhaust housing and burned through a radiator hose, releasing engine coolant. The fire damage to the pump exceeded $2500. Is this a Tier 2 PSE? This is not a Tier 2 PSE. While the temporary portable pump and its diesel-driven engine is part of the process while it is connected to the process, the fire was caused by the hot exhaust and not a LOPC; therefore, the fire damage is excluded from the Tier 2 determination. Additionally, the fire induced LOPC of engine coolant did not result in any of the Tier 2 consequences. A company may choose to record this event as a Tier 3 fire.	Not a Tier 2 PSE 3.1.21, Fire definition 6.2, Tier 2 definition

Table E.3—Process Safety Event Examples and Questions: Loss of Primary Containment

Example/Question	Tier 1/2
E.3-1 A spill of 20 bbl of weak bleach occurred in less than 1 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 and 14 (i.e. a strong base per 3.1.2). Using the SDS listed property, this would be classified as a Tier 2 PSE due to the volume released exceeding 7 bbl in 1 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 base; therefore, there would be no Tier 2 TQ. Should this event be classified as a Tier 2 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. Per Note 1 in 5.2.2 and 6.2.2, 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.	May be Tier 2 PSE 3.1.2, Strong base definition Table 1
E.3-2 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 (7,000 kg, 15,500 lb) of liquid overflows into the tank's diked area within minutes. This event is a Tier 1 PSE since it is a release of 2,200 lb or more within any 1-hour period, regardless of secondary containment. If the spill had been less than 2,200 lb (7 bbl), but equal to or greater than 220 lb (0.7 bbl), it would be a Tier 2 PSE.	Tier 1 PSE 5.2, Tier 1 definition and Table 1 Tier 2 6.2, Table 1
E.3-3 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 event had resulted in a recordable injury, it would be a Tier 2 PSE.	Tier 1 PSE 5.2, Tier 1 definition 6.2, Tier 2 definition
E.3-4 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 or Tier 2 Table 1 TQs in any 1-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
E.3-5 An operator opens a QC 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 PSE 6.2, Tier 2 definition Not a PSE 1.2, Applicability

Example/Question	Tier 1/2
E.3-6 A bleeder valve is left open after a plant turnaround. On start-up, an estimated 15 bbl of fuel oil, a liquid with a flash point above 60 °C (140 °F), is released at 38 °C (100 °F) (below its flash point) 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 flash point; 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 does the event in the first example above not qualify the LOPC as a Tier 1 PSE per Tier 1 Release Category 7? In determining the TRC 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 UNDG 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 TRC. In that case, the TRC 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 PSE 6.2, Tier 2 definition Table 1 Tier 1 PSE 5.2, Tier 1 definition Table 1
E.3-7 There is a loss of burner flame in a fired heater, resulting in a fuel-rich environment. The operator responds incorrectly and adds air to the firebox, which results in an 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 event had resulted in less than $100,000 in damages, but greater than $2,500 in damages, it would be a Tier 2 PSE since there was an explosion resulting in greater than $2,500 in damages.	Tier 1 PSE 5.2, Tier 1 definition Tier 2 PSE 6.2, Tier 2 definition
E.3-8 The regenerative thermal oxidizer (RTO) is typically fed materials with low concentrations of flammable gas [lower explosive limit (LEL)]. For the event 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 event exceeds $100,000. Is this a Tier 1 PSE even though the explosion was not specifically caused by a LOPC? Per 5.2.1 Note 3, an internal fire or explosion that causes a LOPC of any material from a process triggers an evaluation of the Tier 1 consequences. The LOPC does not have to occur first. The $100,000 direct cost damage classifies the PSE as a Tier 1 event.	Tier 1 PSE 5.2, Tier 1 definition 5.2.1, Note 3
E.3-9 A pump seal fails, releasing a TRC 7 liquid. The liquid ignites causing $10,000 in damages to surrounding equipment. Engineers calculate that a total of 7,000 lb of liquid was released. Is this a PSE? This is Tier 2 PSE. The evaluation of the fire/explosion direct cost damage would conclude a Tier 2 PSE classification ($10,000 damage). An evaluation of the material release quantity would conclude a Tier 1 PSE classification (greater than TRC 7 Tier 1 TQ). If the material released ignites, 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. This is a Tier 2 PSE.	Tier 2 PSE 3.1.17, Direct cost definition 6.2, Tier 2 definition

Example/Question	Tier 1/2
E.3-10 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.	Tier 1 PSE 5.2, Tier 1 definition Table 1
In the example above, if a crude oil with a flash point above 60 °C (140 °F) and ≤ 93 °C (200 °F) is released at a temperature below the flash point, it would be a Tier 2 PSE.	Tier 2 PSE 6.2, Tier 2 definition Table 1
If the drainage system is a closed system and goes to a closed API separator and the oil is recovered (refer to 3.1.9), this would not be a Tier 1 event because the crude oil did not leave primary containment. If the closed drainage system is breached, ineffective, or overwhelmed, then the amount of oil lost from the closed system would be evaluated for a possible Tier 1 or Tier 2 event.	Not a Tier 1 or Tier 2 PSE 3.1.9, 3.1.10 Primary containment, secondary containment definitions
E.3-11 An operator purposely drains 20 bbl of material with a flash point > 60 °C (140 °F) and ≤ 93 °C (200 °F) at a temperature below its flash point into an open oily water collection system within 1 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.	Not a Tier 1 or Tier 2 PSE 5.2, Tier 1 definition
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.	Tier 2 PSE 6.2, Tier 2 definition Table 1
E.3-12 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 a 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.	Possible Tier 1 or Tier 2 PSE 3.1.26, LOPC definition
E.3-13 Oil-water/process wastewater is collected in a cone roof tank with an internal floating roof. 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 internal floating roof 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 is internal or external.	Tier 1 PSE 5.2, Tier 1 definition Tier 2 PSE 6.2, Tier 2 definition
E.3-14 A cold rain on a hot summer day results in the thermal contraction of the flare header. As the result of a LTA 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.	Not a Tier 1 or Tier 2 PSE
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.	Tier 1 PSE 5.2, Tier 1 definition

Example/Question	Tier 1/2
E.3-15 A flammable gas was released from a pipe, ignites (a jet fire), and causes $3500 in damage before it could be isolated and extinguished. The Company engineers were able to calculate that 800 kg (1800 lb) total was released. Is this a Tier 1 or Tier 2 PSE? The $3500 direct cost damage exceeds the Tier 2 threshold. The total 800 kg release exceeds the Tier 1 threshold quantity for a TRC 5 material. If the material released ignites, 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. This is a Tier 2 PSE.	Tier 2 PSE 5.2, Tier 1 definition 6.2, Tier 2 definition
E.3-16 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 PSE 6.2, Tier 2 definition
E.3-17 Steam is used to purge a hydrogen header during a brief shutdown. Steam flow is discontinued prior to start-up; however, the header cools down creating a slight vacuum. Air leaks into hydrogen header, resulting in a hydrogen/air explosion during start-up. 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 1 The $4 million in lost production is by definition excluded from the calculation of direct cost damage. NOTE 2 The direction of the LOPC is governed by the pressure differential; it does not have to be from internal to external.	Tier 1 PSE 5.2, Tier 1 definition 3.1.17, Direct cost definition
E.3-18 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, UNDG Division 2.2, Class 2 definition

Example/Question	Tier 1/2
E.3-19 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 lb) 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 3.1.26, LOPC definition
E.3-20 A flash fire occurred during top loading diesel into a third-party carrier truck. The driver sitting on top of the truck compartment at the manhole per loading procedures suffered burns requiring hospitalization. No liquid spilled from the truck, and there was no significant damage to equipment. The fire may have started due to static ignition and/or switch loading. Vapors are expected to be present in normal top loading operations. Is this a Tier 1 PSE or an occupational safety event? This is a Tier 1 PSE. When the ignition occurred, the flame front inside the vessel expanded the gases in the vapor space, causing them to exit the manway at a much faster rate (and much hotter) than what would be considered “normal operation,” and therefore it was an unplanned and uncontrolled release resulting in a third-party hospitalization. Also, top loading operations qualify as being connected to the process for the purpose of loading.	Tier 1 PSE 1.2, Applicability 5.2, Tier 1 definition
E.3-21 While loading lime powder into a hopper connected to the process, there was an unplanned release of lime powder. Is this a PSE? LOPCs of solid materials are evaluated in the same way as liquid or gas LOPCs. If the solid material release was unplanned or uncontrolled, it would be assessed against the Tier 1 and Tier 2 consequences to determine its categorization.	5.2, Tier 1 definition 6.2, Tier 2 definition
E.3-22 An operator discovered a drip leak in a section of piping containing a material with a Tier 1/Tier 2 threshold quantity. To prepare the piping for repair, operations isolated the line and began purging it with water to the process water header. After a while, they realized that the line had not yet cleared. They determined, through a drop in a tank liquid level, that a valve connecting the tank to the piping to be cleared was leaking. Due to the leaking valve, operations inadvertently transferred a Tier 1 threshold quantity of the material into the process water header. Is this a Tier 1 PSE? This is not a Tier 1 PSE. Even though there was an inadvertent (uncontrolled) transfer of material from the tank into the process water header via the leaking valve, there was no LOPC. As defined in 3.1.9, primary containment includes “… closed systems that have a pressure boundary such that there is no exposure of process material to the atmosphere…” This event was a transfer of material from one process to another process rather than a LOPC from a process.	Not a Tier 1 PSE 5.2, Tier 1 definition 3.1.9, Primary containment definition

Example/Question	Tier 1/2
E.3-23 As the result of a faulty sensor, there was an unplanned release of Halon from the fire suppression system indoors. The quantity released exceeded the Tier 1 indoor threshold quantity for a Category 7 UNDG Class 2, Division 2.2 material. However, per API 754, G.4, for a multicomponent stream to be considered an asphyxiant (UNDG Class 2, Division 2.2 material), it must contain less than 12 % oxygen by volume. Based upon the design of the fire suppression system, the release of Halon would result an indoor oxygen concentration of 17.8% by volume. In other words, the multicomponent gas (air and Halon indoors) is not less than 12 %; therefore, it is not an asphyxiant and therefore not a Tier 1 PSE. Is this release a Tier 1 PSE? This scenario is not a Tier 1 PSE, but not for the reason stated. The reference and use of Annex G in this scenario is incorrect. The TRCs in API 754 are based upon the classification on the material released and not the resulting atmosphere created by the release. The purpose of Annex G is to help the reader determine the TRC of a multicomponent material. Halon (Bromotrifluormethane) itself is not a multicomponent gas; therefore, Annex G does not apply. The SDS for Halon lists it as a UNDG Class 2, Division 2.2 material. The fact that the fire suppression system is designed so that the resultant release atmosphere within the protected area is not oxygen deficient (from a human perspective) does not change the release category of the Halon. Halon is a Category 7 material. However, the Category 7 determination is moot in this scenario. The definition of Tier 1 requires that the LOPC be from a process. While the fire suppression system is a mitigation barrier associated with the process, it is not part of the process. Therefore, this scenario is not a Tier 1 PSE because there was no LOPC from a process.	Not a Tier 1 PSE 3.1.38, Process definition
E.3-24 Following an API 754 webinar, our company engineers had a discussion about shell and tube heat exchanger leak and whether or not these leaks would be considered LOPCs subject to Tier 1/Tier 2 PSE categorization. Our engineers discussed the following three scenarios. 1) A hydrocarbon leak into a cooling water system. 2) A non-volatile heavy hydrocarbon leak into a steam condensate system that creates an undesirable mess. 3) Similarly, an exchanger leak that resulted in hydrocarbon/hydrocarbon contamination that remained within a distillation column and resulted in off-spec products. Do these “release” scenarios constitute LOPCs? The answer lies in the definition of “primary containment.” Scenario 1 is a LOPC since the hydrocarbon did not remain inside of primary containment. The cooling water system is not primary containment since it is open to the atmosphere at the cooling tower. Scenarios 2 and 3 are not LOPCs since the exchanger leaks released material into a closed pressure boundary (i.e. another part of the process).	Possible Tier 1 or Tier 2 PSE 3.1.9, Primary containment definition

Example/Question	Tier 1/2
E.3-25 A reverse flow of Diluted Bitumen from a rundown line to a plant area caused multiple PRVs to lift at elevation releasing liquid Diluted Bitumen to grade. During the reverse flow, Diluted Bitumen also backflowed into a jumper drain line that was not in service prior to or during the release and was expected to be empty. The jumper drain line had a crack that resulted in a release of Diluted Bitumen. Is this event a single LOPC or multiple LOPCs? This event has at least two distinct LOPCs that need to be evaluated against the Tier 1 and Tier 2 PSE criteria and possibly more. PSEs are always viewed from the perspective of the LOPC and not the initiating event. In this case, we had one LOPC from the out-of-service line and one from the PRD's. Grouping multiple LOPCs is possible dependent upon the specifics of the releases. For example, if there had been multiple leak locations in the out-of-service line occurring in the same vicinity that would potentially impact the same population or equipment, they would be considered one LOPC. They would be considered separate LOPCs if they had occurred in separate locations or if they could impact different populations or equipment. Likewise, multiple PRDs that act as a system (e.g. staged valves) would be considered a single LOPC, whereas individual PRDs on individual lines and vessels would be multiple LOPCs. Each LOPC would be judged against the appropriate criteria Tier 1 or Tier 2 PSE criteria.	Possible Tier 1 or Tier 2 PSE 3.1.26, LOPC definition

Table E.4—Process Safety Event Examples and Questions: A Release Within Any 1-hour Period

Example/Question	Tier 1/2
E.4-1 There is a 10 bbl spill of gasoline that steadily leaks from piping onto soil over a 2-week time period. Simple calculations show the spill rate was approximately 0.03 bbl/hr. It was determined that the gasoline was a TRC6 material. This is not a Tier 1 or Tier 2 PSE since the spill event did not exceed the threshold quantity in any 1-hour period. A company may choose to count this as a Tier 3 other LOPC event. 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 0.7 bbl within 1 hour, thus it is a Tier 2 PSE. 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 1-hour period, this event would be a Tier 1 PSE.	Not a Tier 1 or Tier 2 PSE 6.2, Tier 2 definition Table 1 5.2, Tier 1 definition Table 1
E.4-2 An operator discovers an approximate 10 bbl liquid spill of aromatic solvent (e.g. benzene, toluene), a TRC 6 material, near a process exchanger that was not there during his/her last inspection round 2 hours earlier. How do you determine the duration of the spill? If possible, the start time of the spill should be determined from available data (e.g. process data, CCTV, community complaint, etc.). In the absence of reliable data, the spill duration can be assumed to be 1 hour (this is the most conservative and inclusive choice), or the spill start time can be assumed to be just after the last known time there was no spill. The choice of which assumption to use is a Company decision. The choice should be used for all cases where reliable data is unavailable. In this example, there is no reliable data from which to determine the start time. If a company chooses the most conservative and inclusive assumption that the entire release occurred in a 1-hour period, then this example would be a Tier 1 PSE (i.e. 10 bbl of a TRC 6 material exceeds the Tier 1 TQ). If a company chooses the less conservative approach and assumes the spill started just after the operator had completed their last round, then this would be a Tier 2 PSE (i.e. 10 bbl over 2 hours equals 5 bbl in a 1-hour period, which is less than the Tier 1 TQ but greater than the Tier 2 TQ).	Tier 1 PSE 5.2, Tier 1 definition Table 1
E.4-3 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/hr) did not exceed the threshold quantity of 500 kg or more within 1 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 PSE 6.2, Tier 2 definition

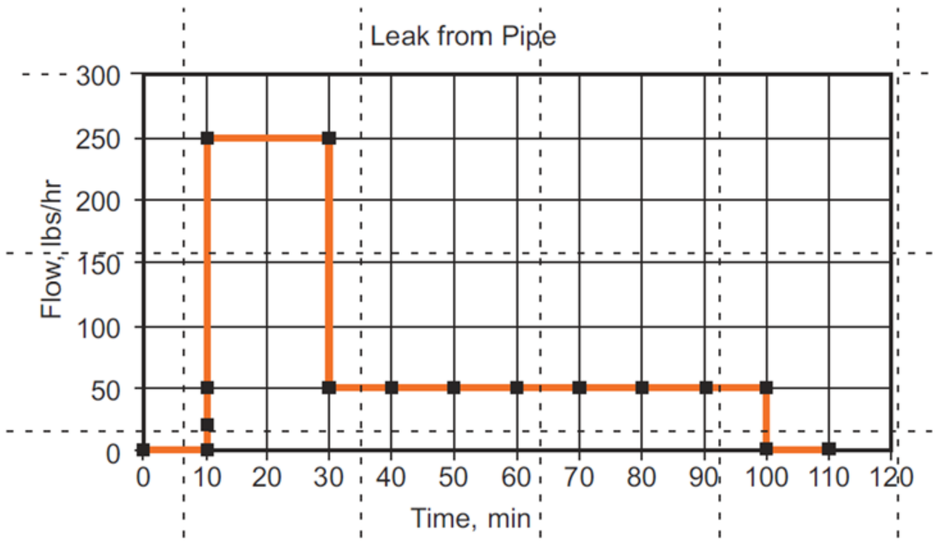
Example/Question	Tier 1/2
E.4-4 A flammable gas (propylene) is found leaking from a pipe at 250 lb/hr. After 20 minutes, operations personnel were able to partially isolate the line reducing the leak rate to 50 lb/hr. The line continued to leak at 50 lb/hr for an additional 70 minutes before the line 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 1-hour period." In this case, the release rate profile is known, and the greatest release volume in any 1-hour period occurs during the first hour. First Hour of Event Amount Released: 20 min = 0.33 hr @ 250 lb/hr = 82.50 lb Amount Released: 40 min = 0.67 hr @ 50 lb/hr = 33.50 lb Total release in first hour = 116 lb; therefore, this a Tier 2 PSE since the volume release in "any 1-hr period" exceeds the Tier 2 threshold quantity for flammable gases.	Tier 2 PSE 6.2, Tier 2 definition Table 1
E.4-5 A company experienced a LOPC of 20 gallons of low sulfur diesel over a period of 2 minutes. This translates into a release rate of 10 gpm. Low sulfur diesel is a TRC7 material with a Table 1 threshold quantity for TRC 7 of 14 bbl in any 1-hour period. This translates into a release rate of 9.8 gpm. Therefore, the 10 gpm spill would be classified as a Tier 1 PSE. Is this correct? This analysis is incorrect; this is not a Tier 1 PSE. The Table 1 threshold quantities are absolute values for a 1-hour period; they do not represent a release rate. If the total release duration is less than or equal to 1 hour, the entire release volume is compared to the threshold quantity. In this case, the release duration is less than 1 hour; therefore, the total release volume of 20 gallons is compared to the threshold quantity of 14 bbl. A release rate is only used when the release duration exceeds 1 hour and the actual release pattern is unknown (see Example E4-4).	Not a Tier 1 PSE 5.2, Tier 1 definition Table 1

Table E.5—Process Safety Event Examples and Questions: Mixtures and Solutions

<table>
<tr><th>Example/Question</th><th>Tier 1/2</th></tr>
<tr><td>E.5-1 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 1 hour. This mixture is not classified by the UNDG/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.

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

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

NOTE This is an alternative shortcut approach and can give more or less conservative results. A more precise approach is to use the rules of DOT 49 CFR 173.2a [22] or UN Recommendations on the Transportation of Dangerous Goods, Section 2. [18]</td><td>Tier 1 PSE
5.2, Tier 1 definition
Table 1
Annex G</td></tr>
<tr><td>E.5-2 A leak from a superheated hydrochloric acid line results in a spill of 2500 lb of hydrochloric acid. Flash calculations indicate that 250 lb of hydrogen chloride is released as a vapor. Is this a Tier 1 or Tier 2 PSE?

Following the advice in Annex G, the flashed material and the remaining liquid are evaluated separately. The 2250 lb of remaining liquid release exceeds the Tier 2 threshold release quantity of 2200 lb for a strong acid.

However, the 250 lb of flashed anhydrous hydrogen chloride exceeds the Tier 1 TIH Zone C threshold quantity of 220 lb.

Although the 2250 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 PSE
5.2, Tier 1 definition
Table 1
Annex G</td></tr>
<tr><td>E.5-3 A pipe containing CO_2 and 10,000 vppm H_2S (1 % by volume) leaks and 7,000 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 6,945 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 6,999 (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 PSE
5.2, Tier 1 definition
Table 1</td></tr>
</table>

Example/Question	Tier 1/2
E.5-4 A day tank leaks 1500 kg of 35 % HCl. The physical properties of the solution qualify it as a strong acid. Is this a PSE? In making the determination, do I evaluate the anhydrous HCl (525 kg) component separately from the water component of the solution (975 kg), or do I use the mass of the entire solution (1500 kg)? Per Annex G, the total quantity of the solution should be used to determine whether or not the threshold quantity has been exceeded. In addition, any flashed/evolved/released HCl should be evaluated against the corresponding threshold quantity for anhydrous hydrogen chloride. Refer to G.5 of Annex G as well as Example E.5-2. In this case, the quantity released exceeded the threshold quantity for a TRC 8 material; therefore, this is a Tier 2 PSE. Annex G, Application of TRCs to Multicomponent Releases, describes a solution as a homogeneous mixture composed of only one phase. Therefore, the properties of the solution are used to determine the TRC that applies to the released stream as a whole. Annex G further states that if the properties or hazards of the solution are unknown, a company may use the properties or hazards of the solute and solvent separately and the release quantities to determine the applicable TRC and the threshold release quantity.	Tier 2 PSE 3.1.2, Acids/bases, strong definition Table 1 Annex G
E.5-5 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 Packing Group 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 1
E.5-6 2400 lb (in first hour) of an 18 wt% sodium hydroxide solution was released from primary containment outdoors. An 18 wt% sodium hydroxide solution has a pH of greater than 12.5, which makes it a strong base per the API 754 definition. The SDS also list the solution as Packing Group II. Is this a Tier 1 or Tier 2 PSE, and is the assessment based upon the weight of the solution or the anhydrous weight of sodium hydroxide? Annex G provides advice on how to categorize multicomponent releases. In the case of a solution, G.8 states to use the properties of the solution if known to determine the TRC. In this case, we know both the pH and packing group number of the solution. They both state a priority of categorization (i.e. toxicity, flammability, corrosivity, then packing group); therefore, as a strong base, this solution would be a TRC 8 material with an outdoor TQ of 2200 lb. Since the 2400 lb release exceeds the Tier 2 TQ, this is a Tier 2 PSE. NOTE A LOPC of a weak, moderate, or strong acid/base cannot be Tier 1 PSE based upon quantity released no matter the volume.	Tier 2 PSE 6.2, Tier 2 definition Table 1 Annex G

Table E.6—Process Safety Event Examples and Questions: Pressure-relief Device, Unsafe Location

Example/Question	Tier 1/2
E.6-1 There is a unit upset and the PRD opens to an atmospheric vent, resulting in a release of 300 lb of propane to the atmosphere with no adverse consequences. Is this a PSE? This is not a Tier 1 or Tier 2 PSE. Although the release volume exceeded the Tier 2 threshold quantity for propane, the PRD release did not result in one of the defined negative consequences, and it is not a Tier 2 PSE. A company may choose to count this as a Tier 3 demand on a safety system. Alternate Scenario: Same as above, but there was a non-precautionary site shelter-in-place. This is a Tier 2 PSE because it exceeded the Tier 2 threshold quantity for propane and resulted in one of the defined PRD negative consequence	Not a Tier 1 or Tier 2 PSE Tier 2 PSE 6.2, Tier 2 definition Tier 2 PSE 6.2, Tier 2 definition
E.6-2 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 Tier 1 criteria for PRD releases is independent of whether the PRD opened at, above, or below its set point or any other factors associated with design and installation. Releases from PRDs are only classified at Tier 1 or Tier 2 PSEs if one or more of the listed consequences occurs (i.e. rainout, discharge to a potentially unsafe location; an on-site shelter-in-place; public protective measures) and the release volume at the PRD discharge exceeds the Table 1 threshold quantity. None of those negative consequences is identified in the question; therefore, this event is not a Tier 1 PSE.	Not a Tier 1 PSE 5.2, Tier 1 definition Table 1
E.6-3 A facility had an event where the hot oil system overpressured 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. How should this event be classified? Since the event did not result in any of the Tier 1 or Tier 2 consequences, it is not a Tier 1 or Tier 2 PSE. However, a Company may choose to classify it as a Tier 3 challenge to a safety system. Section 7 describes several example Tier 3 indicators, including demands on safety systems and other LOPCs. Utility systems, including hot oil systems, fit 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 demands on safety systems.	Not a Tier 1 or Tier 2 PSE 3.1.38, Process definition 5.2, Tier 1 definition Table 1

Example/Question	Tier 1/2
E.6-4 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 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. 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. 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 demands on safety systems.	Not a Tier 1 or Tier 2 PSE 5.2, Tier 1 definition 6.2, Tier 2 definition
E.6-5 A shell of a tube and shell heat exchanger is protected from rupture in case of a tube leak by a PRD routed to atmosphere. The tubes contain ethylene and the shell contains cooling water. A tube ruptures and the shell side PRD opens. The ethylene is dispersed into the atmosphere, but the entrained cooling water rains out. The water is cool/ambient temperature and there is no risk of thermal burns to personnel. Is this a PSE? This is not a Tier 1 or Tier 2 PSE. To qualify as a PSE, the PRD would have to result in one or more of the defined negative consequences and the release volume would have to exceed the threshold quantity for that material. The rainout of cooling water does satisfy one of the PRD negative consequences; however, there is no threshold quantity for cooling water in Table 1, so the second condition for categorizing this PRD release is not satisfied.	Not a Tier 1 or Tier 2 PSE 5.2, Tier 1 definition 6.2, Tier 2 definition Table 1 3.1.42, Rainout definition

Example/Question	Tier 1/2
E.6-6 An atmospheric relief device lifts and discharges greater than a Tier 1 threshold quantity of material. Dispersion modelling conducted as part of the relief device design indicates that a flammable mixture could impact an elevated work platform on an adjacent tower. Knowing that the platform could be impacted, the company controls access to the platform via their authorization system. At the time of the release, the wind was blowing in the direction of the elevated work platform, but no one is on the elevated platform. Is this a Tier 1 PSE? This is not a Tier 1 PSE. Although the relief volume exceeded the Tier 1 threshold quantity, the discharge did not result in one of the four defined consequences. One of those consequences is release to a potentially unsafe location. The definition of unsafe location specifically excludes 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 that location is a controlled by virtue of authorized access or hard barriers with appropriate warning signs. Alternate Scenario 1:	Not a Tier 1 PSE 5.2, Tier 1 definition 3.1.56, Unsafe location definition
A worker was present on the platform in accordance with the site authorization requirements. The worker was able to escape unharmed. This is not a Tier 1 PSE. Even though a worker was present, by definition the work platform is not an unsafe location under the exclusion for controlled access. If the worker had been injured, then the event would be a Tier 1 or Tier 2 PSE dependent upon the severity of the injury. Alternate Scenario 2:	Not a Tier 1 PSE 5.2, Tier 1 definition 3.1.56, Unsafe location definition
The company did not control access to the platform via their authorization system or hard barriers and signage. This is a Tier 1 PSE, since the elevated work platform was impacted by the discharge and the exclusion for controlled access did not apply. The definition of unsafe location is independent of whether or not personnel are actually present at the time of the relief device discharge. Alternate Scenario 3:	Tier 1 PSE 5.2, Tier 1 definition 3.1.56, Unsafe location definition
The company did not control access to the platform via their authorization system or hard barriers and signage. A worker was present on the elevated work platform at the time of the relief device discharge, but the wind direction was away from the platform. This is not a Tier 1 PSE. Since the work platform was not actually impacted at the time of release, it did not qualify as an unsafe location. The assessment of a LOPC for Tier 1 or Tier 2 categorization is based upon actual conditions and results at the time of release and not on alternate what-if conditions.	Not a Tier 1 PSE 5.2, Tier 1 definition 3.1.56, Unsafe location definition

Table E.7—Process Safety Event E Examples and Questions: Company Premises, Process Safety Event with Multiple Outcomes, Pipelines

Example/Question	Tier 1/2
E.7-1 A pipeline leaks and releases 2000 lb of flammable gas above ground within 1 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 5.2, Tier 1 definition Table 1
E.7-2 A pipeline leaks and releases 2000 lb of flammable gas 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 5.2, Tier 1 definition Table 1
E.7-3 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 days away from work injuries, fire, and threshold quantity of liquid with a flash point < 23 °C (73 °F) and toxic gas].	Tier 1 PSE 5.2, Tier 1 definition
E.7-4 A transportation pipeline that is owned, operated, and maintained by Company A (a pipeline company) crosses through Company B's property (a refinery). The pipeline has a release from primary containment of flammable gas that ignites and causes greater than $100,000 damage to Company B's equipment. Is this a PSE and for which company? This is a Tier 1 PSE for Company A since there was an unplanned or uncontrolled LOPC that resulted in $100,000 fire damage. Company A is the responsible party since it owns, operates and maintains the pipeline.	Tier 1 PSE Annex A, Applicability 3.1.17, Direct cost definition 3.1.45, Responsible party definition 5.2, Tier 1 definition

Table E.8—Process Safety Event Examples and Questions: Marine Transport

Example/Question	Tier 1/2
E.8-1 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) and ≤ 93 °C (200 °F) released at a temperature below its flash point. The event is not a PSE since marine transport operation events are specifically excluded, except when the vessel is connected to the process for the purposes of feedstock or product transfer.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability
If the marine transport vessel was still connected to the process when the spill occurred, it would be a Tier 2 PSE.	Tier 2 1.2, Applicability 6.2, Tier 2 definition Table 1
E.8-2 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—Process Safety Event Examples and Questions: Truck and Rail

Example/Question	Tier 1/2
E.9-1 A Company railcar derails and spills more than 7 bbl of gasoline while in transit. The event 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
E.9-2 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.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability 3.1.4, Active staging definition
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 2). NOTE These examples illustrate the concepts of "active staging" and "on-site storage" and the boundary between transportation and process.	Tier 2 PSE 1.2, Applicability 3.1.4, Active staging definition
E.9-3 A third-party truck/trailer on company premises connected to the process has a spill of gasoline greater than 7 bbl in less than an hour while loading. The event is a Tier 1 PSE since the truck is considered part of the process while it is connected or in the process of connecting/disconnecting from the process for the purpose of feedstock or product transfer.	Tier 1 PSE 1.2, Applicability 5.2, Tier 1 definition
E.9-4 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. Alternate Scenario: A truck enters the refinery and parks with other trucks waiting to be loaded. The truck contains several hundred gallons of product from the previous load. The truck develops a leak, resulting in a LOPC of product in excess of the Tier 1 threshold quantity. Is this a Tier 1 PSE? This is not a Tier 1 PSE since the truck was not connected to the process nor in the process of connecting/disconnecting from the process. Similarly, the truck would not qualify as "active staging" since by definition active staging only applies to truck/rail waiting to be unloaded. Therefore, the LOPC should be counted as a transportation event.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability

Example/Question	Tier 1/2
E.9-5 Background: Caustic and aluminum react exothermically and generate hydrogen gas. Company X contracted its normal transport company for a routine delivery of 50 % caustic (a TRC 8 strong base). The transport company inadvertently selected an aluminum trailer and drove it to the caustic supplier's facility for loading. The trailer was delivered (dropped) at the Company X delivery yard on Sunday; the trailer was subsequently moved to the unloading station early Monday to begin unloading. The Company X loader noticed that the trailer was hotter than it should have been and began troubleshooting the problem. Before the problem could be rectified, the aluminum trailer ruptured and spilled the entire contents, which were well above the Tier 2 threshold amount. NOTE TRC 8 only has a Tier 2 threshold. The amount of hydrogen released was less than a Tier 2 amount. There were no injuries and the material was contained to prevent environmental impact. Is this is considered a Company X PSE? Although the trailer was not yet 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 2 release quantity was exceeded, this would be considered a Tier 2 PSE. Alternate Scenario: The trailer ruptures 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. 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 to be part of the transportation process vs being connected to the process or "in the process of connecting" to the process.	Tier 2 PSE 1.2, Applicability 3.1.4, Active staging definition 6.2, Tier 2 definition Table 1
E.9-6 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 to re-inventory the unit for start-up; 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 PSE 1.2, Applicability 3.1.38, Process definition 5.2, Tier 1 definition

Table E.10—Process Safety Event Examples and Questions: Downstream Destructive Devices

Example/Question	Tier 1/2
E.10-1 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 a release to a potentially unsafe location. 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 PSE 5.2, Tier 1 definition Table 1 Tier 3 PSE
E.10-2 100 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 PSE 5.2, Tier 1 definition Table 1
E.10-3 A PRD release, less than Tier 1 threshold quantity but greater than the Tier 2 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. Is this a Tier 1 or Tier 2 PSE? As described, both a Tier 1 and a Tier 2 consequence were realized. The Tier 1 consequence is the days away from work injury. The Tier 2 consequence is the PRD discharge greater than the Tier 2 threshold quantity discharged to a potentially unsafe location. This is a Tier 1 PSE; for events with multiple consequences, the highest classification prevails. Alternate Scenario: Same as above, except the toxic material was observed or detected, without injury, at an unrestricted 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 (discharge to a potentially unsafe location) as specified in the list of Tier 2 consequences. If the elevated platform was restricted, see 3.1.56, then this is not a Tier 1 or Tier 2 PSE and a company may choose to include this event in their Tier 3 indicators.	Tier 1 PSE 5.2, Tier 1 definition Tier 2 PSE 6.2, Tier 2 definition 3.1.56, Unsafe location definition
E.10-4 A propane tank overpressures through a PRD to the flare system. The pilots on the flare system are not working properly, and the flare does not combust the flammable gas. The event transpires over a period of 45 minutes. The volume of propane release was estimated to be 1300 lb. 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 Table 1
E.10-5 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. Alternate Scenario: An upset causes a PRD to open and release a two-phase mixture exceeding a Tier 1 or 2 threshold quantity. The liquid is carried over to the flare drum knockout, but no release to atmosphere in the form of rainout occurs. Is this a Tier 1 or Tier 2 PSE? 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 6.2, Tier 2 definition Table 1

Table E.11—Process Safety Event Examples and Questions: Vacuum Truck Operations

Example/Question	Tier 1/2
E.11-1 After collecting a load from an adjacent unit, a vacuum truck is parked near the wastewater treatment facility awaiting operator approval to connect to the process and discharge its load. 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
E.11-2 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 since the direct costs from the fire damage exceeded $2,500. The excess of hydrocarbon vapors absorbed by the carbon canister is the uncontrolled LOPC.	Tier 2 PSE 1.2, Applicability 6.2, Tier 2 definition
E.11-3 During the routine cleaning of sludge from a tank with the use of a third-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 overpressurization 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 PSE. Based upon the direct cost damage from the explosion that exceed $2500, the event would be classified as a Tier 2 PSE.	Tier 2 PSE 1.2, Applicability 6.2, Tier 2 definition

Table E.12—Process Safety Event Examples and Questions: Direct Cost

Example/Question	Tier 1/2
E.12-1 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 inspection to determine the extent of the damage and the necessary repairs totaled $8,500. The cost of the repairs, replacement, and cleanup totaled $20,000. Is this a Tier 1 or Tier 2 PSE? This is a Tier 2 PSE since the direct costs from the fire damage exceeded the Tier 2 threshold of $2,500 but was less than the Tier 1 threshold of $100,000. 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. Also excluded from the direct cost calculation is the cost for engineering or inspection assessments to determine the extent of damage or necessary repairs	Tier 2 PSE 6.2, Tier 2 definition 3.1.17, Direct cost definition
E.12-2 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 3.1.17, Direct cost definition
E.12-3 Upon shutdown of a H_2/CO partial oxidizer (gasifier), the high-pressure nitrogen purge failed to sweep the O_2 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 lb (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 led 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 PSE 3.1.17, Direct cost definition 5.2, Tier 1 definition
E.12-4 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 the destroyed reactor vessel ($225,000 to replace/repair). The company has decided to not replace or repair the damaged vessel. Is this a Tier 1 PSE? 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 whether those repairs are completed or not.	Tier 1 PSE 3.1.17, Direct cost definition 5.2, Tier 1 definition

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

Example/Question	Tier 1/2
E.13-1 A small quantity, less than a Tier 2 TQ amount, of very odorous material enters a cooling water system via an exchanger 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. Is this a Tier 1 or Tier 2 PSE? This is not a Tier 1 or Tier 2 PSE. The school teacher acting from an abundance of caution and deciding not to conduct recess outside does not constitute an officially declared shelter-in-place or evacuation. 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 3.1.32, Officially declared definition
E.13-2 Less than 1 lb 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/her neighbors to evacuate because “an alarm like that means there’s a problem at the refinery.” Is this a Tier 1 or Tier 2 PSE? This is not a Tier 1 or Tier 2 PSE. In this situation, the officer is acting as a private citizen suggesting a precautionary measure rather than an officially declared shelter-in-place or evacuation. 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 3.1.32, Officially declared definition
E.13-3 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? This is not a Tier 1 PSE. The school administrator does not have authority to declare a “community” evacuation or shelter-in- place.	Not a Tier 1 or Tier 2 PSE 5.2, Tier 1 definition 3.1.32, Officially declared definition

Table E.14—Process Safety Event Examples and Questions: Upset Emissions

Example/Question	Tier 1/2
E.14-1 Hydrocarbon vapors 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
E.14-2 A process furnace is permitted for SOx emissions. A process upset results 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 emissions during the upset period exceeded the TQ values in Table 1 in any 1-hour period, and one or more of the above criteria for an unsafe location was met, then the event would be categorized respectively as a Tier 1 or Tier 2 PSE. Since the upset emissions of SOx did not result in any of the negative consequences, it does not constitute a PSE.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability 3.1.57, Upset emission definition 5.2, Tier 1 definition 6.2, Tier 2 definition
E.14-3 During routine monitoring by the facility Leak Detection and Repair (LDAR) contractor, a valve was determined to have emissions of 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
E.14-4 A propylene truck unloading station is designed to vent residual propylene from the unloading hoses to atmosphere at a height of approximately 100 feet. Due to the frequency of propylene unloading, the vent stack is a permitted emissions source for propylene. During the PHA for this process, the PHA team identified the potential for the vent valves to leak during the unloading process. As mitigation, the PHA team recommended the installation of (1) a flow limiting orifice, (2) a knock-out pot, and (3) a dispersion analysis. The dispersion analysis, based upon a range of possible vent valve leaks, including a valve left open, show that a propylene release at 100 ft does not create a hazard to on-site personnel or the off-site community. Following an unload, an employee forgot to close the hose vent valve. During the subsequent unloading, the error was not discovered, resulting in liquid propylene flowing into the vent system. The quantity of propylene vapor released to atmosphere exceeded the threshold quantity for a Tier 1 PSE; however, there was no rainout, no on-site shelter-in-place, no evacuation, no public protective measures, and the discharge was previously proven to be to a safe location. Is this a Tier 1 PSE? This is not a Tier 1 PSE. This release does satisfy the definition of an upset emission, so it is correct to evaluate it for possible classification as a Tier 1 or Tier 2 PSE. Although the release volume exceeded the Tier 1 PSE threshold quantity, the release did not result in one of the four defined consequences; therefore, it does not qualify as a Tier 1 PSE.	Not a Tier 1 or Tier 2 PSE 1.2, Applicability 3.1.57, Upset emission definition 5.2, Tier 1 definition

Example/Question	Tier 1/2
E.14-5 While docked and connected to the process for loading, the crude ship's cargo tanks are manually vented to atmosphere to relieve pressure buildup as part of normal operations. This venting operation is permitted by the regulator agency under defined weather conditions (e.g. wind direction and speed). An operator manually vents the tanks and releases greater than a Tier 1 TQ of material without first checking that the weather conditions met the permit requirements. The weather conditions at the time of venting did not meet the required conditions. The released gas cloud migrated to an unsafe location being identified by gas detector net (20 % LEL), causing an emergency shutdown of the plant without any other consequence. Is this a PSE? This is a Tier 1 PSE. The venting of the cargo tanks did not conform to the permit requirements; therefore, this event meets the definition of an upset emission. Per 1.2, upset emissions are required to be evaluated as a possible Tier 1 or Tier 2 PSE. The release to an unsafe location combined with a release volume greater than the Tier 1 TQ qualifies this event as a Tier 1 PSE.	Tier 1 PSE 1.2, Applicability 3.1.57, Upset emission definition 5.2, Tier 1 definition

Table E.15—Process Safety Event Examples and Questions: Ancillary Equipment/Active Staging/Active Warehouse

Example/Question	Tier 1/2
E.15-1 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." The reporting scope includes any material that is part of the process, in on-site storage, or in an active warehouse. The consumables that are mentioned (hydraulic fluids, lubricating oil, etc.) are in the reporting scope provided the release occurs from ancillary equipment, which is defined in 3.1.7. Ancillary equipment must be connected to the process for the release to be part of the reporting scope. A release during on-site fueling operations of mobile and stationary equipment is outside the reporting scope per 1.2.l.	1.2, Applicability 3.1.38, Process definition 3.1.7, Ancillary equipment definition
E.15-2 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 awaiting transport to the disposal facility but was not connected to the process. Is this a Tier 2 PSE? This is not a Tier 2 PSE. The frac tank was not connected to the process but was instead awaiting transport for disposal or recycle. The frac tank had transitioned from being part of the process (while connected) to being in transportation mode. 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. Alternate Scenario: Instead of awaiting transport to a disposal facility, the frac tank was awaiting transport to a crude tank where the material could be recycled back into the process after the turnaround. In this situation, 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 for the refinery.	Not a Tier 2 PSE 1.2, Applicability Tier 2 PSE 1.2, Applicability 6.2, Tier 2 definition
E.15-3 An operator on the night shift was removing an intermediate bulk container (IBC) of reactant with a forklift from the warehouse for the upcoming production in Reactor #3. When pulled from the storage rack, the IBC container slipped off the forklift blades turned over and dropped to the ground. The top lid opened and released the reactant. Is this a PSE? The warehouse in this situation meets the definition of an "active warehouse" (i.e. an on-site warehouse that stores raw materials, intermediates, or finished products used or produced by a process). Active warehouses are part of the process, so we do have an unplanned or uncontrolled release of material from a process. The consequences of the release would need to be compared against the Tier 1 and Tier 2 consequences to determine if it qualifies as either/or Tier 1 PSE or Tier 2 PSE.	Possibly a Tier 1 or Tier 2 PSE 1.2, Applicability 3.1.5, Active warehouse definition 5.2, Tier 1 definition 6.2, Tier 2 definition
E.15-4 A spurious trip of the fire suppression system discharged Halon gas into the equipment room. Halon gas qualifies as a UNDG Class 2, Division 2.2 asphyxiant. The volume released exceed the Tier 1 TQ for an indoor release of Class 2, Division 2.2 material. Is this a Tier 1 PSE? This is not a Tier 1 PSE. The fire suppression system is mitigation equipment not connected to the process; therefore, by definition there was no unplanned or uncontrolled release from a process. NOTE In some locations, a Halon discharge may require environmental reporting to the applicable authorities.	Not a Tier 1 PSE 1.2, Applicability 5.2, Tier 1 definition

Example/Question	Tier 1/2
E.15-5 Acetic acid drums are being unloaded from a box trailer into the site active warehouse when a drum is punctured releasing 417 lb inside the box trailer. Acetic acid exhibits multiple hazards; it is a TRC 8 material skin corrosion (1A) and a TRC 7 material for flash point (39 °C). Is this a PSE? This is a Tier 2 PSE. By definition, the active warehouse is part of the process and the active unloading of drums from the box trailer “connects” the box trailer to the process. The 417 lb release exceeds the Tier 2 indoor threshold quantity for a TRC 7 material.	A Tier 2 PSE 1.2, Applicability 3.1.5, Active warehouse definition 6.2, Tier 2 definition
E.15-6 A tote of raw material is being moved from one area to another within the active warehouse. The tote is tipped over while being positioned on an outside loading dock and a flammable liquid exceeding the Tier 2 outdoor TQ is released from the tote. Is this a PSE? This is a Tier 2 PSE. Active warehouses are by definition part of the process; therefore, there was an unplanned uncontrolled release of material from a process that exceeded the Tier 2 outdoor TQ.	A Tier 2 PSE 1.2, Applicability 3.1.5, Active warehouse definition 6.2, Tier 2 definition

Table E.16—Process Safety Event Examples and Questions: Responsible Party

Example/Question	Tier 1/2
E.16-1 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 3.1.45, Responsible party definition
E.16-2 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.	3.1.45, Responsible party definition
E.16-3 A third-party tank truck operator begins filling his/her 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. Is this a Tier 1 PSE? This is a Tier 1 PSE since the LOPC occurred while disconnecting from the process (i.e. the loading rack). Although the third-party tank truck operator has an obligation to follow the operating procedures (i.e. close the belly valve before disconnecting the loading hose), he/she is not the operator of the facility and therefore he/she 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 third parties to use the facility, etc.	Tier 1 PSE 1.2, Applicability 3.1.45, Responsible party definition
E.16-4 A contractor performing work overpressured the contractor supplied tank, which is connected to a process. 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 event 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 PSE 1.2, Applicability 3.1.45, Responsible party definition 6.2, Tier 2 definition
E.16-5 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. Is this a Tier 1 PSE for the pipeline company or the refinery? This is a Tier 1 PSE for the pipeline company. 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 PSE 1.2, Applicability 5.2, Tier 1 definition 3.1.45, Responsible party definition

Example/Question	Tier 1/2
E.16-6 Company A owns a pipeline that has been out of service for 2 years. The pipeline runs from Company A's facility to a marine terminal owned by the government. Company A is in the process of cleaning up and decommissioning the line for removal via a pigging operation. During the course of this operation, 23 bbl of a TRC 8 material (60°C < FP < 93 °C, released < FP) is released in an hour due to a failure of a piping component. The failure does not occur on Company A's property but on the government's property. The entire release is contained in a concrete bunker on the government's property. Since this line has been out of service for a number of years, is no longer connected to the process, and the spill did not occur on Company A's property, is this a PSE? This is a Tier 2 PSE for Company A. There was an unplanned or uncontrolled release of TRC 8 material from a process that exceeded the Table 1 threshold quantity in a 1-hour period. Even though the line was out of service and had been for several years and was no longer connected to the process, it is still process equipment. Also, Company A is the responsible party; it doesn't matter that the release occurred on government property.	Tier 2 PSE 1.2, Applicability 3.1.45, Responsible party definition 6.2, Tier 2 definition
E.16-7 Two pipeline companies share a common right of way. The pipelines are independently owned and operated. Company A's pipeline experiences a LOPC leading to a Tier 1 fire and explosion that subsequently causes Company B's pipeline to also have a Tier 1 LOPC. Both companies follow Annex A in API 754. Is this one or two Tier 1 PSEs, and who reports the PSEs? In this case, there are two responsible parties. Each pipeline company is the responsible party for their own line. Each pipeline company experienced a LOPC that resulted in a Tier 1 consequence. Each company would report a Tier 1 PSE. The fact that Company A's LOPC and fire was the initiating cause for Company B's LOPC does not make the Company B LOPC a continuation of the first event. Alternate Scenario:	Tier 1 PSE 1.2, Applicability 3.1.45, Responsible party definition 5.2, Tier 1 definition
In the case that both pipelines were owned by the same company and the two LOPCs impact the same population or equipment, there is only one responsible party and only one Tier 1 PSE is recorded.	Tier 1 PSE 1.2, Applicability 3.1.45, Responsible party definition 5.2, Tier 1 definition

Annex F
(informative)

Listing of Chemicals Sorted by Threshold Quantity (Based on UNDG 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. A copy of the list of chemicals can be found on the CCPS website. The user must verify that the version is valid for the Third Edition of API 754.

CCPS Website:

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 UNDG classification system can be found at the following websites.

UNECE Website:

https://unece.org/transportdangerous-goods/adr-2021-files

The Dangerous Goods List Complete with UN Numbers in PDF Format:

https://unece.org/sites/default/files/2021-01/ADR2021_Vol1e_0.pdf (see Table A)

Alphabetical Cross Reference in PDF Format:

https://unece.org/sites/default/files/2021-01/ADR2021_Vol1e_0.pdf (see Table B)

The following discussion, extracted from AIChE CCPS's *Process Metrics: Guide for Selecting Leading and Lagging Indicators* [10], 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]

	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)	$V \geq 500\ LC_{50}$ and $LC_{50} \leq 200$ mL/M^3
I (Hazard Zone B)	$V \geq 10\ LC_{50}$; $LC_{50} \leq 1000$ mL/m^3; and the criteria for Packing Group I, Hazard Zone A are not met
II	$V \geq LC_{50}$; $LC_{50} \leq 3000$ mL/m^3; and the criteria for Packing Group I, are not met
III	$V \geq 0.2\ LC_{50}$; $LC_{50} \leq 5000$ 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 UNDG 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 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 RP. 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 website.

Annex G
(informative)

Application of TRCs to Multicomponent Releases

G.1 General

Many streams involved in LOPC scenarios contain multiple components that may cover more than one TRC. The following sections provide guidance on the determination of the TRC for these streams.

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 the release or the properties documented in a SDS. Companies should be consistent in their approach for all LOPCs.

G.2 Gases or Vapors with Toxic Components

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 a 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 E.5-1.

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 (TRC 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 Hansen and Crowl (2009). [23]

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

LOPC of some gases have the ability to create atmospheres insufficient in oxygen for human life without being TIHs 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. Multicomponent 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 TRC 7 for Tier 1 and Tier 2.

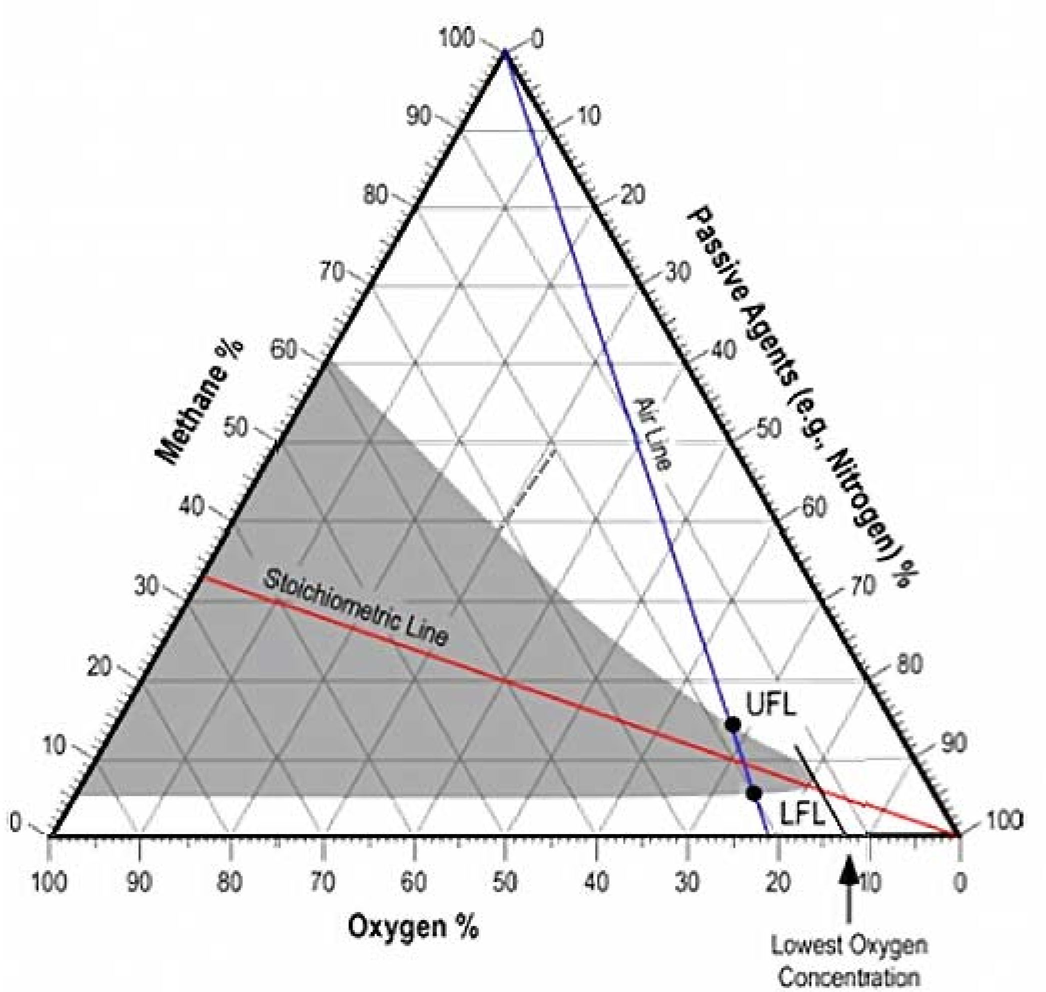


Figure G.1—Flammability Limits of Methane, Nitrogen, Oxygen Mixtures

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 TRCs, 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 1 hour or less would be considered a Tier 1 PSE.

G.5 Flashing Liquid Streams Containing TIHs

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, E.5-2 and E.5-4.

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. 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 Streams 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 TRCs 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 flash point below 93 °C (200 °F) and qualify for a Tier 2 threshold release quantity of 1000 kg (2200 lb) or 7 bbl. In that case, the volume of the entire release would be compared to the 1000 kg (2200 lb) or 7 bbl 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 1 hr 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 are used to characterize the stream in Table 1 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 TRC 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 TRC and threshold release quantity.

Annex H
(informative)

PSE Tier 1/Tier 2 Determination Decision Logic Tree

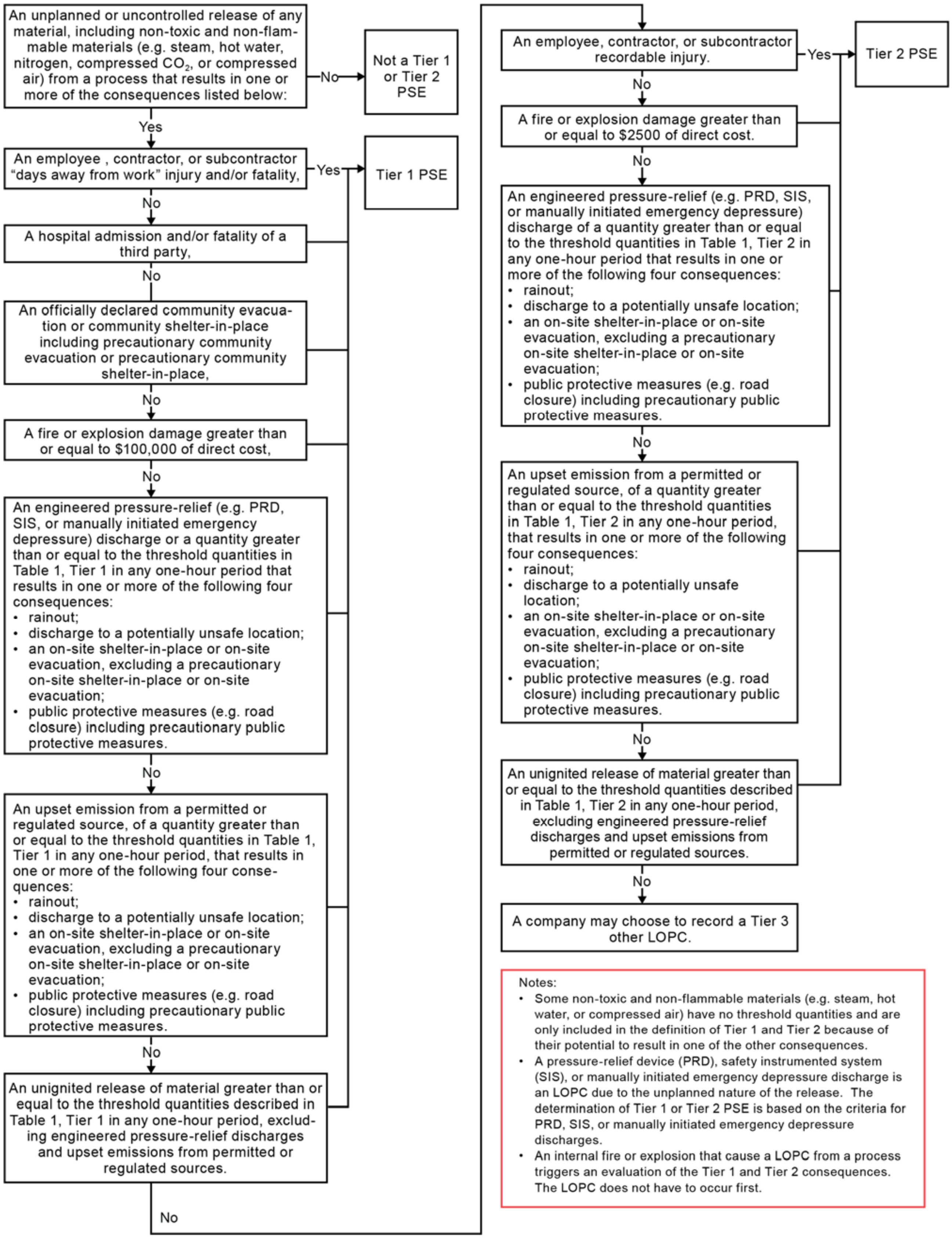


Figure H.1—PSE Tier 1/Tier 2 Determination Decision Logic Tree

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 PSEs 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 API 754, provide baseline 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 and 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 SOL, 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 PSEs. Identifying, defining, and measuring Tier 4 indicators are 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 do not 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 PSEs 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.

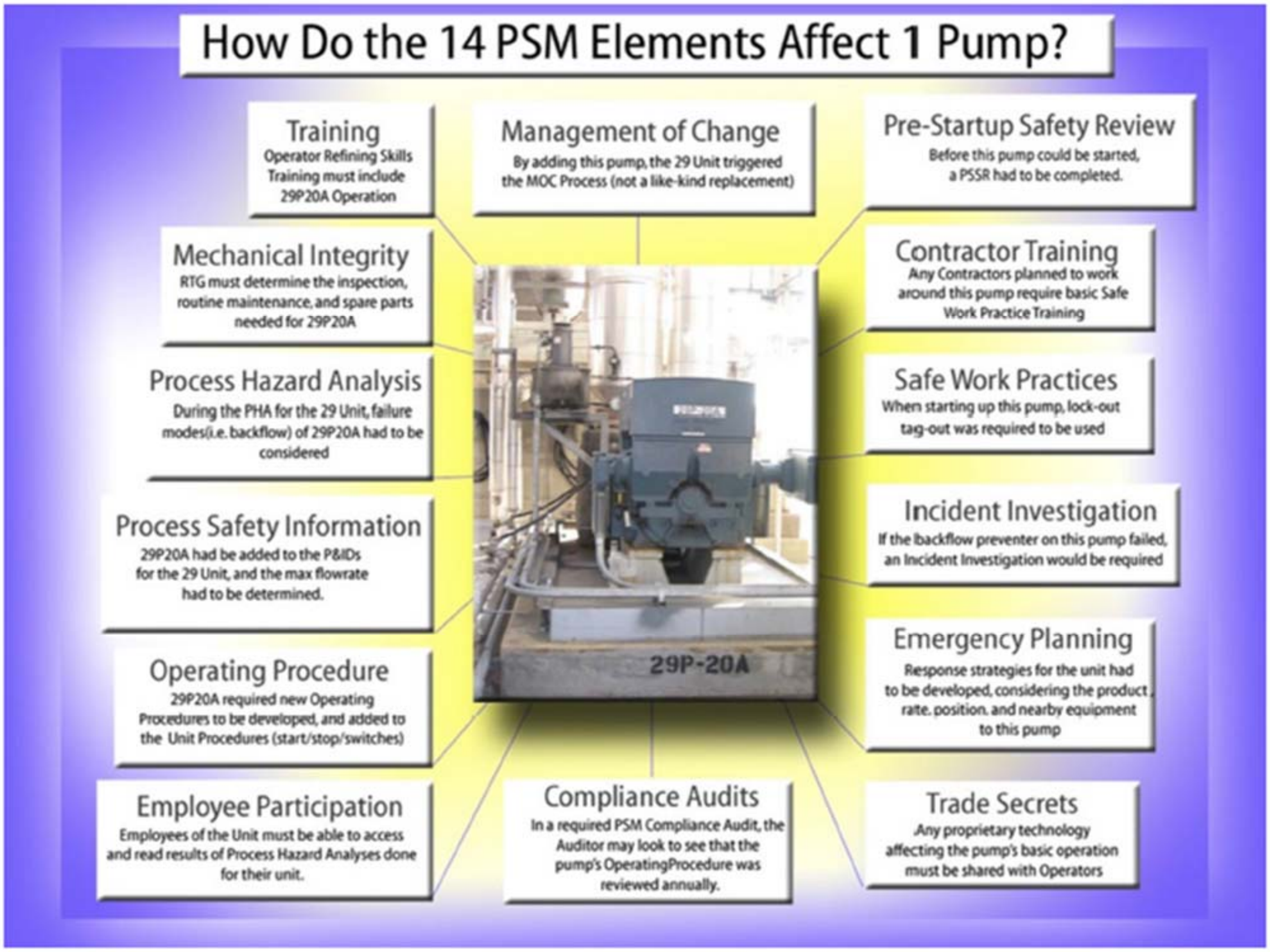


Figure I.2—Illustration of Process Safety Elements Relating to Equipment

c) Use past company or industry incidents and investigation results to illustrate how PSEs have impacted the facility. The U.S. Chemical Safety Board [1] 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.

[1] http://www.csb.gov/investigations/.

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.

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.3.2.2 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 does not 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, SISs, relief devices) and processes (e.g. inspection and testing, training, MOC) in place to prevent or mitigate PSEs.

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 PSEs. 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 accident investigations to identify weaknesses in or missing prevention and mitigation barriers or processes critical to the prevention of future PSEs. 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 QA/QC 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 PSE 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.

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

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

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

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

e) 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 PSE 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, and what electronic tools are available and/or may be required? What data is "tactical" vs "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 subcategories 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 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 subcategories is standardized (otherwise a data analyst may be required to take additional time to manipulate and interpret data for their analysis).

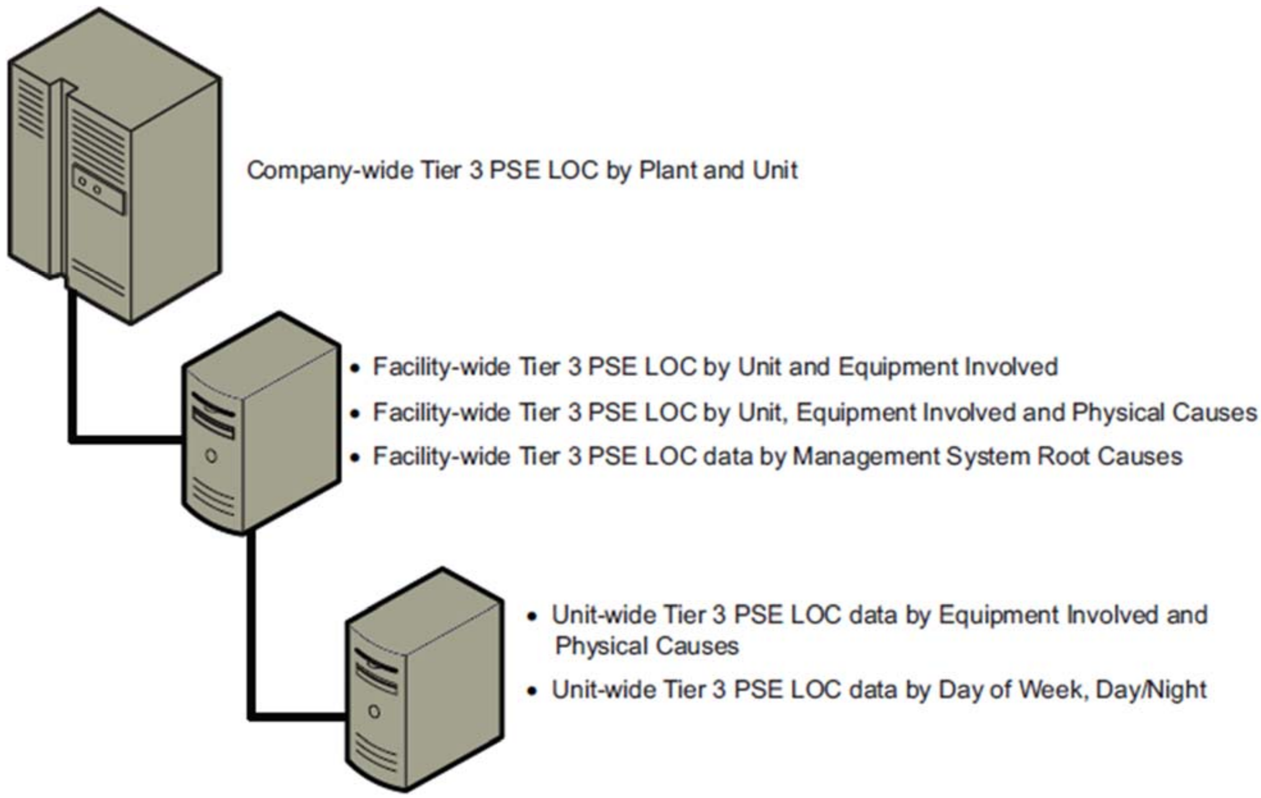


Figure I.4—Illustration of Data Flow and Need for Categorization

A good starting point for potential categories and subcategories would be use of the information in 10.4.4 of API 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 LOPC PSEs by site.

— Tier 3 LOPC PSEs by site and unit.

— Tier 3 LOPC PSEs by equipment.

— Tier 3 LOPC PSEs by equipment and physical cause(s).

— Tier 3 LOPC 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 I.5.4 of this annex.

I.5.3.4 QC 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 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 are 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 are 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. These 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 and conducted less frequently are illustrated in I.5.4.

Finally, a company should consider how the data are 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 are tactical vs 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 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 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 % 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.

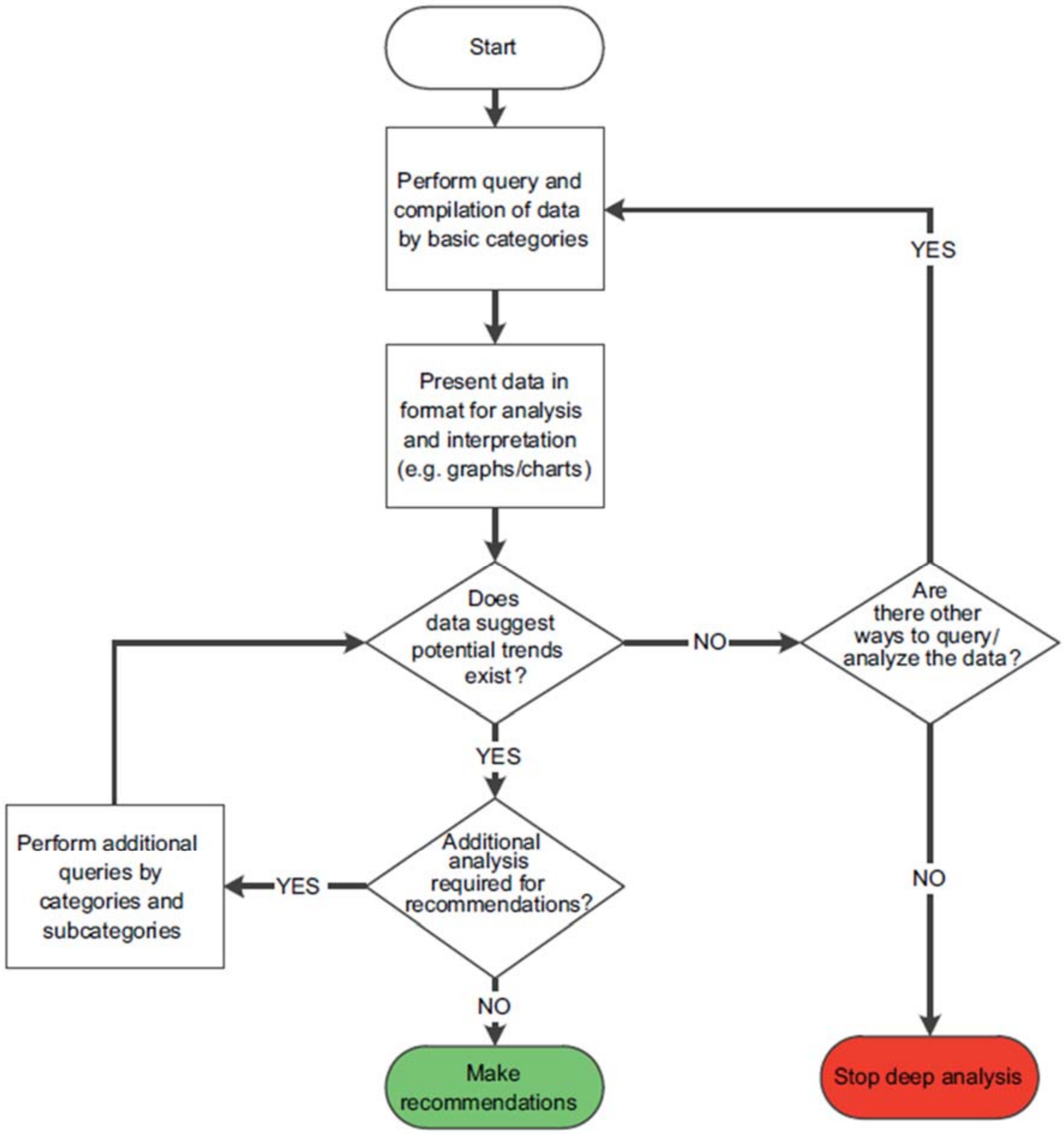


Figure I.5—Example of Data Funneling Flow Diagram

As illustrated in the Figure I.7, over 80 % 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 widespread 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 average of 3 months. Three was chosen because a quarter of a year is a natural subset that is commonly used in businesses.

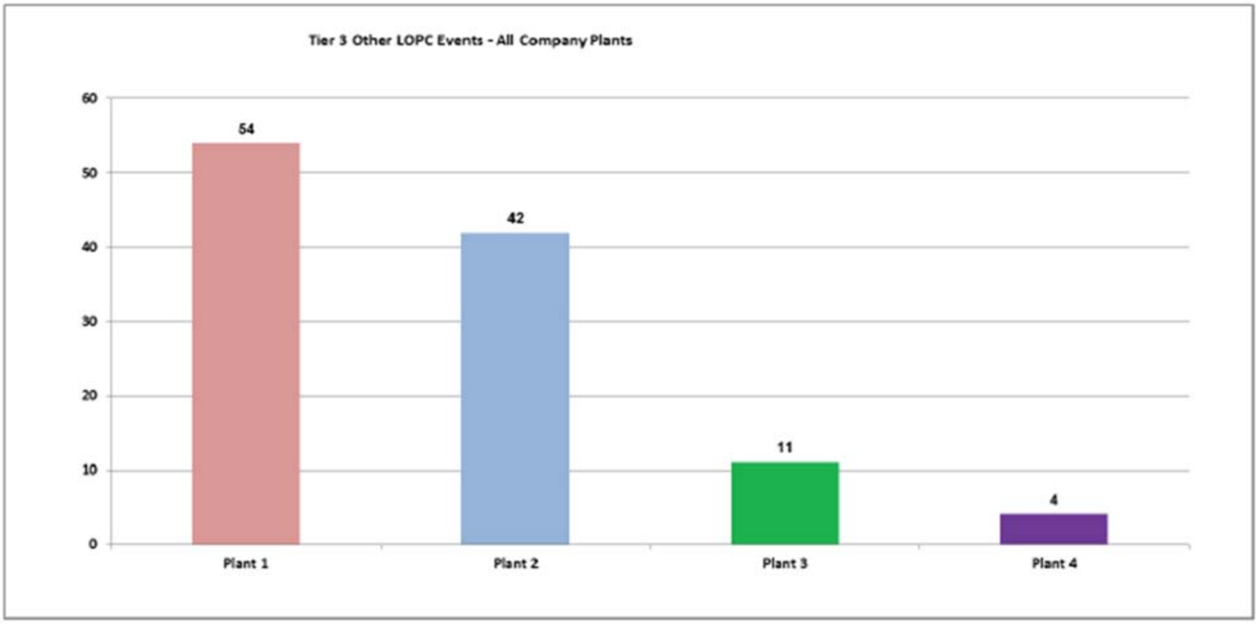


Figure I.6—Example PSE Tier 3 Other LOPC Graph

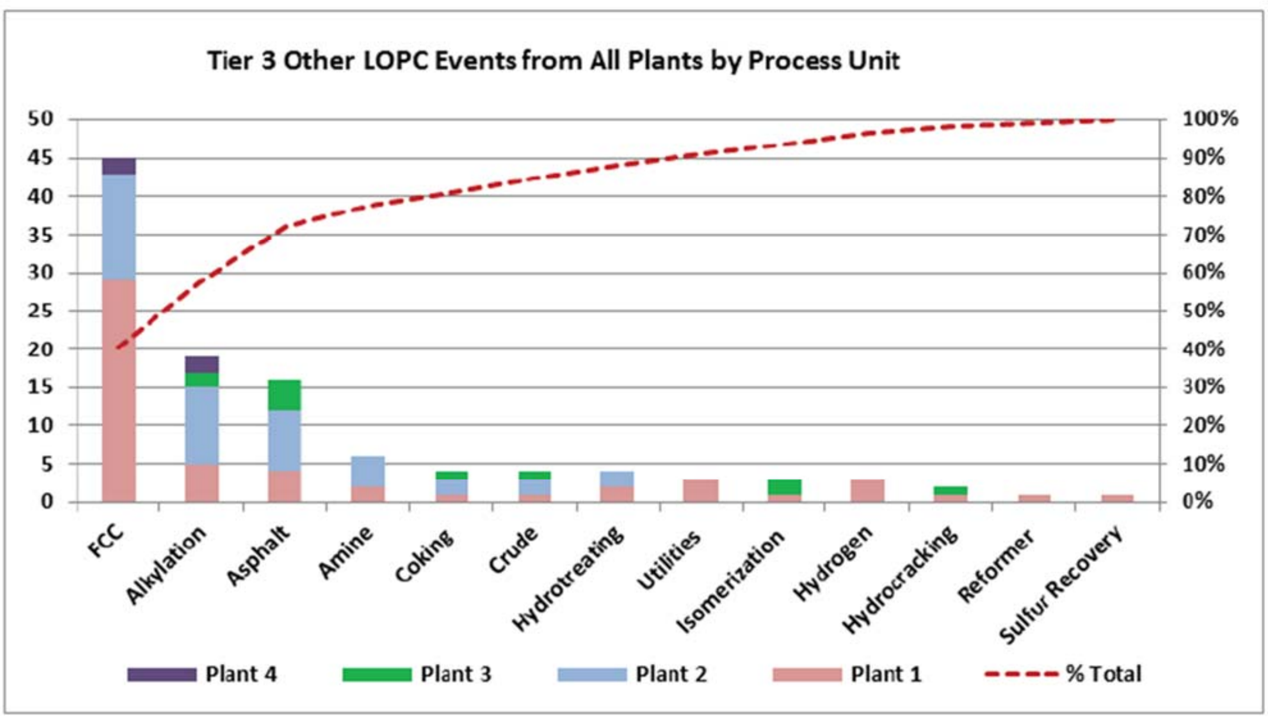


Figure I.7—Example PSE Tier 3 Other LOPC Graph by Plant and Process Unit

In Figure I.12, the red lines are upper and lower control limits and 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 have 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).

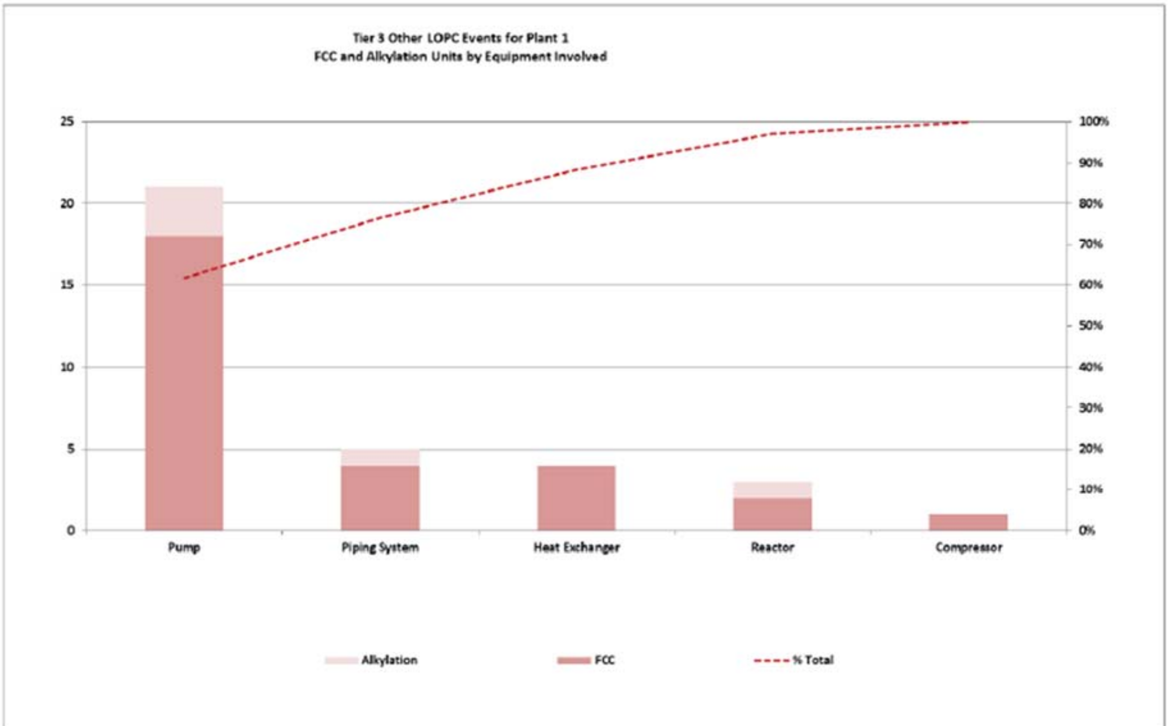


Figure I.8—Example PSE Tier 3 Other LOPC Graph for Plant 1 FCC and Alkylation Units by Equipment Involved

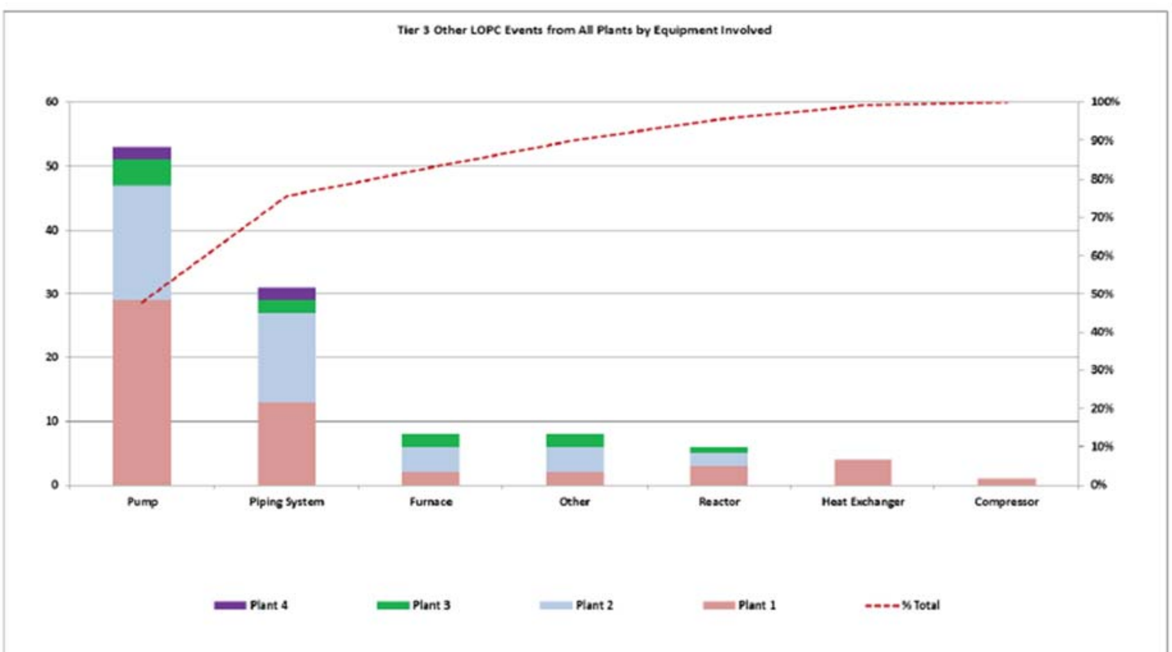


Figure I.9—Example PSE Tier 3 Other LOPC Graph by Plant and Equipment Involved

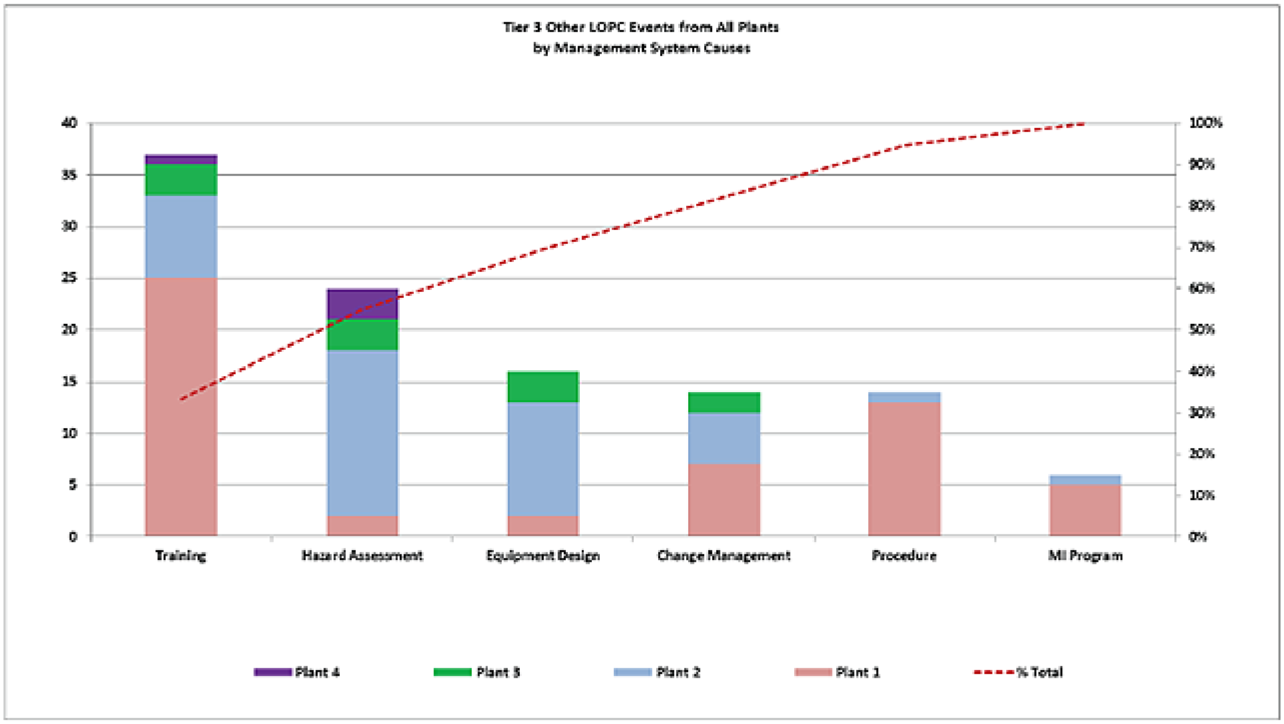


Figure I.10—Example PSE Tier 3 Other LOPC Graph by Plant and Management System Root Causes

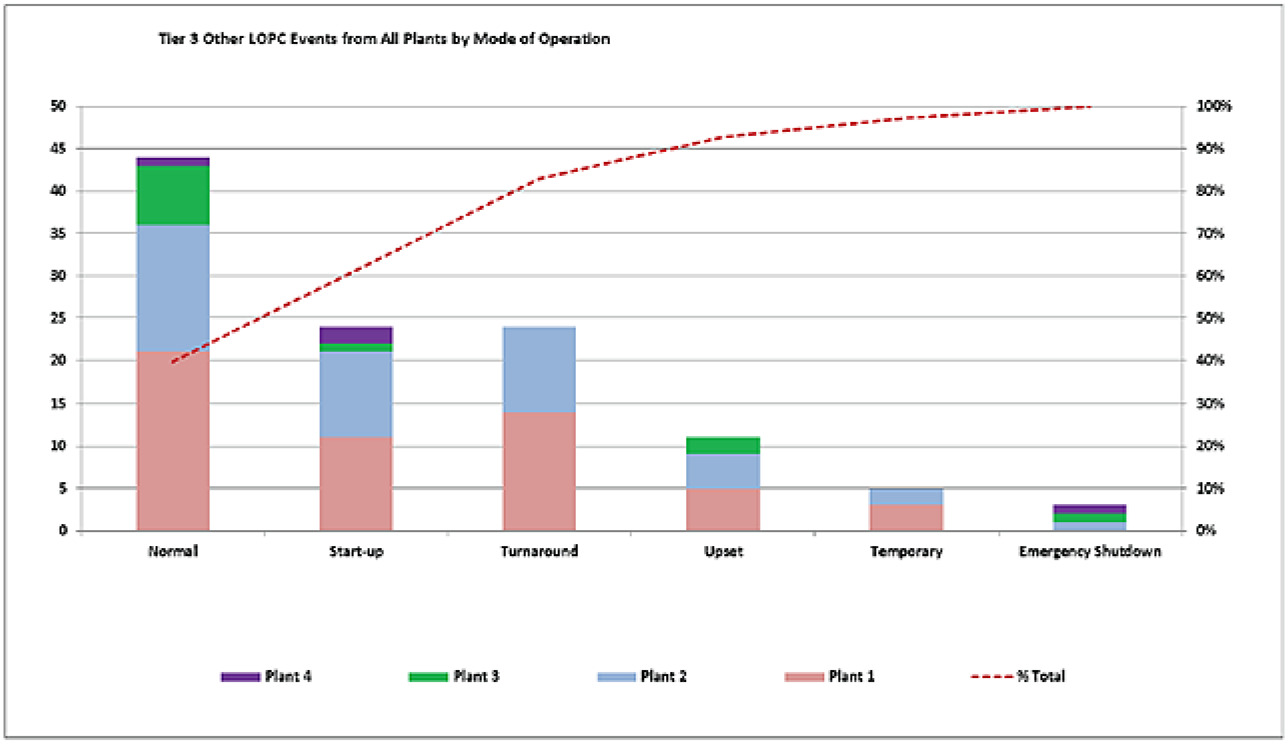


Figure I.11—Example PSE Tier 3 Other LOPC Graph by Plant and Mode of Operation

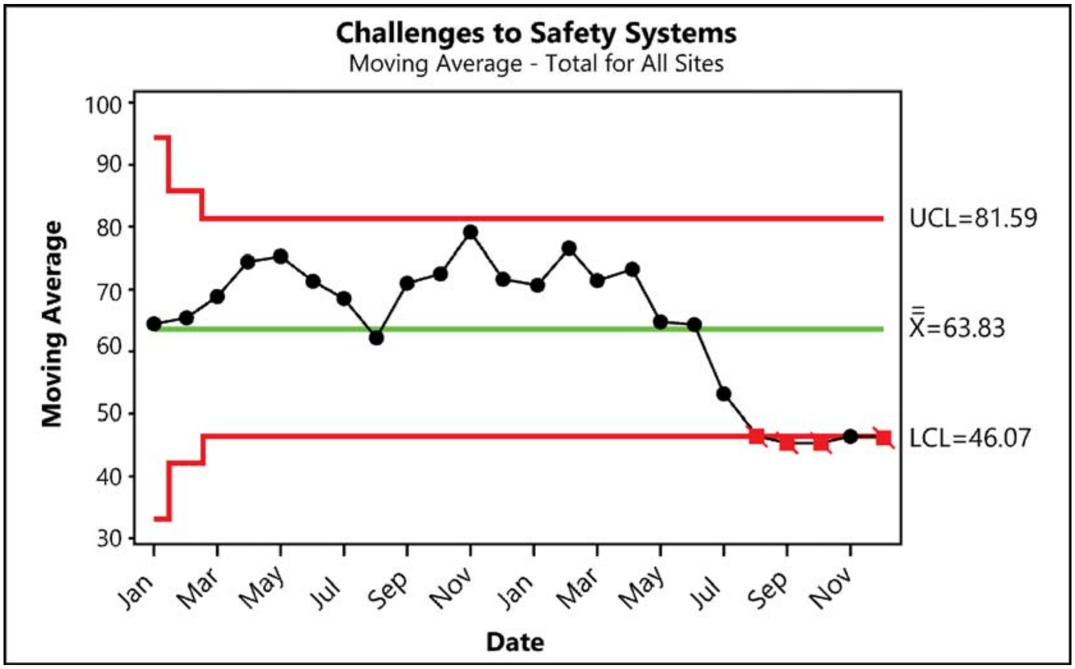


Figure I.12—Example of Moving Average for Demands on Safety Systems

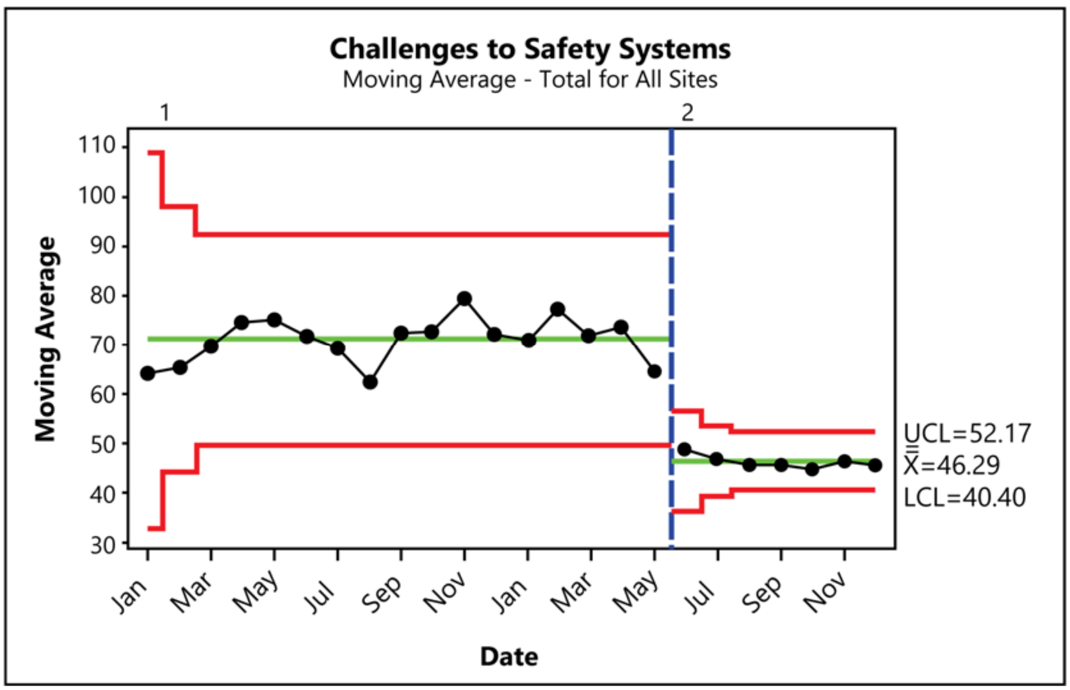


Figure I.13—Example of Moving Average for Demands on Safety Systems—Separated into Stages

The data now have 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 analyses 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, and 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 are well understood and re 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 accident 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, accident 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, accident 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, the 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 the 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, PRDs, 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 vs 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 MOC and 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 vs 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 755. [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, start-up).

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.

Bibliography

The following documents are directly referenced in this RP.

[1] API Standard 521, *Pressure-relieving and Depressuring Systems*, Seventh Edition

[2] ANSI/API Recommended Practice 755, *Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries*, First Edition

[3] ASTM D86-12 [2], *Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure*

[4] ASTM D92-12b, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*

[5] ASTM D93-15, *Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester*

[6] ASTM D3941-14, *Standard Test Method for Flash Point by the Equilibrium Method With a Closed-Cup Apparatus*

[7] ASTM D56-05, *Standard Test Method for Flash Point by Tag Closed Cup Tester*

[8] ASTM E1719-12, *Standard Test Method for Vapor Pressure of Liquids by Ebulliometry*

[9] AIChE CCPS [3], *Guidelines for Process Safety Metrics*, New York, 2009

[10] AIChE CCPS, *Process Metrics: Guide for Selecting Leading and Lagging Indicators*, Appendix B (additional information regarding UN dangerous goods classification and listing of chemicals), New York, 2018, https://www.aiche.org/sites/default/files/docs/pages/ccps_process_safety_metrics_-_v3.2.pdf

[11] Hart, C., "Stuck on a Plateau: A Common Problem," workshop paper prepared for the National Academy of Engineering Program Office Accident Precursors Project, Washington, DC, 2003

[12] Heinrich, H.W., *Industrial Accident Prevention*, New York, McGraw-Hill, 1931

[13] Hopkins, A., "Thinking About Process Safety Indicators," Working Paper 53 prepared for the Oil and Gas Industry Conference, Manchester, UK, 2007

[14] ISO 10156:2010(E) [4], *Gas cylinders—Gases and gas mixtures—Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*, Third Edition

[15] IOGP Report No. 456 [5], *Process Safety—Recommended Practice on Key Performance Indicators,* http://www.ogp.org.uk/pubs/456.pdf

[16] Reason, J.T., "The Contribution of Latent Human Failures to the Breakdown of Complex Systems," *Philosophical Transactions of the Royal Society B*, *327*:475–484, 1990

[17] UK HSE [6], *Developing Process Safety Indicators: A Step-by-Step Guide for Chemical and Major Hazard Industries*, Series Code HSG254, Sudbury, Suffolk, UK, 2006

---

2 ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.

3 American Institute of Chemical Engineers, Center for Chemical Process Safety, 120 Wall Street, 23rd Floor, New York, NY 10005, www.aiche.org/ccps.

4 International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

5 International Association of Oil & Gas Producers, City Tower, 40 Basinghall Street, 14th Floor, London EC2V 5DE, United Kingdom, www.iogp.org.

[18] UNECE [7], ECE/TRANS/202, Vol. I and II ("ADR 2009"), *European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)* http://www.unece.org/trans/danger/publi/adr/adr2009/09ContentsE.html

[19] United Nation's *Globally Harmonized System of Classification and Labeling of Chemicals (GHS)*, Eighth Edition, New York and Geneva, 2019, https://www.unece.org/fileadmin/DAM/trans/danger/publi/ghs/ghs_rev08/ST-SG-AC10-30-Rev8e.pdf

[20] OSHA 3245-01R [8], *OSHA Recordkeeping Handbook: The Regulation and Related Interpretations for Recording and Reporting Occupational Injuries and Illnesses*, http://www.osha.gov/recordkeeping/index.html

[21] U.S. DOT [9], 49 *CFR*, Part 172, *Subpart B—Table of Hazardous Materials and Special Provisions*, https://www.ecfr.gov/cgi-bin/text-idx?node=pt49.1.172#sp49.2.172.b

[22] U.S. DOT, 49 *CFR* 173.2a, *Classification of a Material Having More Than One Hazard*, http://edocket.access.gpo.gov/cfr_2006/octqtr/49cfr173.2a.htm

[23] Hansen, J.T. and D.A. Crowl, "Estimation of the Flammability Zone Boundaries for Flammable Gases," *Process Saf. Prog.,* 29(3):209–215, December 2009

[24] Baker, J.A. et al., "The Report of the BP U.S. Refineries Independent Safety Review Panel," January 2007

Further Reading

The following documents are not directly referenced in this document but provide a useful source of relevant information.

[25] Broadribb, M.P. et al, "Cheddar or Swiss? How Strong Are Your Barriers? (One Company's Experience with Process Safety Metrics)," presentation at CCPS 5th Global Congress on Process Safety, Tampa, FL, April 26–30, 2009

[26] AIChE CCPS, *Guidelines for Risk Based Process Safety*, New York, 2007

[27] NEI 99-02 Revision 5 [10], *Regulatory Assessment Performance Indicator Guideline*, 2007

[28] OECD 12 [11], *Guidance on Safety Performance Indicators Related to Chemical Accident Prevention, Preparedness and Response for Industry*, Second Edition, 2008, *OECD Environment, Health and Safety Publications, Series on Chemical Accidents,* No. 19, Paris, 2008

[29] U.S. Chemical Safety and Hazard Investigation Board, Investigation Report No. 2005-04-I-TX 13, "Refinery Explosion and Fire," BP, Texas City, March 2005

[30] AIChE CCPS, *Guidelines for Integrating Management Systems and Metrics to Improve Process Safety Performance*, John Wiley and Sons, Hoboken NJ, 2016

---

6 Health and Safety Executive, Knowledge Centre, (1G) Redgrave Court, Merton Road, Bootle, Merseyside L20 7HS, United Kingdom, www.hse.gov.uk.

7 United Nations Economic Commission for Europe, Information Service, Palais des Nations, CH-1211 Geneva 10, Switzerland, www.unece.org.

8 U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue NW, Washington, DC 20210, www.osha.gov.

9 U.S. Department of Transportation,1200 New Jersey Avenue SE, Washington, DC 20590, www.dot.gov.

10 Nuclear Energy Institute, 1201 F Street NW, Suite 1100, Washington, DC 20004-1218, www.nei.org.

11 Organisation for Economic Co-operation and Development, 2, rue André Pascal, 75016 Paris, France, www.oecd.org.

American Petroleum Institute

200 Massachusetts Avenue, NW
Suite 1100
Washington, DC 20001-5571
USA

202-682-8000

Additional copies are available online at www.api.org/pubs

Phone Orders:	1-800-854-7179	(Toll-free in the U.S. and Canada)
	303-397-7956	(Local and International)
Fax Orders:	303-397-2740	

Information about API publications, programs and services is available on the web at www.api.org.

Product No. K75403