Marsh

Marsh Specialty

100 largest losses
in the hydrocarbon industry

1974 - 2023

28th edition

Contents

Foreword

Accidents in the hydrocarbon industry have devastating consequences. When they occur, people can be seriously or fatally injured, property destroyed, communities significantly disrupted, and the environment severely damaged. This fact is heartbreakingly apparent when examining the US Chemical Safety and Hazard Investigation Board's (CSB) accident investigations that appear in Marsh's 100 Largest Losses in the Hydrocarbon Industry report.

The CSB's mission is to drive chemical safety excellence through independent investigations to protect communities, workers, and the environment. The CSB investigates chemical accidents, shares lessons learned, and advocates for safety improvements. In the CSB's 25-year history, the agency has deployed to over 170 chemical incidents and issued nearly 1,000 recommendations that have led to numerous safety improvements across a wide range of industries. Moreover, in just the three years since the CSB's Accidental Release Reporting Rule came into effect in the US in March 2020, the CSB has received reports of 341 chemical incidents involving fatalities at 46 facilities, serious injuries at 185 facilities, and substantial property damage (defined as US$1 million or more) at 160 facilities.

In addition to identifying some of the CSB's investigations, this edition of the 100 Largest Losses report includes links to videos produced by the CSB. These videos provide detailed accounts of selected accidents, offering a deeper understanding of the factors involved and the lessons learned from them. The videos make the CSB's investigative findings and recommendations available to millions of people and are part of our strategic goal to advocate safety and achieve change through recommendations, outreach, and education.

Driven by the growing focus on environmental, social, and governance factors, there is a greater demand for industry to manage its risks effectively and demonstrate responsible practices. This is especially the case in the chemical industry, given the devastating impacts that a chemical disaster can have on the people who work in a chemical facility and the families who live in the community near it.

Marsh's 100 Largest Losses report serves as a powerful reminder of the imperative to prioritize safety and prevent losses. It is a message to industry leaders, regulators, and stakeholders to take every possible step to mitigate risks and protect lives and assets. By examining the causes and financial impacts of these significant loss events, we gain valuable insights into the importance of effective risk management, process safety, and organizational culture.

Steve Owens
Chairperson
US Chemical Safety and
Hazard Investigation Board

Introduction

Welcome to the 28th edition of Marsh Specialty's 100 Largest Losses in the Hydrocarbon Industry report which details the largest property damage losses from the hydrocarbon extraction, transport, and processing sectors between 1974 and 2023.

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By examining the causes and trends of significant incidents, we aim to offer valuable insights and lessons that will support and aid organizations across the energy industry to progress and improve operational and risk management practices.

This report reflects on the 2022 – 2023 period, highlighting significant events and their impact on the energy industry, p05. Additionally, feature articles authored by Marsh's engineers, advisors, and industry specialists explore:

p13 The importance of knowledge sharing across the industry, learning lessons from past incidents, and acting on recognized risks.

p18 The reality of climate change and the growing relevance of climate risk assessments for operational and future energy infrastructure.

p23 The factors that can affect coverage for business interruption related claims and the importance of reviewing insurance indemnity periods.

p26 Primary causes of construction phase losses and ways to mitigate common risks.

We provide summary details of each loss in the top 100, and present comprehensive data on the distribution of losses by date, location, and industry sector.

It is important to note that the data in this report is drawn from Marsh Specialty's loss database, and the value of losses is reported in two ways:

- The original property damage value at the time of the incidents' occurrence.
- The adjusted property damage value at December 31, 2023 using various cost indices. This enables a like-for-like comparison of losses that have occurred years apart.

Loss values include property damage, debris removal, and clean-up costs, but exclude costs related to business interruption, extra expenses, workforce injuries or fatalities, and liability claims. Furthermore, losses during construction and marine transportation, except those involving marine vessels moored at plant docks, are not included.

We extend our gratitude to Everen for providing updated claims data and incident details that have allowed us to complete a review of historic losses. As a result of this research, nine past incidents have now been incorporated into the top 100 dataset. Updated data shared by insurance markets is vital to the integrity of this report and reinforces our ongoing commitment to data accuracy and reliability.

We invite you to explore the insights and analysis presented in this report, and to learn from past incidents as we all work towards improving the risk landscape and resilience of the energy industry.

Reflecting on the last two years

The 2022-2023 period was defined by a number of factors that challenged the energy and power industry as well as the global economy. Recovery from the Covid-19 pandemic was further complicated as the spotlight on energy security intensified as a result of the Russia-Ukraine war, soaring energy and commodity prices contributed to inflationary pressures and tightening of fiscal policies, and supply chain constraints impacted most industries.

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At the same time, the global groundswell of social and political commitments to address climate change and adopt sustainability measures renewed the urgency to transition to clean energy sources. Despite the macro-economic landscape, the current volume and scale of investment in the energy and power industry is unprecedented. The terms energy security and energy transition have become the part of our common language and serve as reminders of how essential the industry is to both developed and emerging economies.

The past two editions of this report have highlighted the dynamic factors that can affect the operating conditions and risk landscape for the industry. The 2020 report reflected the aftermath of the active loss period of 2017-2019, while the 2022 report captured the uncertainty, heightened risk considerations, and reduced operational activity through the Covid-19 pandemic. The past two years have been a mix: there was more loss activity in 2022, though this subsided in 2023, particularly in relation to onshore assets.

Since our last report, only two incidents have resulted in property damage losses in excess of US$240 million, which is the adjusted threshold for the 100 highest value losses. In researching this edition, we have also revisited historical losses where additional information is now available that may not have been at the time of our previous report publication. Using updated investigation reports and data from insurance markets, we have identified twelve incidents that now qualify for the top 100 ranking.

2022-2023 LOSSES ADDED TO THE TOP 100

#26

GULF OF MEXICO
JULY **2023**

This is the first upstream sector loss to be added to the dataset since 2016.

#44

OKLAHOMA, US
JULY **2022**

A fire and large explosion at a gas processing plant.

> **“Despite the macroeconomic landscape, the current volume and scale of investment in the energy and power industry is unprecedented.”**

HISTORIC LOSSES ADDED TO THE TOP 100

1974
NORWAY
UPSTREAM
MECHANICAL FAILURE
#65

1982
CANADA
UPSTREAM
MECHANICAL FAILURE
#84

1987
US
UPSTREAM
FIRE AND EXPLOSION
#18

1991
NORWAY
UPSTREAM
MECHANICAL FAILURE
#31

1999
ANGOLA
UPSTREAM
MECHANICAL FAILURE
#59

2003
NORWAY
UPSTREAM
MECHANICAL FAILURE
#35

2007
CANADA
REFINING
FIRE
#78

2009
SOUTH CHINA SEA
UPSTREAM
NATURAL CATASTROPHE
#87

2013
KAZAKHSTAN
UPSTREAM
MECHANICAL FAILURE
#21

2014
NETHERLANDS
PETROCHEMICALS
EXPLOSION
#53

2015
US
UPSTREAM
MECHANICAL FAILURE
#27

2017
CANADA
REFINING
FIRE
#99

Marsh engineers have also analyzed a number of incidents that did not rank in the top 100 but are notable to insurance markets because the combined value of property damage and business interruption claims for each loss was significant. Many of these incidents are still under investigation to determine the cause of the loss, and will undoubtedly provide valuable learnings for energy operators.

US | FEBRUARY 2022

A fire at a refinery in the US on a unit processing alkylate.

NIGERIA | FEBRUARY 2022

A floating production storage and offloading (FPSO) vessel sank off the coast of Nigeria following a fire and explosion.

AUSTRIA | JUNE 2022

A mechanical incident caused significant damage to a crude oil distillation unit at a refinery in Austria following a legally required water pressure test.

US | JUNE 2022

A fire at a refinery in the US.

US | JUNE 2022

An explosion at a liquefied natural gas (LNG) facility in the US where investigators identified deficiencies in operating practices and shift crew management.

US | SEPTEMBER 2022

A fire and explosion at a refinery in the US. Investigators identified violations of process safety rules and inadequate training of workers.

POLAND | SEPTEMBER 2022

A fire at a refinery in Poland.

SPAIN | APRIL 2023

A fire at a refinery in Spain.

US | JULY 2023

An explosion and fire on a glycol unit at a petrochemical complex in the US

US | AUGUST 2023

A fire at a refinery in the US.

EXAMINING THE CAUSES

Operational discipline

In the 2022 report, one of the major risk factors identified was the potential downsizing of operations and loss of experienced staff as organizations focused on recovering from the Covid-19 downturn. While the energy industry demonstrated exceptional resilience and innovation to overcome the challenges during the lockdown period, there have been a number of recent incidents that may indicate a loss of operational discipline. The examples below are not in the top 100 dataset but demonstrate the importance of embedding robust operational processes and ensuring personnel are appropriately trained.

Refinery fire

EUROPE | 2022

A fire occurred on a furnace during start-up. The incident is under investigation but it is understood that operational procedures may not have been adhered to which subsequently lead to a gas leak.

LNG line rupture

US | 2022

A LNG line ruptured when left blocked for an extended period without a thermal relief path. Investigation identified inadequate procedures, procedures not followed, high overtime rates leading to operator fatigue, and poor alarm management.

Refinery fire

US | 2022

A fire occurred when a light naphtha stream was drained to the refinery oily water system, creating a vapour cloud which ignited. One of the factors leading to the incident was an inadequate response to an abnormal situation.

FOCUS AREAS TO IMPROVE OPERATIONAL DISCIPLINE AND MINIMIZE INCIDENTS

1. Identify and document the specific key processes such as standard operating procedures, effective communication, training programs, risk assessments, incident reporting systems, and continuous improvement initiatives.

2. Establish key performance indicators for critical elements and processes and evaluate through regular audits, inspections, performance metrics, employee feedback, incident analysis, and benchmarking against industry best practices.

3. Identify gaps, weaknesses, and areas for improvement and prioritize plans to correct these areas. Conduct internal and external audits, management reviews, independent assessments, third-party certifications, and compliance checks against regulatory requirements.

4. Build a strong safety culture that encourages proactive hazard identification, reporting of near misses, and continuous learning and improvement. Robust training programs, competency assessments, job hazard analyses, incident investigations, and lessons learned exercises can all strengthen hazard recognition skills. Regular drills, simulations, and scenario-based training can help build confidence in recognizing hazards in abnormal operating situations.

Insurance indemnity periods

Two key factors are increasingly influencing the need to review indemnity periods for business interruption coverage: the intervention of local regulators, and an upswing in global construction activity. Both of these issues have the potential to delay the restart or prolong the rebuild of plant following an incident.

Interventions from regulators and public authorities

Regulators are becoming more involved in the aftermath of major incidents at operating sites, particularly those involving serious injuries or fatalities. Notable incidents that have triggered significant regulatory interventions include an explosion at a LNG facility in Texas, US (2022), a fire at a refinery in France (2019), an explosion at a refinery in Germany (2018), and an explosion at a refinery in Wisconsin, US (2018).

Regulatory interventions can introduce various implications including:

ACCESS RESTRICTIONS

Onsite teams may have limited access to the area affected by plant damage. In some cases, plant repairs may be prohibited until external investigations are completed and comprehensive plans developed.

PERMITTING REQUIREMENTS

Permits to operate may need to be reviewed and reissued before plant repairs can commence. Regulators may mandate changes to some plant hardware.

ASSURANCE ACTIVITIES

In addition to hardware modifications, regulators will thoroughly evaluate the effectiveness of management systems and operating practices.

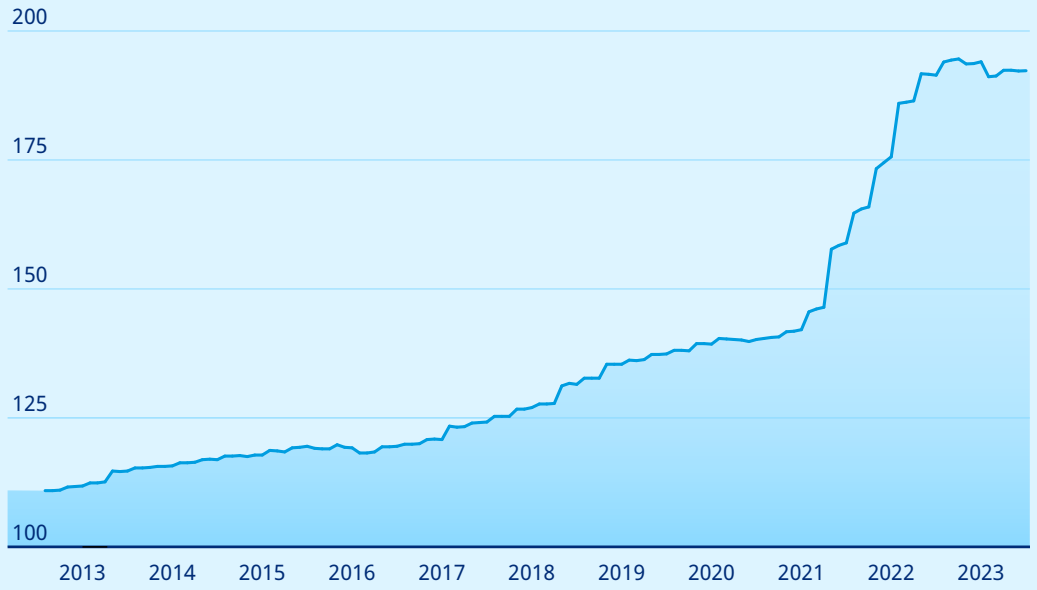
Increasing rebuild costs and timeframes

Construction activity ramped up post the Covid-19 restrictions but the backlog of projects coupled with high inflation has led to higher costs and longer lead times.

Construction cost indices in the ten-year period from 2010 to 2020 recorded average annual increases of 1% to 2.0%. However, prices started to spike from late 2021 as the world emerged from lockdowns, and in 2022 alone, many indices recorded double-digit increases.

01| Producer price index by industry: new industrial building construction

US Bureau of Labor Statistics

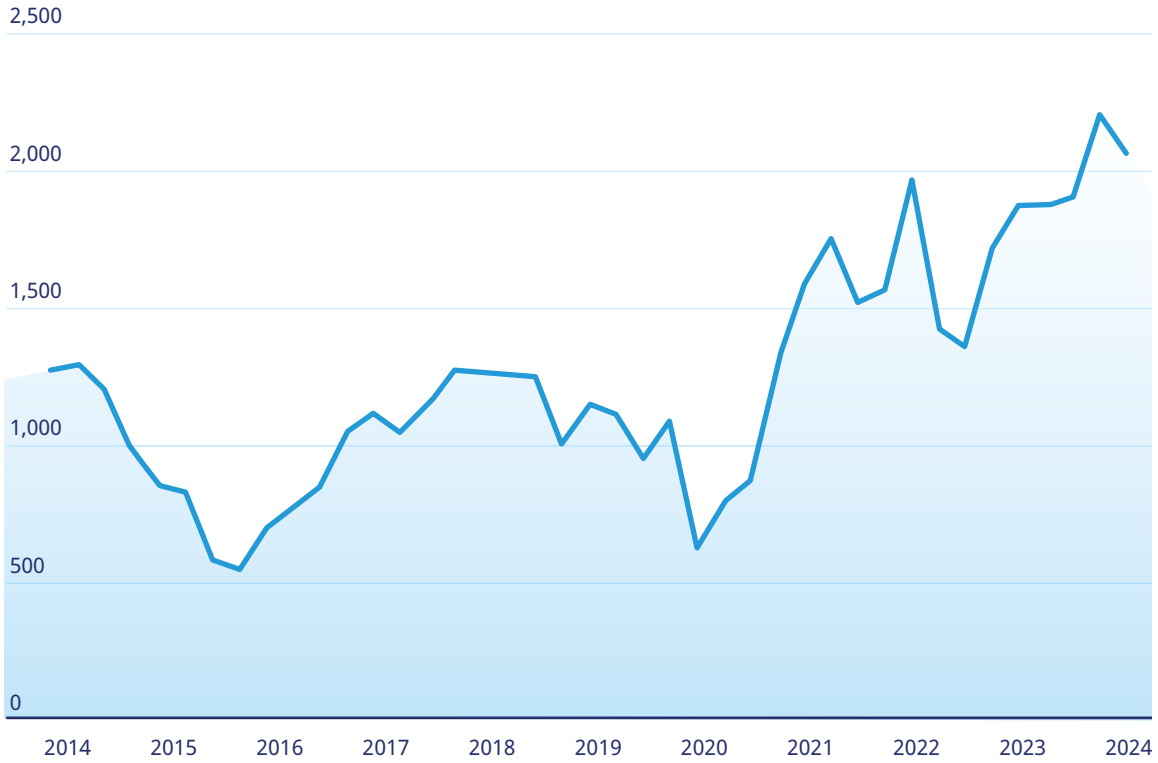


Index base adjusted, January 2013 = 100.

Data source| US Bureau of Labor Statistics

Although the rate of increase has decreased in the last year, overall construction costs are still at significantly higher levels. For example, steel prices are at or close to a 10 year high.

02| NYSE Steel Index, 2014-2024



Data source| WSJ Online

Increasing construction costs, supply chain constraints, as well as labor and material shortages highlight the importance of carefully evaluating policy indemnity periods and conducting comprehensive reassessments of plant rebuild values to align with prevailing economic conditions.

LOOKING FORWARD – MANAGING EMERGING OPERATIONAL RISKS

Workforce and operational excellence

The scale of investment in energy projects is creating competition for talent as companies strive to secure resources to manage existing operations and new strategic initiatives. The competition for skilled personnel and the migration of talent between industries may pose tangible risks for energy operators. Companies must find ways to manage workforce turnover while maintaining knowledge, competence, and operational excellence to mitigate the inherent hazards involved in building and operating energy assets.

Existing energy operators may have a robust safety culture, but ensuring regular reviews of operationally critical processes and procedures is essential. Similarly, new operators should be mindful that building culture and expertise will take time. Operators can improve their chances of preventing significant and avoidable losses by using benchmarking studies, implementing comprehensive training and development programs, ensuring consistent maintenance practices, and regularly testing risk management and response plans.

Climate and sustainability considerations

The reality of climate change means companies have to rethink their infrastructure needs and design. Increasing variability in weather conditions and more frequent natural catastrophe hazards increase the risk exposure of most energy facilities. Operators are challenged with improving the resilience of existing operations today, and elevating climate considerations into expansions or investments. Furthermore, with the increasing scrutiny of environmental, social, and governance policies, future insurance market capacity and risk transfer mechanisms for traditional energy facilities may narrow.

Digitalization

Cyber risks are escalating with the digitalization of energy systems. A cyberattack on operational technology (OT) such as SCADA applications could paralyze production or power generation. But even the operational management of change associated with OT deployment needs careful planning, process management, and implementation to prevent significant business interruption losses and workforce risk.

Geopolitical dynamics

Regional conflicts increase the risk of energy infrastructure been strategically targeted. Aside from increased insurance costs, operators need to be aware of war and other exclusion clauses that may affect insurance coverage.

4 Missed opportunities The consequences of ignoring risk recommendations

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The energy industry operates on a delicate balance of progress and risk. Major incidents and losses can have far-reaching consequences, some of which could have been prevented had the root cause been addressed. Analyzing, reviewing, and learning from incidents and others' experiences can help organizations strengthen their risk management practices and plans.

To build and maintain resilient and sustainable operations, organizations need to avoid risk complacency in order to ensure the safety and well-being of their workforce, communities, environment, and their long-term financial viability. The repercussions of ignoring risk recommendations can range from reputational damage to financial loss and, in the worst-case scenario, loss of life. Failure to address identified risks erodes the trust stakeholders place in an organization's ability to operate with integrity and purpose.

Risk management practices in the energy and power industry have continued to improve largely driven by structural dynamics such as digitalization and regulation, as well as advanced operational awareness and procedures. But eliminating or at least reducing bias remains one of the most important actions to integrate into operational and strategic risk reviews. Biases often operate subconsciously and can lead to irrational or uninformed decision-making, increasing rather than reducing risk. By understanding the known biases, and uncovering some of the imperceptible ones, companies can develop a culture of awareness, agility, and vigilance.

RECURRING THEMES: CULTURE, COST, COMPLIANCE

Several common themes emerge in relation to major loss incidents, primarily relating to process safety management: culture, cost, and compliance. These factors can influence the level of success in learning from past incidents, or in taking action on learnings effectively over time and across multiple sites.

CULTURE

Culture is a big factor and sometimes overlooked when assessing risk. Checklists, documented procedures, and technical know-how can be compromised without a mature process safety culture that is woven into the fabric of an organization's psychology.

While personal safety is essential, focusing solely on it can lead to a skewed perception of overall safety. For instance, many companies measure process safety performance with personal safety indicators, such as the safe number of hours worked. The US Chemical Safety and Hazard Investigation Board (CSB) found that only measuring personal safety-related KPIs can provide a false sense of safety to organizations, which can inflate their risk tolerance. Or worse, it can breed complacency rather than drive towards building team culture and shared, enterprise-wide, purpose-aligned goals.

COST

A common misconception in the energy industry is that the traditional benefit-cost approach may only partially justify investments in reducing exposures to low-probability, high-consequence events. In a risk-based operational environment, it is crucial to strike a balance between financial considerations and the imperative to prevent catastrophic incidents. Alternative approaches, such as real-time monitoring and control systems, that prioritize process safety without solely relying on traditional benefit-cost analyses can provide a more comprehensive evaluation of risk management investments.

Beyond financial implications, the reputational damage caused by ignoring risk recommendations can be devastating. Stakeholders including customers, investors, and the public, expect organizations to prioritize safety and responsible practices. Failing to heed risk warnings undermines trust, tarnishes brand image, and can have long-term consequences for business relationships and market standing.

COMPLIANCE

Neglecting recognized risks can also lead to regulatory non-compliance and legal violations, including criminal charges in the most extreme cases. The energy industry is highly regulated to promote adherence to safety guidelines designed to protect workers, the environment, and the public.

INACTION LEADS TO HISTORY REPEATING ITSELF

The 100 largest losses detailed in this report illustrate that lessons from prior incident investigations did not always spark action and better prevention steps. Some of the most significant risk management themes for the energy industry are evidenced in a few examples below.

Piper Alpha oil rig explosion

July 1988

The Piper Alpha incident remains the costliest recorded property damage loss, and with 165 fatalities, one of the most devastating in terms of loss of life.

An audit before the explosion had identified shortcomings in maintenance and safety procedures on the rig. The audit recommended the installation of a valve to isolate a specific section of the pipeline in the event of a fire, and the implementation of a lockout tagout (LOTO) procedure. The recommendations were not actioned.

In 2017, a similar root cause led to a major loss in the UAE. This incident was linked to a lack of proper control of isolation, a lesson and engineering requirement that could have been applied after Piper Alpha.

Buncefield oil depot explosion

December 2005

A risk assessment had indicated significant deficiencies in the depot's overfill prevention systems. No action was taken, and a massive explosion led to extensive damage to the depot, nearby properties, and the environment.

The American Petroleum Institute (API) made changes to the Tank Overfill Prevention Standard, API 2350, which outlines best practices for preventing tank overfills in petroleum facilities. Despite this, some companies may not have yet applied the necessary overfilling protection hardware and system measures.

Deepwater Horizon oil spill

April 2010

To date, this is the largest marine oil spill in history.

Prior to the incident, risk improvement recommendations were identified for the integrity of the well's cementing and the functionality of the blowout preventer. The work was not commissioned due to the significant cost, and the consequences of a failure were grossly underestimated.

Risk perception and risk tolerance highlight the need for a balanced approach to decision-making and budgeting that considers short-term gains and long-term safety implications.

Port Neches explosion and fire

November 2019

Three years before the incident, a process hazard analysis (PHA) identified the risk of popcorn polymer buildup in dead legs. The PHA proposed flushing the lines monthly to prevent any potential accumulation and localized corrosion.

The operator did not follow through with the recommendation, due in part to cost concerns. The monthly flushing was considered unwarranted as the risk of polymer build-up was perceived to be low. An investigation by the US Chemical Safety Board (CSB) revealed that ignoring risk recommendations significantly contributed to the explosion.

This incident underscores the critical importance of acting on risk recommendations, as seemingly small decisions can have far-reaching consequences.

REFLECTIONS

History has demonstrated that the industry can continue to improve its efforts at addressing recognized hazards and proactively implementing risk improvement recommendations.

The key takeaways from these incidents are clear:

Prompt action: Operators must address known risks without delay, and risk improvement recommendations should be implemented as soon as practical to mitigate potential hazards.

Effective communication: Clear communication among stakeholders, including risk engineers, operational personnel, and management, is essential to ensure that identified risks are effectively understood and actioned.

Compliance and oversight: Regulatory compliance and rigorous change management oversight are necessary to implement risk improvement recommendations and promote the safety and integrity of operations.

Continuous improvement: A culture of continuous improvement, aligned to shared goals should be fostered within an organization - and across the energy industry - encouraging regular review and reassessment of risk management practices.

By investigating and learning from operational incidents, organizations can strengthen risk management practices, minimize losses, protect the environment, and safeguard the well-being of people and property. Through a collective commitment to proactive risk management the industry as a whole can become more resilient.

5

From climate risk, to climate resilience and adaptation

Climate-induced losses are already material events forcing organizations to develop new strategies and adapt business models to protect their assets and balance sheets.

For instance, in the US there were 376 confirmed weather/climate disaster events with insured losses exceeding US$1 billion between 1980 – 2023.

Extreme weather and natural disasters — including hurricanes, droughts, floods, and heatwaves — can lead to injury and death, property damage, supply chain disruptions, reputational damage, and more. Business leaders across many industries now consider natural disasters as one of the top five risks globally, according to the World Economic Forum's Global Risks Report 2024.

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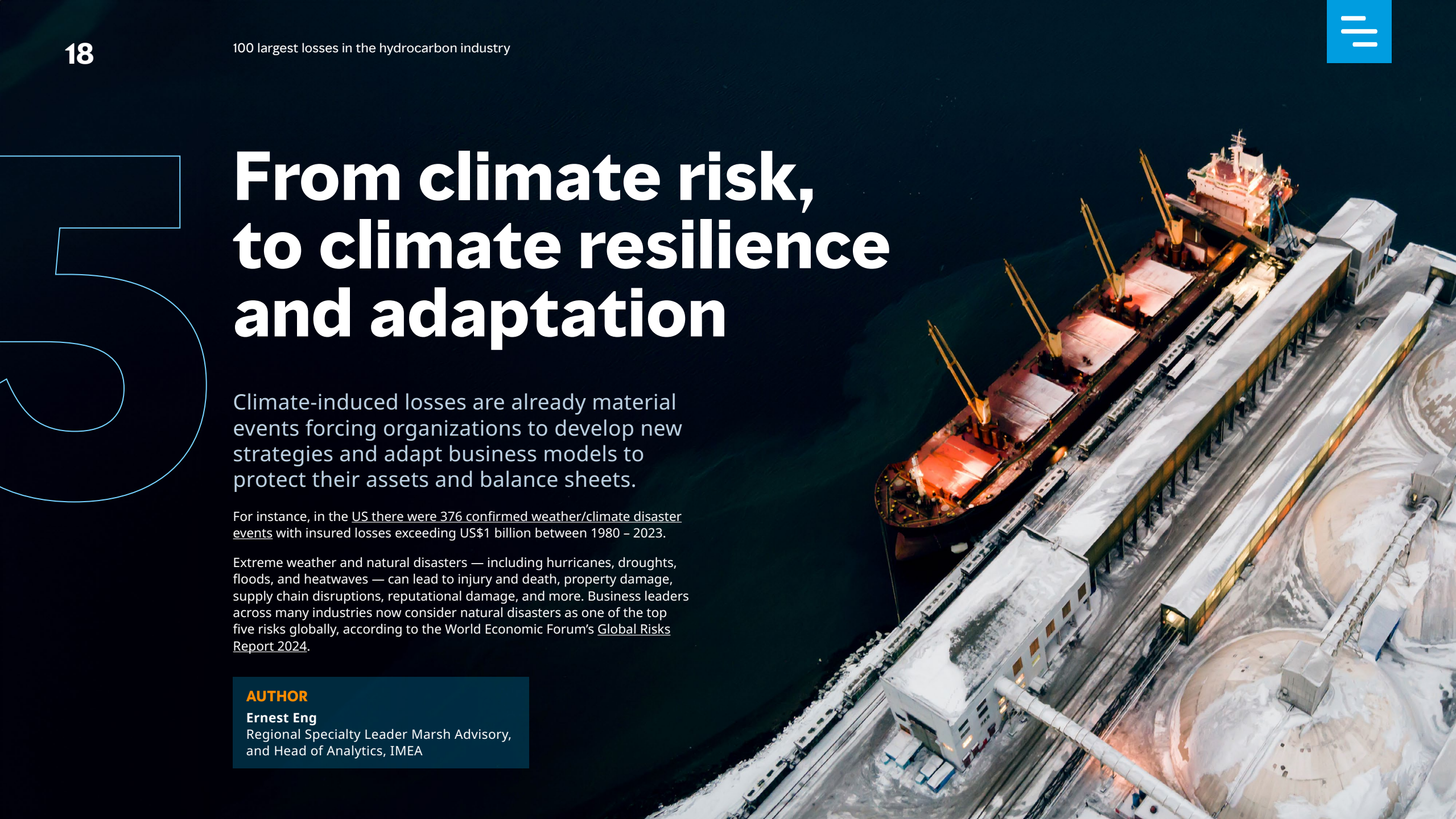
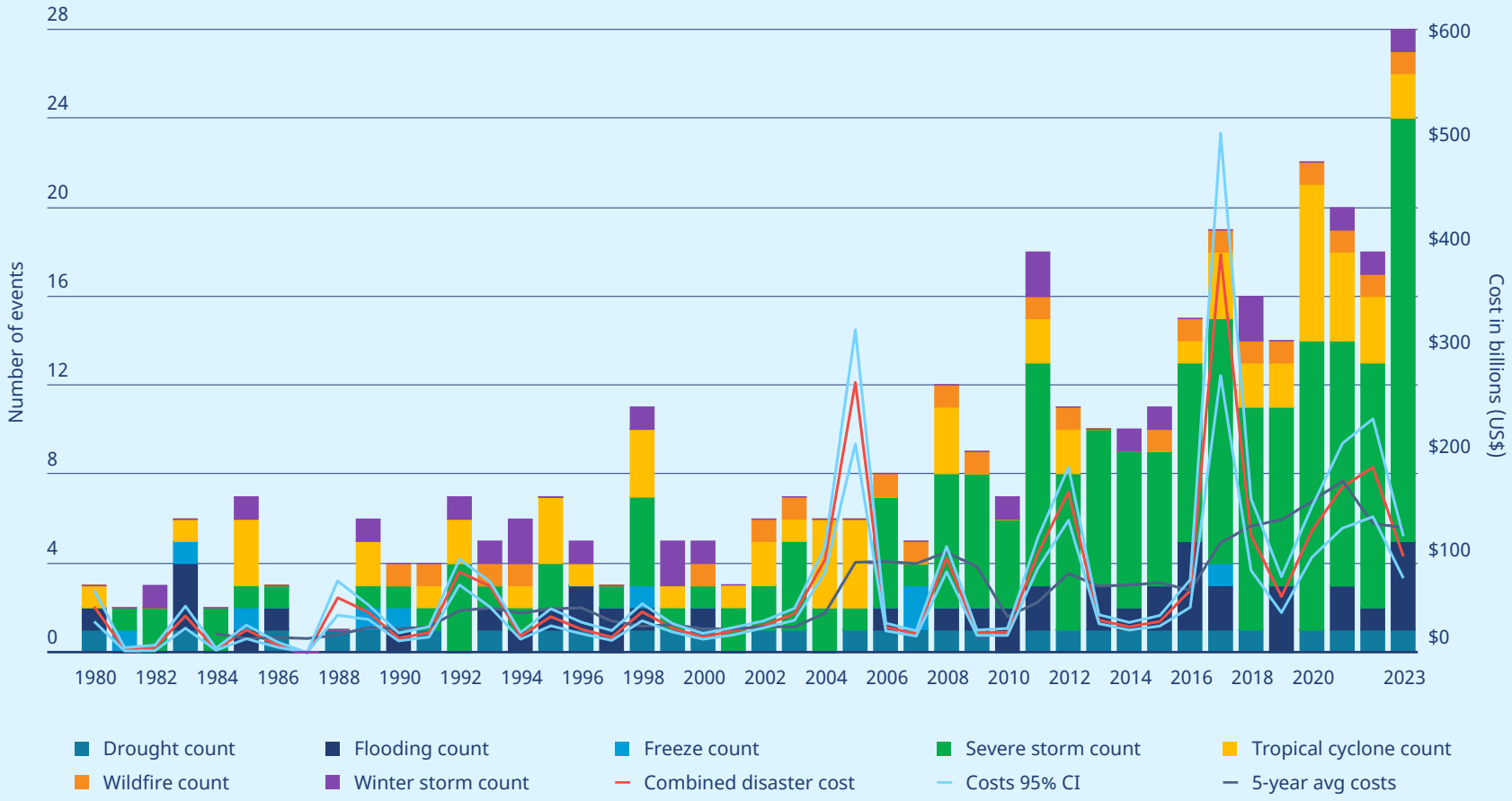


03| US billion-dollar disaster events 1980-2023

CPI adjusted



Data source| National Oceanic and Atmospheric Administration

For the energy industry, climate vulnerability is especially relevant for certain asset classes where building codes may be insufficient given the rising exposure to extreme events. Energy infrastructure is often not designed to withstand more frequent and intense weather extremes, either because of its age, or due to its function.

This is one of the driving factors behind the cost multiplication of climate-related losses. Geographical variations in weather patterns add another layer of complexity for multi-site/multinational operators who may have assets exposed to heat stress and coastal flooding/inundation in the Middle East, versus tropical cyclones in Asia or Australia. Companies with direct and indirect exposures in vulnerable regions may experience higher credit and market risks, as well as increased underwriting scrutiny, which can affect operational expenses and profitability.

The reality of climate change means companies have to rethink their infrastructure needs and design. As energy systems become more complex with the integration of different types of technology, infrastructure resilience is no longer only about returning single assets to full operation after a disruptive event. When interdependent parts of a system are affected, the system as a whole is at risk. Incidents such as the recent wildfires in Canada illustrate that restarting the energy system can be delayed by days, possibly weeks, if critical system parts cannot be restarted autonomously.

Proactive risk management may also mean that companies have to invest in additional infrastructure, such as backup systems and flood defense infrastructure.

EVIDENCE AND IMPACT
EXTREME WEATHER AND NATURAL CATASTROPHES

The number of extreme weather events recorded each year have risen by a factor of five over the past 50 years. The US Energy Information Administration estimates that a high-impact hurricane could result in a temporary loss of monthly offshore crude oil production of about 1.5 million barrels per day (b/d) and a nearly equivalent temporary loss of refining capacity. And Marsh McLennan's Flood Risk Index shows that 23% of the world's power generation capacity is currently threatened by flooding, with exposure expected to increase to 37%, 41%, and 48% under the 1.5 °C, 2 °C, and 3.5 °C temperature increase scenarios.

Changes in the intensity and frequency of extreme weather events, as well as seasonal deviations from average weather conditions, affect current and future energy infrastructure, jeopardizing energy security and reliability. Potential impacts on energy systems include blackouts, shutdown of nuclear and thermal power plants due to extended heatwaves or droughts, and changing rainfall patterns affecting hydropower generation. In a recent survey, extreme weather events ranked among energy leaders' top uncertainty issues in the US and in parts of Asia Pacific, Latin America, and Africa.

Facilities and infrastructure are typically designed for the expected weather conditions where they are situated, which partly explains why the impact of atypical and extreme weather events can be pronounced. Consider, for example, cold weather conditions in Texas in 2021 that led to plant shutdowns, or heatwaves in Europe that led to supply constraints.

Organizations that understand these risks and deploy resilient and adaptable infrastructure design will be best placed to reduce the potential impact of extreme weather losses.

23%

of the world's power generation capacity is currently threatened by flooding.

Climate risk assessments can inform investment and operational strategy

Climate risk assessment scenarios can be challenging due to the unpredictability of weather events and the potential correlation of impacts on the global economy from factors such as involuntary migration, changing land use, and increased urbanization. Nevertheless, given the significance of climate risks and increased disclosures to stakeholders and regulators, these assessments are becoming mainstream as quantification methodologies and access to data supported by academic research continue to improve.

A key priority should be to gain a clear understanding of current and future climate risk as a basis for developing engineering and financial resilience and adaptation plans to provide confidence to all stakeholders including investors, customers, and regulators.

To aid preparedness to respond to potential climate induced losses, Marsh uses a three-step process to analyze the risk and resilience of three primary dimensions – hardware, software, and emergency response.

Everything to play for

The energy transition offers the opportunity to develop a more robust and resilient energy industry.

The evolving risk landscape presents new demands for operators, including new regulations and growing scrutiny from investors and other stakeholders. Climate change and the increasing risk of weather-related losses represent an enterprise-wide risk with implications for operations, supply chains, environmental obligations, corporate reputation, and more.

To mitigate weather-related losses, organizations are increasingly conducting sophisticated climate risk assessments to evaluate the scale, nature, and complexity of their exposures.

Increasing the resilience of energy infrastructure to safeguard against extreme weather events is no longer optional — it is now a necessity. Energy systems must be smarter, not just stronger; and now is the time for energy leaders globally to focus on aiming to future-proof the assets that power our world.

When ‘business as usual’ is interrupted

Following a property damage event, the amount of the financial loss from disrupted business operations can sometimes exceed the cost of repairing the physical damage to the facility. Organizations should seek a clear understanding of their vulnerabilities and the factors that can impact them in order to mitigate potential risks.

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Energy facilities are subject to a variety of factors that can disrupt business operations and impact continuity; integrated supply chains can compound the disruption or create a domino effect. Operational disruption can stem from physical damage to assets due to process safety incidents, cyberattacks, supply chain failure, or volatile and severe weather.

Standard business interruption (BI) coverage included in first-party property policies may not address the unique needs of energy and power operations. Given the diverse range of use cases in this industry, it is impossible to adopt a one-size-fits-all approach. The rapid expansion of the renewable energy sector, the growing interdependencies among multi-site facilities, and the various contractual arrangements within integrated supply chains have led policyholders to adopt different approaches to pursuing and purchasing BI coverage. Operators should be prepared to assess and then re-assess their BI risks and exposures, and revisit their approach to BI coverage accordingly.

BI coverage included within property policies is designed to compensate a business for financial loss following property damage or machinery breakdown. Policies can be structured to protect gross profit or fixed costs and debt servicing, and often contemplate unplanned increases in operating expenses, such as the cost of using temporary facilities or importing feedstock to maintain operations.

Considering the mechanisms of BI coverage in light of an organization's actual commercial agreements is an important step in evaluating the level of coverage and how any future BI claim may be treated. While historical and projected data, beyond standard accounting metrics, are foundational, BI calculations should also take account of the coverage terms and basis for recovery.

Some organizations discover during the claims process that the insured values differ meaningfully from the basis used by accounting teams for budgeting and forecasting.

An organization's risk professionals should aim to confirm that the organization's commercial and regulatory arrangements are likely to be satisfied based on the accounting standards, metrics, and calculations contemplated in the BI coverage.

Another important confirmation point is that the organization has the necessary information, systems, and capabilities to prepare loss data based on the BI coverage purchased.

KEY FACTORS TO CONSIDER FOR BI EXPOSURES

Equipment shortages and lead times can significantly impact operations

High inflation, coupled with supply chain delays and material shortages, can lead to prolonged reinstatement times. For example, recent delays in securing steel pipes and casing for drilling have limited production in the US. It is important to review the length of indemnity periods and identify any potential impacts of underinsurance.

Changing business models are driving optimization and profitability

Integrated value chains and consolidated assets can help drive optimization and improve profitability. Energy transition is likely to see the trend for consolidating assets as operators rationalize the least profitable and redundant infrastructure. For example, offshore oil and gas assets that have reached the end of their commercial life for producing hydrocarbons may be repurposed to be part of a carbon capture transport and storage network.

However, integrating and consolidating actions can introduce a new layer of contingent BI exposures. An increased dependency on fewer facilities could mean that any disruption may have broader consequences beyond the location of the physical damage. For instance, if one location experiences an unplanned outage, it could result in economic losses across the entire value chain.

While a leaner operational strategy may improve margin, unplanned issues could potentially offset any gains. BI losses could be greater than expected if appropriate consideration is not given as to how an event could affect interdependent value and supply chains.

Protecting the value of growth

Recent higher commodity prices have boosted balance sheets, but the value of that growth may not be fully protected by existing BI coverage. The variability of markets, together with regulatory and geopolitical dynamics can make it difficult to accurately forecast operating margins.

Insurance policies are often based on forecasts made several months before a policy is renewed. Including a BI coverage clause that aims to allow for a level of volatility in values may be helpful but organizations should aim to update and/or maintain the accuracy of values declared throughout the life of the policy that includes BI coverage.

Risk exposures in the energy and power industry are some of the most challenging to identify, assess, manage, and mitigate. The resilience of an organization to BI risk needs to be continually assessed as operational and commercial arrangements evolve. Stress testing BI coverage against a range of credible loss scenarios can assist in building confidence that the coverage mechanism responds appropriately, and conducting business interruption reviews provides an opportunity to realign to prevailing business conditions.

Changes that could increase BI exposure

1. Market conditions that significantly impact insured values e.g. increase in gross profit.
2. Contractual obligations affected in a loss situation.
3. Changes in operations that could introduce critical node (single point of failure).
4. Changes in customer or supplier profile that may create contingent BI risks.
5. Prolonged reinstatement periods that may impact the length of the indemnity period.

Managing risks in energy construction

The construction phase of energy projects introduces unique risks and challenges that, if not properly managed, can lead to substantial financial losses for project owners, contractors, and insurers alike. This article explores some common risks, and prevention measures to mitigate losses and improve overall project outcomes.

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Relevance of construction losses

Construction losses in the energy industry impact all parties involved in the project. From delays and cost overruns to accidents and equipment failures, construction losses can significantly affect project timelines, budgets, and ultimately, operational success. By analyzing these losses, the construction, energy, and risk industries gain invaluable insights to strengthen risk management practices, enhance safety protocols, and improve project planning and execution.

Valuable insights and lessons are everywhere

Every project is another opportunity to learn, evolve, and improve. But for that to happen, project stakeholders must be prepared to constructively evaluate and share the learnings across the industry. Here are the four common themes that energy operators and their construction contractors should focus on to improve the likelihood of project success.

Risk assessment

Risk assessment and management practices during the planning, design, and construction stages are constantly evolving. While insurers and risk engineers have a tendency to focus on the worst case scenarios, sharing learnings about the practical elements of a build may aid decision making for construction contractors. For example, if construction is in a location that's susceptible to both windstorm and flood, should items be tethered down to prevent them being blown away or is it more beneficial for them to be portable? If they aren't tethered, are they more prone to theft? Timing can alter loss scenarios dramatically, and every action has a consequence.

Project management

Construction losses often result from inadequate supervision, poor coordination, or communication gaps among various stakeholders. Implementing robust project management practices, employing experienced personnel, and fostering a culture of collaboration can minimize the occurrence of losses. A recent hydroelectric project in South America provides a good example of the importance of stakeholder management and the need to be agile. The project was divided into several work sites and contractual portions. At the start of work, the project manager of one portion spent a significant, unbudgeted amount on aggregate to improve the site roads within his remit. The decision and overspend were initially criticized by senior management but that work parcel was completed on time and on budget. Without sharing of information between the various contractual portions, lessons were unable to be learnt across the entirety of the project. Other portions of the project experienced significant delays and cost overruns because laden trucks couldn't manoeuver around their sites.

Equipment failure

Critical equipment failures during construction could jeopardize the whole project, causing significant delays and cost overruns. While these types of incidents may happen without warning, they highlight the importance for contractors to have rigorous quality control protocols in place and complete thorough testing on all equipment. Implementing strict adherence to industry standards, regular inspections, and comprehensive maintenance programs can help prevent similar equipment failures and subsequent claims resulting from physical damage and loss of revenue due to the inevitable project delays.

Construction accidents

A primary cause of major accidents is the failure to implement or adhere to critical safety protocols such as hot works permits or lifting of heavy equipment. Poor safety practices can result in injuries to workers, damage to the project and surrounding site, and potential damage to the environment. These incidents emphasize the need for robust safety training, adherence to regulatory guidelines, and continuous monitoring of safety practices throughout the construction phase. Implementing a strong safety culture, regular audits, and comprehensive emergency response plans can significantly reduce the likelihood and severity of construction accidents and associated losses.

LOSS PREVENTION MEASURES

Comprehensive risk assessment

Conduct thorough risk assessments prior to project inception as well as during the construction phase, identify and evaluate potential risks throughout and deploy mitigation measures.

Effective project management

Employ experienced project managers and ensure proper coordination, communication, and oversight across all stakeholders.

Quality control

Implement stringent quality control measures, adhere to industry standards, conduct regular inspections and rigorous testing of equipment and materials.

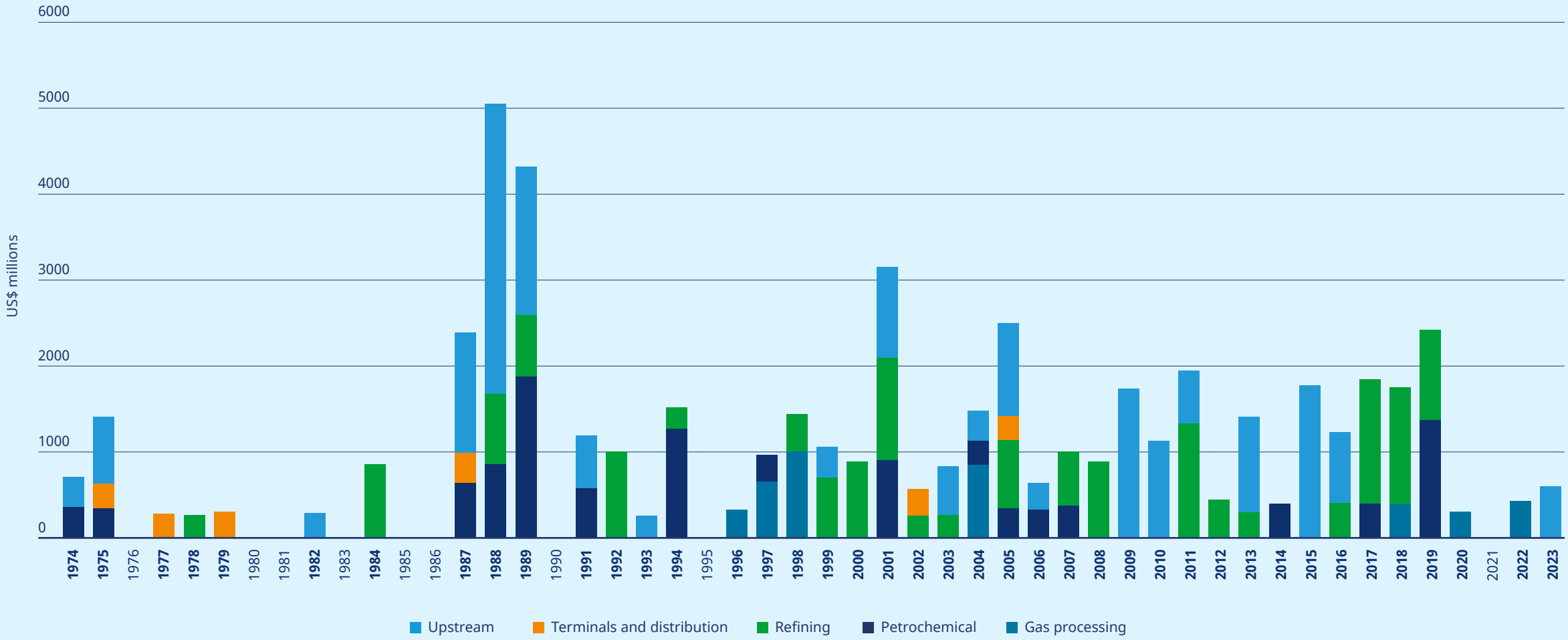
Safety protocols

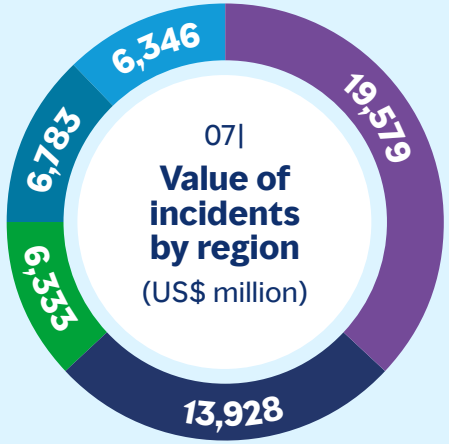
Establish and enforce robust safety protocols, provide comprehensive training to workers, and follow regulatory and industry guidelines.

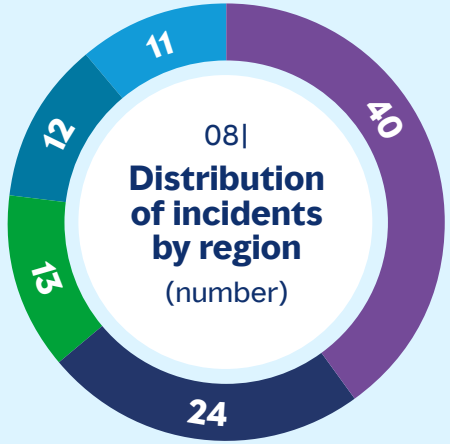
Construction related losses can impact the operational success of projects as well as insurer perception and confidence. Learning from past incidents, recognizing common themes, and implementing preventive measures, are pivotal in addressing potential risks and improving project outcomes.

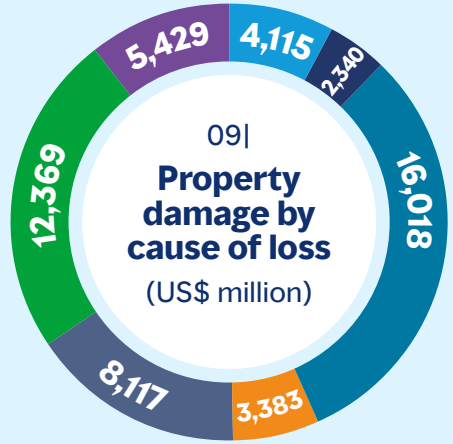
3 100 largest losses graphical data

04| **100 largest losses by year and sector**









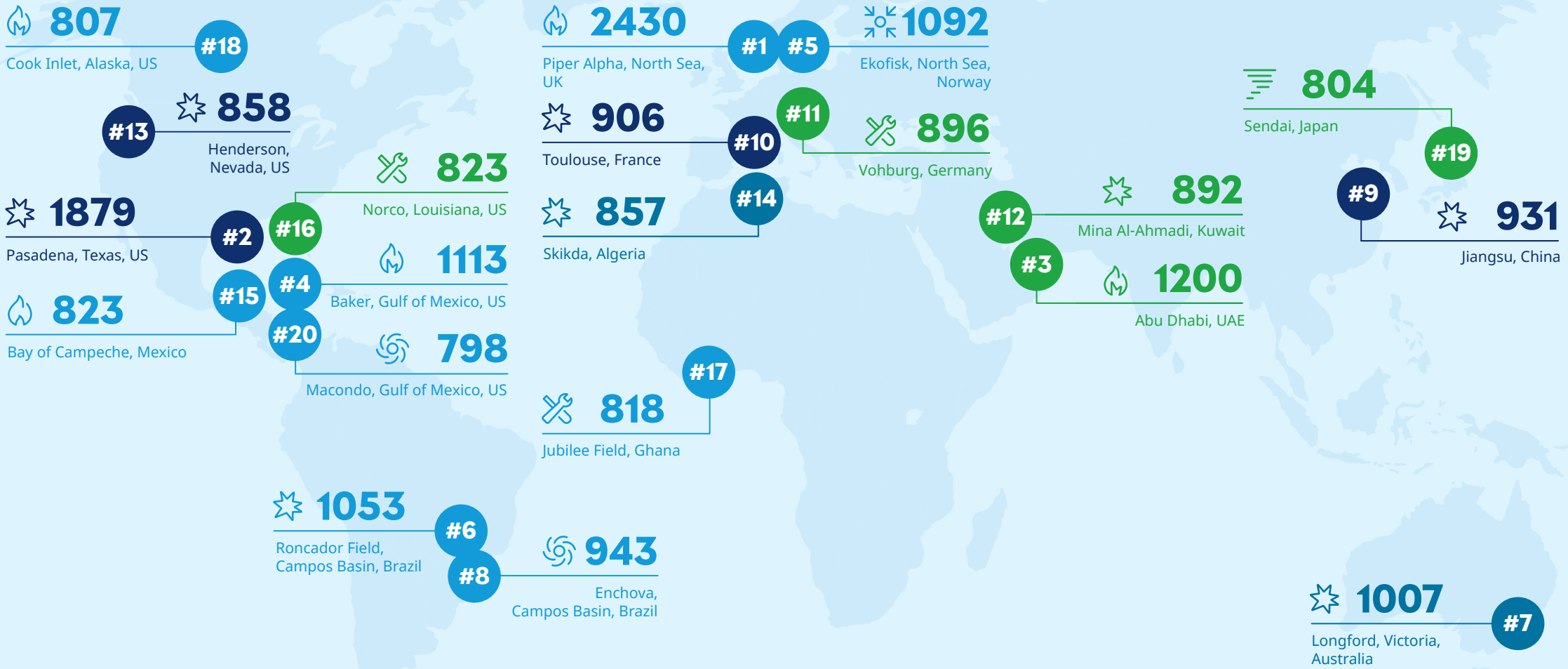
- Refining
- Petrochemical
- Upstream
- Gas processing
- Terminals and distribution

- Asia Pacific
- Europe
- Latin America
- Middle East & Africa
- US & Canada

- Blowout
- Collision
- Fire
- Explosion
- Natural catastrophe
- Fire & explosion
- Mechanical failure

10| 20 largest losses

Adjusted property loss value at December 31, 2023 (US$ million)



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Details of the 100 largest losses by sector

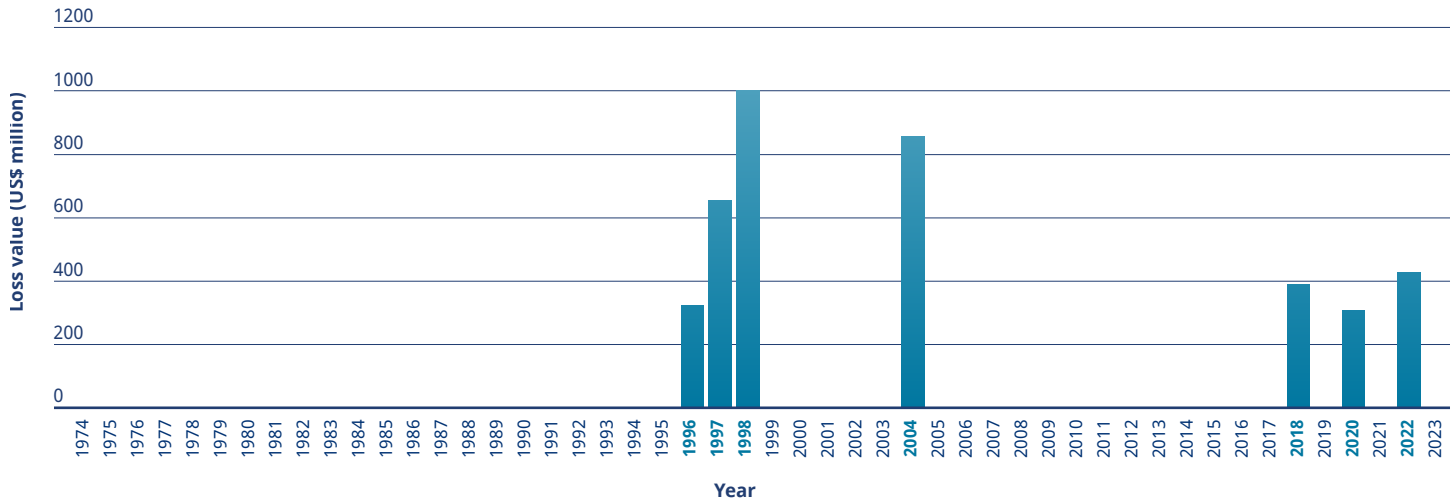
34 GAS PROCESSING | **38** PETROCHEMICALS | **48** UPSTREAM | **61** REFINING | **77** TERMINALS AND DISTIBUTION

Gas processing

Seven property damage losses associated with gas processing feature among the 100 largest losses. There was one new gas processing incident in Oklahoma, US in July 2022 that was of sufficient value to qualify for this edition.

Another explosion at a liquefied natural gas (LNG) facility in the US in June 2022 doesn't make the top 100 list but reinforces the critical role that robust engineering and design play in ensuring the integrity of LNG facilities. The exact cause of the loss is still under investigation, but initial reports suggest that it may have been triggered by a failure in the facility's containment system. The complexity of gas processing facilities, coupled with the high value of the assets involved, necessitates a comprehensive approach to risk management and safety.

11| Gas processing losses



#07

Longford, Victoria, Australia

25/09/1998

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
443	1007

EXPLOSION

Gas supplies to Australia's Victoria state were disrupted when an explosion and fire occurred at a gas processing plant. The cause of the incident was traced back to a heat exchanger rupture triggered by the abrupt shutdown of hot oil pumps that led to a process upset. The cessation of hot oil supply and cold oil exposure caused chilling in some vessels. When hot oil was re-introduced to the heat exchanger, it ruptured from a brittle fracture.

An initial release of approximately 22,000 pounds (lb) of hydrocarbon vapor exploded, and an estimated 26,000 lb burnt as a jet fire that lasted for almost two and a half days. The incident highlighted how a combination of ineffective management procedures, staffing oversights, communication problems, inadequate hazard assessment, and training shortfalls combined to result in a major malfunction and tragic loss of life.

#14

Skikda, Algeria

19/01/2004

470	857

EXPLOSION

An explosion at an LNG plant resulted in 27 fatalities, 72 injuries, and seven individuals reported as missing. It destroyed three liquefaction trains, damaged a nearby power plant, and necessitated the shutdown of a 335,000 bbl/d refinery. Neighboring industrial facilities were also affected. Initially attributed to a faulty boiler, subsequent investigations revealed a large hydrocarbon release from a cold-box exchanger that ignited upon entering the boiler. LNG complex trains 5, 6, and 10 restarted in May and September 2004. However, trains 20, 30, and 40 were destroyed in the incident, representing 50% of the LNG complex's capacity.

#23 Bintulu, Sarawak, Malaysia

25/12/1997

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
285	655

FIRE AND EXPLOSION

An explosion and subsequent fire occurred at a gas-to-liquids (GTL) plant, with the fire brought under control the following day. The plant was one of only two commercially viable GTL facilities globally, capable of producing 12,500 bbl/d of middle distillates and waxes from natural gas feedstocks. The explosion occurred in the air separation unit (ASU), which provided oxygen for the synthesis gas feedstock production.

Investigations pinpointed an initial combustion event in the ASU as the most likely cause. This event is believed to have initiated the explosive burning of aluminum heat exchanger elements in the presence of liquid oxygen, resulting in an explosive rupture. The incident caused twelve injuries and the plant remained shut for several months to facilitate repairs.

#44 Medford, Oklahoma, US

09/07/2022

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
425	425

FIRE

A fire erupted at a natural gas liquids (NGL) fractionation facility, resulting in substantial damage to the plant and significant loss of production.

Temporary evacuation of local residents was taken as a precautionary measure. The root cause of the fire at the facility is currently under investigation.

#54 Komo, Papua New Guinea

26/02/2018

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
335	390

NATURAL CATASTROPHE

A magnitude 7.5 earthquake struck Komo with multiple aftershocks over the following weeks. The event caused significant building and infrastructure damage, and more than 100 people died. The damage affected the local airport, a gas conditioning plant — which was safely shut down with some damage but no loss of containment — and the associated pipeline system, where there was no loss of containment but a need to remediate the pipeline “right of way” along most of its onshore length. Note: The value quoted here relates to the reserve across all elements of the loss, including the gas plant and the associated pipeline.

#71

Cactus, Reforma, Chiapas, Mexico

26/07/1996

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
137	322

EXPLOSION

A sequence of explosions rocked a gas processing complex, stemming from a vapor cloud explosion in cryogenic unit no.2, followed by two more blasts in cryogenic unit no.1. The latter suffered significant damage, including the destruction of its control rooms and extensive damage to the liquefied petroleum gas (LPG) product pumps. The incident originated during maintenance work on one of the pumps in cryogenic unit no.1, where a seal leak was found and addressed.

However, an ensuing LPG product leak led to a vapor cloud that ignited and triggered the initial explosion, resulting in extensive damage and disrupting a substantial portion of Mexico's gas processing capacity. Firefighters managed to quell the fires after around three hours.

#81

Hammerfest, Norway

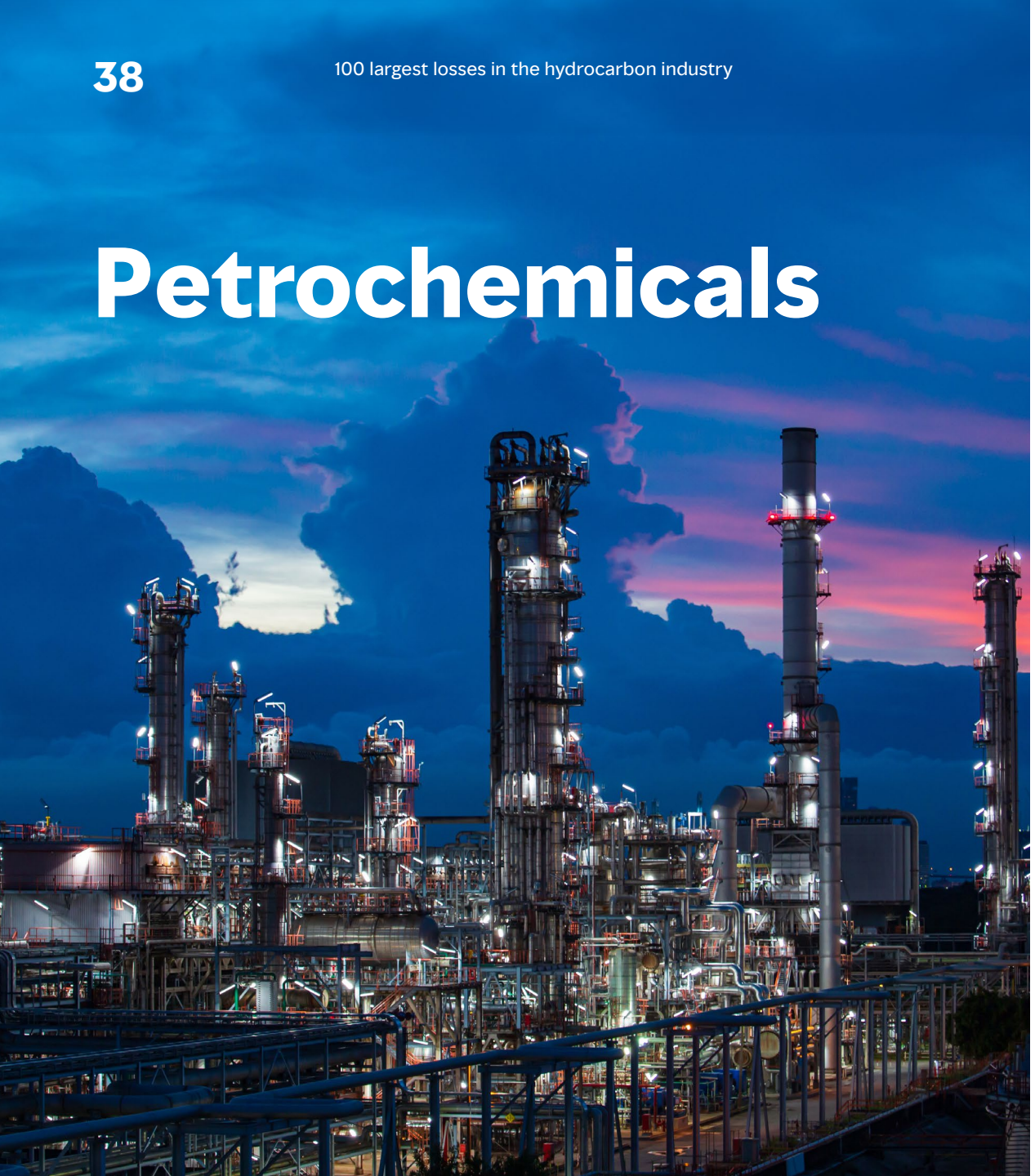
28/09/2020

300	306

FIRE

During a scheduled restart at the facility, a fire occurred within the filter housing of a gas turbine generator. An investigation determined that the primary cause was "autoignition in the filters in the turbine's air inlets," resulting from using the anti-icing heat exchanger in the air inlet beyond its intended scope, which led to elevated temperatures and ignited the fire. No injuries were reported, and the facility has since recommenced operations.

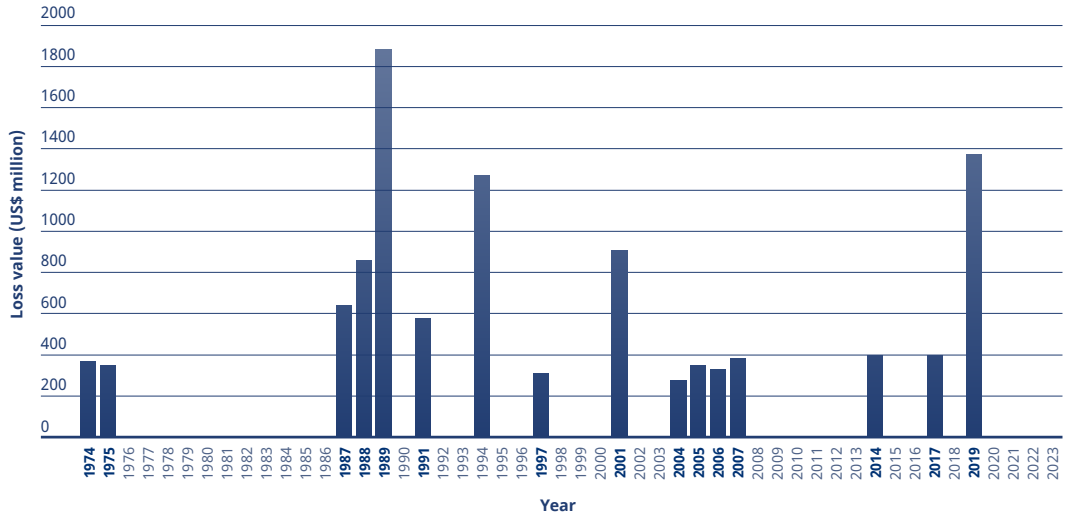
Petrochemicals



There have been no new petrochemical incidents added to the dataset in the last two years. However, there was a notable explosion and fire on a glycol unit in Louisiana, US in July 2023.

Petrochemical losses can be exceptionally large due to several factors. The concentration of high-value equipment and machinery within these facilities, and the large volumes of highly flammable or hazardous materials means that any damage or failure can result in significant property damage losses. Additionally, the interconnectedness of petrochemical supply chains means that disruptions in one facility can create a ripple effect throughout the industry, impacting production, distribution, and pricing on a global scale.

12| Petrochemical losses



#02

Pasadena, Texas, US

23/10/1989

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
675	1879

EXPLOSION

Ethylene and isobutane were inadvertently released from a high-density polyethylene (HDPE) unit at the chemical complex. Approximately 60 seconds later, the released gases ignited and caused an explosion. The explosion led to the destruction of two HDPE units, which encompassed eight particle-form, loop reactor trains. The explosion's heat caused boiling liquid expanding vapor explosions in nearby pressurized storage tanks. Other process units at the chemical complex suffered minimal damage and resumed standard operations within a few weeks. The accident investigation established lapses in maintenance procedures, including that the single isolating ball valve was open at the time of the gas release.

#09

Chenjiagang Chemical Industry Park, Jiangsu, China

21/03/2019

800	931

EXPLOSION

An explosion occurred at a fertilizer and pesticide production chemical plant located in an industrial park. The blast caused significant damage to surrounding factories and offices. Windows up to six kilometers (km) away were shattered and another chemical factory's roof (approximately 3km away) collapsed. The explosion registered as a 2.2 magnitude seismic shock, necessitating the deployment of more than 900 firefighters to control the ensuing fires.

According to China's Ministry of Emergency Management, the incident was caused by the long-term illicit storage of nitrated waste in the on-site solid waste warehouse. It is understood that nearly 80 people were killed and over 600 people injured as a result of the incident.

#10

Toulouse, France

21/09/2001

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
430	906

EXPLOSION

An explosion occurred at a fertilizer plant near Toulouse, France. The facility stored approximately 300 tons of off-specification ammonium nitrate crystals. The explosion had the strength of a 3.4 magnitude earthquake, and caused extensive damage to the plant and surrounding areas.

Thirty people were killed in the blast and approximately 3,000 people were injured. The incident highlighted the importance of proper handling and storage procedures for hazardous materials to help prevent such disasters.

#13

Henderson, Nevada, US

04/05/1988

300	858

EXPLOSION

An explosion occurred at a plant producing ammonium perchlorate (AP) for rocket fuel. The incident resulted in the flattening of the local industrial park, creating a crater 125 meters wide and damaging walls up to 15 miles away. Two fatalities were reported. The cause was related to a fire in a batch dryer.

The initial explosion had a force equivalent to 108 tons of TNT, with a subsequent explosion four minutes later equivalent to 235 tons of TNT. Roughly half of the buildings in the nearby town of Henderson were destroyed. A natural gas pipeline running under the plant was ruptured in the event and burned for a week.

#25

Pampa, Texas, US

14/11/1987

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
215	639

EXPLOSION

During a startup procedure, an explosion occurred in an air line connected to a reactor. The reactor was designated for the liquid phase oxidation of butane. The explosion ruptured the external section of the air line, causing the reactor's contents to vaporize and form a hazardous cloud.

The vapor cloud ignited approximately 25 to 30 seconds after the initial release. The explosion resulted in substantial property damage within the immediate vicinity and considerably impacted the entire site, with reports of broken windows up to seven miles away. The primary cause was believed to be inadequate purging of the reactor during a prior shutdown.

#38

Port Neal, Iowa, US

13/12/1994

203	501

EXPLOSION

An explosion in the ammonium nitrate process area led to the destruction of the seven-story main process building and the creation of a 30-foot diameter crater. During the explosion, metal fragments punctured one of the plant's two 15,000-ton refrigerated ammonia storage tanks, releasing approximately 5,700 tons of ammonia. The event necessitated the evacuation of around 2,500 people in the vicinity.

Additionally, metal fragments struck a nitric acid tank, causing the release of approximately 100 tons of nitric acid. The force of the explosion also ripped metal siding from nearby buildings, damaged three third-party electric generating stations, shattered windows in buildings located 16 miles away in Sioux City, and was felt more than 30 miles away.

#42

Belpre, Ohio, US

27/05/1994

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
182	449

EXPLOSION

An abnormal chemical reaction occurred during the batch production of a thermoplastic rubber product, resulting in an explosion. The event led to the destruction of the reactor, process controls, associated equipment, control room, and the facility dedicated to the production unit. The ensuing fire spread to affect a section of the tank farm, causing extensive damage to five atmospheric storage tanks.

The crisis escalated when the first of four 1,000,000-US-gallon and one 500,000-US-gallon styrene storage tanks erupted. In response, firefighting teams employed a combination of cooling water and foam hose streams to prevent the fire from spreading to other nearby storage tanks, notably two containing highly flammable butadiene. The fire was brought under control after approximately nine hours.

#47

Port Neches, Texas, US

27/11/2019

380	442

EXPLOSION

Approximately 6,000 US gallons (about 30,000 lb) of liquid butadiene were released after a pipe rupture in the final fractionation section of the 1,3-butadiene production unit. This release subsequently vaporized and ignited, leading to multiple fires and explosions at the facility, causing three injuries. The US Chemical Safety and Hazard Investigation Board (CSB) determined that the inadequate management of popcorn polymer in a dead leg of piping caused the incident.

Popcorn polymer, a sticky substance, accumulated within the dead leg, ultimately building enough pressure to rupture the piping and release flammable butadiene that quickly ignited. The investigation revealed a failure to properly manage the hazard, and resulted in safety recommendations and regulatory changes.

View CSB investigation video

#52 Pori, Finland
30/01/2017

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
325	397

FIRE AND EXPLOSION

A fire broke out at a titanium dioxide manufacturing facility, leading to substantial damage at the plant and a halt in pigment production.

The incident is believed to have originated in the electrostatic precipitator and rapidly spread to the pipe network and manufacturing halls.

#53 North Brabant, Netherlands
03/06/2014

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
302	396

EXPLOSION

An explosion occurred at a styrene monomer production complex during the start-up phase after routine maintenance. The initial explosion happened in a reactor, fragmenting shrapnel widely and causing a more powerful explosion in a second reactor during a shift changeover. Subsequently, a fire broke out. The flash vessels experienced ductile overloads due to excessive internal pressure generated by an uncontrolled catalytic reaction.

#55 Niigata, Japan
20/03/2007

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
240	379

EXPLOSION

An accident occurred at a methylcellulose manufacturing facility, involving an initial explosion and subsequent fire that was extinguished after approximately seven hours. Of the individuals working on-site, 17 sustained injuries; three were classified as critical, five as serious, and nine with minor injuries.

Additionally, one off-site minor injury was reported. Static electricity likely ignited the incident, culminating in a powder dust explosion. As a result, all methylcellulose operations were halted for two months before gradually resuming.

#56 Flixborough, UK

01/06/1974

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
58	366

EXPLOSION

A large vapor cloud explosion caused extensive damage to a chemical facility, resulting in the loss of 28 lives and 36 others injured. The incident happened at the weekend when the main office block was unoccupied. Eighteen of the fatalities occurred in the control room as a result of windows shattering and the roof collapsing. Offsite, 53 individuals reported injuries, and properties in the vicinity experienced varying degrees of damage.

Before the incident, a reactor was removed, and a bypass assembly was installed to maintain production. This 20-inch bypass system ruptured, possibly triggered by a nearby fire on an eight-inch pipe. The rupture led to the release of 30 tons of hot cyclohexane, forming a flammable cloud that found an ignition source. Subsequent fires continued to burn over three days.

#61 Antwerp, Belgium

02/10/1975

60	347

MECHANICAL FAILURE

An explosion and fire resulted in significant damage at a low-density polyethylene plant. The incident occurred due to a high-pressure ethylene leak, caused by the fatigue failure of a vent connection on the compressor's suction side.

The event led to six fatalities and 13 injuries.

#63 Munchmuster, Germany

10/12/2005

200	347

EXPLOSION

A hexane release led to the ignition of a vapor cloud when it encountered an electric motor, resulting in an explosion. The incident caused damage to a process unit and 20 injuries.

One firefighter was killed, and another was seriously injured while fighting the blaze.

#68 Port Arthur, Texas, US

29/04/2006

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
200	332

EXPLOSION

A shelter-in-place directive was issued when a fire broke out following an explosion in the propylene refrigeration section of an ethylene unit.

The fire, which burned for three days, forced the facility's shutdown for six months but caused no deaths or serious injuries.

#72 Cedar Bayou, Texas, US

20/10/1994

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
130	321

NATURAL CATASTROPHE

Severe floods along the San Jacinto River in Texas resulted in the shutdown of a major industrial site. The complex comprised facilities that produced 650,000 tons per year of ethylene, 200,000 tons per year of LLDPE, and 280,000 tons per year of LDPE, in addition to general utilities.

The widespread floods impacted the site and disrupted downstream clients who depended on these utilities. The floodwaters breached protective dikes surrounding the main substation, leading to the inundation of control rooms and offices causing extensive operational disruptions.

#73 Sterlington, Louisiana, US

01/05/1991

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
120	319

FIRE AND EXPLOSION

An incident unfolded as workers prepared to inspect a compressor in the nitroparaffin unit. They discovered a small fire and promptly activated the plant's fire alarm system. In approximately 30 seconds, a substantial explosion occurred, followed by a series of smaller explosions.

The initial blast's impact extended as far as eight miles away, destroying an area within the plant roughly the size of a city block. Fires ignited in the aftermath and persisted for over seven hours. While the incident didn't harm the two on-site ammonia units, the entire plant was temporarily shut down.

#77

Deer Park, Texas, US

22/06/1997

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
135	310

MECHANICAL FAILURE

A petrochemical plant was rocked by a substantial explosion and a subsequent large fire. The explosion reverberated over a 10-mile radius while the ensuing fire burned for roughly ten hours. The incident caused significant damage to the plant and several workers sustained minor injuries. The surrounding area and property were also affected, leading to temporary road closures. Local residents were advised to remain indoors to prevent exposure to potentially harmful substances.

The event was traced back to a cracked gas compressor system in the Olefins unit. It was initiated by the structural failure of a 36-inch pneumatically-assisted, non-return valve on a high-pressure light hydrocarbon gas line. The escaping gas formed a vapor cloud, which eventually encountered a source of ignition, culminating in an unconfined vapor cloud explosion.

#89

Illiopolis, Illinois, US

23/04/2004

150	274

FIRE AND EXPLOSION

An explosion occurred at a plastics plant producing 200 million barrels of specialty-grade PVC per year. The explosion, which could be felt eight kilometers away, took place in a reactor where vinyl chloride and vinyl acetate were mixed.

Up to 75% of the plant was destroyed in the incident, resulting in two serious injuries and the loss of five lives.

View CSB investigation video

#93

Pajaritos, Coatzacoalcos, Mexico

11/03/1991

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
97	258

MECHANICAL FAILURE

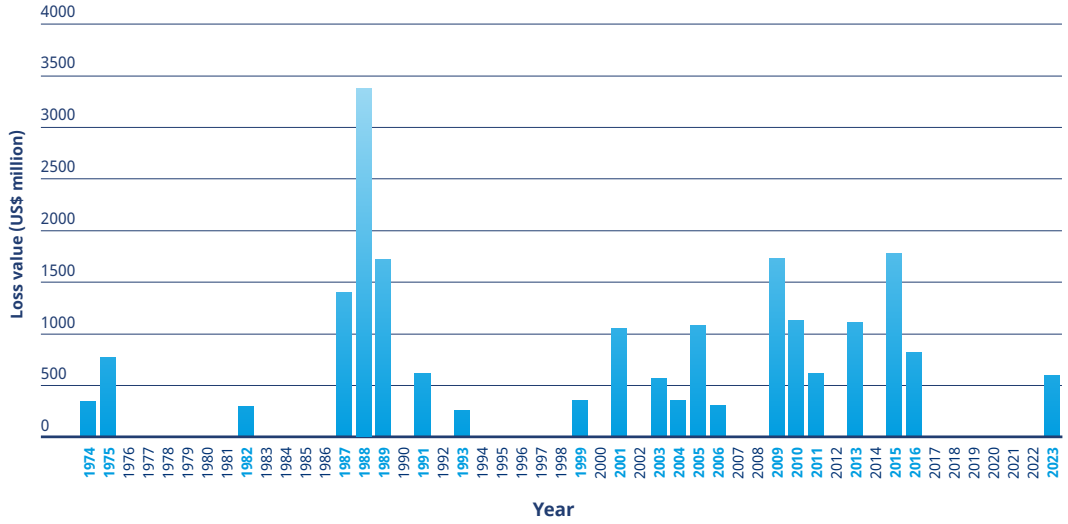
A gas leak involving a pipe rack that ran to a terminal in the petrochemical complex led to an explosion near the complex's chemical plant. This caused additional damage to the pipe rack and resulted in a major gas leak. A powerful second explosion occurred, which could be felt more than 15 miles from the complex. This second explosion and the subsequent fire destroyed the chemical plant, damaged the pipe rack, and caused moderate damage to other complex buildings and adjacent third-party facilities. The fire was extinguished after approximately three hours. The complex was completely shut down for seven months to allow for the reconstruction of the plant and pipe rack.

Upstream

There are 32 upstream sector losses in the top 100, including the latest incident which occurred in July 2023 in the Gulf of Mexico. Nine historical losses have also been added to this edition following a review of updated loss data from insurance markets.

In this dataset, the upstream sector accounts for the highest cumulative losses, US$20.25 billion. Various factors contribute to the cost of upstream losses, including the remoteness of offshore facilities which presents challenges for emergency response and recovery measures.

13| Upstream losses



#01 Piper Alpha, North Sea, UK

06/07/1988

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
850	2430

FIRE AND EXPLOSION

A pressure relief valve was removed for maintenance, causing pressurization of a piping section, which led to the release and ignition of gas condensate in the platform's gas compression module. The event initiated a chain of fires and explosions, resulting in substantial facility damage. The accident's severity was compounded by ruptured pipelines, which released oil and gas, and the subsequent disabling of most emergency systems.

The gas compression module's proximity to the control room rendered it non-functional. The manual operation of firewater pumps, due to divers in the water before the incident, complicated response efforts. There were 226 individuals on the platform at the time of the accident; only 61 survived. This was partly due to the location of the living quarters above the initial release site.

#04 Baker, Gulf of Mexico, US

19/03/1989

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
400	1113

FIRE AND EXPLOSION

While installing a pig trap on an 18-inch export gas pipeline, a cold cut in a pipe resulted in the release and ignition of hydrocarbons. The incident triggered a destructive explosion and fire that engulfed the main structure and led to further explosions when nearby pipelines ruptured due to the intense heat. The accident led to the destruction of the platform and seven fatalities. It took two years to replace the platform.

#05 Ekofisk, North Sea, Norway

04/06/2009

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
750	1092

COLLISION

A well-intervention vessel lost power and collided with an uncrewed platform in the 230,000 bbl/d complex. The force of the collision caused the vessel's bow to compress by about two meters. The collision caused severe damage to the platform, reportedly affecting 23,000 bbl/d oil production.

The platform was partially displaced, resulting in the loosening of several support legs from the main load-bearing structure. There was also damage to the linking access bridge, well equipment, one of the platform's water injection risers was significantly bent, and several wellheads were displaced.

#06 Roncador Field, Campos Basin, Brazil

15/03/2001

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
500	1053

EXPLOSION

Explosions from a gas release affected the world's largest offshore production facility. The explosions led to the displacement of a support pillar on the semi-submersible platform, allowing seawater to enter the vessel.

In an attempt to maintain the rig's buoyancy, workers injected nitrogen and compressed air and pumped out almost 3,000 tons of seawater. However, these efforts were unsuccessful, and five days after the incident, the rig sank to the sea floor. Eleven lives were lost.

#08 Enchova, Campos Basin, Brazil

24/04/1988

330	943

BLOWOUT

During the conversion of a platform well from oil to gas production, a high-pressure gas pocket forced the drill pipe out of the well, leading to a well blowout. The blowout preventer failed to shut in the well, resulting in the ignition of the escaped gas. The fire lasted 31 days, destroying most of the platform's topside structure.

The facility was declared a total loss. To expedite the resumption of operations, the production module underwent a redesign within 45 days. Full production recovery was achieved 18 months after the incident. This accident showed the importance of robust well-control measures and disaster recovery planning in offshore drilling operations.

#15 Bay of Campeche, Mexico

04/01/2015

640	823

FIRE

In the Gulf of Mexico, a fire erupted in a complex of six offshore platforms situated in 30 meters of water. The blaze originated on the lower decks of the production platform, causing severe damage to the platform and radiation and fire damage to an adjacent compression platform. Bridge links and pipelines were lost and other bridge links sustained radiation damage.

A government investigation attributed the initial failure to corrosion within a small-bore pipeline. The incident underscored the importance of proactive infrastructure maintenance and corrosion prevention measures in offshore environments.

#17 Jubilee Field, Ghana

11/02/2016

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
650	818

MECHANICAL FAILURE

The main turret bearing on a floating production storage and offloading vessel experienced a seizure and eventual failure, causing the vessel to lose its weather-vaning capability. Production was resumed with a revised operating regime employing tugs to maintain a constant heading.

Subsequently, the vessel was converted to establish a permanent spread moored configuration. The reconfiguration secured the vessel's heading and the integration of a deep-water offloading buoy to facilitate operations.

#18 Cook Inlet, Alaska, US

20/12/1987

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
273	807

FIRE AND EXPLOSION

During cementing operations on the offshore platform, a surge in formation pressure led to a well blowout. The catastrophic event caused the release of substantial amounts of fluid, gas, and subsoil debris into the atmosphere.

Sparks generated during the ejection of sand and rocks from the well led to its ignition. The platform sustained extensive damage as a result of the incident.

#20 Macondo, Gulf of Mexico, US

20/04/2010

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
560	798

BLOWOUT

In Mississippi Canyon block 252, about 50 miles off Louisiana's coast, a well integrity failure led to a major explosion and fire on a deepwater semi-submersible drilling rig. Eleven lives were lost and 17 crew members were injured. Within 36 hours, the rig sank in a water depth of approximately 5,000 ft. The exploration well had reached a total depth of 18,360 ft and was undergoing cementing operations for temporary abandonment when the well control incident occurred.

A buckled drill pipe in the blowout preventer (BOP) hindered the blind shear ram from cutting the pipe and sealing the well. Hydrocarbons continued to flow through the damaged BOP for 87 days before a successful static kill. The event required an unprecedented subsea and surface spill control response, ending after five months with the successful interception of a relief well, releasing approximately five million barrels of hydrocarbons into the environment.

View CSB investigation video

#21 Caspian Sea, Kazakhstan

24/09/2013

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
596	796

MECHANICAL FAILURE

A newly operational offshore pipeline in Kazakhstan was found to have a gas leak. The affected section was repaired, but more leaks appeared in both the gas and oil pipelines.

The root cause was identified as localized hardness in the pipes that led to sulfide stress cracking. To resolve the issue, both pipelines were replaced.

#24 Mumbai High North Field, India

27/07/2005

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
370	642

COLLISION

A significant incident led to the destruction of an oil platform and the loss of 22 lives. A multi-purpose support vessel was taking a worker to a medical center when it collided with the platform's riser, causing a major explosion. The vessel caught fire and eventually sank. The crews of two nearby platforms were saved when connecting bridges collapsed. The 150 individuals on board were transferred to a nearby water injection platform.

An additional 348 individuals were safely evacuated from the oil platform despite challenging weather conditions. The fire also engulfed a cantilever jack-up rig linked by a bridge to the process platform, and one employee died. Six divers were trapped in a saturation chamber on the vessel in a separate but related incident. They were successfully rescued after 36 hours.

#26 Cantarell Field, Gulf of Mexico, Mexico

07/07/2023

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
600	600

FIRE AND EXPLOSION

A fire at a production platform caused extensive damage and a production loss of approximately 100,000 bbl/d. The fire was extinguished the next day, and production fully restored after several days.

Eight workers sustained injuries and two individuals lost their lives. An ongoing investigation is underway to determine the cause of the fire.

#27 Big Foot Field, Gulf of Mexico, US

18/04/2015

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
488	628

MECHANICAL FAILURE

During the process of connecting an extended tension leg platform to freestanding tendons, adverse weather and challenging loop current conditions necessitated a temporary suspension of installation operations. During this delay, nine of the 16 freestanding tendons collapsed to the seafloor.

The incident was attributed to bolt failure. The bolts didn't secure the temporary buoyancy modules, causing the tendons to collapse. A debris removal operation was initiated for the tendons that had fallen to the seabed and some of the piles on the seabed also incurred damage.

#29 Gryphon, North Sea, UK

04/02/2011

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
450	613

NATURAL CATASTROPHE

Severe North Sea storm conditions caused four of the floating production storage and offloading (FPSO) vessel's 10 anchor chains to fail, displacing the FPSO. The vessel faced 53-knot winds and nine-meter waves. The incident damaged the complex piping system connecting the seabed wells to the FPSO.

In response, all wells were promptly shut down. Subsequent assessments revealed no oil loss. Seventy-four non-essential crew members were evacuated to nearby platforms, while 43 essential crew remained on board, with two sustaining minor injuries. Prior to the event, the facility had an estimated average oil production of 18,400 bbl/d.

#30 Treasure Saga, North Sea, Norway

20/01/1989

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
220	612

BLOWOUT

A semi-submersible rig experienced a gas kick at 15,527 feet while attempting to clear cement from the drill pipe during drilling. This led to a well blowout.

It took 11 months to regain control of the well by injecting heavy mud through a relief well. An additional four months were needed to complete the cleanup and the final abandonment of the blowout well.

#31 Troll, North Sea, Norway

23/08/1991

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
230	612

MECHANICAL FAILURE

After construction of the gravity base structure of a platform was completed, deep submergence tests were underway to verify the structure's integrity before mating with the deck and module installation.

Upon reaching the seabed, the structure experienced a catastrophic failure, leading to its submersion and fragmentation. An investigation revealed cracks in the tricell walls and insufficient reinforcement, which resulted in the failure of the structure. All 14 people onboard the platform were uninjured and rescued by nearby boats.

#33 Bourbon Field, Gulf of Mexico, US

04/11/1987

200	594

BLOWOUT

Sustained casing head pressure leaked from the production casing into the outer casing strings, leading to the failure of one of the casing strings.

The event triggered an underground blowout, which significantly damaged the platform and a gas plume around the platform. To restore stability to the seabed, the well was successfully killed.

#35 Siri Field, North Sea, Norway

14/03/2003

291	567

MECHANICAL FAILURE

During an inspection of the Siri platform in the North Sea, cracks were discovered in the sponson cantilever extension connected to the primary oil storage tank. To enable an internal examination, access openings were created in the sponson walls, with miniature remotely operated vehicles (ROVs) deployed for the inspection.

A total of 39 internal cracks were identified. The primary issue was attributed to the insufficient design of the support structure for the caisson.

#41

Fateh L3, Dubai, UAE

01/07/1975

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
79	457

BLOWOUT

The Fateh Field L-3 development well had reached a depth of 4,180 feet when an unexpected kick occurred during drilling operations. As attempts to control the kick failed, the rig was evacuated due to a gas breakthrough around the 20-inch casing shoe, with gas seeping beneath the platform.

Eight days after the initial blowout, the accumulated gas ignited. Over the subsequent two weeks, both the drilling rig and platform sank.

#48

Thunder Horse, Gulf of Mexico, US

10/07/2005

250	434

NATURAL CATASTROPHE

Hurricane Dennis swept through the platform's vicinity, causing it to partially sink. The incident was attributed to the incorrect installation of a seawater valve in a ballast tank, which caused an overflow of water in the tanks. Fortunately, the platform had already been evacuated, and no oil, fuel, or hazardous substances were released.

However, it setback production by three years. The company retrieved and reconstructed all the sea-bed production equipment to address the issue. Subsequent testing identified metallurgical failures in various components of the field sub-sea systems.

#57

Montara, Timor Sea, Australia

21/08/2009

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
250	364

BLOWOUT

Oil, condensate, and hydrogen sulfide were released from a wellhead on a platform undergoing maintenance in the Timor Sea. As a safety measure, 69 workers on the jack-up rig were evacuated. The incident was triggered when a plug obstructing one of the project's 1,200-meter-deep wells came free, leading to oil and gas spills. A spill measuring 12 km in length and 30 m in width was reported the next day. Efforts were made to seal the well over the following two months, with an estimated daily leak rate of 400 barrels of oil and gas.

On November 1, it was reported that drillers had successfully intercepted the well and commenced the injection of heavy mud to seal it. However, a fire broke out on the drilling platform while attempting to plug a deeper leak. The fire was extinguished two days later. Approximately 4,140 tons of oil were estimated to have been lost in this incident. Both the platform and the drilling rig were impacted.

#59

Straits of Malacca

22/01/1999

158	354

MECHANICAL FAILURE

A semi-submersible vessel was subcontracted to transport a newly constructed platform from Singapore to Angola. The vessel capsized after striking a submerged object, which ruptured four empty ballast tanks and penetrated one cofferdam and a space between the forward and aft engine rooms.

Rapid flooding caused the vessel to sink within approximately five minutes of striking the object. The object was likely an unmarked reef or rock. The platform sank in 35 meters of water and had to be rebuilt.

#64

Temsah, Egypt
10/08/2004

Original property loss value (US$ million): 190

Adjusted property loss value 2023 (US$ million): 347

BLOWOUT

A fire erupted during drilling operations at an offshore gas production platform due to a well-control incident. The fire was initially contained but eventually spread to a nearby jack-up drilling rig owned by a major drilling contractor, causing significant damage and the rig's collapse.

All 79 people on the drilling rig were safely evacuated; the production platform, accommodating 150 personnel, had been evacuated earlier. The drilling rig sank and couldn't be salvaged. The platform sustained irreparable damage, leading to its ordered decommissioning by the authorities.

#65

Frigg Field, North Sea, Norway
15/03/1974

Original property loss value (US$ million): 54

Adjusted property loss value 2023 (US$ million): 341

MECHANICAL FAILURE

A series of underwater visual inspections revealed cracks in a platform's concrete external diaphragm walls. Investigations revealed that the stresses endured by these diaphragms throughout their construction, towing, and platform installation phases were sufficient to initiate the cracks. The cracks was not attributed to a single isolated incident but as a result of cumulative stress factors over time.

#67

Caribbean Sea, Venezuela
13/05/2010

Original property loss value (US$ million): 235

Adjusted property loss value 2023 (US$ million): 335

MECHANICAL FAILURE

A natural gas drilling rig submerged in the Caribbean Sea. All 95 workers were safely evacuated, and no reported leakage transpired.

The sinking resulted from a sudden inflow of water into one of the submarine rafts supporting the platform legs. Automatic sub-sea safety valves sealed the wells, preventing any oil leakage.

#70 Camarupim Field, Brazil

03/11/2015

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
250	322

EXPLOSION

An explosion occurred on a floating production storage and offloading (FPSO) vessel off the coast of Brazil, leading to nine fatalities and multiple injuries. The incident took place while the vessel was anchored in the Atlantic Ocean, approximately 120 km off the coast of Espirito Santos, Brazil. The FPSO, originally a large crude oil tanker converted to produce up to 10 million cubic meters of natural gas, experienced a condensate leak during a fluid transfer operation, releasing a flammable vapor cloud into the engine room. The cloud ignited, causing an explosion in the machinery space. Although the FPSO took on water, the explosion did not breach the vessel's hull. Most of the fatalities were among the emergency response team.

#74 Auk Field, North Sea, UK

01/08/1975

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
55	316

COLLISION

A supply vessel collided with a jacket on the Auk field, causing severe damage to the platform. Three braces were lost and a fourth was severely bent. The impact also damaged the platform's topside facilities.

The supply vessel that collided with the Auk field platform was a semi-submersible drilling rig that was used as a supply vessel at the time of the incident.

#76 Atlantic Ocean, near Angola

01/07/2013

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
235	315

MECHANICAL FAILURE

A jack-up drilling rig sank as the seabed unexpectedly collapsed beneath one of its three support legs. The incident occurred during the rig's positioning for drilling operations in roughly 40 meters of water.

The abrupt tilt led to the rig taking on water and subsequently capsizing. At the time, the rig accommodated 103 workers. One crew member was listed as missing, and six others sustained minor injuries.

		Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
#80	**North Sea, Norway** 05/11/2006		
MECHANICAL FAILURE	Offshore gas alarms on the floating production unit were activated and a subsequent investigation confirmed a leak from one of the production risers. Further examinations showed that five additional risers were impacted by similar issues. Corrective measures were implemented to address the situation.	185	307
#84	**North Atlantic Ocean, near Newfoundland, Canada** 15/02/1982		
MECHANICAL FAILURE	A semi-submersible rig vanished from radar screens amid a powerful storm. The storm generated waves of up to 37 feet and winds of up to 90 knots. The rig designed to operate in harsh weather conditions, was battered by the waves and wind for several hours, and eventually capsized and sank. The rig was discovered submerged upside down in 300 feet of water. All 84 crew members on board died.	92	292
#87	**South China Sea** 15/09/2009		
NATURAL CATASTROPHE	Typhoon Koppu reached maximum intensity with estimated wind speeds of approximately 140 km/hr (about 75 knots) near its center. A floating production storage and offloading vessel (FPSO) was positioned roughly 60 miles from Typhoon Koppu's center. Adverse weather conditions led to four out of eight mooring lines failing, particularly those near the Buoy Turret Mooring (BTM) system. Consequently, the BMT/FPSO was anchored in place by the remaining four mooring lines, although it had shifted approximately 600m to 700m north of its original location. There was extensive damage to the mooring system, risers, pipeline end manifolds (PLEMS), and varying degrees of damage to piping and power cables near the PLEMS.	191	278

#94

Lama, Lake Maracaibo, Venezuela

25/03/1993

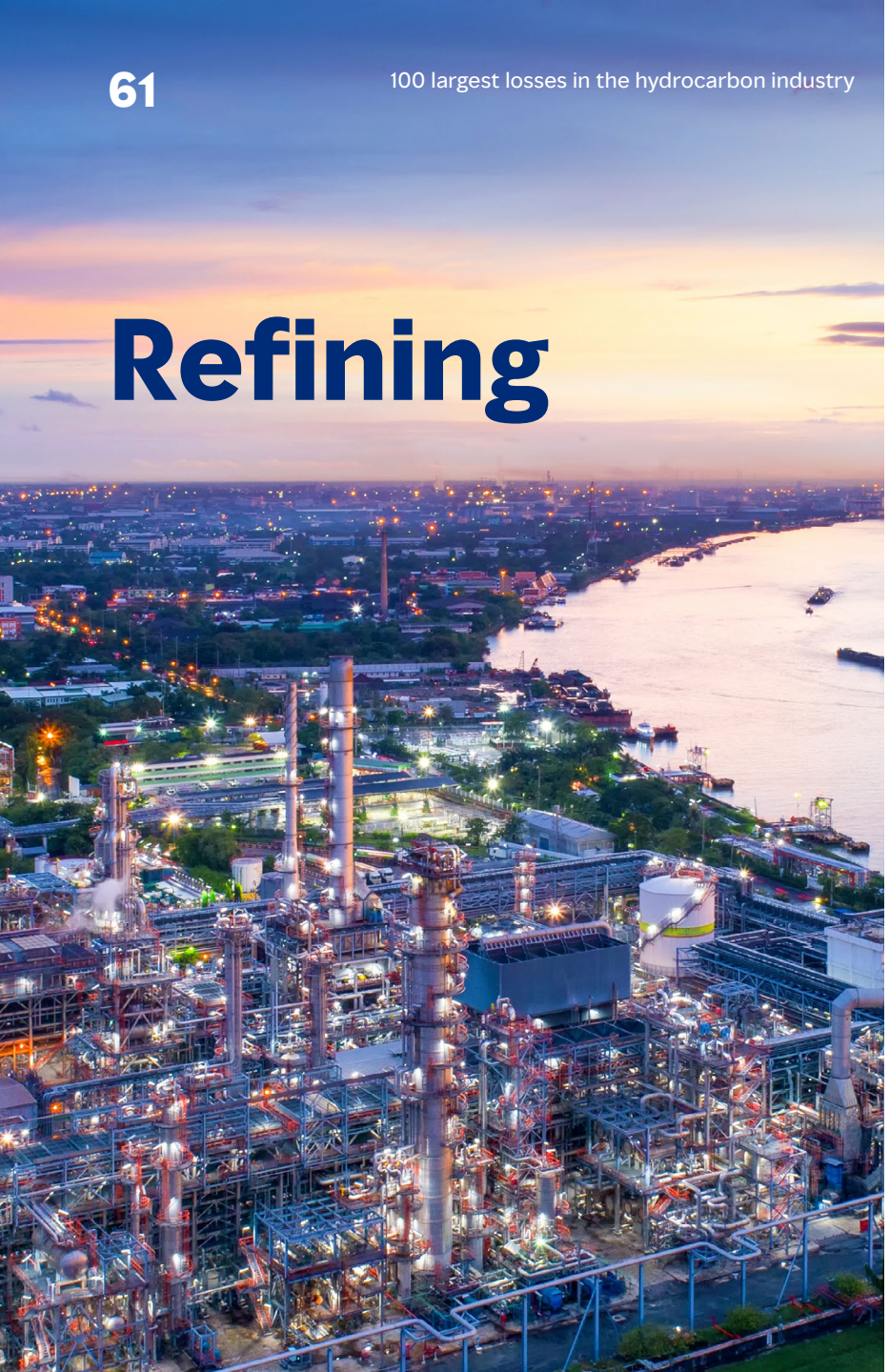
Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
100	254

MECHANICAL FAILURE

An apparent failure of a propane intercooler liquid level control during unsupervised maintenance led to an explosion and fire.

The control room on the main platform was destroyed, and adjacent platforms were affected by the blast wave. The incident resulted in eleven fatalities.

Refining

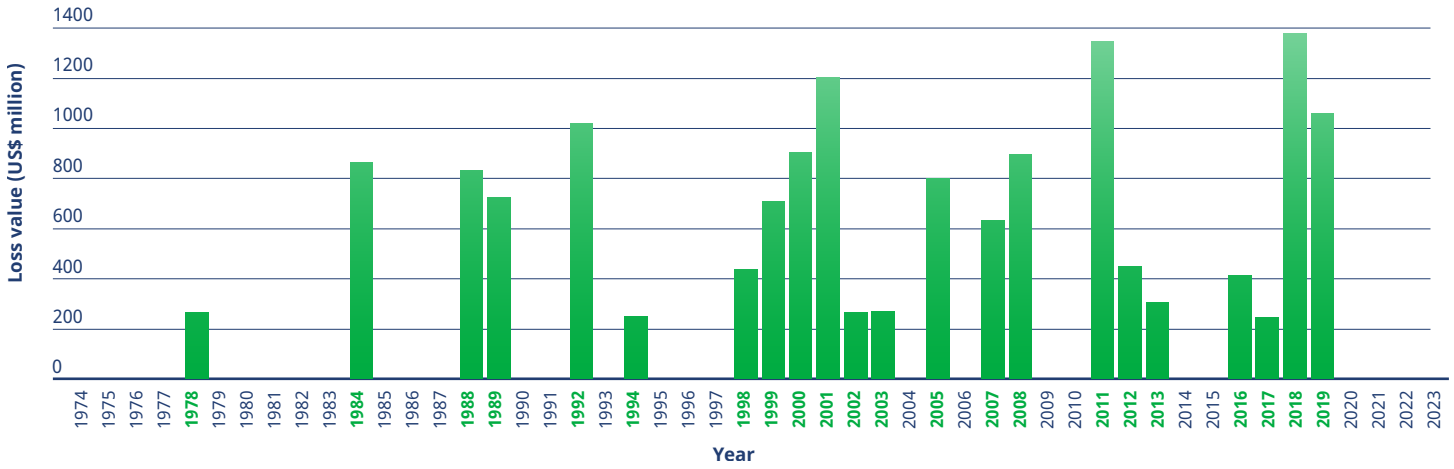


There were no new additions to the top 100 from this sector in the last two years. However, there have been several notable refining losses: a fire in Spain (April 2023), a fire in the US on a unit processing alkylate (February 2022), a mechanical incident causing significant damage in Austria (June 2022), a fire in the US (June 2022), a fire and explosion in the US (September 2022) and a fire at a refinery in the US (August 2023).

The worldwide group of oil refineries is, with some exceptions, a group of aging assets. Older assets have often been subject to both expansion projects to increase capacity, and retrospective installation of high-value, high-conversion assets. These factors have resulted in higher concentration of value at sites. Refineries process crude oil and therefore, have a far more dynamic and broad feedstock range than the other asset classes.

The combination of aging assets, increased concentration of value, and diverse feedstocks, are all likely to have contributed to the fact that this sector makes up the largest proportion of the top 100 losses.

14| Refining losses



#03

Abu Dhabi, UAE

11/01/2017

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
1000	>1200

FIRE AND EXPLOSION

During a maintenance operation, the accidental release of hot, light hydrocarbons led to a significant fire. The incident occurred at a newly commissioned residual fluid catalytic cracking (RFCC) unit, part of a major expansion effort that doubled the refinery's overall capacity.

The severity of the fire led to the temporary closure of the expanded refinery area and required extensive rebuilding work to restore normal operations.

#11

Vohburg, Germany

01/09/2018

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
770	896

MECHANICAL FAILURE

A hydrocarbon release occurred from a reactor vessel on a naphtha hydrotreater unit operating at approximately 25 bar and 140 degrees celsius. The release of hot naphtha and hydrogen formed a vapor cloud that ignited, resulting in an explosion and fire. The explosion triggered additional releases from other parts of the plant, including a nearby diesel hydrotreater that intensified the fire. Eight on-site employees suffered injuries, but no fatalities were reported. Residents of a nearby town were evacuated as a precaution, and hundreds of firefighters were deployed to control the fire.

Extensive damage occurred in several refinery process units, offices, and maintenance buildings, and even caused window breakage in a village approximately 3km away. The initial release of hydrocarbon was attributed to a 1.5-meter crack near the welded vessel support in the reactor vessel, although detailed investigation findings have not been widely disclosed.

#12

Mina Al-Ahmadi, Kuwait

25/06/2000

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
412	892

EXPLOSION

An explosion happened when employees tried to isolate a leak in a condensate line connecting an off-site NGL plant and refinery gas plant. Three crude units were damaged and two reformers destroyed. It took around nine hours to extinguish the subsequent fire, which resulted in five fatalities and 50 injuries.

The investigation revealed a deficiency in the inspection and maintenance of the condensate line, which was not owned by the refinery. The lack of a clear understanding regarding the line's ownership is thought to have caused delays in isolating it.

#16

Norco, Louisiana, US

05/05/1988

288	823

MECHANICAL FAILURE

In a 90,000 bbl/d fluid catalytic cracking (FCC) unit operation, an eight-inch diameter carbon steel elbow, positioned 50 feet above ground in a depropanizer column overhead piping system, suffered a catastrophic failure due to internal corrosion. Approximately 20,000 lb of C3 hydrocarbons were released, creating a substantial vapor cloud within the 30 seconds before ignition. The depropanizer column and accumulator depressurized through the breach.

The vapor cloud most likely ignited from the FCC charge heater. The initial explosion obliterated the FCC control building, toppling the 26-foot diameter main fractionator and causing widespread damage across the 215,000 bbl/d refinery. Off-site damage resulted in around 5,200 property claims. The FCC unit was eventually demolished and a new unit was constructed. Preliminary findings revealed unexpectedly high localized corrosion rates in the failed elbow.

#19 Sendai, Japan

11/03/2011

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
590	804

NATURAL CATASTROPHE

A major explosion occurred at a 145,000 bpd refinery in Sendai just hours after Japan's largest-ever earthquake and subsequent tsunami. The fire originated in the oil product shipping area.

No fire suppression capabilities were in place and workers were evacuated. The fire extended to the storage and shipping facilities, causing damage to a 35,500 bpd fluid catalytic cracker (FCC) at the refinery.

#22 Limbe, Cameroon

31/05/2019

600	698

FIRE AND EXPLOSION

A fire and subsequent explosion occurred near the distillation unit of a refinery, necessitating a complete site shutdown.

Four of the 13 units at the site were destroyed, and three suffered partial damage. The cause of the incident has not been widely shared.

#28 Romeoville, Illinois, US

23/07/1984

191	614

MECHANICAL FAILURE

Before the rupture of a 55-foot-tall, 8.5-foot-diameter monoethanolamine absorber column at a refinery, a crack was discovered at a circumferential weld that was leaking propane. Efforts to close the inlet valve were underway when the crack expanded to 24 inches. The area was evacuated, and the plant's fire brigade was notified. The column eventually failed, propelling most of the 20-ton vessel 3,500 feet before striking and toppling a 138,000-volt power transmission tower.

The rupture happened along a lower girth weld which was made during repairs a decade earlier. Substantial fires occurred in various refinery units, with one explosion breaking windows up to six miles away. Extensive structural damage disrupted electrical power, affecting firefighting capabilities. Responding fire departments, including those from neighboring plants, worked collectively to manage the incident.

#32

Lemont, Illinois, US

14/08/2001

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
285	601

MECHANICAL FAILURE

The 160,000 bbl/d capacity refinery underwent a shutdown due to a pool fire originating from a pipework release within the crude distillation unit. Three days later, an internal fire caused a structural failure in the crude column, resulting from air ingress due to the previous ruptured pipework's reaction with pyrophoric material and oil in the column.

This led to a 12-month shutdown of the crude distillation unit. The initial pool fire resulted from incorrect piping material specification in one elbow, which ultimately failed.

#34

La Mede, France

09/11/1992

225	586

MECHANICAL FAILURE

A vapor cloud explosion disrupted a gas plant associated with a 29,700 bbl/d fluid catalytic cracker (FCC) unit in a 136,000 bbl/d refinery. The initial explosion involved around 11,000 lb of light hydrocarbons and could be heard miles away. The unit's detection system had picked up a gas leak, likely due to a ruptured recovery pipe for butane and propane from the FCC unit.

The incident severely damaged nearly two hectares of the refinery, including the gas plant, FCC unit, and control building. The construction of two new process units nearby was also heavily impacted, and windows broke in neighboring areas. Firefighters from several locations and the refinery's brigade spent over six hours controlling the situation, using around 37,000 US gallons of foam concentrate.

#36

Big Spring, Texas, US

18/02/2008

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
380	562

EXPLOSION

An explosion occurred at a 70,000 bbl/d oil refinery, damaging several components, including the fluid catalytic cracker (FCC), storage tanks, and the asphalt unit. Four people were injured. The accident occurred on a public holiday, with only 40 people present on-site (typically, four times that number would be on duty).

With assistance from local fire departments, the refinery's fire brigade managed to control the fire on the same day. The release is believed to have been linked to the catastrophic failure of a pump during a propylene splitter unit start-up. Some processing operations resumed two months later, and the FCC was re-commissioned eight months after the event.

#37

Fort McKay, Alberta, Canada

06/01/2011

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
385	524

EXPLOSION

An explosion occurred on an oil sands upgrader site north of Fort McMurray, Alberta, injuring five workers, including one who suffered third-degree burns. Shortly afterward, a fire broke out at the top of one of the facility's four coke drums and burned for nearly four hours, rendering two inoperable. Most of the damage was concentrated above the cutting deck and derrick infrastructure of the coke drum.

The plant was already operating under bypass conditions due to process upsets during the incident. The fire resulted from the opening of the top unheading valve on an active low-pressure coke drum, which allowed hot hydrocarbons to be released within the coker-cutting deck building, which led to ignition. Freezing conditions following the incident hindered access to the coker unit's cutting deck and caused additional damage during firefighting efforts.

#39

Wisconsin, US

26/04/2018

Original property loss value (US$ million)

Adjusted property loss value 2023 (US$ million)

400 | 465

FIRE AND EXPLOSION

An explosion and ensuing fire at the refinery caused injuries to 36 individuals and the partial evacuation of the nearby town of Superior, Wisconsin. The incident happened when the refinery's fluid catalytic cracking unit (FCCU) was undergoing planned maintenance. The probable cause was the erosion of the FCCU spent catalyst slide valve, which couldn't maintain the catalyst level necessary to prevent the mixing of air and hydrocarbons during transient operation.

Consequently, air traveled backward from the regenerator into the reactor and downstream equipment, leading to the explosion. Debris from the explosion scattered across the plant, with one fragment piercing a nearby large above-ground storage tank. The breach resulted in the release of approximately 15,000 barrels of hot asphalt, which subsequently ignited, sparking a substantial fire.

View CSB investigation video

#40

St Croix, Virgin Islands

18/09/1989

167 | 465

NATURAL CATASTROPHE

Hurricane Hugo struck the refinery, severely damaging 14 of the 500,000 to 600,000 barrel storage tanks in the tank farm area, along with the administration building and company housing. The process units were safely shut down in anticipation of the hurricane and incurred limited harm, with the impact primarily affecting asbestos insulation on process columns and piping.

The hurricane's maximum recorded wind speed was 192 mph. About 1,500 company employees and contractors worked daily for 15 weeks to remove asbestos debris from the refinery, incurring significant additional costs.

#43

Korfez, Gulf of Izmit, Turkey

17/08/1999

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
200	448

NATURAL CATASTROPHE

A seismic event registering 7.4 on the Richter scale triggered the collapse of a 312-foot-high concrete chimney within one of the crude units, leading to fires at the 226,000 bbl/d refinery. Fires also ignited on various on-site storage tanks. The refinery's emergency response teams promptly isolated and extinguished the fire in the affected crude unit. The decision was made to allow fires in the tank farm to burn out as extensively as possible after draining the storage tanks.

The firefighting efforts faced considerable challenges due to broken water mains. International support, including personnel and equipment, was mobilized to help. The incident resulted in the complete loss of six storage tanks, deformation of another four storage tanks, and 50% damage to several floating roof tanks. The damage extended to various process units, including the fire on the crude distillation unit, and harm to a reformer and several connecting pipelines.

#45

Falcon State, Venezuela

25/08/2012

330	445

EXPLOSION

A powerful explosion occurred at a refinery, impacting an area where propane and butane were stored under pressure. The incident resulted in the loss of 48 lives and more than 80 people were injured.

The explosion caused significant damage to nine storage tanks. There had been leaks reported at the refinery in the previous year.

#46

Fort McMurray, Alberta, Canada

04/01/2005

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
256	444

MECHANICAL FAILURE

A fire ignited in the upgrader 2 section of the oil sands refinery, dedicated to converting bitumen into crude oil products. Approximately 250 personnel were safely evacuated, and no injuries were reported. The fire blazed for nine hours before being extinguished. Witnesses observed two explosions occurring minutes apart, which generated a substantial fireball reaching six stories in height.

The plant endured additional damage from ice formation due to firefighting efforts in the extreme cold, with temperatures plunging below -35 degrees celsius. The likely source of the fire appeared to be a ruptured recycle line.

#49

Pascagoula, Mississippi, US

01/09/1998

190	432

NATURAL CATASTROPHE

Hurricane Georges inflicted severe damage on the refinery, forcing its complete shutdown for three months. The plant was submerged under more than four feet of saltwater from the Gulf of Mexico despite the hurricane only reaching a category 2 storm. Prolonged exposure to the hurricane's slow-moving winds and rain over 17 hours led to a storm surge, which breached the protective dikes surrounding the facility.

Extensive repairs were needed, including replacements for about 2,100 motors, 1,900 pumps, 8,000 instrument components, 280 turbines, and 200 other machinery items. Notably, newer control buildings and electrical substations with elevated ground floors, suffered minimal or no damage during the incident.

#50 Sodegaura, Japan

16/10/1992

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
161	420

EXPLOSION

An explosion and ensuing fire caused significant property damage at the 146,500 bbl/d refinery. The incident stemmed from a heat exchanger failure in the light oil hydrodesulfurization unit. During the event, parts of the heat exchanger (specifically, the channel cover and lock ring, each measuring five feet in diameter and weighing 4,000 lb and 2,000 lb, respectively) were ejected into a neighboring factory located approximately 650 feet away.

The incident occurred during the unit's restart following catalyst exchange work. Initial signs of hydrocarbon release from the heat exchanger prompted tightening work on the bolts. The subsequent fire was contained within three hours by firefighters using 15 fire trucks.

#51 Sannazzaro de Burgondi, Italy

01/12/2016

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
325	408

FIRE

A process disruption occurred when the recycle gas compressor linked to the site's prototypical processing unit tripped, leading to the loss of hydrogen quench flow to the ebullated bed reactor. This event triggered an exothermic runaway reaction within the reactor.

Reportedly, the reactor was not properly depressurized in accordance with the operating guide. Consequently, a 12 inch coupling failed due to the rising pressure, which resulted in the loss of primary containment and a subsequent significant fire.

#60

Philadelphia, US

21/06/2019

Original property loss value (US$ million): 300

Adjusted property loss value 2023 (US$ million): 349

FIRE AND EXPLOSION

A significant loss of process fluid containment, primarily involving propane and hydrofluoric acid (HF), occurred in the refinery's HF alkylation unit, leading to a substantial fire and explosions. A 38,000 lb fragment from one of the larger explosions was propelled approximately 2,100 feet before landing outside the refinery's designated area. The firefighting efforts continued for over 24 hours, and five people were injured during the incident.

The release likely resulted from the rupture of a thinned pipe elbow, which was installed around 1973. Although the pipe elbow complied with metallurgical requirements at the time of its installation, it did not align with the updated recommendations of the American Society for Testing and Materials made some 20 years later. Following the incident, the refinery ceased operations, and the operating company filed for bankruptcy.

View CSB investigation video

#62

Texas City, Texas, US

23/03/2005

Original property loss value (US$ million): 200

Adjusted property loss value 2023 (US$ million): 347

EXPLOSION

An explosion at the 460,000 bbl/d refinery resulted in 15 fatalities and 105 injuries. The incident happened when the isomerization unit was restarted following its annual major maintenance turnaround. Issues during the restart led to the overfilling of one of the unit's splitter columns with light hydrocarbon.

This caused the release of hot liquid through relief valves to a 30-meter-high blowdown stack on the unit. The release created a substantial vapor cloud in the unit's vicinity. The explosion happened when the vapor cloud found a source of ignition. Many of the fatalities had been attending meetings in temporary buildings near the blowdown stack.

View CSB investigation video

#66 Wickland, Aruba

09/04/2001

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
159	335

MECHANICAL FAILURE

An oil spill occurred when a block valve failed to seat correctly during maintenance on a pump strainer in the visbreaker unit. The oil auto-ignited, leading to a fire that consumed the visbreaker and impaired adjacent equipment. Successive explosions and intense heat obstructed firefighting efforts.

An insufficient number of fire brigade personnel and damage to the firewater distribution system further complicated efforts to extinguish the blaze. The fire was inadvertently propagated the firewater application, but it was finally extinguished with help from the local fire department.

#69 Texas, US

12/09/2008

220	325

NATURAL CATASTROPHE

The 365,000 bbl/d refinery incurred severe damage when Hurricane Ike swept through the Houston area, bringing extensive flooding that extended as far as Louisiana.

Hurricane Ike's large storm surge inundated the refinery.

#75 Pascagoula, Mississippi, US

16/08/2007

200	316

FIRE

A fire erupted in the refinery's crude unit number 2, with a capacity of 325,000 barrels per day, and blazed for over six hours. There were no reported injuries.

Company representatives noted that a substantial portion of the refinery could sustain operations, with the number 1 crude unit remaining fully operational.

#78

Fort McMurray, Alberta, Canada
02/06/2007

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
195	308

FIRE

A fire ignited in the boiler unit of the flue gas section at a coker facility. The incident was triggered by a blockage caused by freezing water at valve XV-4, where heat tracing was insufficient, leading to a hazardous accumulation of combustible coke in the precipitators.

Notably, the facility was in full operation when the incident occurred.

#83

La Plata District, Ensenada, Argentina
02/04/2013

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
225	300

NATURAL CATASTROPHE

During a severe rainstorm, a fire erupted at the 188,000 bpd refinery due to flash floods. The heavy rainfall overwhelmed the refinery's storm drainage system, leading to the runoff of hydrocarbons across the site. An explosion was reported in the crude distillation unit (CDU), resulting in two fires within the CDU, one in the coking plant and two in the topping distillation plant.

The government agency determined that the incident happened when hydrocarbons exploded within one of the still-hot coke manufacturing furnaces despite its shutdown status. It took eight hours to extinguish the fire and ten hours to regain control of the situation. There were no reported fatalities or injuries.

#90

Fort McMurray, Alberta, Canada
06/01/2003

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
137	267

EXPLOSION

An incident occurred at an oil sands facility, resulting in minor explosions in the froth treatment plant. The damage was primarily limited to electrical cables in the solvent recovery area. The cause of the fire was a hydrocarbon leak in the piping.

The plant's emergency response team and the local fire brigade managed to extinguish the fire within two hours. One minor injury was reported. The incident took place eight days after the new facility began operating.

#91

Port of Mohammedia, Morocco

25/11/2002

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
130	264

NATURAL CATASTROPHE

Following torrential rain, rising floodwater brought waste oil floating on the surface and into contact with hot equipment at the refinery, resulting in explosions and a fire. A second blaze broke out, and several storage tanks reportedly caught fire and exploded. The damage to the refinery was extensive. Two people were killed, and three others reported missing.

Later reports indicated that the fire had affected two or three production units, including the crude unit, the 20,000 bbl/d vacuum distillation unit, the 24,000 bbl/d catalytic reformer unit, and the 24,000 bbl/d distillate hydrotreater. The incident was forecast to disrupt production at the refinery for eight to twelve months.

#92

Texas City, Texas, US

30/05/1978

55	261

MECHANICAL FAILURE

A vessel failure led to the release of light hydrocarbons that quickly dispersed and found an ignition source. An intense fire erupted in the tank farm. After less than five minutes, a 5,000 bbl storage sphere failed, resulting in a large fireball and sending fragments of the sphere rocketing throughout the plant.

Within 20 minutes, five 1,000 bbl horizontal vessels, four 1,000 bbl vertical vessels, and one additional 5,000 bbl sphere failed, due to missile damage or a boiling liquid expanding vapor explosion. Fragments from the tanks traveled in all directions, causing other fires. Some fragments struck the firewater storage tank and electric fire pumps, leaving only the two diesel fire pumps operational.

#95

Richmond, California, US

25/03/1999

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
113	253

MECHANICAL FAILURE

The incident stemmed from a valve bonnet failure in a high-pressure segment of a 60,000 bbl/d hydrocracker. This malfunction led to the release of hydrocarbons, forming a vapor cloud. The cloud ignited, resulting in a substantial fire fueled by high-pressure hydrocarbons. The explosion caused a large section of the pipe rack to collapse, and a significant fin-fan cooler mounted above the rack was destroyed.

Many pumps were destroyed and a separator was badly damaged. Around 300 firefighters and 33 fire trucks worked for more than two hours to bring the fire under control. Approximately 3,200 US gallons of foam concentrate were used. The hydrocracker remained out of service for 12 months.

#96

Carson, California, US

23/04/2001

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
120	253

MECHANICAL FAILURE

A fire in the refinery's coker unit was caused by a piping leak. Significant smoke emissions reached an altitude exceeding 3,000 feet. The coker unit was shut down for two months.

#97

Richmond, California, US

10/04/1989

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
90	251

MECHANICAL FAILURE

A fire occurred due to the failure of a two-inch diameter hydrogen gas line pressurized at 3,000 psi, stemming from a weld issue. The fire led to the impingement of flames on the calcium silicate insulation of a reactor skirt standing at a height of 100 feet within the hydrocracker unit. Subsequently, the reactor, featuring a steel skirt with dimensions between 10 and 12 feet in diameter and a wall thickness of 7 inches, sustained damage and fell.

The incident resulted in extensive damage to air coolers and various process equipment, amplifying the overall scale of the incident. Notably, the hydrocracker unit was undergoing a maintenance shutdown when the hydrogen leak occurred. The initial leak appears to have originated from a weld failure in the elbow-to-reducer connection of a two-inch diameter hydrogen preheat exchanger bypass line.

#98

Ryazan, Russia
07/08/1994

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
100	247

FIRE

An incident occurred on the crude unit at the 360,000 bbl/d refinery. A worker conducted a hot cut during maintenance activities, inadvertently releasing material.

The probable causes of this incident appear to be inadequate flushing and blinding procedures, and a work scope that did not align with typical industry practices.

#99

Fort McMurray, Alberta, Canada
14/03/2017

197	241

FIRE

A leak resulted in pooled naphtha which subsequently caused a vapor cloud. The vapor cloud migrated towards a hot exchanger located on another unit, where it ignited, along with the pooled naphtha.

The incident led to fire damage, process disturbances, and freeze/thaw events at the plant. A contributing factor to the loss was the internal component failure in an electrically heat-traced controller.

#100

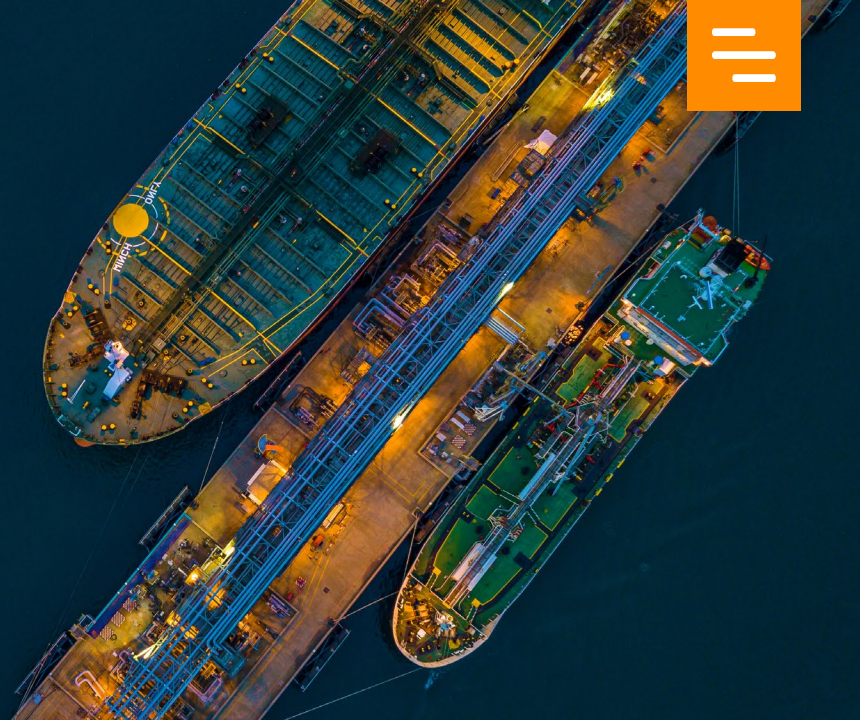
Fort McMurray, Alberta, Canada
15/08/1984

75	241

MECHANICAL FAILURE

In an 82,000 bbl/d fluid bed coking unit, a 10-inch diameter slurry recycle oil line suffered erosion failure and released liquids close to their auto-ignition temperature. The ensuing vapor cloud, covering a large area, ignited immediately, causing a ground fire that led to the failure of additional lines. This severely damaged the reactor fractionator,

light gas-oil stripper, 15,000hp air blower, pumps, and pipe racks. A metallurgical examination showed that a 1.8-inch-long piece of carbon steel pipe had been inadvertently placed into the slurry recycle line, exacerbating the incident. About 2,700 barrels of hydrocarbon liquids were released, further complicating firefighting efforts.

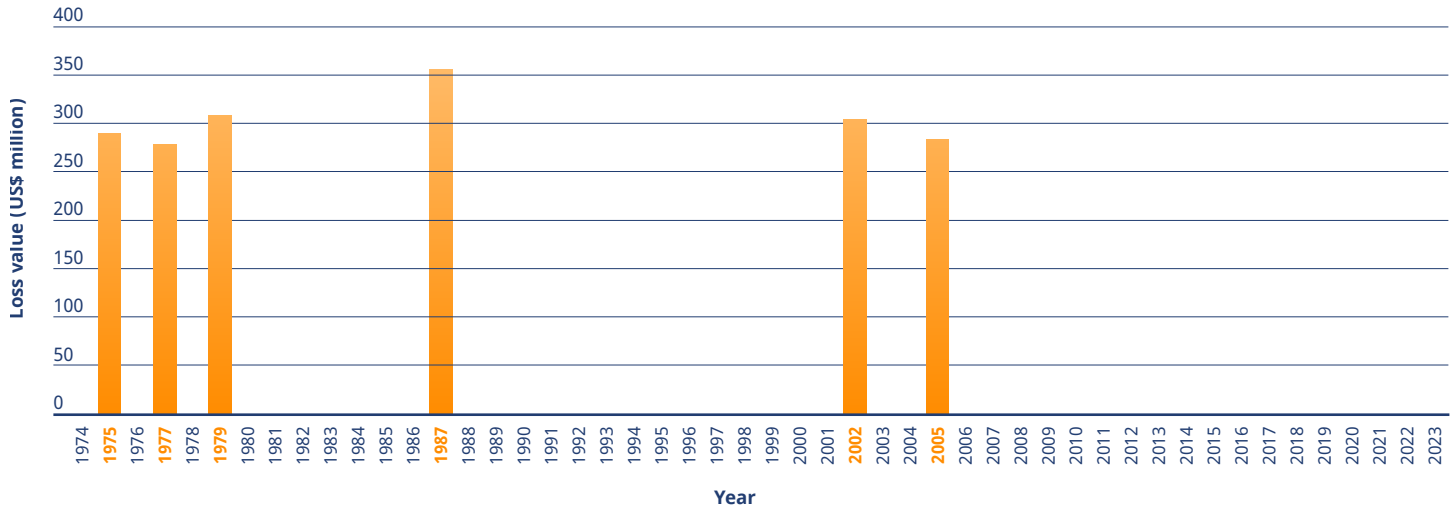


Terminals and distibution

In the 49-year period analyzed, only six terminal and distribution losses are included in the top 100 dataset; the most recent incident was in 2005. By share of both value (US$) and number of incidents, terminals and distribution sector losses account for the smallest proportion of Marsh's dataset.

The terminals and distribution sector plays a crucial role in the transportation, storage, and distribution of hydrocarbon products, and the consequences of losses can extend beyond the primary property damage and short-term financial impact. Incidents can disrupt supply chains and lead to fuel shortages, price fluctuations, and economic disruption. Furthermore, environmental damage from spills or leaks can harm ecosystems, wildlife, and local communities.

15| Terminals and distribution losses



#58 Andes, Ecuador

05/03/1987

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
120	356

NATURAL CATASTROPHE

A total of 25 miles of the Trans-Andean pipeline was affected by an earthquake, resulting in damage to natural gas and gasoline pipelines. All 285 producing wells were taken offline, and oil exports halted, necessitating a swap agreement with Venezuelan suppliers.

The initial earthquake registered 6.0 on the Richter scale, followed by a second one at 6.8, with ten earthquakes recorded overall. The required repairs extended over several months.

#79 Bantry Bay, Ireland

08/01/1979

70	308

FIRE

The incident occurred after an 11-year-old tanker weighing 121,000 deadweight tons discharged its first Arabian heavy crude parcel at a deep-water port. No transfer operations between the ship and the jetty were in process when a small fire was detected on the ship's deck. Within 10 minutes, the fire rapidly spread across the vessel, extending into the surrounding sea on both sides. After approximately 30 minutes, there was a massive explosion.

The incident is thought to have been triggered by the buckling of the ship's structure, particularly around the deck level, swiftly followed by explosions within the ballast tanks and the ship breaking. These events resulted from two critical factors: 1) significant hull weakening due to inadequate maintenance, and 2) excessive stress due to erroneous ballasting practices at the time of the incident. Consequently, the ship was entirely lost, 50 people lost their lives, and 1,130 feet of the concrete and steel jetty were damaged or destroyed.

#82

Raudhatain, Kuwait

31/01/2002

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
150	304

EXPLOSION

An explosion and fire consumed the oil gathering center, gas booster station, and power substation. Triggered by a leak from a buried oil pipeline at the gathering station, the explosion propagated to a power substation, sparking a fierce blaze. The rapid flash explosion and ensuing fire significantly damaged the gathering center and adjacent gas booster station.

Nineteen people suffered injuries, predominantly characterized as first- and second-degree burns. Four individuals lost their lives. The fire was extinguished two days after the incident.

#85

Marcus Hook, Pennsylvania, US

31/01/1975

50	289

COLLISION

A flag tanker collided with a Greek tanker when the latter was unloading 400,000 barrels of crude oil at a refinery jetty in Marcus Hook on the Delaware River. The collision led to a massive initial explosion, followed by subsequent explosions and fires on the Greek tanker.

The incident resulted in the loss of 25 crew members on board the Greek tanker, and one crewman on the US tanker. The Greek tanker subsequently sank and was later salvaged for scrapping.

#86

Hemel Hempstead, Hertfordshire, UK

11/12/2005

Original property loss value (US$ million)	Adjusted property loss value 2023 (US$ million)
164	283

FIRE AND EXPLOSION

A gasoline storage tank was being filled from a pipeline at the fuel terminal. The safety systems and barriers designed to prevent overfilling failed, leading to a spill of gasoline from the vents on the tank roof. This released a heavy, flammable vapor cloud which ignited. This initial explosion triggered a series of subsequent explosions and fires across the terminal.

Firefighters worked for several days to fully extinguish the flames. More than 40 people were injured, and the substantial damage to surrounding properties and businesses forced about 2,000 people to be displaced.

#88

Abqaiq, Saudi Arabia

11/05/1977

55	278

MECHANICAL FAILURE

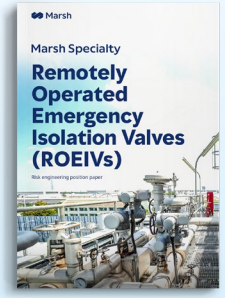
A 30-inch diameter crude oil pipeline ruptured, destroying three spheroids, pumping units, and other equipment.

The ignition of the released oil was caused by motor vehicles.

10

Risk engineering position papers

Marsh Specialty's position papers offer guidance on a range of topics that have been linked to major incidents in the energy industry. The position papers are written by experienced Marsh Specialty risk engineers and incorporate learnings and best practices across the energy industry.



Remotely operated emergency isolation valves (ROEIVs)

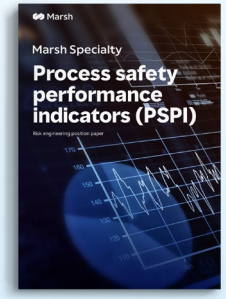
ROEIVs are safety-critical equipment. Their primary purpose is to provide effective and timely isolation of plant items containing hazardous substances in the event of the primary containment system failing (including leaks from pipework and associated fittings, and pump seals).

Many smaller incidents have escalated into major losses because personnel were unable to reach and close manual block valves safely or quickly enough, leading to unconstrained supply of fuel to the fire. An example from the 100LL, where a gap in this topic contributed to the magnitude of the loss, is Longford, Australia, 1998 – US$1007 million (#7).

Pre-start-up safety review

A pre-start-up safety review (PSSR) is carried out to confirm that all appropriate elements of process safety management have been addressed satisfactorily, and that the facility is safe to startup.

This position paper covers the value of the PSSR process — when to conduct one, who should be involved, the steps in a PSSR, monitoring, and checklists. An example from the 100LL where a gap in this topic contributed to the loss is Pampa, US, 1987 – US$639 million (#25).



Process safety performance indicators (PSPI)

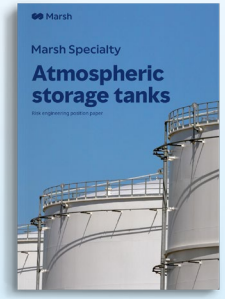
The development of an effective PSPI system can provide a clear view on how well process safety is being managed at a site and across the wider organization. Common PSPI systems can allow comparisons to be made, and can lead to more focused knowledge sharing (both proactive and reactive).

An example from the 100LL where a gap in this topic contributed to a loss in Texas City, US, 2005 – US$347 million (#62). One of the recommendations in the Baker Panel investigation report recommendations refers to establishing leading and lagging performance indicators for process safety.

Fire pre-plans

The potential for major fires in any installation that handles large quantities of hydrocarbon products is self-evident. There have been numerous damaging fires over the years, including tank fires, which involve massive product losses, and process unit fires that cause major plant damage and process interruption.

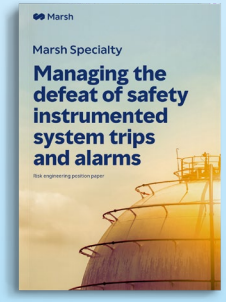
The scope of this position paper includes the description and purpose, the ownership and development, and the format and content of fire pre-plans. It is applicable to any facility handling hydrocarbons and toxic materials.



Atmospheric storage tanks

There have been numerous incidents in the oil, gas, and petrochemical sectors involving atmospheric storage tanks. Data compiled by a reputable operator in the US indicates that the overfilling of atmospheric storage tanks occurs once in every 3,300 filling operations.

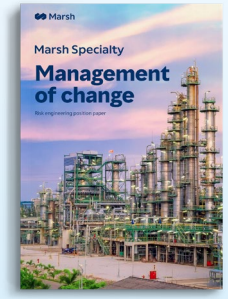
An incident at Buncefield in the UK in 2005 resulted in an independent investigation commissioned by the Health and Safety Commission in the UK. As a result of this, more guidance has been provided to designers and operators of facilities. The guidance has been included within this Marsh Specialty position paper.



Managing the defeat of safety instrumented systems (SIS) trips and alarms

Safety-instrumented systems (SIS) are used extensively in the hydrocarbon processing industry to protect against hazardous events.

A system for managing the defeat of SIS trips and alarms should be robust enough to cater for all eventualities; details on how to best manage this process are covered in this position paper. An example from the 100LL where a gap in this topic contributed to a loss is Illiopolis, US, 2004 – US$274 million (#89). The US Chemical Safety and Hazard Investigation Board (CSB) final report concluded that defeat control contributed to the loss.



Management of change

During the lifetime of an operating process plant, many changes will occur. These could be changes to the physical hardware of the plant, the control systems, the business processes, or the plant operators.

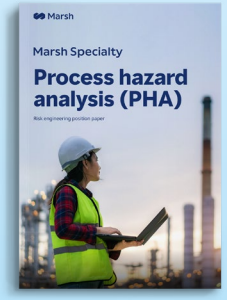
Each one of these changes has the potential to increase the risks involved in operating the plant.

It is well-documented that poor control of plant changes have contributed significantly to large loss events in the energy industry. The need to avoid such incidents and maintain good process safety management is the reason why all sites operating process plant need a robust Management of Change (MoC) process as described in this position paper. The best known example from the 100LL where a gap in this topic contributed to the loss is Flixborough, UK, 1974 – US$366 million (#56).

Shift handover

A lack of effective information transfer has led to serious process safety incidents in the energy industry.

This position paper provides guidance on how to establish accurate and reliable communication of information from one set of shift workers to another. An example from the 100LL where a gap in this topic contributed to a loss is Piper Alpha, UK, 1988 – US$2.43 billion (#1).



Process hazard analysis (PHA)

Marsh Specialty's position paper on PHA looks at the steps that can be taken to minimize the risk of a serious incident. Many of the PHA techniques discussed in this paper are considered to be well established within the industry, and standardized templates have been developed for organizations. An example from the 100LL where a gap in this topic contributed to a loss is Texas City, US, 2005 – US$347 million (#62).

Management of temporary repairs

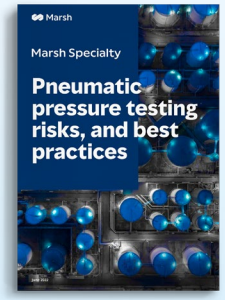
Installation of temporary repairs in the energy and power industry is an integral activity that enables businesses to manage ongoing plant operation for decades.

Whether to address a fault, or maintain equipment approaching end of life, the safe installation of robust temporary repairs is essential to asset integrity for the remainder of the turnaround cycle or until a permanent repair can be completed.

This position paper reviews common repair techniques and focuses on the management, inspection, audit, and life-cycle analysis of a variety of temporary repair types.

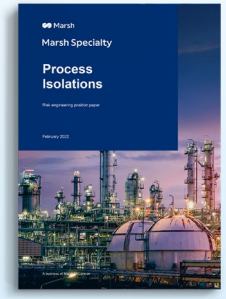
Management of organizational change

Some organizational changes – for example, changes to minimum staffing levels – are not always analyzed and controlled as thoroughly as engineering changes, such as those made to a plant's operation. But in any part of an organization, insufficient analysis can increase the potential risk of accidents. This report aims to help operating sites identify various types of organizational change, and provides practical guidance on how to manage them.



Pneumatic pressure testing

Pressure testing of process equipment is a common activity carried out in the energy and power industry. The inherent risk of pressure testing is associated with the release of stored energy when test equipment fails under pressure. In this paper, we summarize some of the key considerations when conducting a pressure test on process equipment. Common practical limitations, and respective solutions, are also described.



Process isolations

Many maintenance activities require breaking the pressure envelope on hazardous systems, which increases the risks involved in operating the plant. This paper defines the key attributes and processes required to establish a good process isolation management system in the oil, gas, and petrochemical industries. The paper focuses primarily on operating site activities that require a break of the pressure envelope on systems that contain hazardous fluids, or critical utilities that have the potential to lead to significant losses.

Benchmarking the Middle East energy industry

The 4th edition of this report presents the risk quality trends across the energy industry in the Middle East, with a comparative view of global peers. The objective is to give industry operators and insurers an understanding of the risk quality across the industry. This includes the impacts of marked global topics, such as climate change, and the increased relevance of topics that are becoming more prevalent such as environmental, social, and governance considerations, digitalization, and the effects of the COVID-19 pandemic.

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