Learning from Global Upstream Process Safety Event Data

Kirsty Walker, Schlumberger; David Fargie, bp; Wendy Poore, Olav Skar, IOGP

Abstract

The International Association of Oil and Gas Producers (IOGP) is a global forum in which Member companies identify and share best practices to achieve improvements in many areas including upstream process safety. In 2010, the IOGP started a pilot project to collect upstream process safety event (PSE) data in alignment with the upstream and downstream reporting criteria.

In 2014, a PSE section was added to the annual Member company IOGP safety data collection process. Participating companies initially provided their lagging Tier 1 and Tier 2 PSE data for trending and benchmarking. In recent years, the data request has included a requirement to submit a narrative description for Tier 1 PSE, with identification of the barrier failure and causal factors that contributed to the event. The narrative descriptions and detailed information on the material released, rate and consequences of the event are used in an annual data quality control validation exercise to confirm the Tier 1 classification. The validation process is conducted with Member company representatives who are specialists in process safety and data reporting. This group has developed a point of release list and a set of key words, based on the threat lines in a generic PSE bow tie, to further categorize the Tier 1 PSEs. This analysis has provided the basis for a standardized industry approach to the prevention of process safety fatal incidents, known as Process Safety Fundamentals.

This is the largest database of upstream process safety performance and fatality data, and it puts IOGP in a unique position to be able to encourage international collaboration and sharing of best practices to prevent process safety incidents and their potential impact on life, the environment and asset loss. At IOGP we welcome the opportunity to present our data collection process and lagging indicator trends (2014 to 2021) as well as the industry initiatives based on this data.

Introduction

The International Association of Oil and Gas Producers (IOGP) is a global upstream forum in which Member companies identify and share best practices to achieve improvements in many areas including upstream process safety. The IOGP Safety Committee has undertaken a multi-year strategic project to focus on fatality prevention, known as Project Safira, focused on personal safety, transportation safety and process safety (Walker et al, 2020). This paper presents the IOGP data collection methodology for process safety events, the latest data analysis work conducted on process safety events (PSE) and some associated learnings.

Process safety events are one of the most significant causes of fatalities in the upstream oil and gas industry (Figure 1). They can result in significant impact to the environment, and they have a financial impact due to production losses and asset damage. IOGP Member companies investigate and analyse these events to identify the causes and implement lessons learned to prevent recurrence. However, as these events are relatively infrequent in any particular company, collecting process safety lagging performance indicators at an industry level allows for a larger dataset to improve learning.

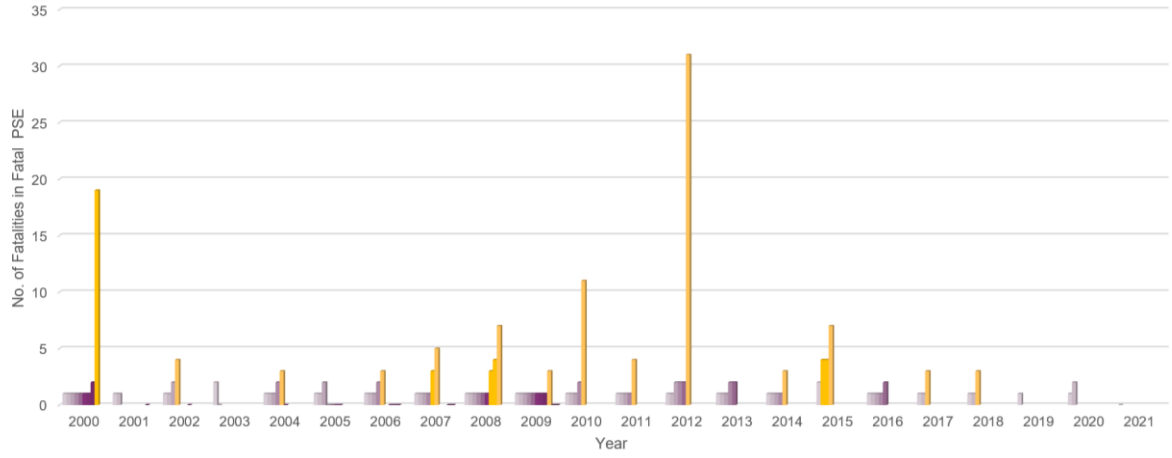

Figure 1—IOGP Reported Fatal Process Safety Events (2000-2021 inclusive)

Each bar in the graph represents a fatal incident, with the height of the bar indicating the number of fatalities. As shown in Figure 1, process safety events with one or more fatalities have occurred annually from 2000 to 2020 and 19 involving three or more fatalities, which have occurred, on average every 14 months. In the 96 fatal PSEs reported to the IOGP from 2000 to 2021, 216 people lost their lives (215 workforce and 1 third party). In 42 of these events, where 127 people lost their lives, ignition occurred, as was the case in almost all the process safety events where three or more people were fatally injured.

2021 was the first year since 2000 that no fatal process safety event was reported by IOGP Member companies.

Data Collection Process

In 2010, IOGP recognized the need to develop specific upstream industry guidance for process safety event reporting related to wells operations and production activities (Walker et al, 2020). The IOGP published Report No. 456 “Process Safety –

Recommended Practice on Key Performance Indicators" (IOGP Report 456, 2011) built on the framework and definitions included in the equivalent downstream Recommended Practice (RP), published by API (ANSI/API RP 754,1st Edition, 2010) and specific upstream examples.

The IOGP also started a pilot project to collect upstream PSE data in 2010. In 2014, following the pilot study, a formal Member company annual data submission has been requested and a PSE section was added to the annually published IOGP Safety Data User Guide (for latest see IOGP Report 2021su). The data request has been refined over recent years to include additional information for the purposes of learning, including the development of a list of point of releases (Table 1) and a taxonomy of keywords based on a generic PSE bow tie (Figure 2), both having been based on analysis of previously reported PSE Tier 1 events.

Participating companies provide their lagging Tier 1 and Tier 2 PSE data for trending and benchmarking, with a narrative description for Tier 1 PSE, identification of barrier failures and causal factors that contributed to the event, as well as information on the material released, release rate and consequences of the event. Recently categorization against the IOGP Process Safety Fundamentals has also been added.

This information is used in annual data validation exercises (Walker et al, 2014, 2018 and 2020) performed by Member company experts to confirm the Tier 1 classification and check the associated point of release and key word categories to enable consistent trending and benchmarking across the entire Tier 1 data set. As the IOGP has a strict confidentiality policy concerning data reported by Member companies, any clarifications required are followed up with the company involved by the IOGP secretariat to preserve anonymity.

Table 1 – Point of release for PSE Tier 1 categorization

Piping Systems	**Equipment**	**Tanks and Sumps/Pits**
- Piping joint - Piping material/tubing - Valve (body, stem, plugs) - Choke - Instrumentation and small bore tubing - Sight glass - Platform/well pad flowline - Flexible hose/piping	- Pressure vessel - Pig launcher/receiver - Pump - Compressor/blower/fan - Meter - Filter - Fired heater/Boiler/Furnace - Power generation unit - Reactor - Heat exchanger	- Atmospheric tank - Atmospheric tank overflow - Pressurized storage vessel - Sump/pit overflow
Relief, Vent and Discharge Systems	**Breaking Containment Locations**	**Wells, Drilling and Intervention**
- Relief valve (body, plugs) - Flare and atmospheric vent systems (intended discharge location) - Flare and atmospheric vent systems (not at intended discharge location) - Drain - Discharge to sea	- Breaking containment location - Loading/unloading coupling - Sample system - Piping/valve (inadvertently left) open to atmosphere	- Well - Subsea well - Well intervention equipment - Mud circuit/tanks
Subsea	**Onshore Pipelines/Flowlines**	**Unknown/Insufficient Information**
- Subsea Pipeline/Flowline - Subsea equipment	- Onshore pipeline - Onshore flowline - Unknown/ insufficient information	- Unknown/Insufficient Information

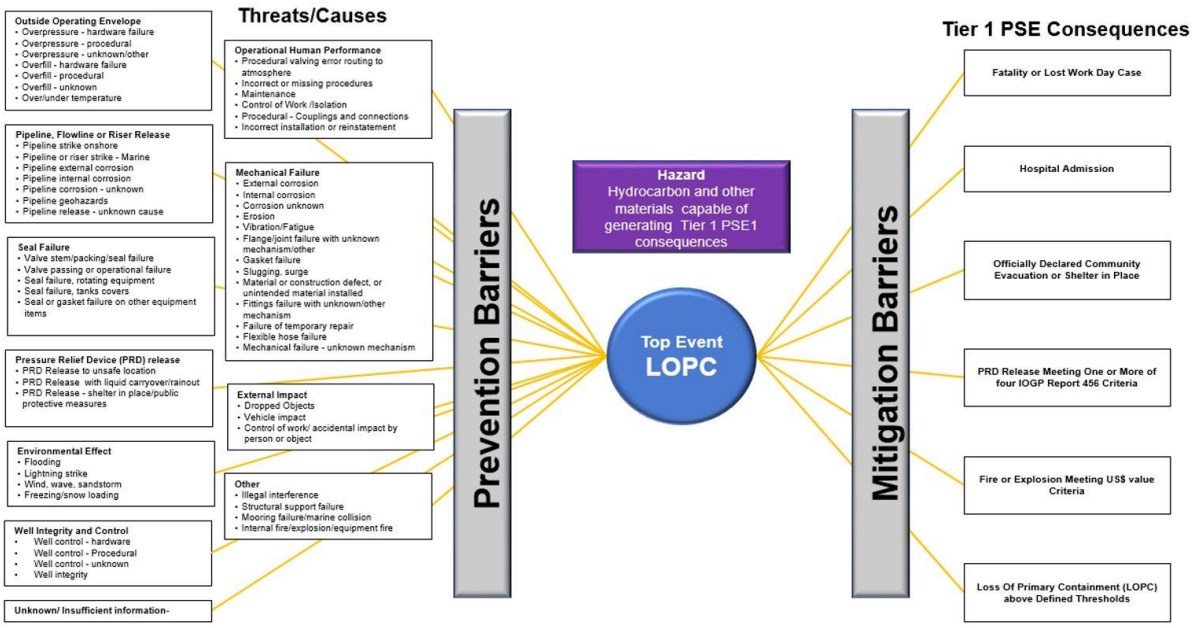

Figure 2—PSE generic Bow and associated 'Key Words'

Results - Annual Process Safety Indicator Report

Annual IOGP process safety indicator reports provide the number of Tier 1 and Tier 2 PSE reported by participating Member companies (IOGP 2021p), broken down by:

- Onshore and offshore
- Drilling and production
- Geographic region
- Activities
- Consequences
- Material released.

IOGP has provided guidance on the development and use of Tier 3 and Tier 4 process safety KPIs (IOGP Report 456, 2018) however, these are not included in the annual PSE indicators report as they are primarily intended for use at company or site level.

Tier 1 and Tier 2 PSE are normalized by work hours associated with process safety events in the drilling and production work functions (as defined in the annual safety data user guide) as reported by Member companies in their safety data submission. The formula below is used to calculate the PSE Rate (IOGP Report 456, 2018).

$$\text{PSER} = \frac{\text{Total PSE Count}}{\text{Total Hours Worked (for drilling and production activities)}} \times 1{,}000{,}000$$

Data are only included in the normalized results where both work hours and process safety event data are reported for the year, country and work function by the submitting company. In 2021, the published PSE data covered over one and a half billion upstream work hours and 47 IOGP Member companies, operating in 87 countries. The overall PSE Tier 1 and Tier 2 rates for 2012 to 2021 are shown in Figure 3 (note: 2011-2012 PSE rates reflect the introduction of IOGP reporting; data collected since 2013 carry greater confidence). The full IOGP Process Safety Indicator reports are publicly available (latest report is IOGP 2021p).

A separate category has been created for process safety events which were caused by wilful damage or sabotage. These events are not included in the normalized PSE rates published, as the lessons learned are mainly related to security rather than process safety controls.

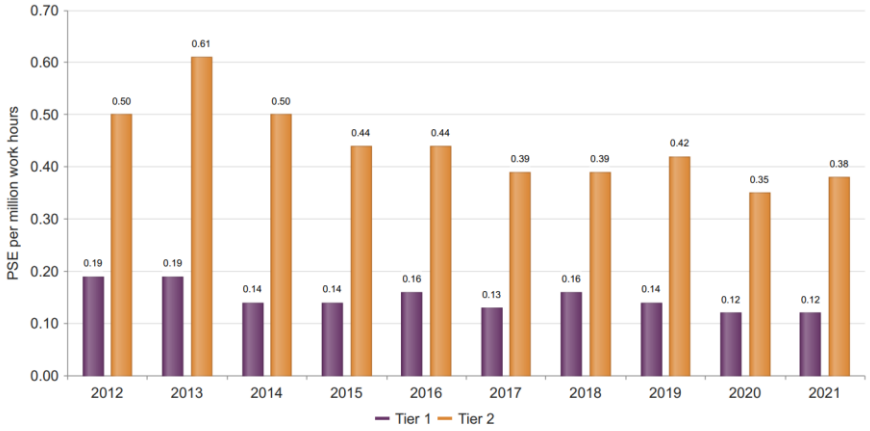

Figure 3—IOGP Member Company reported Tier 1 and Tier 2 PSE Rates (2011-2021 inclusive)

Results – Key Word Analysis

From 2014 to 2021, 1808 Tier 1 PSE have been reported to IOGP (excluding sabotage/willful damage related PSE), of these 1449 were provided with a narrative description A keyword analysis was conducted for all 1449 Tier 1 PSEs reported from 2014 to 2021. The preliminary observations presented represent the 1,345 events which had sufficient information provided to enable assignment of a key word. The key word category analysis shows mechanical failures to represent the cause of 36% of the Tier 1 PSE reported, Figure 4.

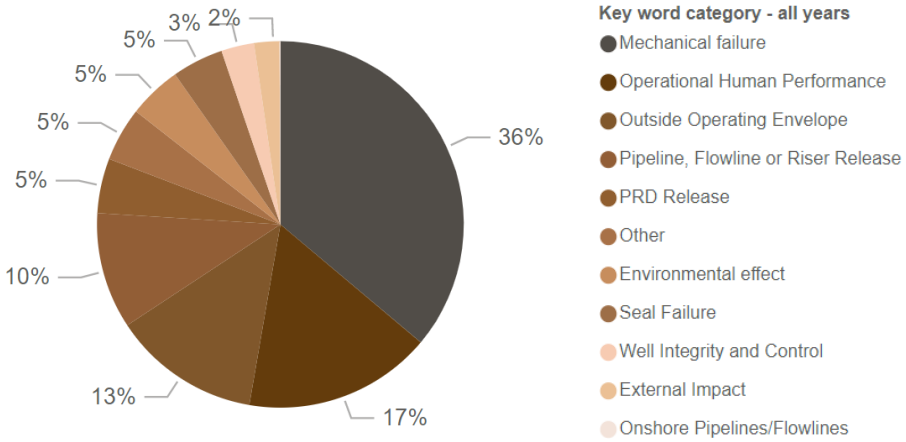

Figure 4—PSE Tier 1 keyword category analysis 2014-2021, excluding PSE with 'Unknown/insufficient information'.

A year-on-year analysis of the percentage key word categories shows similar trends, as shown in Figure 5. The key word categories were very similar for the seven years of data analyzed.

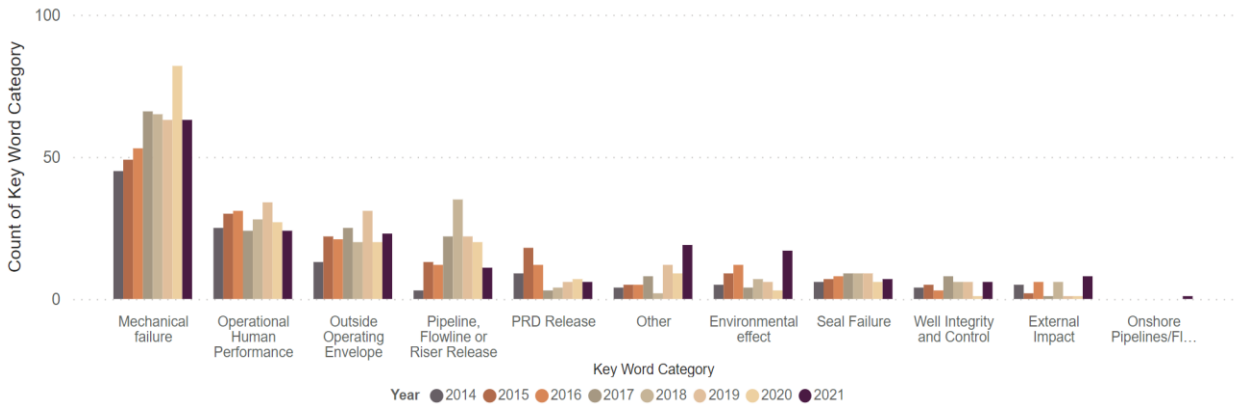

Figure 5—Number of Tier 1 PSE per key word category by year, 2014-2021.

Mechanical Failures

The mechanical failure keywords assigned to 486 Tier 1 PSEs are shown **in Figure 5.** Over the seven-year period shown, 22% of the Tier 1 PSEs were as a result of mechanical failure of unknown cause, almost 27% were due to corrosion (internal, external or unknown), and erosion accounted for a further 11% of the mechanical failure events.

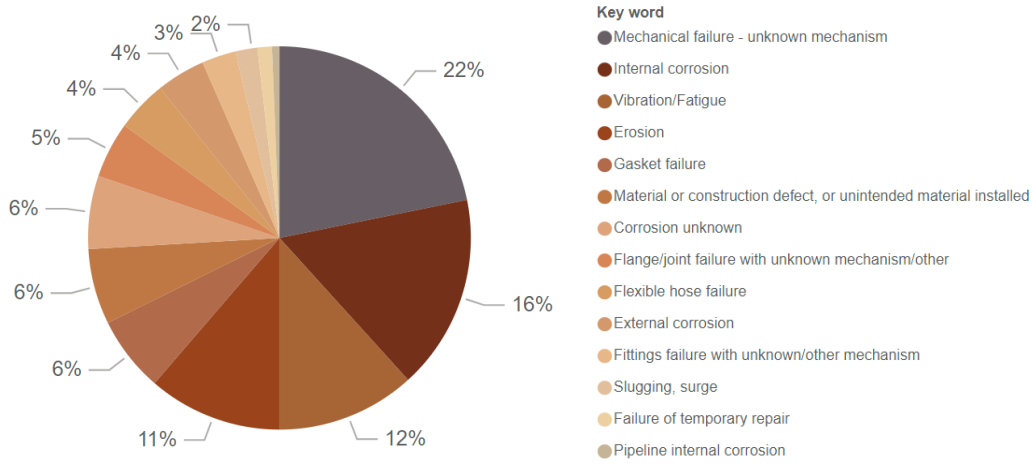

Figure 5—Tier 1 PSE mechanical failure key word assignments, 2014-2021 combined.

A year-on-year analysis of the 486 events assigned a mechanical failure keyword reveals similar annual results, as shown in Figure 6. For 106 of the events, the specific type of mechanical failure could not be identified from the narrative descriptions provided.

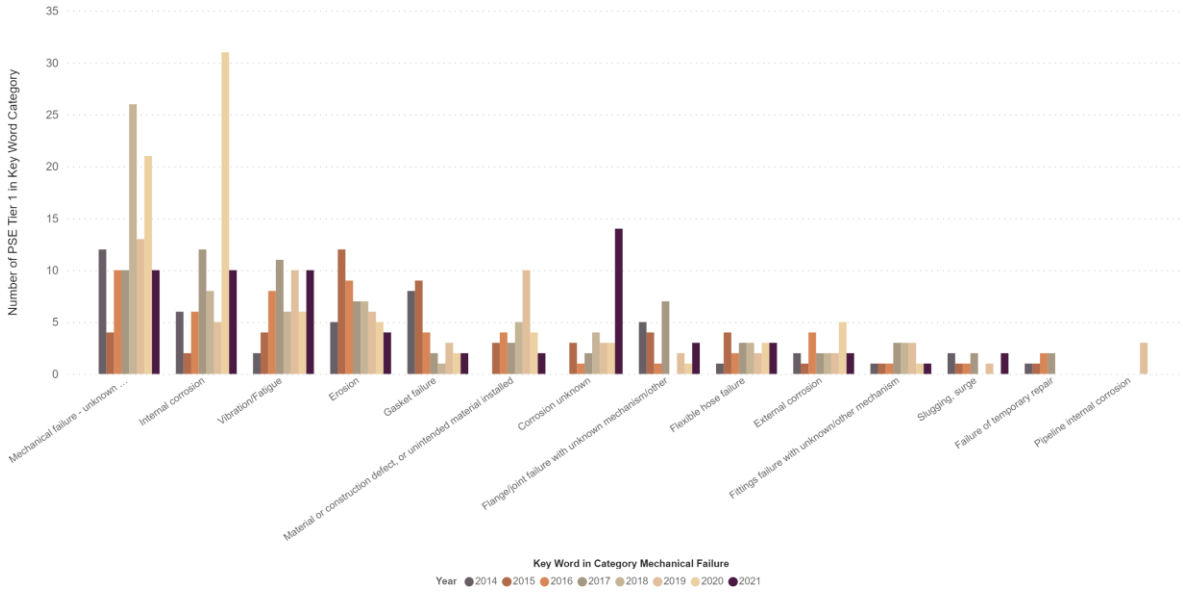

Figure 6——Number of Tier 1 PSE mechanical failure key word assignments, 2014-2021 by year.

The top three reported causal factors for mechanical failure related PSEs were:

- Inadequate maintenance/inspection/testing
- Inadequate design/specification/management of change
- Inadequate/defective tools/equipment/materials/products

Operational Human Performance

The 223 Tier 1 PSE assigned to operational human performance were also analyzed in more detail. Figure 7 shows that 36% were associated with control of work and isolation practices, and a further 30% were associated with procedural errors that involved a valve being inadvertently opened to the atmosphere.

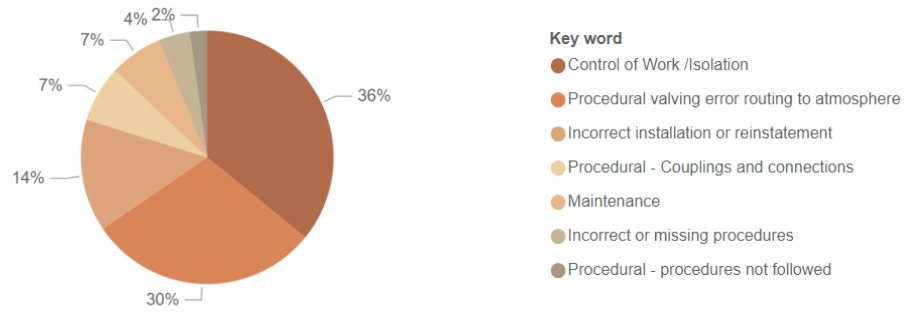

Figure 7—Tier 1 PSE operational human performance key word assignments, 2014-2021 combined.

A year-on-year analysis of the 223 events assigned an operational human performance keyword category shows similar annual results, Figure 8.

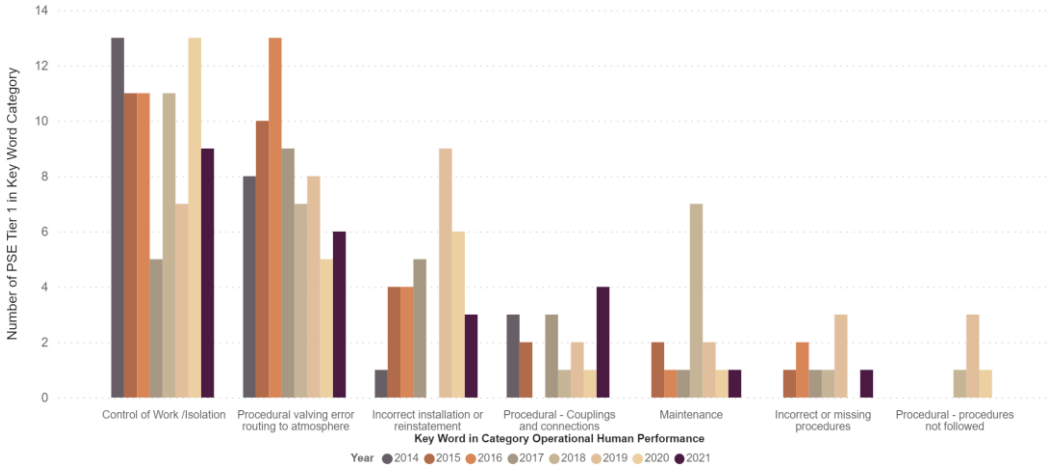

Figure 8—Number of Tier 1 PSE operational human performance key word assignments, 2014-2021 by year.

The top three reported causal factors for operational human performance related PSEs were:

- Inadequate work standards/procedures
- Inadequate hazard identification or risk assessment
- Violation unintentional (by individual or group)

Outside Operating Envelope

The keyword category outside the operating envelope was assigned to 175 Tier 1 PSE, with overfill assigned to 75% of the events in this category, Figure 9.

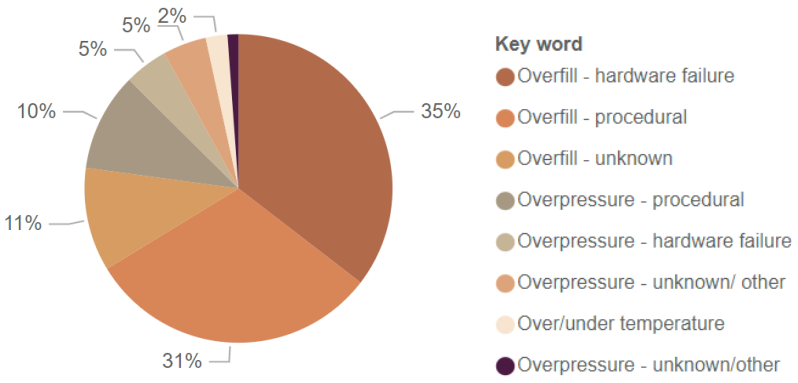

Figure 9—Tier 1 PSE outside operating envelope key word assignments, 2014-2021 combined.

Figure 10 shows that the percentage of overfill events due to hardware or procedural causes remains significantly higher than overpressure events.

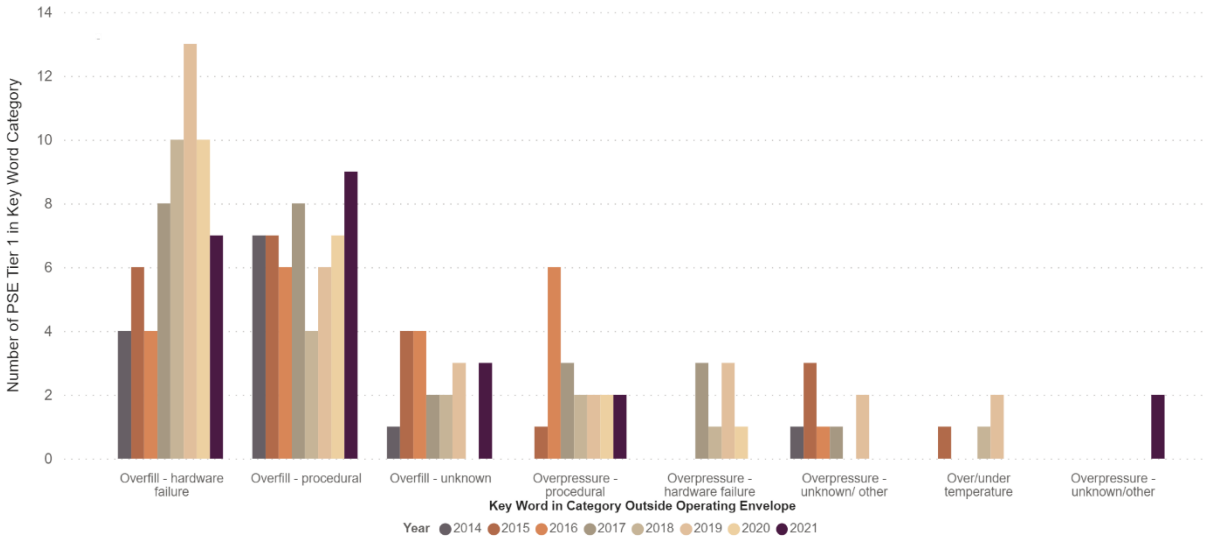

Figure 10— Number of Tier 1 PSE outside operating envelope key word assignments, 2014- 2021 by year.

Results - Point of Release Analysis

The keyword categories for point of release have been defined to enable consistent assignment (Walker et al, 2020).

Analysis was conducted on the point of release of all 1,449 Tier 1 PSEs reported from 2014 to 2021 (excluding sabotage/willful damage related PSE). The data presented represent 1,321 Tier 1 PSEs where the point of release could be identified, Figure 11. The category analysis shows piping systems to be the point of release of 31%, tanks and sumps/pits 17%, onshore pipelines/flowlines 15%, and equipment representing 13% of the Tier 1 PSE reported.

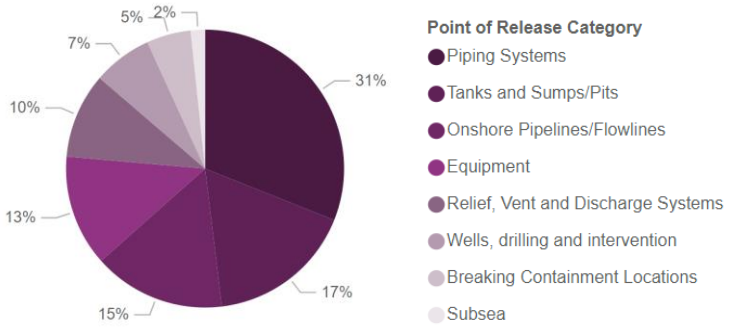

Figure 11—Tier 1 PSE point of release assignments, 2014-2021 combined.

A year-on-year analysis of the number of point of release categories assigned showed similar annual levels, Figure 12.

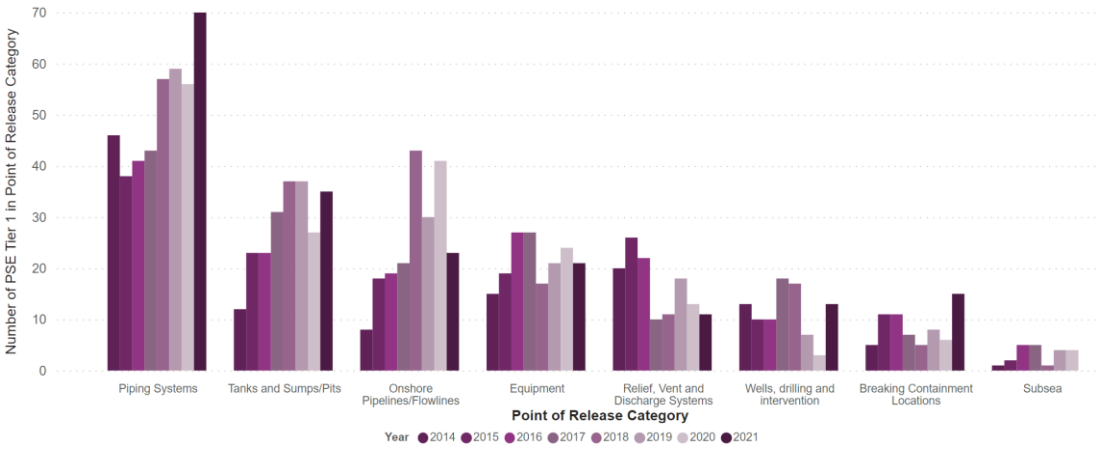

Figure 12— Number of Tier 1 PSE by point of release category, 2014- 2021 by year.

Piping Systems

A total of 408 Tier 1 PSE were included in the piping systems point of release category. 32% were releases from piping material/ tubing, 20% from piping joints, 19% from valves, and 13% from instrumentation and small bore tubing, Figure 13.

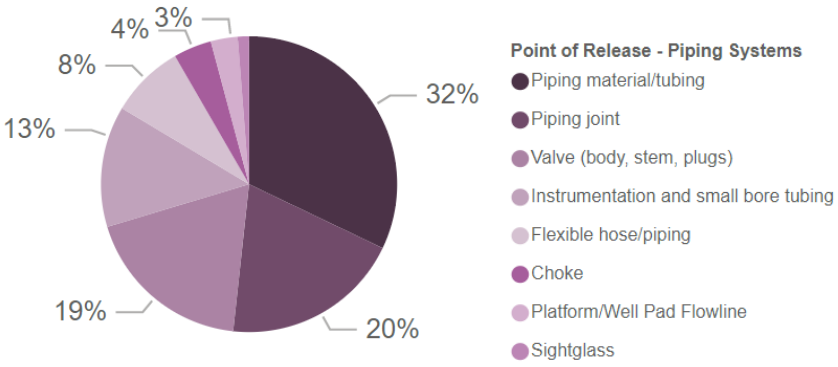

Figure 13—Tier 1 PSE point of release assignments – piping systems, 2014-2021 combined.

Tanks and Sumps/Pits

Releases from tanks and sumps/pits were involved in 225 events. 55% involved atmospheric tank overflows, and a further 38% were due to other releases from atmospheric tanks.

Onshore pipelines and flowlines

Onshore pipelines and flowlines accounted for a further 110 Tier 1 PSEs, with 62% of releases from onshore pipelines and 38% from onshore flowlines.

Equipment

Releases from equipment were associated with 171 Tier 1 PSE as shown in Figure 14.

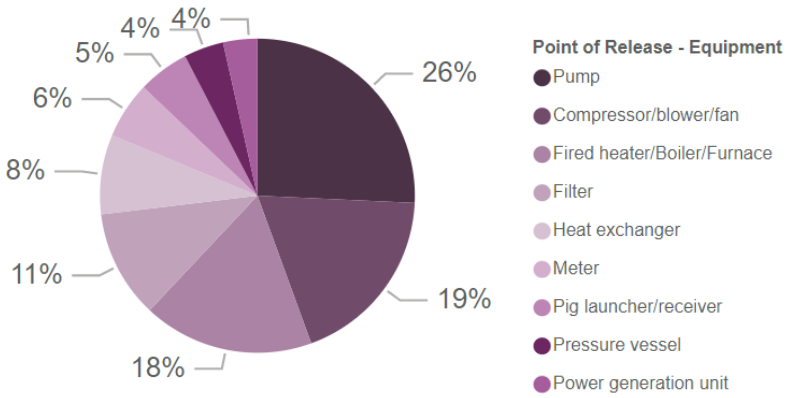

Figure 14—Tier 1 PSE point of release assignments – equipment, 2014-2021 combined.

Results – Causal Factors

In their IOGP data submissions, participating companies are asked to assign causal factors to PSE Tier 1 events. The same list of causal factors is used across all applicable IOGP safety data reporting, and is available in the annual user guide (IOGP Report 2021su). The list includes process (conditions) and people (acts) options, and companies can assign as many causal factors as necessary. From 2014 to 2021, 3,038 causal factors have been assigned to 1,264 Tier 1 PSE (of the total of 1446 reported), 79% of these were in the process (conditions) categories and 21% in the people (acts) categories. The results have shown the following causal factors, which are all in the process (conditions) category, are in the top 10 reported every year from 2014 to 2021, inclusive:

- Tools, Equipment, Materials and Products : Inadequate/defective tools/equipment/materials/products
- Tools, Equipment, Materials and Products : Inadequate maintenance/inspection/testing

- Tools, Equipment, Materials and Products : Inadequate design/specification/management of change
- Organizational : Inadequate hazard identification or risk assessment
- Organizational : Inadequate work standards/procedures
- Organizational : Inadequate training/competence

In 2021, the causal factor "Storms or acts of nature" appeared in the top 10 reported. This was a reflection of a significant cold air outbreak across central USA from the 10th to the 19th February 2021 (https://ncei,noaa.gov, 2021) which resulted in more than double the number of Tier 1 PSE in the North America region compared to any other month in 2021.

Results – Barrier Analysis

Member companies also report barrier failures (IOGP Report 544) related to Tier 1 PSE. The following are consistently the top 10 reported from 2014 to 2021 inclusive:

- Hardware Barrier Failures: Process Containment
- Management System Element Barrier Failure: Asset design and integrity
- Human Barrier Failures: Operating in accordance with procedures – PTW, Isolation of equipment, Overrides and inhibits of safety systems, Shift handover, etc.
- Management System Element Barrier Failure: Risk assessment and control
- Hardware Barrier Failures: Structural Integrity
- Human Barrier Failures: Surveillance, operator rounds and routine inspection
- Management System Element Barrier Failure: Plans and procedures
- Management System Element Barrier Failure: Execution of activities

Development of Process Safety Fundamentals

The IOGP focus on Project Safira for the elimination of fatalities led to the analysis of 56 fatal and 139 high potential Tier 1 PSEs from 2007 to 2017, inclusive, Figure 15.

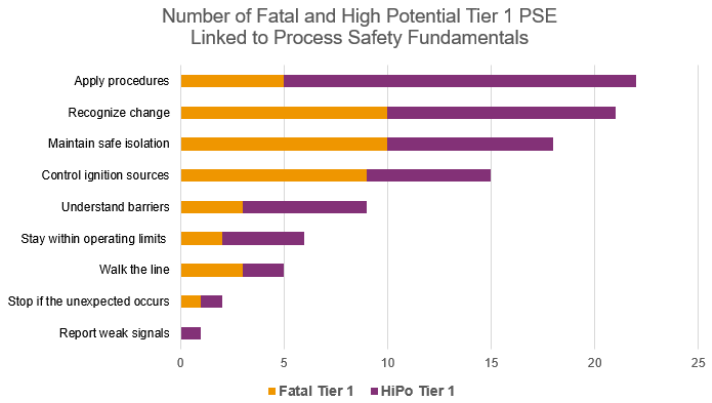

Figure 15—Tier 1 PSE analysis for development of Process Safety Fundamentals

The results of the analysis were used to develop a set of 'process safety fundamentals' (PSF) designed to support those working in front-line operations, maintenance, and on wells teams, by drawing attention to situations that are most likely to lead to process safety event fatalities, Figure 16 (IOGP Report 638).

Figure 16—IOGP Process Safety Fundamentals

The first request for IOGP Member companies to report against the PSF was for the 2021 data submission. This data was reviewed during the annual quality assurance process. The data showed that the PSF were applicable for 68% of the reported Tier 1 PSE (122 of the 190 Tier 1 reports submitted with a narrative description, excluding sabotage/wilful damage related PSE). The assignment of the PSE is shown in Figure 16.

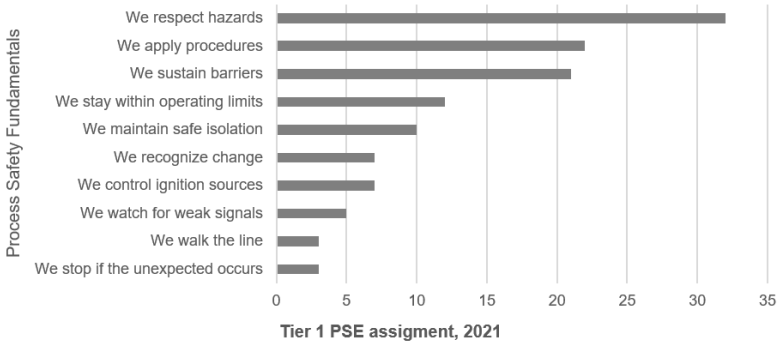

Figure 16—Assignment of IOGP Process Safety Fundamentals to Tier 1 PSE, 2021

Conclusions

Global industry oil and gas industry reporting of PSEs for upstream and downstream activities has significant advantages for companies and other stakeholders. The use of standardized metrics, and key word and point of release taxonomies, enables a much wider ability for benchmarking and improved opportunities to use the data for learning. Industry associations and regulators have aligned on definitions, thresholds and metrics, both upstream and downstream, which now makes process safety performance benchmarking a realistic aim.

Having the largest database of upstream process safety performance and fatality data enables analysis of upstream PSE trends and learning that is not possible within individual companies. IOGP is in a unique industry position to encourage international collaboration, sharing of industry best practices, and the development of tools to prevent process safety incidents and their potential impact on life, the environment and assets loss.

Companies are encouraged to reflect on the data presented in this paper in the anticipation that it may assist them in identifying and executing relevant risk reduction activities in their facilities.

Acknowledgements

The authors would like to thank the IOGP Member companies for their commitment to continued data submission, the members of the IOGP Process Safety Subcommittee, in particular all those involved in the annual Tier 1 data validation process.

References

API (2010 1st edition and 2016 2nd edition) ANSI/API Recommended Practice 754. Process safety performance indicators for the refining and petrochemical industries. Washington DC: American Petroleum Institute.

IOGP Report No.456 (2018, 2nd edition), Process safety – recommended practice on key performance indicators

https://www.iogp.org/bookstore/product/process-safety-recommended-practice-on-key-performance-indicators/

IOGP Report No. 544 (2016), Standardization of barrier definitions (supplement to Report 415)

https://www.iogp.org/bookstore/product/standardization-of-barrier-definitions/

IOGP Report No. 638 (2020), Process Safety Fundamentals

https://www.iogp.org/bookstore/product/process-safety-fundamentals/

IOGP Report No. 2021p, Safety Performance Indicators – Process safety Events – 2021 data
https://www.iogp.org/bookstore/ or https://data.iogp.org/

IOGP Report No. 2021su, Safety Data reporting user's guide–scope and definitions (2021 data)
https://www.iogp.org/bookstore/product/safety-data-reporting-user-guide-scope-and-definitions-2021-data/

U.S. Selected Significant Climate Anomalies and Events for February and Winter 2021, website source, accessed Mar 19th 2022: https://www.ncei.noaa.gov/news/national-climate-202102

Smithsonian Institution, 1903, Annual Report of the Board of Regents of the Smithsonian Institution, , U.S. Government Printing Office

Walker, K., Toutain, P., & Poore, W. (2014, March 17). Upstream Oil and Gas Industry Process Safety Event Data: A First Step. Society of Petroleum Engineers. doi:10.2118/168514-MS

Walker, K., Hawkes, C., Poore, W., & Carvalho, M. (2018, April 16). Industry Safety Data, What is it Telling Us? Society of Petroleum Engineers. doi:10.2118/190545-MS

Walker, K., Fargie, D., Kannan, S., Skar, O., Carvalho, M., (2020, July). Process Safety - Learning From Upstream Event Data. Society of Petroleum Engineers. DOI: https://eureka.slb.com:2083/10.2118/199393-MS